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Safe Delivery mHealth application and clinical decision making among nurses and midwives on basic emergency obstetric and newborn care in district hospitals in Rwanda

Nishimwe, Aurore

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Safe Delivery mHealth Application and clinical decision making among nurses and midwives on Basic Emergency Obstetric and Newborn Care in district hospitals in Rwanda.

Thesis submitted to the Faculty of Health Sciences, University of the Witwatersrand, in fulfillment of the requirement for the degree of Doctor of Philosophy

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and

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Declaration

I, **Aurore Nishimwe**, declare that this thesis is my own original, unaided work. It is being submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg, South Africa. It has not been submitted before for any degree or examination at any other University or institution. All materials adopted from previously published work have been appropriately cited in this thesis.

Signed on the 5th October 2022 in Johannesburg, South Africa



Aurore Nishimwe

Dedication

I dedicate this PhD to all mothers who sacrify themselves by all means to give life.

This PhD is also dedicated to my sons, Davis and Darly, who have been my constant source of encouragement and inspiration.

Abstract

Background

Maternal and newborn mortality is a major problem especially in low- and middle-income countries, like Rwanda. Several causes that lead to these deaths are preventable. These include pre-eclampsia, obstructed labor, infections, post-partum hemorrhage, hypertensive disorders and newborn's failure to breathe. Strategies for prevention and treatment are grouped in a set of seven key obstetric services which have been identified by the WHO, UNICEF, and UNFPA referred to as Basic Emergency Obstetric and Newborn Care (BEmONC) services that can be provided by nurses and midwives. However, available research evidence on maternal and newborn care remains characterized by gaps on the appropriate measures in assuring the quality of BEmONC. Some of the documented challenges include; poor access to evidence-based clinical guidelines, limited knowledge and skills in BEmONC among healthcare workers, and lack of continuous learning opportunities. Indeed, several researchers have recommended that solutions that use mobile phones to improve health system functions, termed mHealth, potentially overcome some of these challenges. In that perspective, the current research investigated the use of an mLearning and mHealth decision support tool, the safe delivery mHealth application (SDA) in the management of the most frequent birth-related complications of postpartum hemorrhage (PPH) and newborn asphyxia in Rwanda. The study was founded on pragmatism theory and guided by the implementation research model to investigate the effectiveness, the symptomatology, and the acceptability of the SDA in the context of Rwanda.

Methods:

This research is a three-phased research (pre-SDA intervention, SDA intervention, and post-SDA intervention) using a pre-post intervention design with a convergent parallel mixed-method approach composed by four components:

- A qualitative component using semi-structured interview guides to conduct four focus group discussions with 26 nurses and midwives to elucidate their reflections on baseline knowledge and skills surveys results and baseline record review findings, and to explore their perceptions and experience of PPH management and neonatal resuscitation in district hospitals.

- A quantitative component using self-administered questionnaires (SAQs) completed by 54 nurses and midwives to assess the effects of the SDA intervention on knowledge and skills.
- A quantitative component using data extraction sheets to conduct a six months pre-SDA record review and a six months post-SDA record review to examine the effects of the SDA intervention on nurses' and midwives' clinical decision making with regards to maternal and newborn outcomes.
- Qualitative and quantitative descriptions of the acceptability and perceptions of the SDA among end-users and key stakeholders. The quantitative part used a self-administered questionnaire for the acceptability survey completed by all end-users (54 nurses and midwives). The qualitative part included two focus group discussions with 24 nurses and midwives and six key informant interviews with key stakeholders (two maternity matrons, two responsible for maternal and child health, and two district hospital managers).

Descriptive and inferential statistics were used to analyze the quantitative findings from the surveys and thematic analysis was used for qualitative data.

Findings:

Collectively, the findings in this thesis shed light on the beneficial effects of using the SDA as an mLearning and mHealth decision support tool in the context of Rwanda. First, the findings highlighted longstanding challenges faced by nurses and midwives when managing birth-related complications, such as PPH and newborn asphyxia, in district hospitals in Rwanda. Some of the key challenges like insufficient skills, lack of continuous learning opportunities, and limited access to evidence-based clinical guidelines to support their daily clinical decisions are solved by the use of the SDA in routine practices. In addition, Pre-post SDA surveys highlighted the effectiveness of the mLearning feature of the SDA in the context of Rwanda and revealed a significant increase of knowledge scores and skills scores on PPH management and NR among nurses and midwives. Also, the pre-post SDA records review analysis highlighted the effect of the decision support feature of the SDA in the context of Rwanda and revealed a significant association between the SDA intervention and newborns' and maternal' outcomes following neonatal resuscitation and PPH management. Further, the nurses and midwives perceived the SDA as having improved their ability to manage childbirth complications. They indicated general agreement that the SDA is easy to use, is an effective decision support tool, and training tool. They also reflected on future use of

the SDA in Rwanda by suggesting additional features and functions to the SDA developers such as computer/laptop version of the SDA, additional videos, SDA version in the local language, and a discussion forum in the SDA. Key stakeholders also perceived the SDA as a useful tool with a reasonable cost and recommended its implementation in routine practices. They were optimistic that the SDA could be scaled up and be sustained in the whole country.

Conclusion:

This study has proved through its findings the importance of using the SDA in routine practices, which was associated with improved knowledge and skills in PPH and NR as well as improved maternal and newborn outcomes. In addition, The SDA was accepted and perceived useful by both end-users and key stakeholders. The study, thus, concludes that the SDA show promise for improving the management of birth-related complications such as PPH and newborn asphyxia. These findings are highly relevant in low- and middle-income countries like Rwanda, where maternal and newborn deaths from preventable causes are still present and quality emergency obstetric and newborn care is the ultimate target. Future long duration research is needed on the scalability, cost- effectiveness and sustainability of the SDA in the context of Rwanda. A further assessment of the SDA contribution to the reduction of maternal and newborn mortality is also needed.

Keywords: BEmONC; post-partum hemorrhage, neonatal resuscitation, nurses and midwives, mHealth, mLearning, safe delivery mHealth application, Rwanda.

Thesis Material

Original papers

The following are the scholarly work derived from this thesis:

Published articles

1. **Nishimwe, A.,** Nyssen, M., Ibisomi, L. and Nozizwe Conco, D., 2021. Clinical decision making in basic emergency obstetric and newborn care among nurses and midwives: the role of the safe delivery mHealth application_pre-post-intervention study (research protocol). *Informatics for Health and Social Care*, *46*(2), pp.126-135. https://doi.org/10.1080/17538157.2020.1869007

2. **Nishimwe, A.,** Conco, D.N., Nyssen, M. *et al*. Context specific realities and experiences of nurses and midwives in basic emergency obstetric and newborn care services in two district hospitals in Rwanda: a qualitative study. *BMC Nurs* 21, 9 (2022). https://doi.org/10.1186/s12912-021-00793-y

3. **Nishimwe, A.,** Ibisomi, L., Nyssen, M. *et al*. The effect of an mLearning application on nurses' and midwives' knowledge and skills for the management of postpartum hemorrhage and neonatal resuscitation: pre–post intervention study. *Hum Resour Health* 19, 14 (2021). https://doi.org/10.1186/s12960-021-00559-2

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For all of the listed articles, Aurore Nishimwe contributed to the study conceptualization and design, research management, training and supervision of research assistants, data collection, data management (including cleaning/coding and analysis). The co-authors also were involved in the conception and design of the study, supervised the research, supported the data analysis, reviewed the manuscripts, read and approved the final manuscripts.

Conference Presentations

1. **Nishimwe A et al,** the effect of an mLearning application on nurses' and midwives' knowledge and skills for the management of postpartum hemorrhage and neonatal resuscitation: pre–post intervention study. May 2021, The 28th International Congress on Nursing and Primary Health Care. Rome – Italy. https://nursing.conferenceseries.com/

2. **Nishimwe A et al**, The-Effect-of-an-Mlearning-Application-On-Nurses-and-Midwives-Knowledge-and-Skills-for-the-Management-of-Postpartum-Hemorrhage-and-Neonatal-Resuscitation-Pre-Post-Intervention-Study. June 2021. The Academy Health Annual Research Meeting ,USA, https://www.academyhealtharm.org/posters/25686682/1143---

3. **Nishimwe A et al**, The effect of a decision-support mHealth application on maternal and neonatal outcomes in two district hospitals in Rwanda: pre - post intervention study. Sept 2021. Biennial Research Day for School of Public Health, University of the Witwatersrand, South Africa. https://whova.com/portal/webapp/rdsop_202108/Agenda/1904347

4. **Nishimwe A et al,** the effect of an mLearning application on nurses' and midwives' knowledge and skills for the management of postpartum hemorrhage and neonatal resuscitation: pre–post intervention study. Sept 2021, Africa Interdisciplinary Health Conference (AfIHC), University of Rwanda. https://www.afihc.org/

PhD award and grants

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Training Grants

- One Health Fellowship _ Tufts University, USA – Two months' residential fellowship valued at $12,000 (2018).
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- Distinguished Science and Technology award valued at $10,000 (2022) During The 1st Rwanda Science, Technology (STI) Conference offered by the National Council for Science and Technology (NCST), Rwanda.

Research Grants

- Belgium, Flemish project funding (VLIR-UOS)_Short initiative research grant for HeartCare@Home Project RW2022SIN352A103: Piloting a novel, scalable, eHealth technology for the control and management of elevated Blood Pressure in Rwanda, valued at £70,000 (2022-2024).

Service and Collaborations

- Lecturer, School of Public Health. Department of Health Informatics. College of Medicine and Health Sciences, University of Rwanda. 2018 to date.
- Reviewer, Rwanda Journal of Medicine and Health sciences (RJMHS) indexed in African journals online (ajol). 2018 to date.
- Investigator (mHealth component), Laisdar (Leveraging Artificial Intelligence and Data Science Techniques in Harmonizing, Accessing and Analyzing SARS-COV-2/COVID-19 Data in Rwanda) project funded by IDRC Canada. 2020 to date.
- Joined the International Medical Informatics Association (IMIA) for the IMIA recommendations review taskforce (2021).
- Co-Principal Investigator for Smart Healthcare Delivery Project SI-2020-01-50: A pilot project on digitalizing the hospital patient trajectory and secondary use of Electronic Health Records (EHRs) in Rwanda, funded by VLIR-UOS Belgium. 2021 to date.

- Deputy team leader, Digital Health Sub – Program, University of Rwanda - Sweden Partnership (Sida) Program for research, higher education and institutional advancement. 2022 to date.
- Peer reviewed articles for Informatics for Health and Social Care Journal, BMC Human Resource for Health, BMC Pregnancy and Childbirth, and BMC Nursing as result of PhD publications.

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List of Abbreviations

APGAR: Appearance, Pulse, Grimace, Activity, and Respiration

BEmONC: Basic Emergency Obstetric and Newborn Care

CARTA: Consortium for Advanced Research Training in Africa

CHWs: Community Health Workers

CMHS: College of Medicine and Health Sciences

EBI: Evidence Based Intervention

FGD: Focus Group Discussion

HINARI: Health Inter-Network Access to Research Initiative

ICT: Information, communication, technology

IMIA: International Medical Informatics Association (IMIA)

IRB: Institutional Review Board

IQR: Interquartile Range

IV: Intravenous Line

KII: Key Informant Interview

LMICs: Low- and Middle-Income Countries

MDGs: Millennium Development Goals

MNCH: Maternal Newborn and Child Health

mHealth: Mobile Health

mLearning: Mobile Learning

Mls: Milliliters

MOH: Ministry of Health

NICU: Neonatal Intensive Care Unit

NR: Neonatal Resuscitation

PhD: Doctorate in Philosophy

PPH: Post-Partum Hemorrhage

RAM: Rwanda association of midwives

SAQs: Self-Administered questionnaires

SBA: Skilled Birth Attendant

SDA: Safe Delivery mHealth Application

SDG: Sustainable Development Goals

SSA: Sub-Saharan Africa

STATA: Statistics and Data

UNICEF: United Nations International Children's Emergency Fund

UNFPA: United Nations Population Fund

WHO: World Health Organization

The Structure of the Thesis

This PhD submission is structured according to the 'divided block' format. This doctoral thesis is organized into nine chapters under three sections as follows:

SECTION A

Introduction, Literature Review and Methods

Chapter one provides operational definitions of concepts guiding this work and introduces the research by outlining the background information and briefly discussing the research problem and knowledge gap. The chapter defines the scope and central themes of the thesis. The introduction further discusses the Rwandan healthcare system as the research context and highlights the maternal and newborn healthcare in Rwanda. The last part of the chapter explains how the research question arose. This is followed by a brief summary of the chapter.

Chapter two is a comprehensive literature review, focusing on the research gap and the knowledge gap from multiple perspectives of maternal and newborn healthcare including the technology involvement in the healthcare services. In the background, a discussion of the challenges related to quality BEmONC services at the global level, sub-Saharan Africa and particularly in Rwanda is presented. The chapter refers to different interventions targeting maternal and newborn healthcare particularly BEmONC services. It also refers to the gaps in literature on the appropriate measures in assuring the quality of BEmONC. The use of the evolving technologies such as mobile health (mHealth) applications in improving BEmONC services is also discussed. Further, chapter two includes a detailed discussion of concepts like BEmONC, mHealth and Safe Delivery mHealth application, and how they were operationalized in this thesis. This chapter also entails the significance, the purpose of the research and the research questions. The last part of the chapter outlines the theoretical and conceptual framework of the research where the philosophical foundation of this mixed methods research "Pragmatism" is described. The guiding conceptual framework "implementation research model by proctor (2011)" is also explained. A detailed reflection on the choice of the implementation research model and pragmatism as a philosophical foundation for this research is further presented in chapter eight.

In **Chapter three**, I present the overall components of my **methodological approach** to this PhD. The methods, the data collection techniques, the measurement of different variable constructs and

over-arching data analysis strategies used to meet each of the study objectives are set out in this chapter.

SECTION B

Section B is the **results** section of this dissertation, comprising five published articles (one of them being a protocol paper) from chapter four to chapter seven. In this section B, each chapter follows a format of a journal article and provides background of the work, presentation of methods, findings and concludes by a discussion of findings. These articles were written with supervisors playing the role of co-authors, therefore in each paper, the contribution of all individuals is acknowledged. The co-authors agreed to include the publications as part of this thesis submission. (See Appendix A).

SECTION C

In Chapter eight, **Discussion**, I return to the study aims, objectives, theoretical foundation and conceptual framework to highlight research findings and key themes. This discussion revises the pragmatism theoretical foundation and the implementation research framework that guided this PhD work. I summarize how a convergent parallel mixed-method approach was employed to investigate the effectiveness, symptomatology and acceptability of the SDA in BEmONC services in Rwanda. I also discuss the scholarly contribution of this work. I consider the implications of the study findings for policy, practice, public health and research. The strengths and study limitations are presented in this chapter.

In Chapter nine, **Conclusion and Recommendations**, I provide the conclusion derived after analysis and discussion of the study findings. The chapter also includes recommendations for practice, policy and indicate areas where future research would be valuable to improve the BEmONC services. A list of all the references used in the entire thesis is also presented here.

SECTION A: INTRODUCTION, LITERATURE REVIEW, AND METHODS

Operational definitions

Some definitions that will frame and guide this thesis include:

Basic Emergency Obstetric and Newborn Care (BEmONC) is defined as a package of seven medical interventions provided to women and newborns experiencing potentially fatal complications [1]. The services include; the management of post-partum hemorrhage (PPH); removal of a retained placenta; management of maternal sepsis; management of hypertensive disorders; management of prolonged labor; management of complications of abortion and neonatal resuscitation (NR) [1].The concept of BEmONC evolved from EmONC (emergency obstetric and newborn care) [2] and sometimes people use the two concepts interchangeably. The concept EmONC was introduced by WHO, UNICEF, and UNFPA in 1997 as an organizing framework for the delivery of evidence-based clinical services to mothers and newborn during delivery care [2]. Later, another related concept was introduced, that is Comprehensive emergency obstetric and newborn care (CEmONC) typically delivered in hospitals [3]. CEmONC consist of all the seven medical interventions to manage pregnancy and delivery complications highlighted under BEmONC plus the capabilities for performing caesarean sections; safe blood transfusion and the provision of care to sick and low-birth weight newborns [3]. This made the three terminologies clear along with consideration of the specific services. EmONC refer to BEmONC + CEmONC. BEmONC includes the seven basics interventions while CEmONC adds two more advanced services to the seven basics. There is evidence that BEmONC particularly is a critical component of any program to reduce maternal and newborn mortality [4,5]. The seven signal functions of BEmONC can be provided by skilled birth attendants (nurses, midwives and doctors) in health centres, large or small, and in hospitals. The current study will focus on two signal functions of BEmONC, PPH management and NR, which are key to the management of the two frequent birth-related complications of PPH and newborn asphyxia in Rwanda.

Nurse: According to International Council of Nurses (ICN), a nurse is a person who has completed a program of basic, generalized nursing education and is authorized by the appropriate regulatory authority to practice nursing in his/her country [6]. According to the World Health Organization (WHO, 2017), nursing is one of the main pillars of the implementation of health care services [7].

The WHO maintains that the limited availability of human health resources implied transferring a range of health care service responsibilities to registered nurses from other health care professionals [8].In many sub-Saharan African countries, nurses are the primary health care contacts for patients, especially in rural settings [8]. In Rwanda, registered nurses also practise in childbirth care due to the shortage of midwives [9].

Midwife: is a skilled birth attendant (SBA) who has received some type of formal training in midwifery versus a traditional birth attendant (TBA) who is primarily trained through apprenticeship [10]. The pre-service training of midwives in Rwanda varies widely with technical; baccalaureate and graduate training available as pathways to entry to midwifery practice [11]. This variation means that midwives may enter practice with three years of previous training as a nurse plus work experience or without previous nursing training or clinical work experience [11,12].

Clinical decision making: refers to a contextual, continuous, evolving and complex process where clinical data are gathered, interpreted and evaluated, and then a decision, judgment, or intervention is formulated in order to best meet patient needs [13]. Other authors have defined clinical decision making as a process that includes clinical reasoning as part of the decision-making process in which information is collected and evaluated and then an action is taken or decision is made [14–18]. The information processing theory [19] emphasizes on how the experience and knowledge of the decision maker influences how a decision is formulated [19,20]. Similarly, Mattesson et al (1990) stated that the clinical decision making process involves the knowledge, skills and competencies of healthcare providers when considering information, gathering information, and weighing the risks and consequences of their clinical decisions to patient outcomes [14]. Antecedents of a decision include gathering and considering information while being aware of the options available and weighing any potential risks or consequences of that action [13]. In the present study, we refer to clinical decision making as a complex process involving a deliberate choice in which nurses and midwives chose between two and more options and then took committed action based on their knowledge, skills, and/or clinical guidelines with regards to the management of PPH and NR. Nurses and midwives' decisions and actions will be evaluated in consideration of maternal and newborn outcomes following the management of PPH and NR.

Postpartum Haemorrhage is defined as the bleeding from the genital tract of 500 ml or more in the first 24 hours following childbirth [21]. Postpartum haemorrhage (PPH) is a major cause of maternal morbidity and mortality in low-income countries [22].

Newborn Resuscitation is an emergency procedure focused on supporting newborns who do not readily begin breathing and/or experiencing newborn asphyxia, putting them at risk of irreversible organ injury and death [23]. It is a set of interventions at the time of birth to support the establishment of breathing and circulation [24]. These include: providing warmth by placing a baby under a radiant heat source; stimulation alone, such as drying and rubbing; basic resuscitation with a bag-and-mask and suction if required, more advanced measures, including endotracheal intubation, chest compressions and medications when required [25]. The procedure is quick and the healthcare provider worker needs to take timely decision because by one minute of age all newborns should be able to breathe on their own or should be ventilated with a bag mask to avoid irreversible consequences. A rapid method for assessing a newborn immediately after birth and in response to resuscitation is the *Apgar score* [26]. When performing resuscitation, the healthcare provides can measure the Apgar score at 1 minute, 5 minutes and 10 minutes after birth.

Apgar Score is measure of the physical condition of a newborn infant. It is obtained by adding points (2, 1, or 0) for heart rate, respiratory effort, muscle tone, response to stimulation, and skin coloration; a score of 10 represents the best possible condition. The normal Apgar score ranges between 7 and 10 [26]. The Apgar remains the accepted method of newborn assessment and is endorsed by both international societies of obstetricians and paediatricians [26].

Mobile Health (mHealth): refers to the use of mobile and wireless devices (phones, smartphones, tablets, smart watches) to improve health outcomes, healthcare services and health research [27].

Safe delivery mHealth application (SDA) is defined as a mobile health (mHealth) application that is used as an aid for SBA to manage the complications occurring during pregnancy, childbirth and the first weeks after birth [28]. For the purpose of this study, the SDA will refer to an mHealth application that supports clinical decisions for BEmONC and promote in-service continuous learning among nurses and midwives. The SDA covers a diverse range of user patterns as described in figure 2 describing a professional life cycle of a SBA using the SDA. Further details on the SDA are described in chapter two.

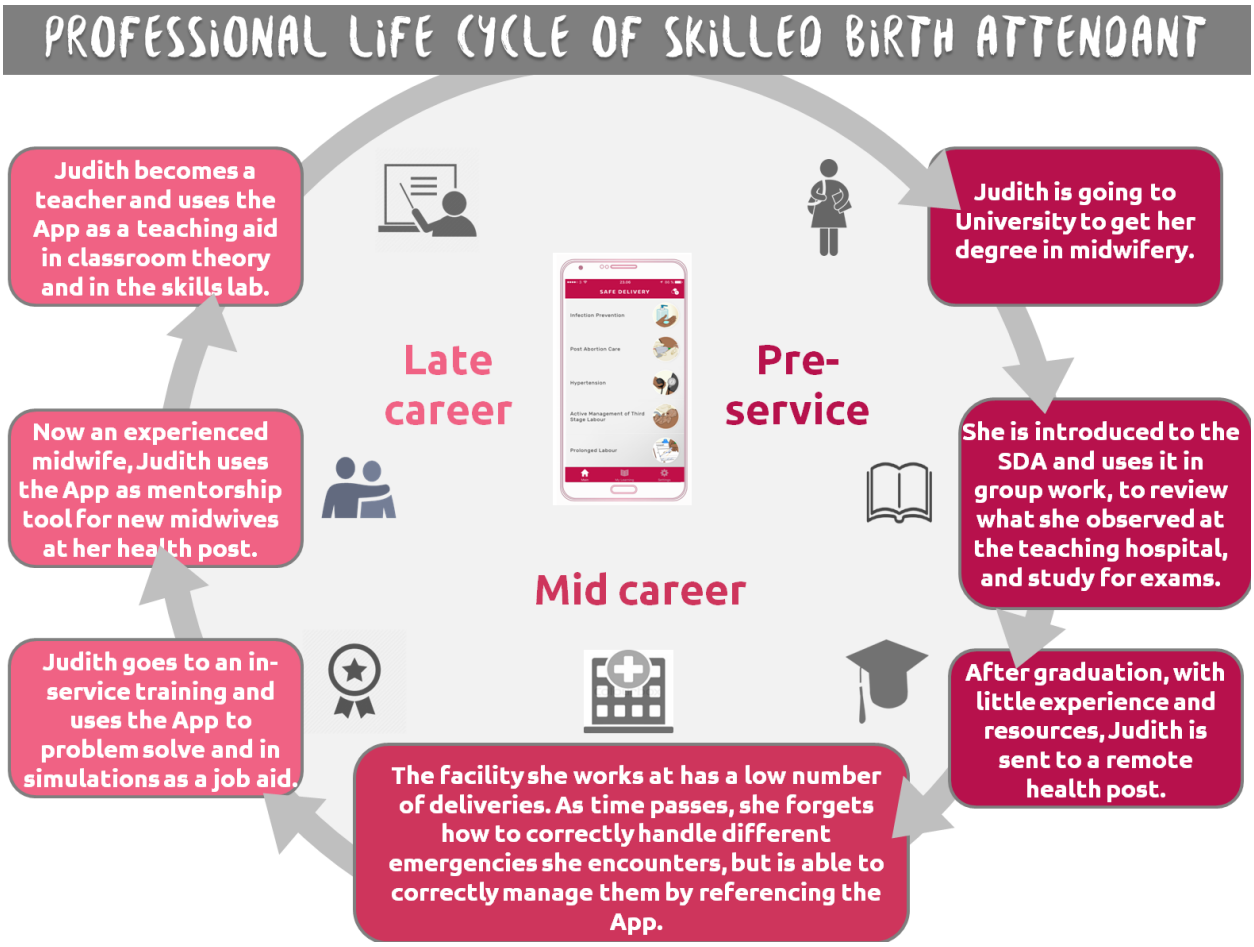

Figure 1.1. The overview of user patterns of SDA, e.g.: user case of a professional life cycle using the SDA for a midwife called "Judith" [28].

Effectiveness is defined as the degree to which an evidence-based intervention/solution is successful in producing desired results [29]. The effectiveness is measured through variables such as relevance, compatibility and usefulness of an evidence-based intervention. Therefore, the degree to which the SDA will be successful in bringing change and achieving desired outcomes will be assessed through knowledge and skills of nurses and midwives about newborn resuscitation and post-partum hemorrhage before the start of the intervention and at six months after the intervention. This will be applied also to BEmONC outcomes through records review of delivery registries which will compose the symptomatology part of the study.

The term *symptomatology* refers to a set of symptoms characteristic of a medical condition or exhibited by a patient [30]. In the context of the implementation research model, the symptomatology was assessed through a pre-post intervention record review of the BEmONC

outcomes: Apgar score and PPH progressions. Newborn deaths or admission to the neonatal intensive care unit (NICU) or to neonatologist's service due to an unstable outcome (Apgar score < 7) after neonatal resuscitation was used as the primary outcome measure to determine the failure of neonatal resuscitation. The mothers' referral to a higher-level facility (referral hospital) following an unstable outcome (persistent bleeding) after PPH management was considered as the primary outcome to measure the failure of PPH management at the district hospital.

Acceptability is broadly defined as the perception among stakeholders (e.g. consumers, providers, managers, policy-makers) that an intervention is agreeable [30]. The acceptability is measured using attributes like approval, likeliness, fitting, welcoming, suitable, applicable, good match, and willingness. The acceptability of the SDA was being measured using a self-administered questionnaire and semi – structured interviews with key stakeholders.

Chapter one: Introduction to the study

In a time when all countries, including Rwanda, strive to achieve the sustainable development goals (SDGs), the SDG three seeks to ensure health and wellbeing for all, at every stage of life [31]. One of the nine targets of the SDG three is the reduction of maternal mortality rate to less than 70 per 100,000 live births and the reduction of the neonatal mortality rate to at least as low as 12 per 1,000 live births by 2030 [32]. Therefore, studies related to maternal and newborn health are critical. In this thesis, I describe a study investigating the use of mobile health (mHealth) technology in basic emergency obstetric and newborn care (BEmONC) services, with a particular focus on the management of the most frequent birth-related complications of post-partum hemorrhage and newborn asphyxia in Rwanda.

This research work focuses on BEmONC services, defined as essential medical interventions to manage delivery complications [1]. They include a set of seven medical interventions : the management of post-partum hemorrhage (PPH), removal of a retained placenta, management of maternal sepsis, management of hypertensive disorders, management of prolonged labor, management of complications of abortion and neonatal resuscitation (NR) [1]. BEmONC services have proved to be of key importance in reducing death and disability of mothers and newborns [2,4,33]. But, available literature on maternal and newborn care remains characterized by gaps on the appropriate measures in assuring the quality of BEmONC [34]. Indeed, several researchers have recommended that solutions that use mobile phones to improve health system functions, termed mHealth, potentially overcome some of these challenges [35–38]. The current research evaluated the usage of a mHealth technology, the safe delivery mHealth application (SDA) as a tool to improve healthcare services delivery in order to illustrate the importance of a mobile health application approach to BEmONC services.

1.1. Research Context

In this segment, I present the structure of the Rwandan healthcare system as the research context of the current study. I also discuss the maternal and newborn health in Rwanda to provide a background of childbirth care and all factors that play an essential role in the process of childbirth care in Rwanda. The three delay model of maternal mortality is used to illustrate the gaps in delivery care with Rwanda as a user case. This is followed by a description of the problem

statement and how the research question arose. The operational definitions of the important terms used in this study are also presented.

1.1.1. Rwanda health care system

Rwanda is an East African country located a few degrees south of the Equator, bordered by Uganda, Burundi, Tanzania and Democratic Republic of Congo. Rwanda is one of the smallest countries on the African continent with an area of 26,338 square kilometers and a total population of 12 million [39]. The population of Rwanda is young and predominantly rural. The population density is among the highest in Africa (416 inhabitants per square kilometer) [39]. Rwandans are drawn from one cultural and linguistic group [40].

The healthcare system in Rwanda is supported by both public and private healthcare institutions. The healthcare system is characterized by a decentralized public sector, supplemented by the private sector (i.e. private hospitals and clinics) [41]. The public health care system has a pyramidal structure made of five levels according to the administrative organization: National (Province), District, Sector, Cell and Village [42]. This pyramid structure comprises seven referral/ university teaching hospitals at the top followed by four provincial hospitals, 36 district hospitals, 499 health centres and 476 health posts. The health centers and health posts use community health workers (n = 45.011) for community outreach activities [43]. Figure 1 provides a pictorial representation of the public healthcare system of Rwanda with an average catchment area (number of people served) and types of services offered at each level.

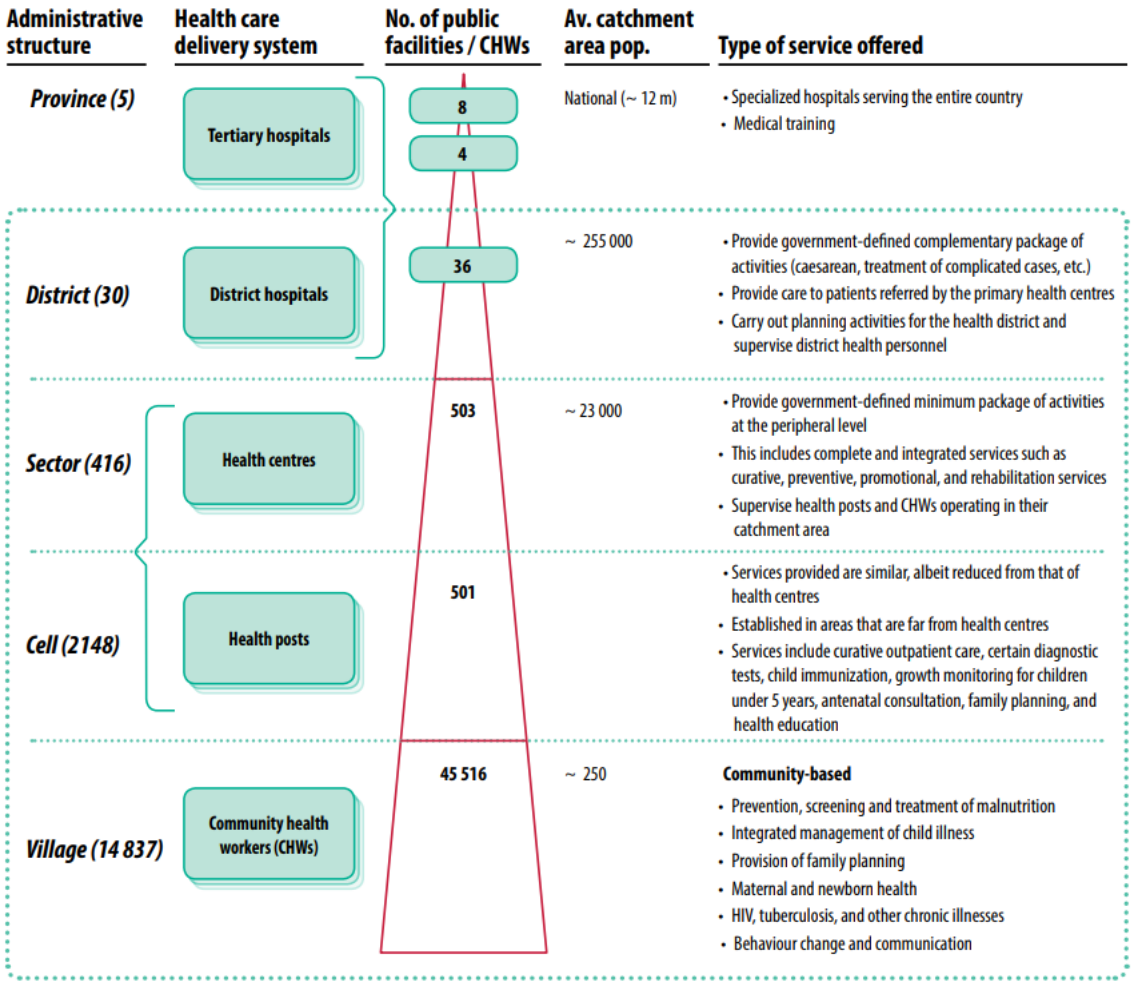

Figure 1.2. Representation of the public healthcare system of Rwanda.

Source: Adapted from the Rwandan ministry of health's health service packages for public health facilities [41].

Rwanda's health sector, like many others in the country, has in the last decades remarkably evolved to guarantee quality health care services for citizens of Rwanda and for people from other countries [44]. The first formal level of health care happens in health centres and health posts which provide primary care services. The second level of the care consists of district hospitals, followed by provincial and national referral and teaching hospitals on the third level in the system [43]. At health centres, nurses and midwives are responsible for deliveries of normal and uncomplicated pregnancies [45,46]. In the event of complications, the pregnant woman is transferred to the district hospital where advanced materials are available and services predominantly offered by nurses and midwives with the help of doctor in case of fatal complication [46]. When the patient's situation becomes severe at district hospital level, the patient is transferred to tertiary/referral hospital,

where, in addition to an experienced nurse and midwife, there are gynecologists, pediatricians and other physicians who support in the provision of care [47].

In addition, to ensure that every patient has equitable and geographic access to the healthcare services, an additional cadre of trained community health workers (CHWs) was introduced in the Rwandan healthcare system in 2009 [48]. The CHWs promote the uptake of maternal and newborn care according to WHO recommendations [49]. The CHWs are serving the population at the household level connecting communities with the healthcare system [43]. Each village has four CHWs, one of them is particularly responsible of maternal and newborn health assisting in early recognition of danger signs and referral of pregnant women [48]. In addition, Rwanda has introduced the use of innovative mobile technology, the RapidSMS, in maternal and newborn care in 2010 [50]. The RapidSMS mobile health programme links community health workers and health facilities. The RapidSMS assists in the monitoring of antenatal care and referrals during emergencies [50,51]. The tool is also used to report births and deaths ensuring synchronization of the health system data and the community data.

In the same vein, the ministry of Health in Rwanda has set a goal of ensuring collective access to equitable and affordable quality healthcare services for all Rwandans. Through a national policy that was established in 2004, health insurance coverage is compulsory by law in 2008 [52]. The annual subscription fees are designed according to family income. Ninety one percent of Rwandans have medical health insurance with Rwanda Social Security Board [53]. Any individual can use the health care services and pay 15% of the costs [53]. Private health insurances are also available for private purchase. The vision of the ministry of Health is to reach 100% health insurance coverage in the next few years [54].

1.1.2. Rwanda's Maternal and Newborn Health

Rwanda, the country of focus for this thesis, has attained a remarquable improvement in the quality of maternity and newborn care services by reaching the millennium development goals; MDGs 4 and 5a: to reduce child mortality and maternal mortality by three quarters between 1990 and 2015 [11,43]. The MDG 4 target for Rwanda's neonatal mortality was 28 per 1000 live births. As of 2015, the neonatal mortality rate was 20 per 1000 live births [40]. Whereas the MDG 5a target for Rwanda's maternal mortality was 268 per 100,000 live births. As of 2015, the maternal mortality rate was 210 per 100,000 live births according to RDHS [40]. Rwanda is now striving towards the

achievement of the 17 sustainable development goals (2030) set up by the United Nations. The SDG three aims at the reduction of maternal mortality rate to less than 70 per 100,000 live births and the reduction of the neonatal mortality to at least as low as 12 per 1,000 live births by the year 2030 [55].

The MDGs success was underpinned by the implementation of recommendations in Rwanda's '2008 – 2012 roadmap to accelerate the reduction of maternal and neonatal morbidity and mortality'[42]. The document highlighted evidence-based practices and programs which have been shown to be highly effective in contributing to the improvement of maternal and neonatal health. These programs include the three pillars of maternal health: Basic Emergency Obstetric and Newborn Care (BEmONC), deliveries by skilled birth attendants (SBAs), and family planning [42]. In addition, the ministry of Health in Rwanda ensured that each village has at least one health facility and has recorded 91% deliveries happening in a health facility assisted by skilled birth attendants [41]. Other programs and interventions helped in achieving these positive outcomes. They include: the support of CHWs in detecting pregnant women in their respective communities and accompanying them to health facilities for ante/postnatal care and delivery; the RapidSMS mhealth program which has enabled the transfer of pregnant women in labour to the appropriate health facilities; and the increased numbers of ambulances country-wide [49,54,56].

Although there was remarkable increase in facility-based deliveries, maternal and neonatal mortalities in Rwanda remained high [46]. These high maternal and newborn mortality rates are, in part, attributed to the shortage of human resources for health. Similar to other sub-Saharan Africa countries, the distribution of human resources for health in Rwanda is uneven in urban and rural areas [44,57]. Rwanda's estimates show the healthcare providers distribution with one midwife per 18,790 inhabitants and one nurse per 1,227 inhabitants [44]. Strategies to improve the availability of human resources for health are an integral part of the health system strengthening policy in the country [43]. Therefore, the lack of sufficient skilled birth attendants linked to the high maternal and newborn mortality rates continue to remain a pressing issue in Rwanda [45]. Some initiatives to reduce the maternal and newborn deaths and to address the shortage of skilled birth attendants are put in place in consideration of the three delays model of maternal and newborn mortality [58].

1.1.3. The Three Delays Model of maternal and newborn mortality

The Three Delays Model [59–61] has been a useful framework for examining approaches to address access to care, care seeking behaviours and quality of maternal and newborn healthcare services. The delays are: "Delay in recognition of danger signs and decision to seek care, Delay in reaching appropriate source of care, Delay in obtaining adequate and appropriate treatment" [60]. Several researches have documented that the majority of women and their unborn infants are healthy at the onset of labor [2,4,62]. Whereas the labor, delivery, and the immediate postpartum periods are when most maternal deaths occur [2,4,62].

A review of maternal death audits in Rwanda identified patient or community-related factors as in 30.3% of deaths [63]. The health system failure was identified as the main factor responsible for the majority of deaths (61%) [63]. These factors are part of the third delay and include: poor case management; delay in referring patient to higher level of care; lack of skilled staff; insufficient diagnostic means; delay in recognizing complications; inadequate monitoring of labor and/or use of partograph and poor monitoring/follow up in immediate post-partum period [59,60]. Evidence has shown that delays in accessing skilled care when complications arise can significantly affect outcomes for both mother and baby [64,65]. Urgent attention to these factors, in particular during intrapartum and immediate postpartum care, is therefore vital in addressing maternal and newborn morbidity and mortality.

Evidence based interventions to deal with the third delay include building capacity in emergency triage and referral to ensure timely care and interventions; adding BEmONC to preservice curricula and ensuring basic competency for all midwives, nurses and physicians in managing birth-related complications; mandatory use of the partograph as a labor management tool; and ensuring adequate skilled staffing for labor, delivery and postnatal units [34,66]. Among other accountability mechanisms in place that the Rwandan government is banking on to bring down the numbers of maternal and newborn deaths, there are performance contracts, as well as performance-based financing models for health providers [66].

1.2. How the research question arose?

This section elaborates on the different elements that influenced my PhD research questions including my personal observations as clinician and the evidence from literature. Before starting my PhD studies, I had experience in clinical practice as a health care provider and as a clinical

instructor. I practiced in both public and private hospitals before joining the academia. Through my exposure to the clinical setting in the field of maternal and child health care; I had observed that some services are not delivered as intended. For instance; postpartum haemorrhage management on the mother side and neonatal resuscitation on the newborn side were not always performed successfully. There was limited access to clinical guidelines and healthcare providers had different approaches to management of birth-related complications and sometimes committing fatal errors. For example, I observed healthcare providers not respecting the golden minute and not knowing how and at which rates to ventilate newborns who were born with asphyxia and sometimes performing suction when it is not necessary. I also observed a lack of uniformity in the postpartum care which led to fatal complications. Also, the rates of complicated PPH as well as newborns asphyxia were increasing in Rwandan district hospitals. The complications sometimes resulted in maternal and newborn deaths from preventable causes. These experiences have given rise to the following question: In addition to formal training (pre-service, and certificated short courses), what do healthcare providers need to improve delivery care?

Nurses and midwives are the frontline workers in the provision of childbirth care worldwide and particularly in sub Saharan Africa [11,34,67]. In Rwanda, ninety one percent deliveries take place in healthcare facilities attended by health professionals; nurses, midwives and doctors [44]. The seven signal functions of BEmONC services are being primarily offered at district hospital level. Even though several efforts have been made to improve maternal and newborn health, the number of maternal and newborn deaths remains high [63]. According to Sayinzoga (2016), common causes are preventable: postpartum hemorrhage (22.7%) and Newborn asphyxia and its complications (38%) [63]. Evidence has shown that limited BEmONC knowledge and skills among nurses and midwives, poor access to clinical guidelines and lack of timely response to delivery complications are the significant causes of maternal and newborn mortality in Rwanda [68].

In a study conducted by Wilmot et al. (2017), the majority of nurses and midwives in Rwanda expressed that both their knowledge (60.6%) and skills confidence (72.2%) across fundamental topics of safe motherhood care need improvement [59]. Also, in-service trainings to keep staff updated with new discoveries for better management of obstetric complications are still few due to limited funds [59]. A brainstorming approach helped in questioning whether there might be

other measures that can be implemented to support the already existing interventions for the reduction of maternal and newborns deaths in Rwanda. What if nurses and midwives need refresher courses and access to updated clinical guidelines so that they can offer uniform and quality care to patients? What if we could attempt to use innovative approaches such as technology to offer instant BEmONC trainings and avail evidence – based clinical guidelines to nurses and midwives? Continuous trainings and timely access to BEmONC clinical guidelines could help in the reduction of clinical errors to ensure the quality of maternal and newborn care.

Furthermore, articles on the implementation research models [69,70] increased my interest given the fact that they deal with evidence-based interventions (EBI) that have been shown to work in other settings and one wishes to scale up the EBI in his/her own setting [71,72]. Beside, electronic tools like mHealth have been shown to work in supporting maternal and neonatal services [73,74]. What if we try the EBI like mHealth and evaluate their feasibility in the Rwandan context? We could possibly learn something new in exploring the use of mHealth in childbirth care in Rwanda. In addition mHealth applications are known for their potential to make relevant and reliable healthcare information available to healthcare providers [74,75]. MHealth technologies, such as the SDA, provide reliable clinical guidelines and could improve knowledge and skills of nurses and midwives [28]. But, from the implementation science perspective, the SDA cannot just be used anywhere even though it was proven to be an effective method in quality of care for newborn resuscitation in Ethiopia [28,76]. Successful implementation of the SDA is context dependent [77,78]. Therefore, the focus of this thesis is to investigate the use of the SDA in supporting the management of birth-related complications in Rwanda. This research investigates the effect of the SDA on nurses' and midwives' clinical decision-making for the management of the two top frequent birth complications in Rwanda (newborn asphyxia and post-partum hemorrhage) via measuring, combining and theoretically interpreting three implementation outcomes: the effectiveness, the symptomatology and the acceptability of the SDA. The research is guided by the implementation research model by Proctor [30].

1.3. The summary

This chapter one provided an overview of the present study about the SDA for clinical decision making on BEmONC among nurses and midwives in two district hospitals in Rwanda. The background of the research context highlighted the essential role of the health care system in preventing maternal and newborn deaths. The achievement of the MDG 4 and 5a targets with a

remarquable improvement in the quality of maternity and newborn care services in Rwanda is presented. The way forward for achieving the SDG three target and possible interventions to deal with quality birth care are introduced. One of the key interventions to stop preventable maternal and newborn deaths is the BEmONC services which is the focus of the current study. The chapter also emphasized the critical role of nurses and midwives in providing BEmONC services in district hospitals in Rwanda. This was followed by definitions of key concepts as well as their impact on maternal and newborn healthcare services. In the following chapter, the analysis of the research problem, the research gap, the theoretical foundation and the conceptual framework will be discussed in detail with the help of a critical review of scholarly literature.

Chapter two: Literature Review

2.1. Introduction to the chapter

This chapter presents the review of theoretical work and research published on the subject to relate the present study with the previous studies on the topic. This review is aimed at covering all the important aspects related to maternal and newborn healthcare and provides the reader with complete details that would help in understanding the subject and its background information. Another purpose of the review is to simplify the complex process of childbirth care with a particular focus to BEmONC services in a way that all the important aspects of this complex process remain in sight. The involvement of mHealth technology in the improvement of maternal and newborn healthcare services is also discussed.

To obtain the literature relevant to this study, a systematic approach was used. The research question was broken down into key thematic areas. These include: BEmONC and quality of childbirth care; BEmONC and maternal and newborn outcomes; BEmONC and knowledge and skills of nurses and midwives; mHealth/SDA and maternal and newborn care; mHealth/SDA and BEmONC; mHealth/SDA and knowledge and skills of nurses and midwives; mHealth/SDA and clinical decision-making; mHealth/SDA and BEmONC Outcomes; and mHealth/SDA user acceptance and feasibility. For each theme, keywords, phrases, synonyms and alternative spellings were identified and later used to search for the literature in Cochrane, Scopus, PubMed, google scholar, HINARI, science direct and ProQuest databases. Because of the critical importance of literature review for this study, only reliable and scholarly literature has been reviewed. The literature reviewed here mainly consists of articles from peer-reviewed journals and books written by the experts on the subject. This was done to ensure that all research evidence that fall within the scope of BEmONC and mHealth applications were retrieved. Only papers published in English were selected according to publication date, study design and study population.

At the end of the chapter, a summary of the literature review has been presented. A theoretical orientation and a conceptual framework were derived from the synthesis of the literature. Based on what has been learnt from the literature review, the researcher developed the objectives to be evaluated through the empirical quantitative and qualitative research on the investigation of the SDA in the context of Rwanda.

2.2 Basic Emergency Obstetric and Newborn Care Services (BEmONC)

2.2.1. Quality of care for BEmONC services

Most maternal and newborn deaths are attributable to a handful of preventable causes. It is estimated that 295,000 women, more than 2 million stillbirths, and 2.5 million early newborn deaths occur each year worldwide [79,80]. More than 90% of these deaths happen in low- and middle-income countries [81]. Several factors that lead to these deaths have been documented. These include pre-eclampsia, obstructed labor, infections, post-partum haemorrhage, hypertensive disorders and newborn's failure to breathe [2,62,82]. Strategies for prevention and treatment are grouped in a set of seven key obstetric services or "signal functions" which have been identified by the WHO, UNICEF, and UNFPA referred to as Basic Emergency Obstetric and Newborn Care (BEmONC) that can be provided by nurses and midwives [83].

Quality of care is essential to maternal and newborn survival. Efforts toward lowering maternal and newborn mortality in countries where levels are high have focused on introducing essential interventions before, during, and after childbirth for millions of women and their babies [42,84]. BEmONC is one of the key interventions to reduce maternal and neonatal deaths. However, the one reason why progress has fallen short of expectations is the quality of care associated with the implementation of these key interventions [85]. Quality care can be defined as "care which is effective, safe and a good experience for the patient" [86]. The WHO defines it as "the extent to which healthcare services provided to individuals and patient populations improve desired health outcomes" [87]. To achieve this, healthcare needs to be safe, effective, timely, efficient, equitable, and people-centered [87].

The quality of BEmONC services is important to improving maternal and newborn health [88]. However, the mere existence of BEmONC services does not guarantee their use for women, nor does the use of those services guarantee optimal outcomes [34,89]. Poor quality of care has been highlighted as a key factor to explain why women either do not access services at all, access them late, or suffer avoidable adverse outcomes despite timely presentation [90,91]. On the other hand, the barriers to instituting quality of care are complex and are often linked to insufficient monitoring to inform appropriate responses [34]. Strong accountability mechanisms are also lacking to ensure that quality of care data informs better practices and care [34].

In Rwanda, access to healthcare services is ensured with 91% deliveries happening in health facilities [44]. However, the health system failure was identified as the main factor responsible for the majority of maternal and newborn deaths (61%) [63]. In this context, the health system consists of timely provision of quality essential services such as BEmONC to deal with birth complications. The services should be offered by skilled birth attendants. Several studies explored different approaches to quality maternal and newborn health care through the availability, affordability, acceptability, and/or quality of the services [92,93].These researches revealed insights on the role of BEmONC in the reduction of maternal and newborn deaths. One of the key indicators to the reduction of maternal and newborns deaths is to increase assistance of midwifes or skilled birth attendants offering BEmONC services [84].

The notion of quality of care in BEmONC is multidimensional [61]. Several frameworks have been developed to operationalize key dimensions of quality of care. Examples include the Donabedian model, which conceptualized quality of care according to three dimensions: (1) "structure", referring to the settings where care is delivered; (2) "process" referring to whether or not what is known to be good medical care has been provided; and (3) "outcomes" referring to the impact of care on health [94]. In the current research, we focused on the two last dimensions: "process" and "outcomes". The reason is that BEmONC services have been adopted and operating in district hospitals of Rwanda for more than 10 years but still we are facing maternal and newborn deaths from preventable causes [66]. Evidence has shown that while remarkable progress has been made toward the reduction of maternal and child mortality in many low-resource countries, including Rwanda, critical challenges remain in provision of high-quality BEmONC services [66]. The evidence further claims the need to ensure that skilled birth attendants have the knowledge and skills needed to provide the BEmONC services that save maternal and newborn lives [95,96].

2.2.2. Knowledge and skills of BEmONC

BEmONC services are crucial in managing pregnancy and delivery complications [81]. There is evidence that if BEmONC services are offered well and in a timely manner they lead to the reduction of maternal and newborns deaths from preventable causes [2]. Research evidence has revealed that BEmONC initiation in health care facilities has helped in the drop out of maternal and newborn deaths by 60% in five years of evaluation [97]. However, many factors govern the success of BEmONC services. For instance, the knowledge and skills of nurses and midwives are essential in the provision of high-quality BEmONC services [83]. Nurses and midwives are the

frontline healthcare providers in childbirth care, mostly in Sub-Saharan healthcare settings [98,99]. Other factors include: the health care facility readiness to provide BEmONC services in terms of materials, consumables, staffs and clinical guidelines [3]. Most of these factors are related to the health care system and context. Several studies have attempted to link BEmONC services with the maternal and newborn outcomes and they have identified a strong association between the provision of BEmONC services and positive maternal and newborn outcomes [2,4,83]. But, few studies focused on the knowledge and skills of nurses and midwives who offer the services. Nevertheless, for any healthcare facility to be ready to successfully provide BEmONC services, it should have highly competent clinicians in BEmONC.

In addition, knowledge and skills of nurses and midwives in BEmONC predict the mother and newborn clinical outcomes [4]. While most pregnancies and births are uneventful, all pregnancies are at risk. Approximately 15% of expected births worldwide will result in life-threatening complications during pregnancy, delivery, or the postpartum period [2]. Healthcare providers skilled in BEmONC services are essential to deal with those delivery complications [100]. Kerina et al (2019) emphasizes the crucial role that nurses and midwives play in the provision of BEmONC services [84]. Nurses and midwives, particularly in Sub-Saharan hospitals, are the key clinicians in childbirth care. They attend a formal education in BEmONC among other components of childbirth care and they are the ones that primarily deal with birth-related complications [11]. However, several studies have documented that knowledge and skills of nurses and midwives in low-resources settings are not always at an acceptable level despite their previous education [67,101,102]. Yet, maternal and neonatal deaths could be prevented by quality obstetric and neonatal care services.

The knowledge and skills of nurses and midwives about BEmONC in sub-Saharan Africa often do not meet the required standards despite their previous training [70, 71]. This particular subject underwent extensive research with conflicting findings in the past [2,4,5,33,34,84,103]. Some studies concluded that nurses and midwives have limited knowledge and skills towards BEmONC [67,104]. Ruchi et al (2017) assessed the knowledge and practices of obstetric care providers in Bugesera district, Rwanda and found that there was a low level of knowledge in safe motherhood services, with the mean of 46.4% of 50 questions answered correctly [105]. On the other hand, Joanna et al (2013) found that nurses and midwives are knowledgeable but they continuously need

refresher courses to update their knowledge and skills [83]. Other studies revealed that on the–job-training in BEmONC was associated with improved knowledge and skills for all cadres of healthcare providers working in maternity wards in both sub-Saharan Africa and Asia [106]. In contrast, research conducted in Ethiopia found that while the majority of trainees had a good comprehension of the BEmONC from the in-service trainings, most of them did not achieve knowledge-based mastery in the immediate post-training [5]. A similar opinion was expressed by Maine (2014) who proposes that in addition to on-the-job training, nurses and midwives need instant access to updated clinical guidelines to be able to offer quality care [3]. One limitation for both these studies is that they did not clearly assess if the trainings were translated into improved service delivery. Also, the improved knowledge and skills through the availability of on-the-job training and access to updated clinical guidelines would not be enough on their own to ensure the prevention of maternal and newborn deaths in the absence of adequate materials and accessible health care in low resources settings.

Assessments of the availability and coverage of BEmONC in low-resource settings, revealed that even with structures in place, equipment and consumables available, staff were unable to deliver the signal functions of BEmONC effectively [2]. A study conducted in South Africa established that the combination of lack of knowledge and skills is likely to be the primary reason the advantageous evidence-based practices are still not widely adopted in resource-poor settings [33]. On the other hand, Grol and Grimshaw (2003) who argue against the assertion that health professionals are not knowledgeable, suggest that health professionals need continuous access to updated healthcare information and clinical guidelines to support their decision making during practices [107]. In summary, BEmONC knowledge and skills of nurses and midwives combined with full access to clinical guidelines could lead to better obstetric care thus the reduction of maternal and newborn deaths. Furthermore, research recommends mHealth, the use of mobile phones to improve health systems, as a solution that could potentially support nurses and midwives for better service delivery [74,108].

2.3. Mobile Health (mHealth) Applications

2.3.1. Mhealth applications overview

Mhealth refers to the practice of medicine and public health, supported by mobile devices (mobile phones, smartphones, tablets, smart watches)[27]. This technology has progressed with a considerable rise in mobile phones subscriptions worldwide. There came a rise in mHealth

initiatives in countries around the world with a general assumption that better data, better communication, and better information will be linked to improved health outcomes [109]. The excitement about the potential of "mHealth" centers especially on how mobile technology can be applied in low-income countries where the population has limited access to quality healthcare services. Also, mHealth strategies are being used to overcome factors that are related to limited access to quality care, such as geographic distance to services, social marginalization, inadequate skilled medical personnel or a lack of financial resources [27,74,75,110]. The mHealth concept with maternal, newborn and child health as a user case was widely discussed by mHealth Alliance [75] which established a model describing three categories of mHealth applications. The three categories are divided according to three components of end-users, namely health systems; healthcare providers; and clients/patients. These categories are characterized by a range of expected outcomes that assume improved population health and/or improved health outcomes [75]. The safe delivery mHealth application which is the focus of the current study belongs to the healthcare providers' category.

Mobile health technologies are being increasingly used to meet the information needs of healthcare workers in sub-Saharan Africa [111]. Recent advances in the mobile telephony technology; significant infrastructure improvements in sub-Saharan Africa; the low start-up development costs; end-user familiarity and increased research funding make mobile phones a strong candidate as the tool for health information delivery in developing countries [112,113]. Also, the mobile phone market in Africa is the fastest growing in the world [114]. Africa was the first continent where mobile phone use exceeded landline use and in 2013 mobile phone penetration rate in Africa was 30% and growing [115]. There is growing interest in using the existing and evolving mobile phone infrastructure in Africa as a means of delivering health information solutions. However, systematic reviews on the topic have found that most published studies have been brief pilot and feasibility studies with limited evaluation and little mention of project scalability and long-term feasibility [116].

In addition, mHealth applications are known for their potential to make relevant and reliable healthcare information available to healthcare providers [117]. Evidence suggests that mHealth applications are good approaches to the better delivery of health care services [79, 80, 81]. Besides, electronic decision support tools can help to reduce clinical errors and to ensure the quality of care

at the point of service delivery. There is growing evidence of the effectiveness of mHealth interventions in LMICs, particularly to improve adherence to treatment, meeting appointments, data collection and the development of supportive networks for health professionals [121,122]. However, many studies related to the use of mobile phones for improving maternal and newborns' health outcomes mainly focused on access to healthcare services [123]. Several mHealth applications are dealing with speed access to health facilities dealing with reminders for antenatal appointments and referrals of mothers [124]. Few mHealth applications are addressing quality service delivery with the main focus on the clinical decision support process in order to strengthen healthcare providers' knowledge, skills and practices [125]. Yet, having the knowledge and skills to diagnose and respond effectively in case the mother or newborn's life-threatening complications occur is a fundamental part of a skilled birth attendant's role and precede a safe delivery.

For instance, Speciale & Freytsis (2013) reviewed the usage of mHealth applications designed specifically for nurses and midwives and reported that most mHealth technologies for improving maternal and newborns' health outcomes mainly focused on access to health care services such as reminders for antenatal appointments and referrals of mothers [126]. A research study by Labrique (2013) which examined twelve common mHealth applications recommended more research for mHealth applications that address better service delivery with the primary focus on clinical decision support process [127]. The SDA is one of the recent mHealth applications (loaded in smartphones) which help in availing BEmONC clinical guidelines to support nurses and midwives' clinical decisions [128].

Effectiveness, feasibility, and acceptability are essential for the success of any mHealth implementation. A study of an mHealth application for rural Ghanaian midwives demonstrated that introducing such technology in low-resource settings can be challenging because of low levels of user acceptance, due to the fact that the application design was not matching the end users' needs and work environment [129]. Another study that evaluated callers' experiences of the health hotline in Malawi, recommended qualitative research methods for in-depth analysis of end users' experiences in order to gain an insight into the feasibility and acceptability of mHealth solutions [130]. Some authors posit that establishing feasibility and user acceptance is imperative for the achievement of any mHealth application in low-income countries [73,131–133].

There are few published studies on the use of mHealth applications in BEmONC in Africa [134] and none in Rwanda [135]. Further, the limited access to clinical guidelines and the lack of timely response to birth complications are significant causes of maternal and newborn complications in Rwanda [136]. Besides, innovative methods such as the usage, exchange, and reference to health care guidelines and protocols using mobile devices (mHealth) may support nurses and midwives in clinical decision making [38]. According to annual reports from WHO concerning Rwanda, there is an opportunity for the usage of mhealth technologies. Mobile phones ownership has been growing and in 2010 Holmes recorded more than 80% of the population with access to mobile phones [39]. This study, therefore, seeks to investigate the use of the SDA and its effects on knowledge, skills and clinical decision-making among nurses and midwives on BEmONC in district hospitals in Rwanda.

2.3.2. Safe Delivery mHealth Application (SDA)

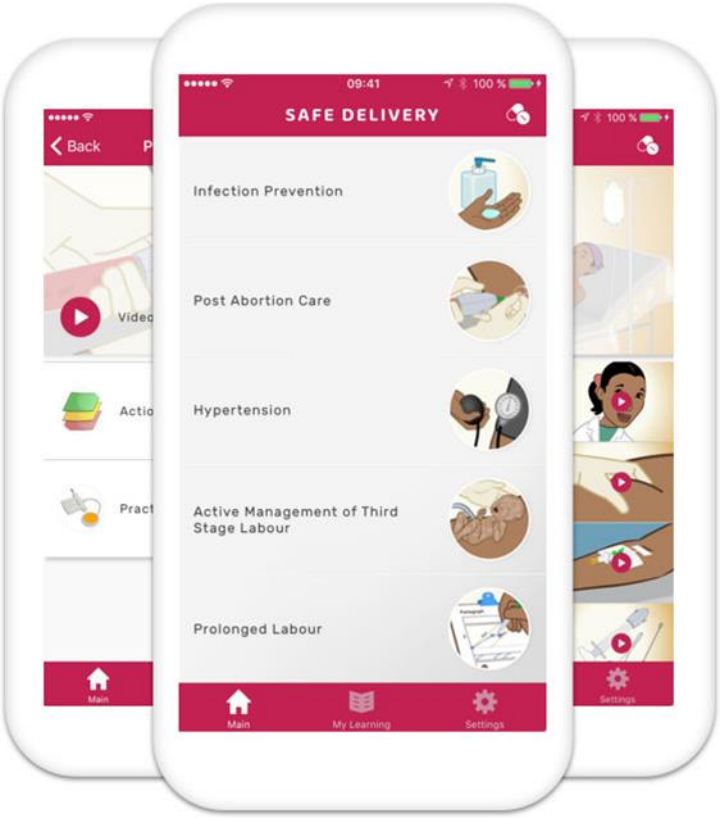

Figure 2.1. Example screenshots of the SDA dashboards

The development of the SDA started with the discovery of a world of inequality. Around 300,000 women and 5 million babies were dying from preventable and treatable birth complications

worldwide [137]. 99% of these deaths were occurring in low-income countries, mostly in Africa, representing an unacceptable global inequality [28]. An innovative solution was needed to deal with this challenge. Given that Africa was the second-largest market for mobile phones [78], the question was straightforward - what if mobile technology could be used to ensure safe births in Africa?

The SDA – developed by Maternity Foundation, Copenhagen University and the University of Southern Denmark – is a smartphone application that provides skilled birth attendants with direct and instant access to the clinical guidelines on BEmONC [78]. The SDA was developed to strengthen maternal healthcare by providing life-saving information and guidance to handle emergencies in pregnancy and childbirth even in the most remote settings [76]. The SDA has different features which help in decision support and continuous learning. The SDA contains easy to understand animated instruction videos, action cards, essential drugs lists with their indications, practical procedures guidelines and a learning platform [78]. All features and functions are designed for low-literacy, low-income settings and work offline once downloaded.

The SDA can be used as a job aid tool, as a training tool and as an instructive aid in emergencies [78]. Skilled birth attendants (SBA) can use the SDA in their practice by consulting action cards and drug lists to be assisted in their decision during an emergency. In the free time, the SBA can again play animated instruction videos and consult procedures descriptions to improve on his/her knowledge and skills [28]. Furthermore, the SDA offers an interactive learning platform "My learning" that can be adopted for a personalized learning journey to further improve knowledge and skills in the seven BEmONC signal functions. My learning offers evaluation process options with structured questionnaires. There are three levels within each module that increase in difficulty. Level one (Familiar) with basic and most essential questions. Level two (Proficient) with increased difficulty in clinical content and Level three (Expert) with extra information that makes the user an expert. To move to the next level, the user needs to pass the previous level. Once a user has become expert in all modules, he/she can take the certification exam. If this exam is passed with at least 70% the user becomes a Safe Delivery Champion and gains a certificate.

The SDA can be downloaded free of charge for iPhone at https://itunes.apple.com/dk/app/safe-delivery/id985603707?mt=8 and for Android at https://play.google.com/store/apps/details?id=dk.maternity.safedelivery&hl=en.



Figure 2.2. Users of Safe Delivery mHealth Application can choose to watch full-length videos (5–10 min duration), or a short sequence (1–2 min) from a particular video. The sequence of images above is from the postpartum hemorrhage video and illustrates how to perform bimanual compression.

In addition, The SDA has been tested for its effectiveness through a randomized controlled trial conducted in Ethiopia [78]. Through this trial, the SDA has been proven to be an effective method to improve and sustain the healthcare workers' knowledge and skills in neonatal resuscitation which is one of the seven signal functions of the BEmONC services [78]. However the implementation research models and theories suggest that any evidence based intervention (EBI) that has proven to work under controlled measures in a particular setting, cannot just be adopted elsewhere [30,138–140]. Proctor et al. (2011) proposes that in order to take an intervention from its efficacy under controlled settings to its effectiveness in a real-world setting with consideration of the specific context, implementation strategies will be needed for the scale-up of the innovation. But this may not work without a proper assessment of its implementation outcomes [30]. Therefore, The context matters in implementation of EBIs in a new setting and successful implementation of the SDA is context dependent [28]. Hence, this study will investigate the use of SDA in the context of Rwanda via measuring, combining and theoretically interpreting three implementation outcomes: The effectiveness, the symptomatology and the acceptability of the SDA.

2.4. Problem Statement

Rwanda's health sector has remarkably evolved, 91% deliveries take place in healthcare facilities attended by health professionals [44]. Despite several efforts to improve maternal and child health, the number of deaths remains high [63]. Common causes are preventable; 71.6% of maternal deaths result from direct causes and postpartum hemorrhage is the leading direct cause with 22.7% of all documented cases [63]. While, newborn asphyxia and its complications is the leading cause of neonatal mortality accounting for 38% of all neonatal deaths [59,141]. Limited BEmONC knowledge and skills among nurses and midwives, poor access to clinical guidelines and lack of timely response to birth-related complications are the significant causes of maternal and newborn mortality in Rwanda [11,68].

In research by Puri et al., (2012), the majority of nurses and midwives in Rwanda expressed that both their knowledge (60.6%) and skills confidence (72.2%) across fundamental topics of safe motherhood care need improvement [105]. Also, in-service training to keep them updated for better management of obstetric complications are still few due to limited funds [59]. Among the accountability mechanisms in place that the Rwandan government has been implementing since 2015 to bring down the numbers of maternal and newborn deaths, there are performance contracts, as well as performance-based financing models for health providers [66].

In addition, mHealth technologies, such as the SDA, can provide reliable clinical guidelines and improve knowledge and skills of nurses and midwives [28]. But, the SDA cannot just be used anywhere even though it was proven to be an effective method in quality of care for newborn resuscitation in Ethiopia [78]. Successful implementation of the SDA is context dependent [28]. Therefore, this study investigated the effect of the SDA on nurses' and midwives' clinical decision making for the management of the two top frequent birth-related complications in Rwanda (newborn asphyxia and post-partum hemorrhage).

2.5. Research gap

Maternal and newborn mortality remains a foremost public health concern as highlighted by the SDG three targets one and two [31]. The majority of maternal and newborn deaths are due to preventable causes and happen in low-income countries, like Rwanda [84,142]. One of the key interventions to help in ending preventable maternal and newborn deaths is the BEmONC services [5,33].The BEmONC is known as a package of seven essential medical interventions or 'signal

functions' that are key to deal with the main causes of maternal and newborn morbidity and mortality [143]. Research evidence has shown that many of the critical birth-related complications can be prevented or treated through timely and effective BEmONC [84]. Mahato et al (2018) emphasized the critical role of nurses and midwives in the provision of BEmONC services particularly in Sub-Saharan Africa [143]. Other studies indicated the benefits of BEmONC services on maternal and newborn outcomes [2,84]. However, the available literature remains characterized by gaps on the appropriate measures in assuring the quality of BEmONC [34].

The quality of BEmONC services is still a pressing issue. Previous studies on BEmONC have noted a number of barriers to successful implementation of BEmONC services in clinical settings, particularly in Sub-Saharan Africa [89]. Among the identified barriers, they include: insufficient knowledge and skills among healthcare providers, lack of in-service refresher courses or trainings, and limited access to clinical guidelines [89]. Indeed several researchers recommended that solutions that use mobile phones to improve health system functions, termed mHealth, potentially overcome these challenges [74,122,144–147]. However, there are very few published studies in the interest of involvement of mobile health in BEmONC services [144,145].

A number of studies have investigated the effectiveness of mHealth interventions in maternal health initiatives in low-income countries [74,122,123,131]. However, so far, no studies on the contribution of mHealth to improve quality of care via effective clinical decision making have been published [110]. In general, the evidence for effectiveness of mHealth interventions, particularly in low-income countries, is weak [74,147]. Many interventions on the use of mHealth for improving maternal and newborns' health outcomes in sub-Saharan Africa mainly focused on timely access to health facilities including reminders for antenatal appointments and referrals of mothers [148]. Few mHealth applications are addressing the support of healthcare providers within service delivery process in order to improve maternal and newborns outcomes [125]. Therefore, conclusions need to be drawn about impacts of mHealth interventions on continuous learning, clinical decision making and patient outcomes.

The SDA is one of the recent mHealth applications (loaded in smartphones) that can support in continuous learning and clinical decision making [28]. Since its development in 2014, the SDA has passed through rigorous scientific evaluations with diverse findings. In a randomized clinical trial conducted in Ethiopia, the SDA was associated with a significant increase in health care

workers' knowledge and skills in neonatal resuscitation and a nonsignificant 24% reduction in perinatal mortality [78]. In another study done in the democratic republic of Congo, the SDA increased health workers' knowledge and self-confidence in the management of obstetric and newborn emergencies [77]. However, in a study conducted in Ghana, the SDA was associated with an insignificant lower incidence of PPH [22]. Therefore, effective implementation of the SDA is context dependent and research on the implementation outcomes of the SDA is recommended, so as to inform interventions for work in specific contexts [28,30]. Besides, there is little knowledge on understanding the implications of the SDA from an implementation research perspective. In the present research, I evaluate three implementation outcomes; the effectiveness, the symptomatology and the acceptability of the SDA in order to understand the impact of the SDA on the delivery care process in the context of Rwanda.

2.6. Justification of the study

In Rwanda, there is an increasing awareness of the need to improve maternal and newborn health outcomes. Thus, several interventions are in place to improve access to healthcare and keeping four ante-natal visits per pregnant woman. These interventions include: the enhancement of community reach by the health system with the usage of community health workers (CHWs) and RapidSMS system for reporting, monitoring and proper follow-up of pregnant women. These interventions seem to be responding to the two first delays of the delay model; delay in recognition of danger signs and decision to seek care and delay in reaching appropriate source of care. However, there is a need to explore the third delay "delay in obtaining adequate and appropriate treatment" as Wilmot et al (2017) reported that in Rwanda, the delay in adequate care is still a critical factor to consider [149].Therefore, we need to put much efforts in interventions that support healthcare providers at the point of service delivery such as clinical decision support tools and in-service trainings. One of the solutions that address the two components (clinical decision support and continuous learning) in an easy, user-friendly format, is the SDA.

The rationale for this study is to seek solutions to the challenges encountered by nurses and midwives in providing BEmONC services in Rwanda, challenges that are due to limited in-service trainings and limited access to clinical guidelines to support their clinical decisions [68]. On the other hand, mHealth applications like the SDA can support nurses and midwives in continuous learning [28]. Research evidence demonstrated that the SDA is an effective method to improve and sustain the healthcare workers' knowledge and skills in neonatal resuscitation as long as three

to six months after introduction [77,78]. Implementing the SDA in district hospitals in Rwanda should facilitate access to BEmONC clinical guidelines, thus helping nurses and midwives in preventing and treating birth-related complications. However, interventions, tools, or treatments that have been shown to significantly solve health problems under controlled conditions still need to be tested before being scaled up in real-life settings [30]. In 2014, the Maternity Foundation documented that the SDA was already adopted in 40 low and middle-income countries [28]. However, the SDA is context dependent requiring consideration of the specific setting and needs of each country [77,78,150]. This study proposes to investigate the use of the SDA in the context of Rwanda.

Evidence on the usage of the SDA in Rwanda will inform policy and planning of the BEmONC prevention strategies. The results of the study describe the effect of the SDA on supporting the nurses' and midwives' clinical decision making in two BEmONC interventions; management of PPH and NR. These interventions, when successfully implemented play an important role in enhancing the safety of the mother and her newborn. The study will be the first step towards adoption of mHealth technology in improving decision making in the provision of BEmONC services in Rwanda. The primary contribution of the SDA is to improve health outcomes. The study sought to add to positive efforts ensuring that no woman/newborn dies during deliveries from causes that can be prevented by the use of the SDA mHealth technology. Furthermore, the research produced evidence that will contribute not only to the limited body of studies that are related to information communication technology (ICT) applications in healthcare in Rwanda but to existing literature on mHealth technology implementation outcomes for future researchers in the domain.

To reach the 17 sustainable development goals, which include reducing maternal mortality and neonatal mortality (Goal 3), [31]. The current research will further provide detailed information which may be utilized by the Ministry of Health in Rwanda to design and implement a carefully-laid strategy towards reduction of maternal and newborn morbidity and mortality. Also, it is crucial to mention that, no earlier studies have explored the effect of the SDA on clinical decision-making using a convergent parallel mixed-method approach. In addition, no previous studies have used an implementation research model to evaluate the SDA implementation outcomes. This study will

provide a significant contribution to the existing literature about the implementation of mHealth–based clinical decision support tools and mLearning applications in low-resource settings.

2.7. Theoretical and conceptual framework

To cater for the understanding of the complexity of the involvement of mHealth technology in childbirth care, particularly in the delivery of BEmONC services, a combination of technical and interpretive approaches, as well as multilevel and interactive processes, are needed. This thesis was informed by the work of several scholars and their theories and conceptual frameworks to understand the implementation of evidence-based interventions in new settings under real world context [30,69,138,151]. For this purpose, the researcher went through the theories and models used in previous studies on the subject and selected the most suitable ones. The theoretical foundation for the present study is pragmatism. This is a practical philosophy that is based on elements and ideas, which employ 'what works by different approaches and valuing both the subjective and objective knowledge [152]. In addition, the implementation research model by proctor [30] has been adopted as a conceptual framework for the study which helped the researcher in defining aspects of implementation of the SDA that were evaluated to determine implementation success.

2.7.1. Theoretical foundation: Pragmatism

Pragmatism definition and philosophical foundations

This research uses a convergent parallel mixed-methods approach. The underlying philosophy of the convergent parallel-mixed methods design is pragmatism [152–154]. Morgan (2014) defines pragmatism as "a philosophy in which the meaning of actions and beliefs is found in their consequences" [153]. Martina (2010) embraces pragmatism as a research paradigm that supports the use of mixed-methods as well as different modes of analysis and a continuous cycle of adductive reasoning while being guided primarily by the researcher's desire to produce socially useful knowledge [154]. Creswell (2011) documents that pragmatism is the leading philosophical worldview that provides foundation for convergent parallel mixed-methods research because it is a practical philosophy that is based on elements and ideas, which employ "what works" by different approaches and valuing both the subjective and objective knowledge [152]. In sum, pragmatism can serve as a rationale for formal research design as well as a more grounded approach to research that focuses on the problem to be researched and the consequences of the research. In this study, we will focus on what works with the SDA implementation in the context

of Rwanda. We will also evaluate the linkage between the SDA and maternal and newborn outcomes influenced by the level of knowledge and skills of nurses and midwives, the quality of services provided, and clinical decision made during the management of birth-related complications

Moreover, according to Morgan (2014), three main elements underpin the pragmatic philosophy. The first element is that actions cannot be separated from the situations and the context in which they occur [153]. This element is in particular related to the pragmatic argument that pragmatic trials, also called effectiveness trials, in which implementation research is part, seek to understand how and why evidence-based interventions function in real-world settings as opposed to highly controlled settings [155]. Similarly, Dahlberg (2007) argue that experience can only be measured within the notion of lifeworld, where we live, work and practice our ordinary actions, and the lifeworld is the "home for both subjective and objective experiencing" [156]. Hence, the significance of investigating the SDA in the context of Rwanda, even though it has been proven effective in a randomized controlled trial in Ethiopia.

The second element is that actions are linked to consequences in ways that are open to change. This entails the contextual nature of consequences. Pragmatists consider that the consequences and significance of an action can vary as much as the situation may change [157]. Pragmatists also believe that it is not probable to experience the same situation twice and the meaning of acts varies over time because of on-going discoveries and new experiences [158]. Hence, the beliefs about how to act in a situation are continually evolving. Such beliefs are called warranted beliefs [154]. The present study considers the recommendations of other studies about exploring the effectiveness of mHealth solutions in specific context, like Rwanda, before putting them into practices [22,159].

The third element is that action depends on worldviews that are socially shared sets of beliefs/principles and knowledge. Pragmatists treat beliefs as interrelated instead of isolated and the worldviews, which shape the experience, as a result of experience. Although, people have different actions, experiences and thus worldviews, varied degrees of shared actions and experiences among different people can be found leading to several degrees of shared beliefs and knowledge. When people share similar beliefs and knowledge about a specific phenomenon, they are likely to act in similar ways and get similar outcomes. Consequently, the worldviews are both

unique at a detailed level and socially shared at a broader level. This element is in particular, related to the clinical practice field in which similar approaches are expected in order to yield positive patients outcomes. When healthcare workers share similar clinical guidelines and have undergone similar type of training, they are likely to practice similarly for individual cases, take similar clinical decisions and get similar outcomes, preferably positive patients' outcomes.

Therefore, the ontological position for this research was both realist and relativist in consideration of the fact that a discoverable reality exists independently of the researcher, but also, what constitutes the reality differs from person to person. The epistemological assumption for the current research was both positivist and constructivist in consideration that the nature and forms of knowledge can be objective and/or subjective at some points. Both deductive and inductive methodologies were used to determine the effect of the SDA on clinical decision making and BEmONC outcomes and to understand the SDA implementation from research participants' perspectives.

It is, therefore I argue that pragmatism is a suitable philosophical foundation for this research. Pragmatism philosophy guided my methodological plan which involved mixed-methods approaches. To investigate the effects of the SDA on nurses' and midwives' clinical decision-making towards PPH management and NR, data on three main variables (effectiveness, symptomatology and acceptability) were obtained, analyzed, combined and scientifically/theoretically interpreted using both quantitative and qualitative research methods. Nothing is known about the effects of the SDA on clinical decision-making from an implementation research perspective as mentioned earlier. Also, the SDA like any other evidence-based intervention is context dependent. Therefore, the focus in this research is on assessing implementation outcomes of the SDA in the context of Rwanda. The implementation research framework by proctor (2011) guides this research in order to ascertain a full exploration of the SDA implementation in Rwanda and explain the research findings.

2.7.2. Conceptual framework: Implementation research model

Implementation research model

The conceptual framework for this study is embedded in the implementation research (IR) model by Proctor (2011) [30]. The research aims to investigate the effect of the SDA on nurses' and midwives' clinical decision-making on the management of the two top frequent birth

complications in Rwanda (newborn asphyxia and postpartum hemorrhage) by measuring, combining and theoretically interpreting three implementation outcomes: the effectiveness, the symptomatology and the acceptability of the SDA. The IR model offers three different but interrelated types of processes. These are:

- The What? (The intervention strategy or the evidence-based solution), in this study, the intervention strategy is the safe delivery mHealth application.

- The How? (The implementation strategies), in the present study, these are strategies that may influence the implementation outcomes. They include: the health system structure and organization (district hospitals), the stakeholders (who cares about the improvement effort, who will be affected, who can facilitate, service consumers, providers, administrators) and all necessary activities that influenced the implementation of the SDA in the Rwandan context and lead to the evaluation of its outcomes.

- The outcomes (primary and secondary outcomes). For the current study they include; the effectiveness, symptomatology, and acceptability.

The current study assumes that the use of the SDA will improve BEmONC outcomes and in the long run help in the reduction of maternal and newborn morbidity and mortality. Proctor et al. (2011) proposes that in order to take an intervention from its efficacy under controlled settings to its effectiveness in a real-world setting with consideration of the specific context, implementation strategies will be needed for the scale-up of the innovation [30]. But this implementation process may not work without a proper assessment of implementation outcomes of the proposed innovation [30]. Besides, implementation research requires intervention outcomes that are conceptually and empirically distinct from those of service and client. The framework positions the service outcomes (effectiveness) as preceding both client outcomes (symptomatology) and intervention outcomes (acceptability). Because the SDA effectiveness would predict its symptomatology, and acceptability. Evidence on the use of the SDA will inform the planning for BEmONC prevention strategies, it will also contribute to existing literature of mHealth implementation outcomes.

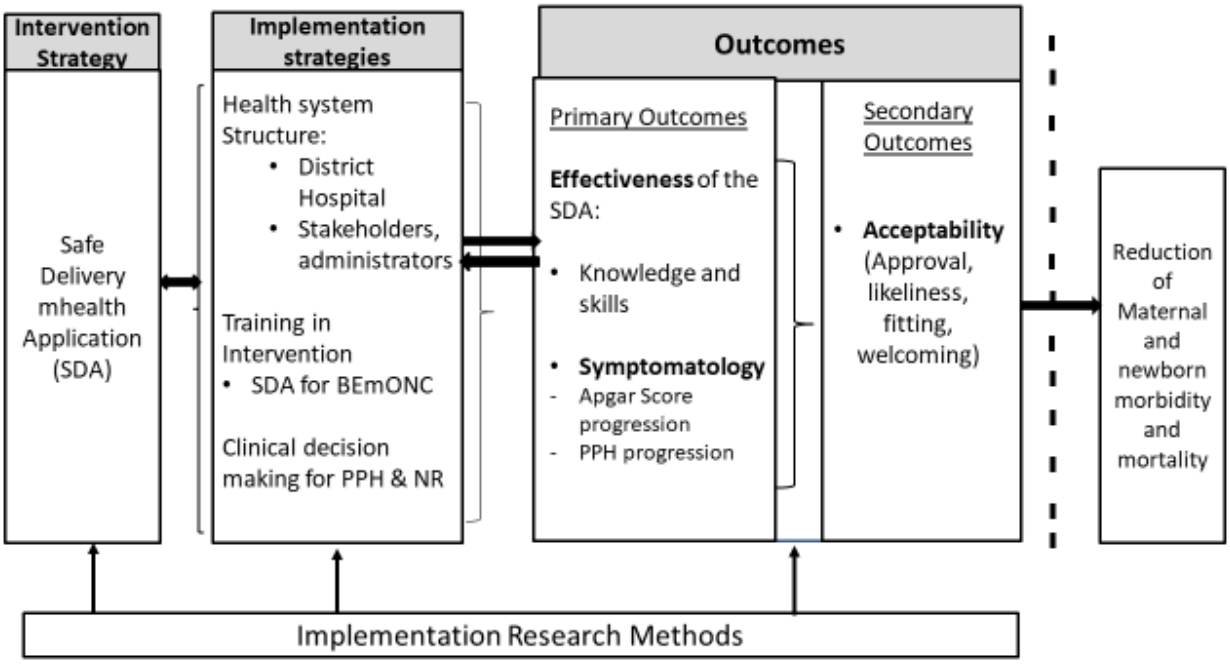

Figure 2.3. Conceptual framework adapted from the Implementation Research (IR) model by Proctor (2011).

2.8. Research questions and objectives

The aim of this research is to investigate the effect of the SDA on nurses' and midwives' clinical decision-making on the management of the two top frequent birth complications in Rwanda (newborn asphyxia and postpartum hemorrhage) by measuring, combining and theoretically interpreting three implementation outcomes: the effectiveness, the symptomatology, and the acceptability of the SDA. The overall research question: As predicted by the implementation research framework by proctor [30] is: can the effect of the SDA on nurses' and midwives' clinical decision-making be investigated by measuring/interpreting its effectiveness, symptomatology and acceptability? This research was guided by specific quantitative and qualitative objectives under three main research questions as follows:

1. What is the effectiveness of the SDA in district hospitals in Rwanda?
   - To describe nurses' and midwives' knowledge, skills and perceptions on the management of PPH and NR at baseline in two district hospitals in Rwanda.
   - To assess the effects of the SDA on knowledge and skills of nurses and midwives in the management of PPH and NR in two district hospitals in Rwanda.
2. What is the symptomatology of the SDA in district hospitals in Rwanda?

- To document BEmONC outcomes: PPH and Apgar score progression at baseline, in two district hospitals in Rwanda.
- To assess the effects of the SDA on nurses and midwives' clinical decision making with regards to maternal and newborn outcomes in two district hospitals in Rwanda.

3. What is the acceptability of the SDA among district hospital stakeholders in Rwanda?
   - To describe the nurses' and midwives' experiences, stakeholders' perceptions and the implementation process of using the SDA in two district hospitals in Rwanda.
   - To explore the acceptability of the SDA in PPH management and NR, among stakeholders: managers, nurses, and midwives in district hospitals in Rwanda.

2.9. Influences for my choice of research method

The choice of research method generally depends on the philosophical paradigm and the level of depth of information needed. The methods used in previous studies of the similar area can also influence the choice of methods with regards to the validity and interpretation of the findings. The current study base on the pragmatism paradigm as a philosophical foundation and uses both quantitative and qualitative methods. This is due to the fact that with only qualitative methods it is difficult to investigate the effect of mHealth technology on patient outcomes. Also, there is no objective results verification with qualitative approach because they mostly use open-ended questions and the participants have more control over the content of the data collected. Yet again, quantitative methods' inability to control the environment may cause biased data. Also, quantitative method provides limited outcome with closed ended questionnaire. This research will improve the design by mixing the two methods to better assess the effectiveness, symptomatology, and acceptability of the SDA in the context of Rwanda.

2.10. The summary

Rwanda, like many other sub-Saharan nations, faces a public health crisis of high maternal and newborn mortality rates. Large health disparities exist between Rwanda and the developed world, as well as within Rwanda itself between the more affluent urban populations and the poorer rural ones. These challenges are exacerbated by a lack of enough trained healthcare workers to meet the needs of the population. In low-Resources settings, primary care is provided primarily by nurses and midwives. These nurses and midwives are responsible for a wide scope of practice, including childbirth care. However, they have little opportunity for continuing education and rely heavily on

pre-service training as their knowledge-base. This is concerning due to the inconsistency in pre-service training as well as the midwives' limited access to updated clinical guidelines. Pre-service training programs may not prepare novice nurses and midwives for the challenges of childbirth care and timely response to birth-related complications. These gaps in training and continuing education should be taken into consideration in the daily clinical practices.

The review of literature highlighted in the chapter two, suggests that BEmONC services are crucial to save mothers and newborns from birth-related complications. The evidence, also recommends mHealth applications as one of the important solutions to support healthcare providers in decision making thus helping in improvement of delivery of healthcare services. One of the recent promising mHealth applications is the SDA that can be used as a job-aid and a training tool. But, from the implementation research perspective, the SDA cannot just be implemented elsewhere even though it was proven to provide promising results. The context matters and there has to be well thought implementation strategies that are in line with the real-world context. Again, according to proctor (2011), there are a number of implementation outcomes that need to be evaluated to determine the success of implementation of any evidence-based intervention [30]. The application of specific implementation strategies and the evaluation of implementation outcomes of the SDA will help us understand the implementation of the SDA in the context of Rwanda. Therefore, assessing the effectiveness, symptomatology and acceptability of the SDA using a pragmatic approach in the context of Rwanda is an important area to explore for additional research. The following chapter will discuss the methodological approaches to this PhD work.

Chapter three: Methodology

This chapter presents the overall methodological approach to the PhD. It does not repeat the methods of the individual papers and draft manuscripts, but rather justifies the study design and overall construction of the PhD [160]. The chapter provides a detailed research approach that was used to investigate the use of the SDA in Rwanda and helps to contextualize the findings of the PhD. The various segments of this chapter include: the study setting, study design and methods, study procedures, study population, sampling and sample size, data collection techniques and study tools, and data management and analysis approaches. Ethical considerations are also discussed in this chapter.

3.1. Study setting

This research was done in Rwanda. The study was conducted in the maternity departments of two district hospitals in Rwanda, one urban (Masaka district hospital located in Kigali city) and one rural (Nyamata district hospital located in the eastern province) of the country. The urban and rural district hospitals were used to provide diverse findings. Each district hospital is serving an average of 255000 people [41]. The two hospitals have been offering BEmONC services for more than 10 years and play a significant role in childbirth care at their specific provinces, with more than 6000 deliveries per year in Nyamata hospital and 7200 deliveries per year in Masaka hospital. These hospitals may not be representative of all district hospitals in Rwanda because this research was a pilot study.[44]. A total of 33 midwives and 21 registered nurses are employed in both hospitals. Two midwives, one nurse and one doctor are available on each shift to offer care for 15 to 20 women.

District hospitals operate on a similar structure but rural hospitals are still lacking sufficient number of staffs [44]. While the overall number of women seems a lot to the capacity of the hospital, women occupy labour at different times and they may experience complication at different periods. In general, one midwife/ nurse takes care of seven women at every shift. Nurses and midwives working at the maternity department are responsible for guiding labour; following the woman up to the delivery and post-delivery care and offering the BEmONC services. They only call the doctor in cases of complications that are out of their control. Women that require critical observation and have prolonged labour are usually admitted to special rooms at the postnatal wards under the care of nurses and midwives working there. The Head of midwives

(maternity matron) work between wards to minimize the work overload and to supervise the service provision.

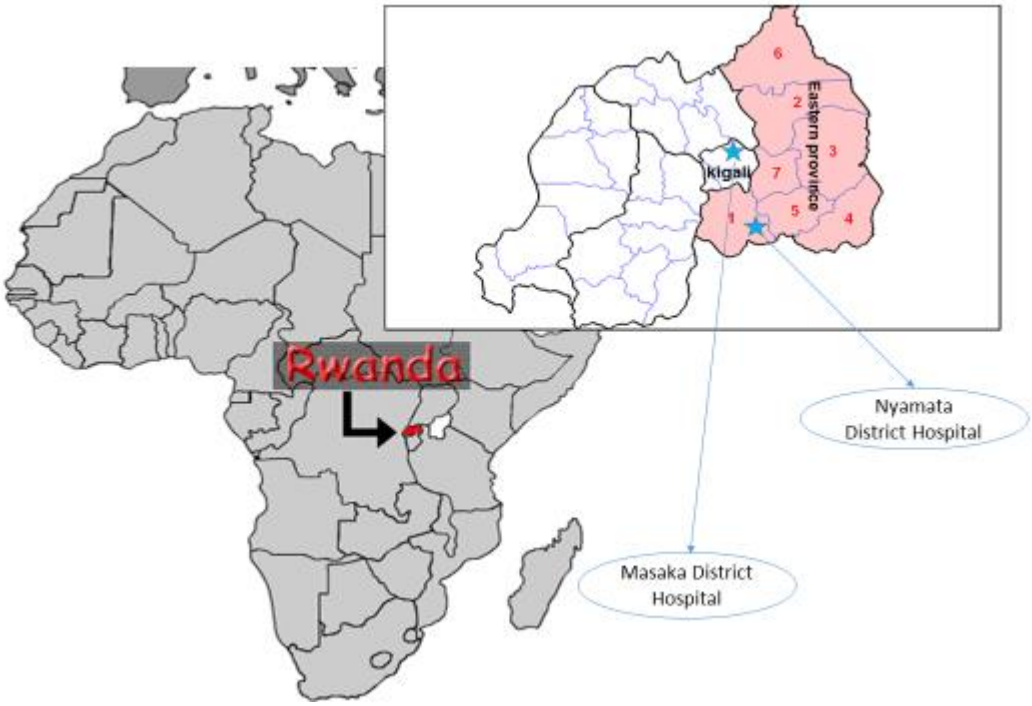

Figure 3.1. Map of Rwanda and study sites, Source: google.com

3.2. Study Design and methods

The study adopts a pre-post intervention design with a convergent parallel mixed-method approach. This method was deemed suitable for this study due to the complexity of the study; investigating the effectiveness, symptomatology, and acceptability of the SDA in the context of Rwanda in consideration of both end users and key stakeholders' perspectives. Quantitative and qualitative data were collected concurrently, analyzed separately and then synthesized to draw conclusions and deeper meaning [161].

Mixed methods study approach is increasingly being recognized as essential in conducting public health research [161,162]. This study used a convergent parallel mixed-methods study approach where both quantitative and qualitative data were integrated in order to obtain a comprehensive understanding. The convergent parallel mixed-methods research is an approach that combine both quantitative and qualitative methods in viewpoints, data collection and analysis with an equal reliance on both the quantitative and the qualitative techniques [161,163]. The convergent parallel mixed method research also adopts a pragmatic approach in consideration of both scientific and

interpretive paradigms with their ontological positions and epistemological assumptions. As was the case for our study, pragmatism was adopted as theoretical orientation that employs convergent parallel mixed-methods in order to understand the implementation of the SDA in the context of Rwanda. Because understanding the context in which evidence-based interventions are implemented is imperative for effective implementation research, the use of mixed methods is critical to understand research findings and the success or failure of implementation efforts. With reference to Creswell [164], the convergent parallel mixed – methods approach allowed the survey findings in this research to be linked with the identified themes in key informant and focus group interviews and generate overall interpretation about the effectiveness, symptomatology, and acceptability of the SDA in Rwanda.

3.3. Study Procedures

The current research is three-phased research using convergent parallel mixed methods to allow integration of quantitative and qualitative findings (See Figure 7 below for the graphic summary of research activities and methodology). The fieldwork spanned from 1st July 2019 to 30th April 2020.

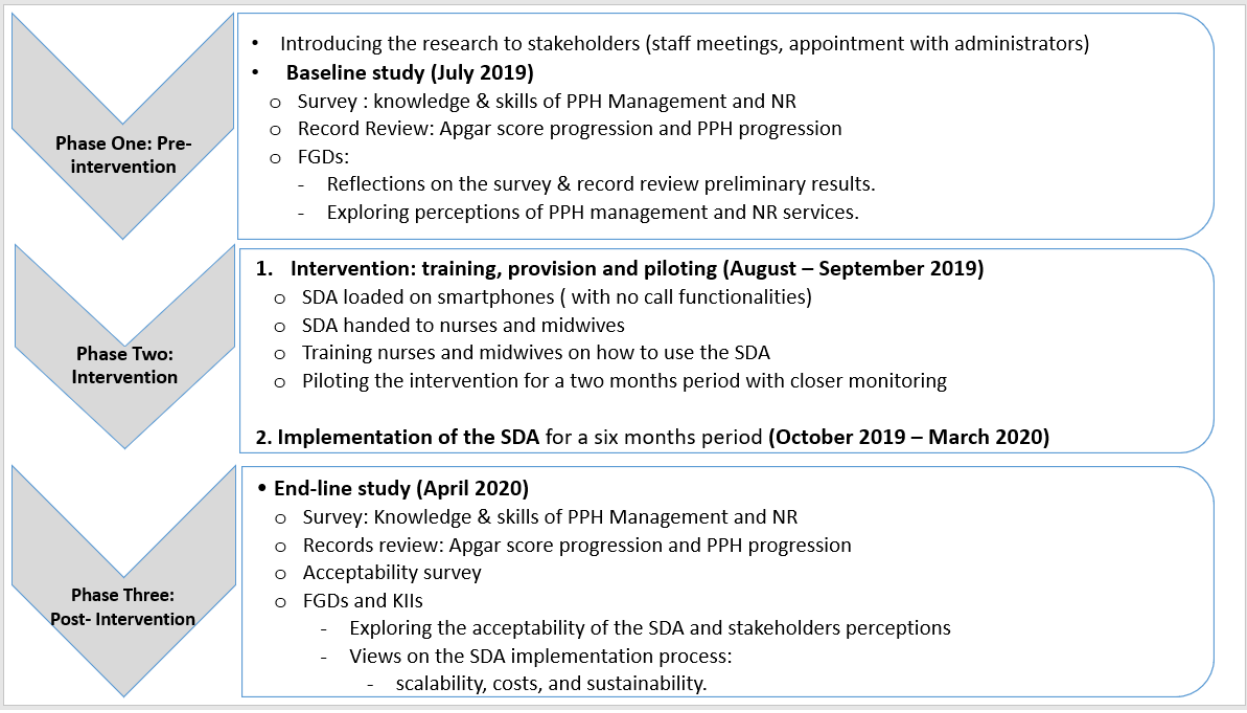

Figure 3.2. Phases of the study

3.3.1. Phase one: Pre-intervention study

Phase one, pre-intervention, involved the exploration and analysis of the health care system structure for the implementation of the SDA in BEmONC services, concluding with the selection of district hospitals as research setting. This phase also included the introduction of the research to different stakeholders via staff meetings at hospitals and appointments with hospital directors. This phase further comprised the baseline study which was mixed-method research using self-administered questionnaires and focus group guides to assess nurses' and midwives' knowledge and skills in NR and PPH management and their perceptions and reflections on PPH management and NR at baseline. Phase one also featured a cross-sectional study using a record review to document BEmONC outcomes; PPH and Apgar score progression at baseline (records for six months' pre-intervention). This phase took place in July 2019.

3.3.2. Phase two: Intervention

Phase two, SDA intervention and implementation, spanned from August 2019 to March 2020 and included two steps: 1) Two months of the capacity building in the usage of the SDA among nurses and midwives; that involved the provision of smartphones with the SDA and the pilot of the SDA with closer monitoring, and 2) The SDA implementation for a period of six months in two district hospitals in Rwanda.

Capacity Building workshop in the use of the SDA

Half-day SDA introduction trainings were conducted in August 2019 at both Masaka and Nyamata district hospitals. In total, the whole team (54 nurses and midwives) working in the maternity departments of the selected hospitals including two maternity matrons, and four research assistants were trained. The research assistants were selected based on their experience and had five years' experience in data collection (quantitative and qualitative) for health-related research. The research assistants had an additional half-day specific session, allowing time to discuss the study background, the importance of working with nurses and midwives as research participants, and ethics. This special session with research assistants centered on data collection activities, with attention to research tools. The trainings in the use of the SDA started with an explanation of the nature and purpose of the research. The content of the SDA introduction training encompassed a description of the SDA features and modules; a description of the SDA clinical content with particular focus on PPH and NR modules; an explanation of how to use the smartphone and SDA with joint video viewing (segments or full videos on symptoms, diagnosis, and management of

PPH and NR); consultation of action cards (clinical guidelines for decision support); searching strategies of information on essential drugs (indications for use and dosage, contraindications and adverse reactions); consultation of practical procedures; studying with MyLearning and testing knowledge using MyLearning questionnaires. Nurses and midwives spent 30 minutes getting to know the SDA on their own. This was followed by a practical session with interactive exercises in small groups on using the SDA as a job-aid during emergencies and as a learning tool. The practical session was performed on instructive mannequins (Mama Nathalie and newborn mannequin). Each of the study hospitals (Masaka and Nyamata) was allocated three smartphones, with pre-installed English and French versions of the SDA. Participants who owned smartphones, were encouraged to download the SDA for use during the training. The majority of participants (n = 47) downloaded the SDA on their personal smartphones for the training. Then, a one-month pilot of the SDA was conducted with nurses and midwives using the SDA as a learning tool and as a decision support tool on real patients.



Figure 3.3. A snapshot of the training practical sessions (using mannequins to perform NR and uterus massage following the clinical guidelines in the SDA)

Description of the six-month implementation of the SDA

Smartphones with the SDA were implemented at two district hospitals in Rwanda for a six months' period. During the six months SDA intervention, nurses and midwives used the SDA as a clinical decision support tool and as a learning tool with the assistance of the SDA installed on their personal smartphones or the smartphones provided by the researcher. The research team ensured that the provided smartphones were available to the team on duty at all times. The intervention also entailed two visits per week by the researcher and four research assistants to each of the study hospitals. During the visits, the researcher and the research assistants observed how the participants were using the SDA and encouraged them to use the action cards for clinical decision and to watch the videos while they were there. The researcher and the research assistants also provided guidance on how to start their learning journeys and made sure that each participant started learning for the PPH and NR modules. The manuscripts in the results section go into great detail on the implementation of the SDA either as a decision support tool or as a learning tool.

3.3.3. Phase three: Post-intervention

Phase three, post-intervention, included the end-line study which was a mixed method study using self-administered questionnaires, focus group guides and key informant interview guides to assess the effects of the SDA on nurses and midwives' knowledge and skills and their perceptions and acceptability of the SDA. Phase three also included a cross-sectional study, using a record review to assess the effects of the SDA on nurses and midwives' clinical decision making with regards to maternal and newborn outcomes. Stakeholders' perceptions of the SDA about its scalability, costs and sustainability were also explored in phase three.

3.4. Study population

The study participants included nurses and midwives, maternity matrons, districts hospitals managers, In charge of maternal and child health at the district hospital level and delivery records in staff registries (delivery registers).

3.5. Sampling and sample size

3.5.1. Sampling strategy

While the details of each population, sampling strategy and results are presented in the results section, the rationale behind each is highlighted here. The sampling method was purposive and used a census method for nurses and midwives working at the maternity departments and for the records review.

Inclusion criteria for district hospitals

- Districts hospitals offering BEmONC services for more than three years
- Per province, district hospitals were selected according to capacity (highest number of deliveries)
- Willingness to participate

Inclusion criteria for nurses and midwives

- Nurses and midwives who have a license to practice and full-time staffs in sampled district hospitals.
- Work experience of at least six months in obstetric care
- Willingness to participate

3.5.2. Sample Size

The participants of the study were purposively sampled and defined according to the outcomes of the study; effectiveness, symptomatology, and acceptability, in the following manner:

- **Effectiveness**

Using a census method, the study participants included all nurses and midwives working in maternity wards of sampled district hospitals estimated to be 21 nurses and 33 midwives. Self-reported questionnaires and simulated clinical scenarios were used to assess nurses and midwives' knowledge and skills in the management of PPH and NR prior to the introduction of the SDA and six months' post SDA intervention in district hospitals in Rwanda.

- **Symptomatology**

All Cases of PPH and neonatal complications recorded in delivery registries were reviewed six months' pre-intervention and six months' post-intervention. The PPH progression and the Apgar progression were abstracted for an assessment of the effects of the SDA on nurses and midwives' clinical decision making with regards to maternal and newborn outcomes.

- **Acceptability**

In addition to the 21 nurses and 33 midwives surveyed for the effectiveness, two district hospital directors, two maternity matrons, and two persons in charge of maternal and child health at the district hospital level participated in the investigation of the SDA acceptability. Semi – structured interviews were conducted to explore the acceptability of the SDA together with opinions on its scalability, costs and sustainability. Table 3.1. below summarizes the research participants by

study objectives and highlights the study tools and links to the variables of the conceptual framework described in Chapter two.

Table 3.1: A summary of research participants and research tools

Objectives	Research Participants	Total number (N)	Research tools	Conceptual contribution
1 & 2: Pre & post knowledge and skills surveys	Nurses and midwives	54 Respondents	SAQs--Quantitative study (Adopted from the Maternity Foundation)	Effectiveness
1: Perceptions and reflections	Nurses and midwives	26 Participants	FGDs--Qualitative study	
3 & 4: Pre & post maternal and newborn outcomes	Records Review	114 cases of PPH and 213 cases of newborn asphyxia	Data extraction sheets	Symptomatology
6: Acceptability survey	Nurses and midwives	54 Respondents	SAQs--Quantitative study (Adopted from the Maternity Foundation)	Acceptability
5 & 6: Acceptability, perceptions on the implementation process	Nurses and midwives	24 Participants	FGDs--Qualitative study	
	Maternity matrons & district hospitals managers, responsible for maternal and child health	6 stakeholders	KII_Qualitative study	

3.6. Data collection and Study tools

Data were collected in accordance with the study objectives. The study proposed to use 3 types of data collection techniques using both quantitative and qualitative methods as follows:

3.6.1. Quantitative Study

- To assess the effects of the SDA on nurses and midwives' knowledge and skills in the management of PPH and NR in district hospitals in Rwanda:

A self -administered questionnaire was used for the before and after assessment of knowledge and skills. A validated tool according to Maternity foundation [28] was adopted, only questions regarding post-partum hemorrhage and neonatal resuscitation were considered. The knowledge questionnaire was composed by 36 questions for PPH management and 37 questions for NR with single and multiple responses options (Appendix 3). The skills questionnaire included six (6) simulated clinical cases for PPH and four (4) simulated clinical cases for NR with single and multiple responses options (Appendix 3). Permission to use the tools was sought from Maternity foundation.

- To assess the effects of the SDA on nurses and midwives' clinical decision making with regards to maternal and newborn outcomes in two district hospitals in Rwanda:

A record review was performed using data extraction forms (Appendix E). The number of minor PPH that progressed to severe PPH, as well as the Apgar score, 1 min, 5min, and 10 min after delivery were recorded and analyzed for relative risk before and after the SDA intervention.

- To explore the acceptability of the SDA in PPH management and NR, among nurses and midwives in district hospitals in Rwanda.

A self -administered questionnaire developed by maternity foundation was adopted and used for the acceptability survey (Appendix 5). In addition, we sought permission to use the tool from the Foundation. The tool was composed of five (5) Likert scale questions and 13 questions with single and multiple responses options.

The content and study tools of the SDA are primarily based on WHO guidelines and have been validated by an international group of global health experts [28].

3.6.2. Qualitative Study

- To explore perceptions and reflections of PPH and NR and the acceptability of the SDA among stakeholders: managers, nurses, and midwives in district hospitals in Rwanda

The researcher used semi-structured interview guides for key Informant Interviews (Appendix 10), as well as focus group discussion guides (Appendix 8 and 9) for focus group discussions. The qualitative study participants were nurses and midwives, maternity matrons, district hospitals

directors and the person in charge of maternal and child health at the district hospital level. They were invited by verbal recruitment and letter. The interviews were tape/digitally recorded and transcribed.

All the instruments were written in English, and a professional translator translated them in French because the two languages are both professionally used in Rwanda. Besides, the FGD guides and KII guides were translated in Kinyarwanda (the local language), and the facilitated key informant interviews and focus group discussions allowed the use of Kinyarwanda when needed to enable participants to express themselves freely.

A pilot survey was conducted to pretest and strengthen the usability of the instruments in a district hospital different from the study settings. The instruments were tested with five nurses and/or midwives and one district hospital manager. The participants consented for participation in the pilot study. Based on the results of the 4 surveys and two interviews, the researcher addressed inconsistencies in the instruments before using them for data collection. The pilot study also helped the researcher to know how long the surveys and interviews will take. More details of all data collection and processing are elaborated upon in respective papers, which are presented in Chapter four.

3.7. Data Management and Analysis

Various types of data analysis were applied over the course of the PhD research, given the number of data sources and methods. These are described in detail with each publication (see Results Chapter) and summarized in the protocol publication [160].

3.7.1. Quantitative data

The Data analysis using STATA software was done. Double data entry was used to maximize the accuracy of the data entry. Data cleaning was done using the study questionnaire to check if the data from participant's answers recorded in the dataset match with the answers that were in the questionnaire. For the knowledge and skills questionnaire, the percentage of correct answers were calculated by dividing the number of questions answered correctly by the total number of questions. Mean scores across all knowledge and skills questions were computed to measure their differences by comparing the means at baseline, and at end-line. Data were summarized with descriptive statistics (mean, median, standard deviation, percentiles for numerical variables; frequencies, and percentages for categorical variables). A paired t-test was used to compare the

mean and medians in two groups respectively. Knowledge and skills of nurses and midwives were correlated with their level of training, the number of years of experience in maternity, their location (urban and rural) the experience with smartphones and the previous attendance to in service trainings to measure if they are differences in knowledge and skills according to considered variables. Then, for the symptomatology evaluation, the recorded newborn outcomes and maternal outcomes were compared at baseline and end-line using Fisher's exact test. Further, descriptive statistics were employed to analyze the acceptability survey data.

3.7.2. Qualitative interviews

The Data analysis using NVIVO software was done. Thematic analysis using a hybrid approach (inductive and deductive) was performed for the qualitative component. The interviews were transcribed verbatim. Braun & Clarke (2014) distinguishes between a deductive thematic analysis, that is driven by the specific research questions, and an inductive one that is more driven by the data itself [165]. This study's analysis was driven by the research questions and the data itself and was both inductive and deductive. The researcher read and re-read the transcripts to be familiar with the data after that she generated a codebook and initial codes. Then tested the codebook in a sample of transcripts, searched for themes, reviewed themes, defined themes and developed a thematic map that illustrates the relationships between themes and finally generated a code report and interpreted the data.

3.8. Validity and Reliability

As defined by Turnock & Gibson (2001), Validity is an indication of the extent to which an instrument measures what it is supposed to measure [166]. In this research, the self-administered questionnaires were pre-tested with nurses and midwives in another district hospital rather than the study setting. Reliability refers to dependability or consistency of the measurements [166]. The research assistant who helped the researcher in data collection were trained to ensure standardization of the data collection process. For the qualitative data, reliability and validity were ensured through coding by multiple persons and disagreements resolved by a team.

3.9. Integration of quantitative and qualitative components

Integration of the quantitative and qualitative data was done at the interpretation and reporting level [167], and was reported differently for the different published and under review articles. A detailed description is provided under each specific article. The interpretation of connected findings is presented in chapter eight.

3.10. Ethical Considerations

This study has been approved by the Human Research Ethics Committee of the University of the Witwatersrand (M190258) and the University of Rwanda, College of Medicine and Health Sciences' Institutional Review Board (No. 377/CMHS IRB/2018). Permission to conduct the study were sought from the Institutional Review Board of the Ministry of Health in Rwanda and the District Hospitals. All participants were informed of their rights before the study in the form of information sheets (see Appendices F-H). Anonymity was ensured by not requiring names from participants but using unique identification numbers in place of names. Data were only collected after written consents were received from all study participants (See Appendix I for example). Since there was a need for interviews to be tape-recorded, separate consent forms were offered to participants to obtain consent for tape-recording them (See Appendix J for example). The information discussed during the individual interviews was only accessible to the researcher and supervisors. All paper-based data were only accessed by the researcher and supervisors, and were kept under lock and key. Electronic data are stored in password-protected files. Informed consents were sought from all the study participants.

3.11. Dissemination of Study Results

A copy of the final report and any published paper(s) or abstracts of papers outlining findings of this study were shared in local and international academic forums and meetings. Furthermore, five articles are already published in peer reviewed journals.

3.12. The summary

The design and methods employed in the present study are described in detail in chapter three. The chapter discussed in detail the phases of the study, the study setting, and population as well as the sampling strategy and the profile of the selected sample. The rationale behind the selection of the study instruments in each component of research design has been explained. Data entry and cleaning process, data management, data analysis, the ethical consideration, and the dissemination of study results were also detailed in this chapter. In addition, the first published paper, entitled " Clinical decision making in basic emergency obstetric and newborn care among nurses and midwives: the role of the safe delivery mHealth application_pre-post-intervention study (research protocol)," is a protocol paper and provides a detailed description of the hypothesis, rationale, methodology and phases of the study. The next section B comprising chapters 4 – 7 describes the study's results on the effectiveness, symptomatology, and acceptability of the SDA in Rwanda.

SECTION B: RESULTS

In this section, I present the publications that were produced from this PhD to answer the study objectives. The research conducted for this PhD aimed to evaluate the effect of the SDA on nurses' and midwives' clinical decision making, so as to inform mhealth interventions for work in specific contexts. The four published articles generated from the PhD work are presented in this section [168–171]. The papers are presented in four chapters (Chapters 4 - 7). Slight modifications have been made, such as removal of acronyms that have already been introduced and the removal of journal-specific requirements, such as conflict of interest statements. Otherwise, they are presented as published with the permission of co-authors:

Nishimwe, A, Conco, D.N.,Nyssen. et al. Context specific realities and experiences of nurses and midwives in basic emergency obstetric and newborn care services in two district hospitals in Rwanda: a qualitative study. BMC Nurs 21, 9 (2022)https://doi.org/10.1186/s12912-021-00793-y

> This first paper discussed nurses and midwives' perceptions and experiences about offering BEmONC services in the selected district hospitals with a special focus on PPH management and NR. Paper one employs a qualitative approach and offer unique insights into context specific realities and experiences of nurses and midwives in the provision of BEmONC services. The paper discusses multiple perspectives and complex reflections on PPH management and NR. The results presented in chapter four provide more insights on barriers and enablers in the provision of PPH management and NR services in district hospitals in Rwanda and highlights the needs of in-service continuous trainings for nurses and midwives as well as clinical guidelines and/or clinical decision support tools.

Nishimwe, A., Ibisomi, L., Nyssen, M. et al. The effect of an mLearning application on nurses' and midwives' knowledge and skills for the management of postpartum hemorrhage and neonatal resuscitation: pre–post intervention study. *Hum Resour Health* 19, 14 (2021). https://doi.org/10.1186/s12960-021-00559-2

> The work in this Paper 2 demonstrated the effect of the SDA intervention on nurses' and midwives' knowledge and skills for the management of PPH and NR in two district hospitals in Rwanda [169]. Using a pre-post intervention approach, we compared knowledge and skills of nurses and midwives in the management of PPH and NR at two measurement points: immediately prior to SDA intervention and after six months of SDA

intervention. The results presented in chapter five provides information on the effect of the mLearning feature of the SDA on knowledge and skills of end-users and responds to the evaluation of effectiveness of the SDA in Rwanda.

Nishimwe, A., Ibisomi, L., Nyssen, M. et al. The effect of a decision-support mHealth application on maternal and neonatal outcomes in two district hospitals in Rwanda: pre – post intervention study. *BMC Pregnancy Childbirth* 22, 52 (2022). https://doi.org/10.1186/s12884-022-04393-9

In this paper three, we draw on a pre-post intervention study using a record review approach, to describe the effects of the SDA on nurses and midwives' clinical decision making with regards to maternal and newborn outcomes; Apgar score and PPH progressions. The results presented in chapter six extend our understanding of the effect of the decision support feature of the SDA and addresses the evaluation of the symptomatology outcome.

Nishimwe, A., Conco, D.N., Nyssen, M. et al. A mixed-method study exploring experiences, perceptions, and acceptability of using a safe delivery mHealth application in two district hospitals in Rwanda. *BMC Nurs* 21, 176 (2022). https://doi.org/10.1186/s12912-022-00951-w

This Paper 4, highlights the SDA acceptability among nurses and midwives, their experiences with the SDA, stakeholders' perceptions and the implementation process of using the SDA in two district hospitals in Rwanda. The results presented in chapter seven heighten our understanding of key stakeholders' perceptions on the SDA and end users' experiences with the SDA and their acceptability of the SDA. This chapter also documents the implementation process of using the SDA in the context of district hospitals in Rwanda. The paper further provides an understanding of multiple views on the SDA implementation process and its scalability, costs and sustainability from the perspective of key stakeholders.

Chapter four: Context specific realities and experiences of nurses and midwives in basic emergency obstetric and newborn care services in two district hospitals in Rwanda: a qualitative study

4.1. Abstract

In low and middle-income countries, nurses and midwives are the frontline healthcare workers in obstetric care. Insights into experiences of these healthcare workers in managing obstetric emergencies are critical for improving the quality of care. This article presents such insights, from the nurses and midwives working in Rwandan district hospitals, who reflected on their experiences of managing the most common birth-related complications; postpartum hemorrhage (PPH) and newborn asphyxia. Rwanda has made remarkable progress in obstetric care. However, challenges remain in the provision of high-quality basic emergency obstetric and newborn care (BEmONC). This study is a qualitative part of a broader research project about implementation of an mLearning and mHealth decision support tool in BEmONC services in Rwanda.

In this exploratory qualitative aspect of the research, four focus group discussions (FGDs) with 26 nurses and midwives from two district hospitals in Rwanda were conducted. Each FGD was made up of two parts. The first part focused on the participants' reflections on the research results (from the previous study), while the second part explored their experiences of delivering obstetric care services. The previous study results included: survey results reflecting their knowledge and skills of PPH management and of neonatal resuscitation (NR); and findings from a six-month record review of PPH management and NR outcomes, from the district hospitals under study. Data were analyzed using hybrid thematic analysis.

The analysis revealed three main themes: (1) reflections to the baseline research results, (2) self-reflection on the current practices, and (3) contextual factors influencing the delivery of BEmONC services. Nurses and midwives felt that the presented findings were a true reflection of the reality and offered diverse explanations for the results. The participants' narratives of lived experiences of providing BEmONC services are also presented.

The insights of nurses and midwives regarding the management of birth-related complications revealed multi-faceted factors that influence the quality of their obstetric care. Even though the study was focused on PPH management and NR, the resulting recommendations to improve

quality of care could benefit the broader field of maternal and child health, particularly in low and middle-income countries.

Adapted from Nishimwe, A., Conco, D.N., Nyssen, M. et al. Context specific realities and experiences of nurses and midwives in basic emergency obstetric and newborn care services in two district hospitals in Rwanda: a qualitative study. BMC Nurs 21, 9 (2022). https://doi.org/10.1186/s12912-021-00793-y. See Appendix 15

4.2. Background

Globally, an estimated 295,000 maternal deaths (211/100,000 live births), 2 million stillbirths and 2.5 million early newborn deaths occurred in 2017 [79,80]. More than 90% of these deaths happened in low and middle-income countries (LMICs), like Rwanda [81]. The risk of mortality is highest during childbirth, where 46% of maternal deaths and stillbirths and 36% of neonatal deaths occur [172]. Preventable causes such as pre-eclampsia, obstructed labor, infections, post-partum hemorrhage (PPH), hypertensive disorders and newborns failure to breathe are frequent [82,173]. To help reduce preventable deaths during the childbirth critical period, the WHO, UNICEF, and UNFPA established a set of seven key obstetric services or "signal functions" referred to as Basic Emergency Obstetric and Newborn Care (BEmONC) [83]. These include the management of post-partum hemorrhage; the removal of a retained placenta; the management of maternal sepsis; the management of hypertensive disorders; the management of prolonged labor; the management of complications of abortion, and newborn resuscitation [2]. The BEmONC services are mostly provided by nurses and midwives in low-resource settings [89]. The WHO further, advocates for all births to be attended by a skilled birth attendant [174]. The BEmONC services were introduced in health facilities of Rwanda in 2004 with over 150 healthcare providers and community health workers trained in BEmONC from 2004 to 2009 [2].

The Rwandan health sector has remarkably evolved, since 2017, 91% of births take place in healthcare facilities and attended by healthcare professionals [44,175]. The Rwandan public health care system has a pyramidal structure consisting of five levels: referral/ university teaching hospitals at the top followed by provincial hospitals, district hospitals, health centres and health posts [42]. An additional cadre of trained community health workers (CHWs) was introduced to link pregnant women in the community with the health facilities [43]. Normal births occur at health post or health center level. In the event of complications, the pregnant woman is transferred to the

district hospital where advanced equipment and services are available. The obstetric care services are predominantly offered by nurses and midwives with the help of physicians in case of potentially fatal complications. The pre-service training of nurses and midwives in Rwanda varies widely with technical (A2); advanced diploma (A1); baccalaureate (A0) and graduate (masters) training available as pathways to entry to nursing and midwifery practice [176]. The work responsibilities vary depending on the level of education with nurses and midwives having A1 level and above, being responsible for managing normal deliveries and birth-related complications.

Efforts to reduce maternal mortality in Rwanda included initiatives to encourage more women to deliver at health facilities with the free birth care advantage and health insurances affordability with 10% out of pocket payment of all received services [53]. In addition public obstetric care services delivered at different levels in line with the required expertise, has contributed to a significant increase of births taking place in healthcare facilities [41,56,177]. However, maternal mortality and neonatal deaths remain high despite these initiatives. The maternal mortality ratio for the period 2014-2015 to 2019-2020 was 203/100,000 live births [178] and PPH at 22.7% was the leading direct cause [142]. The neonatal mortality ratio was 19 deaths/ 1000 live births [178] and newborn asphyxia and its complications was the leading cause, accounting for 38% of all neonatal deaths [59,141]. This situation makes PPH and newborn asphyxia the priority challenges in Rwanda. This suggests that while the rate of heath facility deliveries has risen, the quality of care in health facilities might be suboptimal.

The current paper, was derived from a broader study about implementation of an mLearning and mHealth decision support tool (Safe Delivery Application) in basic emergency obstetric and newborn care services in Rwanda [160]. The aim of this aspect of the study was to explore the participating nurses and midwives' experiences and perceptions of obstetric care with a special focus on PPH management and NR. The objective of this aspect of the study was two-fold; one part was to elucidate from the participants' explanations of the research findings [169] from the quantitative part of the research. The second part was to explore context specific factors that influence their work as obstetric care givers in their respective hospitals.

4.3. Methods

4.3.1. Study setting

The study was conducted in two out of the 12 district hospitals in the Eastern and Kigali provinces in Rwanda [44]. The selected hospitals are: Nyamata district hospital from the rural eastern province and Masaka district hospital from the Kigali urban province. Both hospitals had been offering BEmONC services for more than five years and had a high number of deliveries per year, with more than 6000 deliveries per year in Nyamata hospital and 7200 deliveries per year in Masaka hospital [40].

4.3.2. Study Participants

For the broader study, we invited nurses and midwives working in the maternity departments of the selected hospitals to participate in the study. Participants were selected using the following criteria: 1) having a work experience of at least 6 months in obstetric care, 2) being employed full-time in the selected hospital, and 3) willing to participate in the study. A total of 54 nurses and midwives participated in the baseline survey. For this qualitative study, 17 midwives and nine nurses were purposively sampled. The purpose was to select from participants who had participated in the survey and we were interested in having participants in line with the diverse roles in the maternity departments. Four focus group discussions were planned and the intended size of each focus group was a minimum of four and a maximum of six participants. According to Kitzinger and Barbour (1999), groups of this size are recommended for studies investigating health care systems and organization aspects [179]. In the present study, the number of participants who could attend on a given date per hospital determined the size of each group. Two groups in Nyamata district hospital consisted of six nurses and midwives each. While two groups in Masaka district hospital consisted of six and eight nurses and midwives respectively.

4.3.3. Study design

This exploratory qualitative study was embedded in a three phased pre – post intervention research, investigating the effect of the Safe Delivery mHealth Application on nurses' and midwives' clinical decision making in the management of the two top frequent births complications in Rwanda (newborn asphyxia with its complications and post-partum hemorrhage). The management of these two birth complications include neonatal resuscitation and PPH management [160]. The qualitative research sought to obtain an in depth insight into the nurses' and midwives' experiences about offering BEmONC services in the selected district hospitals. The study adopted

an exploratory qualitative research design using moderated focus group discussions [180] to both explore and describe the nurses and midwives' reflections on the baseline survey results and their lived experiences in managing PPH and NR. The design was chosen as the nurses and midwives, who were delivering BEmONC services in the selected district hospitals, could offer a narrative explaining the baseline quantitative results and description of the phenomenon as they experienced it.

4.3.4. Data collection

The researcher moderated four FGDs, two in each study hospital, using a semi-structured guide. Each FGD session explored both the reflections of the participants to the baseline research results and their experiences of delivering BEmONC services. For the reflections, the researcher presented two sets of baseline findings on PPH management and NR - the survey results of nurses' and midwives' knowledge and skills; and the six-month record review on maternal and newborn outcomes (Apgar score and PPH progressions) following PPH management and NR. The researcher invited participants to reflect and discuss the baseline findings, probing for their reactions and explanations. The second part of the FGD explored nurses' and midwives' experiences in delivering obstetric care services with a special focus on PPH management and NR in their respective district hospitals.

FGDs were conducted in July 2019 at both hospitals. The duration of the interviews ranged from 45 to 60 minutes. The interview guide (Additional file 1) was developed in English, translated to Kinyarwanda, and translated back to English in a blinded manner to ensure accuracy and equivalence [181]. Interviews were conducted in the language of the participants' preference, which was Kinyarwanda. The first author conducted the FGDs with assistance of an experienced research assistant who assisted in taking notes and supervising the tape recording. To ensure the quality and adequacy of the FGD guide, it was pretested with one midwife and one nurse working in a similar department but at a different district hospital. Following the test, minor adjustments were made to the FGD guide. The minor adjustments included expanding one probe for more clarity, the probe was "peer-support" expanded to "possible peer-support in the work environment". Questions were open-ended to allow participants to expand upon topics they felt were important. Interviews were held in private rooms that adequately accommodate 12 people at both Masaka and Nyamata district hospitals to ensure anonymity and confidentiality.

4.3.5. Data Analysis

Audio recordings of the FGDs were transcribed immediately following the discussions and then, translated from Kinyarwanda to English by a professional translator. Transcriptions were done following the True Verbatim method to accurately capture meanings, perceptions, and context [182]. Field notes were incorporated in the written transcripts as additional data. To ensure data quality, two researchers independently double-checked all transcriptions and translations. Data were analyzed using thematic analysis with a hybrid approach (inductive and deductive) [182], consisting of six steps: 1) familiarization with data; 2) identifying initial codes; 3) generating themes; 4) reviewing and defining themes; 5) coding the data; 6) organizing themes and write up. The thematic analysis is broadly used in qualitative research and aims to present the main elements of the participants' descriptions [165]. The first author (AN) and one co-author (DNC) read all transcripts and developed the preliminary coding scheme together. Two interviews were double-coded by the first author (AN) and the co-author (DNC). Any inconsistencies were discussed and resolved to develop the final coding framework. The first author coded all remaining interviews transcripts. New themes, which could not be placed within the established coding framework, were also included in the analysis [183,184]. Nvivo 11 Plus software was used in coding. The consolidated criteria for reporting qualitative research [185] guided reporting for this study (Additional file 2).

4.4. Results

4.4.1. Demographic information of the participants

A total of 26 nurses and midwives participated in the focus group discussions, 16 of whom were females and 10 males. More than a half were from Masaka district hospital (n = 14). The average age of participants was 32 years, ranging from 23 to 61 years. The level of education was predominantly the advanced diploma (A1) in midwifery with 14 of 26 participants having A1 level in midwifery. The majority of the participants had less than 10 years of experience in obstetric care (n = 18), and spent more than 10 hours per week providing obstetric care (n = 20). Table 4.1 shows the demographic characteristics of the participants.

Table 4.1. Participants characteristics (N=26)

	n (%)
Hospital Affiliation	
Masaka District Hospital	14 (54)
Nyamata District Hospital	12 (46)
Gender	
Male	10 (38)
Female	16 (62)
Education Level	
Midwife A0	3 (11)
Midwife A1	14 (54)
Nurse A0	2 (8)
Nurse A1	5 (19)
Nurse A2	2 (8)
Years of experience in obstetrical care	
1–5	9 (35)
6–10	9 (35)
>10	8 (30)
Weekly workload in obstetrical care (hours)	
0–5	2 (8)
6–10	4 (15)
>10	20 (77)
Age, years, Mean (Range)	32 (23 - 61)

Abbreviations: % : Percentage

The analysis revealed three main themes: (1) reflections to the baseline research results, (2) self-reflection on the current practices, and (3) contextual factors influencing the delivery of BEmONC services. During the discussion of results, verbatim quotations were used to support the themes and provide evidence. More details on the main themes and sub-themes (figure 4.1) are presented in the text below, and are illustrated by quotations from the four FGDs.

4.4.2. Thematic framework

For each main theme, there were some associated key concepts that served as the sub - themes and resulted in the formation of the thematic framework shown in the figure 4.1.

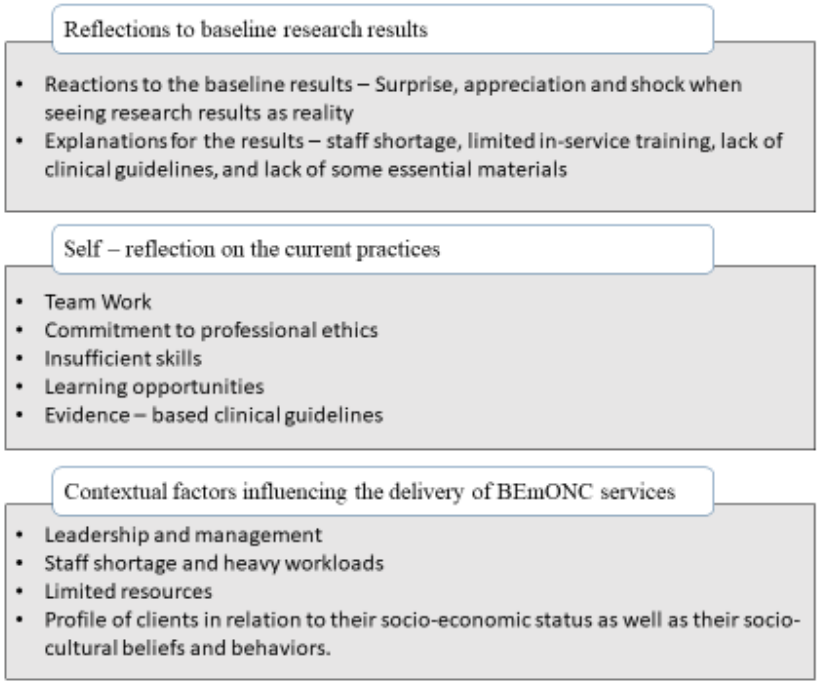

Figure 4.1: Thematic Framework

4.4.2.1. Reflections to baseline research results

This was a reflection about the baseline survey findings on the knowledge and skills in the management of PPH and NR, and on a six months' record review of the BEmONC outcomes - Apgar score and PPH progressions. The survey results indicated that the average knowledge score was 47.2% and the average skills score was 59.9% among 33 midwives and 21 nurses interviewed for the survey [169]. The record review findings revealed an unstable newborn outcome (Apgar score < 7) following 10 minutes NR recorded in 62% (n = 78) newborn cases and an unstable maternal outcome (persistent bleeding ≥ 500mls) following PPH management recorded in 19% (n=13) maternal cases. Under reflections to baseline research results, the sub-themes included reactions such as surprise, appreciation and shock, and explanations for the results which consisted of staff shortage, limited in-service training, lack of clinical guidelines, and lack of some essential materials.

Nurses and midwives admitted to being surprised by the survey and record review results. Some participants voiced appreciation of the research process, specifically receiving feedback on the baseline research results. They indicated that the research results presented to them, helped them reflect on their usual practice and to consider ways of improving the services that they provide.

"It is the first time we get access to the findings from all the surveys that have been conducted here by the research people, this is good even though our performance was not good, I think we need to improve on our knowledge, get refresher courses or read a lot" **Midwife, Female-FGD1.**

Other participants said they were shocked by the realities of the performance of their departments, while others stated that they have always known that their performance was not optimum. The presented baseline results made some participants to consider ways to improve the situation.

"I know our department is not best performing due to some challenges we face here in district hospitals like the shortage of staff and lack of some essential materials, but these findings are not good at all. What can we do to address this issue? … I think the hospital administration need to take the lead to ensure safe environment of work here and help us get in-service trainings, it is really difficult to get them." **Midwife, Male-FGD4.**

Some participants thought that the reasons behind the low knowledge and skills scores was due to limited concentration while filling the survey questionnaires as they were thinking of the huge workload and this may have made them lose concentration.

"I think that the figures reflect the reality. But, I think the research was conducted while people were thinking of the work ahead. As a result of this, it is possible that some participants didn't take time to answer the questions properly with enough concentration. They might simply have ticked the answers without thinking about them. That is my opinion" **Midwife, Male-FGD1.**

Other possible explanations of the low knowledge and skills scores and the high records of unstable maternal and newborn outcomes, included staff related factors such as lack of skills where they describe the lack of in-service trainings as the main contributor.

"When we compare the knowledge and skills scores with the records, …. We can see that the figures from the records review also are too high (62% unstable newborn outcomes and 19% unstable maternal outcomes). *It is still a fact that there is a serious problem regarding lack of skills or experience"* **Nurse, Female-FGD2.**

Another participant said:

> *"I think that the main reason is lack of regular and continuous trainings for us, … Continuous professional development is always needed not only to refresh but also to upgrade what one learnt at school, in other words, staff members regularly need training to get updates"* **Midwife, Female-FGD3.**

Another reason highlighted was the shortage of staff in the maternity department. According to nurses and midwives, the health system plays an important role in the provision of care which later affects patients' outcomes. The unstable maternal and newborn outcomes were attributed to the health system structure with the main highlight on the insufficiency of staff.

> *"The biggest challenge is insufficiency of staff. Sometimes, you may need some assistance when dealing with newborn resuscitation or PPH and you fail to get someone to assist. In this case, you need to do everything by yourself and as a result you may not succeed in everything as it could have been if there were two of you"* **Nurse, Male-FGD2.**

Other participants voiced the need for adequate clinical guidelines that would be accessible and visible in the time of need, especially in case of emergencies, to help in decision making when dealing with birth complications such as PPH and NR.

> *"We need clinical guidelines to refer to regularly to provide better care to patients. The existing guidelines are not enough and not displayed in every labor room, … I think that the hospital should get more to have them displayed anywhere they may be needed"* **Nurse, Female-FGD3.**

The lack of essential materials was mentioned as another reason why there were high records of unstable maternal and newborn outcomes.

> *We might be in a situation where some materials, equipment and medicines are not available. Sometimes, there is a possibility of providing good service but when you fail to get what you need (materials) to provide such a service on time, there is a problem and you can't succeed in your duties"* **Nurse, Female-FGD4.**

4.4.2.2. Self – reflection on the current practices

The participants' narratives of lived experiences of providing obstetric care services in the study district hospitals revealed some insights into their current practices towards providing optimal BEmONC services. The discussions focused on team work, commitment to professional ethics, insufficient skills, learning opportunities and evidence-based clinical guidelines. Firstly, participants discussed the importance of peer-support for improved BEmONC services provision, particularly with regard to the management of PPH and NR. They acknowledged the presence of a team work spirit among nurses and midwives.

> *"I am happy with the teamwork spirit in this hospital and I find this as motivation and support here. Though we have different tasks to perform here, I appreciate the way we work together"* **Nurse, Female-FGD3.**

Likewise, nurses and midwives indicated that sharing responsibilities is a significant enabler of good service provision. They link it to the issue of shortage of staff and high delivery loads. The mechanisms of supporting each other despite everyone's allocated daily responsibility make the work possible with the support of good and timely communication.

> *"I like the fact that people working in maternity ward are good at communicating. I am saying this because when several deliveries are to take place at the same time, they would always call upon the coordinator to send in more staff members for support."* **Midwife, Female-FGD1.**

In addition, participants explained that their motivation which led to their commitment to the professional ethics is a facilitator to better service provision. They discussed the value of wanting to save lives which keep them motivated to do whatever they can to care for women and newborns.

> *"I would like to say that we are motivated because we always wish to save lives. Of course, nobody would wish to experience newborn asphyxia. It is bad for any staff member. You would even get blamed for that. We are motivated and this has good impact on what we do. You can see that people like their job very much. You will see that we come not because we have to come but to save lives of mothers and newborns and to ensure that the work is properly done"* **Nurse, Female-FGD2.**

However, participants acknowledged the presence of insufficient skills to deal with birth complications among some nurses and midwives coupled with the lack of up to date clinical guidelines, which pose barriers to patient care. This was expressed as follows:

> *"The challenge I would raise is limited skills. Maybe it is not an issue for everyone but it is there. Among five team members, you may only find two with the skills that are required for newborn resuscitation"* **Midwife, Female-FGD4.**

Another participant stated that:

> *"Some nurses and midwives may not have enough skills to support the patients. For example, when it comes to cervical tear, they might fail to know how to suture the tear, thinking that it is only done by a doctor and remember that there is only one doctor assigned to maternity service"* **Midwife, Female-FGD2.**

Furthermore, nurses and midwives described the factors in respect of their professional development as significant contributors to the quality of obstetric care. The lack of in-service professional development courses was mentioned as a crucial barrier to quality BEmONC service provision. Participants stated a need to get access to regular in-service trainings and continuous learning opportunities to improve on their knowledge and skills which would positively affect patient outcomes. There was also a recommendation to promote the culture of reading among nurses and midwives.

> *"The big problem is that most of us do not have access to trainings and/or in -service professional development courses. Also, the culture of reading is not in us. We just keep doing things as we have always been doing."* **Midwife, Male-FGD3.**

The study participants also mentioned the few learning opportunities that are available in the district hospitals which currently contribute to their continuous learning. These leaning opportunities include; mentorship sessions and clinical staff meetings. Participants agreed that those mentorship sessions improved their knowledge, skills and confidence, particularly with regard to maternal and child health care, and are key facilitators of evidence-based care provision.

> *"We nowadays have mentors from Rwanda Association of Midwives (RAM) and Ingobyi Project who give training to clinical staff. Trainings are provided to doctors, nurses and midwives working in maternity. Trainees meet and work with these mentors every month.*

They give training in obstetric care. Their support is essential and it has improved our ability in providing better services to mothers and newborns. Those from Ingobyi have given training to four staff members so far, two of these four cascade the training to staff in health centres. Those from RAM together with Rwanda Pediatric Association come here every month to train three people per month." **Midwife, Male-FGD1.**

In addition, several participants felt that nurses and midwives who have not yet participated in the mentorship program should be included in training when possible. For this to happen, the training frequency might be increased to reach more staff. Other related suggestions included pairing already trained staff with non-trained staff during work shifts to improve both care provision and learning. Participants also suggested that the mentorship sessions could focus more on birth complications such as PPH management and NR.

"I would also like to say that a big number of staff members in maternity department have not yet participated in the mentorship program. The number is still too low. If the days of mentorship could be increased, everyone will get a chance to be trained. We need that the sessions focus more on PPH and neonatal resuscitation. Remember, some staff members are fresh graduates who only have knowledge without experience. I think they need a lot of continuous professional development trainings. Also having them on day or night shifts with the more experienced staff who have benefited from the mentorship would make the situation better" **Midwife, Female-FGD4.**

Also, participants discussed the importance of clinical staff meetings that happen every morning to discuss obstetric care management. The meetings involve the presentation of cases of patients managed in the previous night as well as the hospitalized patients. The meetings also focus on the management of particular conditions in critical patients with senior staff advising junior staff. Nurses and midwives acknowledge these meetings as learning opportunities with real patient case presentations. Thus, helping them to improve the service provision. Participants also indicated that they have other educational meetings twice a week which are beneficial to their knowledge and skills refreshment.

"I think it is a good thing that we have staff meetings at hospital level to regularly discuss birth complications and related problems. We do not wait for these structured mentorship initiatives organized by external people. For example, in maternity ward, we also have

educational meetings that are done on Wednesdays and Thursdays in addition to regular staff meetings that we have every morning. In these meetings, we talk about cases we have had and we thereafter have presentations about anything we think is useful. We often talk of PPH, eclampsia and helping baby breath. This is where emphasis is mostly laid to ensure that everyone working in maternity have basic skills in this. We also do some practices using the mannequins" **Midwife, Female-FGD2.**

Further, nurses and midwives discussed the role of evidence-based clinical guidelines in continuous learning and in the provision of evidence-based obstetric care. Participants stated that they need clinical guidelines to support their service provision. However, they pointed out the insufficiency of clinical guidelines as an important barrier to quality service provision. They indicated that the few clinical guidelines available are not displayed wherever needed.

"I would like to add that clinical guidelines are important for us. Clinical guidelines are there but not enough. I think there is a need to have them available in more places including emergency area where we also have PPH cases to deal with. Those working with ambulance should also have the guidelines because they are the ones to take care of the PPH patient while being transferred. They should also be displayed in maternity, emergency and out-patient and even in surgery room and this should be done in a sufficient quantity. I don't think they are available in health centres too. You may visit a place and notice that they don't have a PPH guideline while they may have had two or three PPH cases in a month." **Midwife, Female-FGD3.**

Other participants indicated that the available clinical guidelines are not updated. They stressed that the availability of enough and up to date clinical guidelines would help them in clinical decision making while dealing with birth complications such as PPH and NR.

"A staff member may not be in position to always remember what to do when there is a PPH or neonatal resuscitation. However, clinical guidelines are still few. Only one is displayed in the delivery room, it has been there for long ago and it is not updated." **Midwife, Female-FGD2.**

In addition, participants indicated the challenges with paper based clinical guidelines which are the only ones available. Participants cited the length, the difficulty to update and the deterioration

with time as the main challenges of paper based clinical guidelines. They also stressed that it is hard for them to find time to read the non-summarized paper based clinical guidelines.

> *"There are few clinical guidelines: some are in file boxes and others are displayed on the walls…, it is hard to update these paper based-clinical guidelines and they could get deteriorated easily as time goes. The ones in file boxes are too long and it is unfortunate we do not read them- maybe reading is so difficult! People are too lazy to read or maybe don't have time to read. You will hardly see someone reading the clinical guidelines in files boxes"* **Midwife, Male-FGD4.**

Finally, nurses and midwives, in consideration of the evolving digital age, proposed to have the summarized electronic clinical guidelines which could be easily accessible and regularly updated.

> *"I have read on internet that in developed countries' hospitals, there exist some form of electronic clinical guidelines that people consult on computers or smartphones. And, I think the easy way for us would be to have those electronic clinical guidelines that will be summarized, easily accessible for everyone and could be updated as science evolves."* **Midwife, Female-FGD1.**

4.4.2.3. Contextual factors influencing the delivery of BEmONC services

Nurses and midwives indicated a number of context specific factors that influence the quality of care in BEmONC, particularly in the management of PPH and NR. Under contextual factors, the sub-themes included the realities of working in the context of district hospitals including the leadership and management, the staff shortage and heavy workload, the limited resources, the profile of clients in relation to their socio-economic status as well as their socio-cultural beliefs and behaviors.

The participants highlighted the contribution of the leadership and management in ensuring the quality of obstetric care in the hospitals. Participants described hands on leadership, provided by departmental managers, ensuring that services were well organized and that staff were assigned to where they were most needed. The good organization of service within the maternity department was perceived as key to better service provision.

> *"We actually have a kind of task distribution and daily organization of the work by the maternity matron. When there is an emergency, for example in delivery room, those people in charge of different units get in touch and they may get support from each other by*

sending some members to help. The number of members to support will depend on the size of work to be performed. Such movements often happen between delivery room and hospitalization unit depending on cases." **Midwife, Female-FGD2.**

The participants described the support provided by the hospital management as enabling the service provision for the management of PPH and NR. They felt that the managers of the hospitals give a particular attention to maternal and child care which translate into more resources and supplies to the maternity department. They verbalized that:

"The maternity heads in collaboration with the hospital managers do all they can to have all we need in stock. This include also PPH and NR emergency kits and all other kits. We organize a morbidity day event in which we discuss birth complications and the Director General also attends the event. They take into consideration all our challenges in the provision of maternity care" **Midwife, Male-FGD4.**

"What I can add is that we get a lot of support from the Hospital Management. Top management is very supportive and most importantly, the nursing leader is a midwife too. They are so sensitive about mothers. We usually get all equipments and drugs we need, even though sometimes, we run out of stock" **Midwife, Female-FGD1.**

However, participants described staffing shortages as a significant barrier to care provision. They explained it was common in district hospitals for two midwives or nurses to cover the waiting room, the emergency room, the labor room and the recovery room.

"There is a problem of workload. People here have too much to do. You may find two staff members in the maternity and when you have to attend to six mothers at once, you understand that it can't work. As soon as a delivery has taken place, you immediately go to another mother without considering subsequent stages as you should and then monitoring PPH becomes hard. As a result, sometimes there may be some complications and you may fail to handle them on time" **Midwife, Female-FGD2.**

Some participants stated that high number of deliveries per midwife made it difficult to perform well for every patient in need. They cited the poor staff/patient ratio, as an important barrier to

good service provision in terms of dealing with birth-related complications. They stressed that the number of staff members is too low compared to the number of patients to take care of.

> "*I think there is a problem of staff/patient ratio. Monitoring also becomes very hard due to insufficient staff members. How can two midwives assist three deliveries at once? Who can meanwhile attend to those in the waiting room? Sometimes, you may end up finding the ones you left in waiting room suffering. The problem of insufficiency in staffing is crucial"* **Midwife, Male-FGD3.**

Then again, nurses and midwives stated that the low number of doctors assigned to the maternity department is a challenge to better service delivery. This is partly linked to the shortage of staffs in district hospitals.

> *"I think that availability of medical doctors is also a requirement for these cases of PPH and NR, however they are still few, one allocated to Maternity service daily"* **Nurse, Female-FGD1.**

Other participants felt that they need more specialist doctors like pediatricians when performing neonatal resuscitation and later for the recovery of the newborn.

> *"Another area to improve on is that we should also have a pediatrician to work with newborn resuscitation. The newborn resuscitation should not only be done by a midwife and a nurse. Sometimes, the newborn also needs antibiotics and a pediatrician would be in a better position to prescribe them. I think this is worth noting too"* **Nurse, Female-FGD4.**

Furthermore, participants highlighted the issue of staff rotations in different services and staff turnover as barriers to better service provision. They expressed concerns about staff rotations that is implemented by the health system in district hospitals of Rwanda. Staff, particularly nurses, are rotated to different clinical services such as maternity, pediatric, surgery and sometimes rotating to or from maternity. As a result, the rotating nurses, like new staff may not be familiar with dealing with birth complications and they may take time to get used to the routine work. Also, staff turnover was indicated as an important barrier in consideration of staff moving from one hospital to another hospital. When staff turnover takes place the origin hospital loses an experienced staff.

"We know well that we sometimes have staff rotations and staff turnovers in hospital- for example fresh graduates who have no experience and moving back and forth in different services. These new staff members might proceed with a given management of the birth complications without following the standard clinical guidelines" **Nurse, Male-FGD3.**

Further, nurses and midwives discussed some of the resources challenge they face when dealing with obstetric emergencies. They cited lack of physical resources, including supplies and equipment, as a barrier to care provision. Resources such as oxygen cylinders, heating lamps for newborns, and suction bulbs were often unavailable or non-functional.

"…. We only have one suction bulb here, imagine if we have more than one neonatal who fails to cry after birth, what can we do with one piece only? When this happens, we face a serious problem. For the time being, we only have three penguins and one lamp…. These materials are not sufficient" **Nurse, Female-FGD1.**

Another participant said:

"Another challenge is the problem related to availability and accessibility of some medications and materials. If I think of the number of deliveries we have here, they should match the quantity of equipment and materials needed for that purpose. I don't understand how you can assist in 15 deliveries with only one heating lamp at night…. Sometimes, you may even fail to get oxygen cylinders because they are not there or not in sufficient quantities…." **Midwife, Male-FGD4.**

Also, some participants described the persistent shortages of uterotonics, antibiotics and intravenous fluids. When medications were out of stock, patients or their family members were asked to purchase medications from outside pharmacies or, in emergency cases, nurses or midwives sometimes purchased medications for patients.

"We normally use oxytocin and cytotec. When we don't have these drugs in our hospital pharmacy, the patient attendants go out to buy them in private pharmacy and it might be a bit too late to provide good service by the time they get back to us with these drugs" **Nurse, Female-FGD1.**

Furthermore, nurses and midwives described the limited number of ambulances at the health centers level as an important barrier to better service provision. They highlighted that they receive some of the patients already in critical conditions due to travel delays related to the lack of transport/ambulances.

> *"The real problem starts at health centres because they may wish to transfer a mother with a complication but they fail to get transport for her. Some health centres do not have ambulances. You can see how much time it would then take for an ambulance to leave here and go to pick up that mother at a health centre. That ambulance will reach there when this mother is already in critical conditions"* **Midwife, Female-FGD2.**

Another contextual factor highlighted by nurses and midwives is the financial barrier among the patients. Participants described how financial barriers made service provision challenging for some patients. The lack of financial means for some mothers makes them delay to present themselves to the hospital. And by the time they come, they are in a critical condition.

> *"Some patients are coming to hospital too late due to financial problems and in this case, both the mother and her baby have started to have some complications. It is a fact that sometimes, you fail to save a newborn's life not because you didn't have enough skills but because you started attending to the mother when the situation had gone beyond boundaries"* **Nurse, Male-FGD1.**

Participants also indicated that some patients cannot afford drugs and nurses and midwives cannot assist all of them with the emergency kits available which contain few emergency medications and materials. Other patients also get issues in transfer when they cannot afford the transfer fee.

> *"Another thing is lack of financial means by some patients to afford drugs. It is a fact that we have emergency kits to assist such patients but you may not get everything in those kits that is required for all the cases"* **Nurse, Female-FGD2.**

Another participant stated that:

> *"Sometimes we may have patients who cannot afford the services we provide. For instance, when we have a serious case to transfer, such a patient may not afford the transfer fee…When then time is being wasted discussing this, a patient might get in worse conditions"* **Midwife, Female-FGD4.**

On the other hand, nurses and midwives described low literacy and social-cultural and beliefs behaviors among mothers who visit the hospitals as contributing factors to the outcomes of delivery. Participants indicated that the use of traditional medications was prevalent in local communities. They indicated that most of the mothers coming to the hospitals for delivery, first take traditional medicines and these traditional medicines make the newborn suffer. As a result, the baby is born very weak and subject to neonatal resuscitation which is mainly hard to manage because the newborn in most cases has inhaled these traditional medicines.

> *"Nowadays, based on my personal observation, some mothers come to hospital after taking some traditional medicines and this leads to aspiration syndrome and make the resuscitation of a newborn difficult"* **Nurse, Female-FGD3**.

Another participant said that:

> *"I can add that there is a problem of literacy with the mothers we work with. They think that traditional healers help them to have live newborns. A large number of mothers who come here for delivery, they first take those traditional medicines. Such traditional drugs make the babies suffer a lot"* **Midwife, Female-FGD3**.

Other participants described an overall lack of awareness about the value of medical care during childbirth among some mothers who think that medical care is not enough that it has to be supplemented by traditional healers. There are misconceptions surrounding childbirth that mothers should take traditional medicines before delivery if they want to come up with a live newborn. Further, nurses and midwives expressed the need of health programs to increase the awareness of value of medical care during childbirth among the population.

> *"I think there should be initiatives to tell the mothers to stop taking traditional medicines. They should let these mothers know about the negative effects of these medicines and ask them to stop such practices. This is a common practice with mothers who come here and it really has a negative effect on the newborns they give birth to"* **Midwife, Female-FGD2.**

4.5. Discussion

Our research contributes to existing literature insights from in-depth exploration of the perceptions and experiences of nurses and midwives on obstetric care services particularly, with the management of birth related complications such as PPH and NR. The participants reflected on

survey results and offered diverse explanations of the results. Participants also shared their lived experiences of managing PPH and NR and gave their opinions on what they believe is influencing their work as obstetric care givers in their respective hospital. Our findings illustrate the complexity of the process of managing birth-related complications in district hospitals of Rwanda. The three main themes from the FGDs with nurses and midwives were: reflections to baseline research results, self-reflections on the current practices, and contextual factors influencing the delivery of BEmONC services.

Reflections to baseline research results

The presented baseline research results were accepted as a true reflection of the reality of practice. Participants were shocked by the low knowledge and skills scores in comparison of 50% average as the set minimum satisfying score [169], as well as the high number of unstable newborn and maternal outcomes. This made them reflect on their performance as a department and consequently provided possible explanations of the research results. Among the provided explanations, there were challenges such as staff shortages, limited in-service trainings, limited access to clinical guidelines, and lack of some essential materials. Similarly, a number of studies has explored the barriers to and facilitators of emergency obstetric care provision [143,186–188] and reported similar challenges in multiple health facilities in LMICs. Therefore, engaging nurses and midwives on how they perceive and reflect on obstetric care services reveals realities of practice that decision makers would consider when putting in place strategies to improve obstetric care particularly in low and middle income countries.

Moreover, other participants explained that their low scores in the knowledge and skills surveys were linked to their high workload. They indicate that their failure was due to the fact that they did not fully concentrate while filling the survey questionnaires because they were thinking of the huge work ahead. In the same vein, a study that explored perceptions of emergency obstetric care providers in Malawi on the critical factors of staff shortages and workload in their health facilities, reported the shortage of staff coupled with the unmanageable workloads that exceeded their capacity to cope as key contributors to the substandard provision of obstetric care [189].

Self-reflections on the current practices

Our findings revealed that effective teamwork is a key facilitator to better provision of care. The participants acknowledged mutual support when managing PPH and NR and valued their attitudes of sharing responsibilities. Comparable findings have been seen in a study which focused on optimizing teamwork and leadership in reducing risk in maternity [190]. Another study which documented lessons from a series of research on teamwork, leadership and team training with regards to what makes maternity teams effective and safe [191] reported that teamwork is essential for managing complex pregnancies. Similarly, participants in the study perceived that peer support make a noticeable difference to team effectiveness and patient safety during obstetric emergencies [191]. Evidence of benefits of teamwork in maternal and newborn care have been indicated by several researchers [192–194]. Hence, teamwork is recommended when dealing with PPH and NR. Also, in the current study, the commitment to the professional ethics has been linked to teamwork and shown to promote staff motivation and improve obstetric care services.

Additionally, in the current study, on site mentorship sessions and clinical staff meetings, were identified as learning opportunities and key facilitators of evidence – based care provision. They helped nurses and midwives to update their knowledge and skills through critical discussions of specific cases and hands on practices with mentors. Other mentorship initiatives in partnership with the Human Resources for Health (HRH) Program have also been beneficial to the improvement of health service delivery in Rwanda [9,195]. Similarly, a study in India found that a seven-month simulation-enhanced mentoring program for nurses and midwives from 320 primary health clinics improved their skills and confidence in managing common obstetric and neonatal complications [187]. Similar findings were documented in a prospective before-and-after study in Malawi, which evaluated the impact of a hospital-based mentoring program about EmONC on knowledge and skills among health providers [196]. The study has reported an increase of both short- and longer-term improvement in BEmONC knowledge and skills [196]. However, more research is required to assess whether the improvement in knowledge, skills and confidence leads to changes in practices that improve maternal and neonatal outcomes.

However, this study has identified barriers related to staff development. Study participants acknowledged having insufficient skills in PPH management and NR. They linked this challenge with the lack of professional development courses and the lack of culture of reading. Nurses and

midwives emphasized on their need of continuous learning opportunities as the medical science evolves with new discoveries and approaches to deal with birth complications. They mainly highlighted how difficult it is to access continuous learning opportunities. Other studies have similarly noted that access to continuing professional development opportunities for nurses and midwives is often difficult, especially in LMICs [197][198]. Filby et al (2016) found that the lack of investment in continuing education prevents quality midwifery care [186]. Opportunities to address the in-service training challenges are available through short courses using competency-based learning curricula. However, context realities should be considered in terms of costs. The adoption of innovative methods of on job learning that utilize technology such as eLearning and mLearning could be adopted where face to face trainings are not accessible and less affordable.

In addition, the access to relevant and up-to-date clinical guidelines was another important point of discussion raised by nurses and midwives. Study participants acknowledged the importance of evidence-based clinical guidelines in continuous learning and its support in decision making at the point of care. However, the accessibility is still a challenge, as the available paper based clinical guidelines are few and not updated. Nurses and midwives also indicated that it is hard for them to find time to read the guidelines filed in cupboards. Likewise, a recent study mapped evidence on human resource-related challenges to quality facility-based newborn care provision by nurses and midwives [197] and reported the lack of access to current evidence-based guidelines as a common complaint in LMICs [197]. Other studies indicated that the care during labour and childbirth following evidence-informed clinical guidelines is associated with better patient outcomes [199–202]. Guidelines change regularly and thus dissemination and methods of updating nurses and midwives on new knowledge are essential. But, simple dissemination of paper-based clinical guidelines is ineffective as it was noted by our study participants. Electronic clinical guidelines and electronic decision support tools could be envisaged leveraging the rapidly increasing rates of smartphone access and mHealth technologies. Yet, additional research is needed on electronic clinical decision support tools, particularly in LMICs.

Contextual factors influencing the delivery of BEmONC services

The current study shown that the good leadership and management of the district hospitals is an essential facilitator of care provision for PPH management and NR. Participants referred to the good leadership in consideration of service organization (distribution of tasks and allocation of

duties). The hospital support was an additional facilitator of care provision, particularly with regards to achieving sustainable improvements and the particular support in terms of resources and suppliers. Katie et al (2013) similarly suggested that management practices coupled with leadership behaviours can make a huge difference to outcome and experience for women and their companions [190]. Other studies have also documented the benefits of hospital leadership on patients' outcomes [203,204]. Therefore, leadership is considered a core element for a well-coordinated and integrated provision of care.

However, the staff shortage was highlighted as a significant barrier to good service provision for PPH management and NR. Nurses and midwives indicated that the number of staff was very low compared to the number of patients to take care of. Similar findings have been reported in other LMICs [57,189]. A study by Dani et al (2020) found that healthy term infants' neonatal outcome is negatively associated with a low midwife-to-infant ratio [205]. Similarly, Christine et al (2011) assessed the association between nursing staffing and patient outcomes and reported that inappropriate nursing staffing was linked to negative patient outcomes [206]. Other studies have also documented the effect of staff shortage on adverse events and increased medical costs [57,207–209]. Moreover, Sosa et al (2018) proposes the availability of a one midwife to one woman ratio for all women in labour [210]. Thus, an appropriate patient: staff ratio is revealed to be a determinant of quality obstetric and better maternal and newborn outcomes.

Also, the limited number of staff coupled with staff rotations and turnovers and a limited number of doctors posed significant barriers to PPH management and NR services in the two district hospitals under study. Similar human resource constraints have been reported in other LMICs [211]. Our study findings suggest that there is a problem of shortage of staff which leads to the fact that few nurses and midwives available work under pressure with less time spent with each woman leading sometimes to a lack of proper care. The resulting low quality of services is unpreventable. Therefore, one of the priorities is the need that policy makers put in place strategies that will help to increase the number of trained staff in obstetric care.

Other challenges identified in this study included the lack of some necessary medical supplies and problems related to the referral system such as few ambulances at the health center level. These findings were congruent with a report from a study conducted in India which revealed physical

resource shortage as a barrier to the provision of optimal obstetric and neonatal emergency care [187]. Another study which identified barriers associated with the referral of emergency obstetric cases to a national referral centre in Ghana reported the problems with referral transportation system highlighting limited ambulances as a critical barrier to obstetric care service provision [212]. The quality of care of hospitals providing obstetric care has also been shown to be affected by a lack of required equipment and drugs as demonstrated by studies conducted in past [143]. Therefore, understanding these challenges from the healthcare providers' perspectives is important and informative to policy makers in order to put in place context specific strategies to improve obstetric care.

Additionally, in this study, financial barriers were found to play a crucial role in delaying the access to medical care when needed. Nurses and midwives discussed on how patients with low economic status were likely to reach the hospital late and in critical condition. Other patients were not able to afford drugs and got issues in transfers. Geleto et al (2018) in his systematic review about access and utilization of emergency obstetric care (EmOC) at health facilities in sub-Saharan Africa [213] reported that financial barriers prevent mothers to access EmOC when needed. Other studies have also noted the burden of financial barriers to maternal care particularly in Sub-Saharan Africa [211,214]. Initiatives to reduce maternal mortality in Rwanda have included the facilitation of access to health care services with the help of the national medical insurance scheme [215]. The current hospital delivery rate in Rwanda is 91% [44]. However, some women still face financial barriers to afford other required fees like transfer fees from health centers to district hospitals which delay the care they receive for instance in case of PPH. There is need for more support to the very poor patients for healthcare services.

Moreover, the current study identified barriers related to patient challenges such as social-cultural beliefs and behaviors. With regards to cultural beliefs and behaviors, nurses and midwives were referring to the use of traditional medicines by women while these traditional drugs have a negative impact on the newborn health outcome. Similar findings were documented in a study conducted in Zambia which revealed multiple interconnecting factors linked with cultural beliefs that influence traditional medicine use among pregnant women [216]. Women believed that traditional medicines help them with labour induction, and prevention of childbirth complications [216]. From the modern medical profession perspective, these traditional medicines are always associated

with adverse health outcomes, specifically for the newborn [216]. A lack of awareness about the value of medical care during childbirth among some mothers was also mentioned. It is noteworthy, that in this study, we did not have the perspectives of patients on how they value medical care during childbirth. However, nurses and midwives based on their experience testify that the level of awareness on the benefits of medical care during childbirth is still low in the population, that is why they come to hospital after taking traditional medicines. Nyeko et al (2016) explored the factors associated with herbal medicine use during pregnancy in Ugandan women [217] and reported an association of cultural beliefs with the use of those drugs. This therefore calls for population sensitization programs on the dangers of use of traditional medicines in pregnancy, as well as the benefits of medical care during childbirth.

4.6. Strength and limitations of the study

The limitation of this study was that nurses and midwives were recruited from only two district hospitals. Therefore, the current study will not generalize findings. However, we believe our findings contribute to an increased understanding of the complexity of PPH management and NR services provision in Rwanda. The strength of this study was a comprehensive sampling of the nurses and midwives with different level of specialization. Both young and more experienced nurses and midwives were represented in the focus group discussions. The interviews were thoroughly analyzed to define the three overarching themes and the subthemes. Recruitment was continued until saturation of the data and until any new information was obtained. One FGD included an additional two members who were the maternity matrons and their contribution increased the strength of findings.

4.7. Conclusion

Nurses and midwives were concerned with the survey results and the records review findings. Among possible explanations of the results, the discussions focused on limited in-service trainings, staff shortage, limited clinical guidelines and the lack of some essential materials. Participants also reflected on their current practices focusing on team work, commitment to professional ethics, insufficient skills, learning opportunities, and evidence-based clinical guidelines. Additionally, the study has revealed numerous contextual factors influencing the delivery of BEmONC services in Rwanda with a particular focus on PPH management and NR. The identified factors included; leadership and management, the shortage of staff and heavy workloads, the limited resources, and

the profile of clients in relation to their socio-economic status as well as their socio-cultural beliefs and behaviors. Both the self-reflections and the contextual factors are particularly important to recognize and to address when possible, as they significantly affect the quality of facility-based obstetric care. Moreover, our study participants emphasized the need for innovative technology approaches such as eLearning, mLearning, and electronic evidence-based clinical guidelines to help them in continuous learning and clinical decision making at the point of care when dealing with birth complications. Further, the study provides evidence on how nurses and midwives are better sources of context-specific information through situation based-analysis of practices. Our study findings could inform policy reviews to address real practice challenges and promote identified facilitators in order to improve maternal and newborn care services. Also, an in-depth understanding of the reality of practices from the perspective of nurses and midwives, who are the frontline healthcare workers in obstetric care, is essential to enable the design of contextually-targeted interventions to improve facility-based childbirth care in LMICs, including Rwanda.

Chapter five: The effect of an mLearning application on nurses' and midwives' knowledge and skills for the management of postpartum hemorrhage and neonatal resuscitation: Pre-post intervention study.

5.1. Abstract

Globally, mobile learning (mLearning) tools have attracted considerable attention as a means of continuous training for healthcare workers. Rwanda like other low-resource settings with scarce in-service training opportunities requires innovative approaches that adapt technology to context to improve healthcare workers' knowledge and skills. One such innovation is the safe delivery application (SDA), a smartphone mLearning application for Basic Emergency Obstetric and Neonatal Care (BEmONC) content. This study assessed the effect of the SDA intervention on nurses' and midwives' knowledge and skills for the management of postpartum hemorrhage (PPH) and neonatal resuscitation (NR).

The study used a pre-post-test design to compare knowledge and skills of nurses and midwives in the management of PPH and NR at two measurement points: immediately prior SDA intervention and after 6 months SDA intervention. The intervention took place in two district hospitals in Rwanda and included 54 participants. A paired-sample t-test was used to measure the pre-post intervention, mean knowledge and skills scores differences. Confidence intervals (CIs) and effect size were calculated. Further, stratified analyses were performed in which t-test and ANOVA were employed.

The analysis included 54 participants. Knowledge scores and skills scores on PPH management and NR increased significantly from baseline to endline measurements. The mean difference for PPH knowledge is 17.1 out of 100; 95% CI = 14.69 to 19.49 and 2.6% for PPH skills; 95% CI = 1.01 to 4.25. The mean difference for NR knowledge is 19.1 out of 100; 95% CI = 16.31 to 21,76 and 5.5% for NR skills; 95% CI = 3.66 to 7.41. Increases were unaffected by participants' attendance to in-service training six months prior and during SDA intervention and previous smartphone use. However, pre- and post-intervention skills scores were significantly different by years of experience in obstetric care.

The SDA intervention improved the knowledge and skills of nurses and midwives on the management of PPH and NR as long as 6 months after SDA introduction. The results are highly relevant in low-income countries like Rwanda, where quality of delivery care is challenged by a lack of in-service continuous training for healthcare providers.

Adapted from: Nishimwe A, Ibisomi L, Nyssen M, Conco DN. The effect of an mLearning application on nurses' and midwives' knowledge and skills for the management of postpartum hemorrhage and neonatal resuscitation: pre–post intervention study. Human Resources for Health. 2021 Dec;19(1):1-0. See Appendix 16

5.2. Background

According to WHO, Global numbers from the year 2017 estimates show that 295,000 women die during pregnancy and childbirth [79]. It is also estimated that 2 million stillbirths and 2.5 million early newborn deaths occur each year worldwide [80,218]. More than 90% of these deaths happen in low- and middle-income countries, like Rwanda [81]. Leading experts state that between 70 and 88 % maternal and newborn deaths are preventable or have treatable causes [2,34,62,82]. In Rwanda, the most frequent birth complications are postpartum hemorrhage (71.6%) and newborn asphyxia and its complications (38%) [219]. Strategies for prevention and treatment of birth complications have been proposed by the WHO, UNICEF, and UNFPA in a set of seven signal functions referred to as Basic Emergency Obstetric and Newborn Care (BEmONC). The BEmONC services are mostly provided by nurses and midwives in low-resource settings [83].

Nurses and midwives, particularly in Sub-Saharan hospitals, are the key clinicians in birth care. But, substandard performance of nurses and midwives in managing birth complications has been documented widely as a major cause of maternal and newborn deaths in hospital settings globally [220]. Several studies have documented that knowledge and skills of nurses and midwives in low-resources settings are not always at an acceptable level despite their previous education [83,102,220–222]. Hence, improving competency of nurses and midwives could improve maternal and newborn outcomes. One of the approaches to improve competency of nurses and midwives is to conduct regular in-service training courses. Hosey et al. (2016) documented that promoting continuous professional development of midwives presents a constant promise of more effective and safe birth care in low-resources settings[223]. However, different logistical and financial barriers can make this approach unachievable [67]. Given the accessibility of mobile phones in Africa, it is suggested that mLearning applications that provide essential obstetric training through instructional videos and self-directed learning options, such as the Safe Delivery mHealth Application (SDA), can overcome these barriers and improve birth care outcomes [131,224–226].

A number of studies have investigated the effectiveness of mobile health (mHealth) interventions in maternal and newborn health initiatives in low-income countries [110,227]. For instance, an mLearning pilot study about delivering family planning refresher training using interactive voice response and text messages revealed a substantial increase in knowledge of contraceptive side effects among nurses and midwives in Senegal [228]. On the other hand, Tomlinson et al. (2013) highlighted the fact that the enthusiasm for effective mHealth interventions in sub-Saharan Africa is high, but little is known about their efficacy or effectiveness in resource-limited settings [147]. Also, most of the studies examining mLearning tools are of poor methodological quality [131]. There is limited evidence on the contribution of mLearning applications on healthcare workers' knowledge and skills particularly in low-income countries [127]. Hence, there is a need for evidence of mLearning applications benefits as means of continuous training without interrupting healthcare services. Therefore, this study assessed the effects of the SDA mLearning application on nurses' and midwives' knowledge and skills in the management of the most frequent birth-related complications of postpartum hemorrhage (PPH) and newborn asphyxia in Rwanda.

The SDA is a BEmONC mLearning smartphone application developed by the Maternity Foundation, University of Copenhagen, and the University of Southern Denmark [28]. The SDA was designed to reinforce the professional competences of skilled birth attendants on how to manage BEmONC by means of an mLearning platform made of animated instructional videos and a self-explanatory learning platform called "MyLearning". The videos last about 7 to 15 minutes and can be viewed either in full or by chapter. While, the learning platform allows the user to enter into his/her personalized learning journey and further improve his/her knowledge of the content provided on the SDA. The learning platform offers an opportunity to the user to test his or her knowledge using the MyLearning questionnaires. The learner moves from the beginner, intermediate, expert levels and reaches the Safe Delivery Champion level and gain a certificate as he/she passes the quizzes. We investigated whether Rwandan nurses and midwives' use of SDA had an effect on their knowledge and skills with regards to PPH management and NR.

5.3. Methods

5.3.1. Study Setting

The study took place in two district hospitals in Rwanda: Masaka hospital in Kigali, an urban province; and Nyamata hospital located in the eastern rural province [44]. The two hospitals were

selected out of 12 district hospitals in the two provinces because both had a high number of deliveries per year [40]. The two hospitals have been offering BEmONC services for more than five years.

5.3.2. Study Participants

Nurses and midwives working in the maternity departments of the selected hospitals, who deal with birth care were invited to participate in the study. The inclusion criteria for nurses and midwives were set as follows: having a work experience of at least 6 months in obstetric care, being full-time employed in the selected hospital, and willing to participate in the study. The study participants included 33 midwives and 21 nurses.

5.3.3. Study design

The study adopted a pre-post-test design to compare knowledge and skills of nurses and midwives in the management of PPH and NR at two measurement points: pre and post the SDA intervention. The study was carried out in four phases: establishing the baseline, the educational sessions, the intervention and the end-line. The baseline and end-line surveys were conducted pre and post the intervention respectively. The six-month intervention period was preceded by training of the participants on how to use the SDA. The study took place between July 2019 and April 2020. Figure 5.1 provides more detail on this study design.

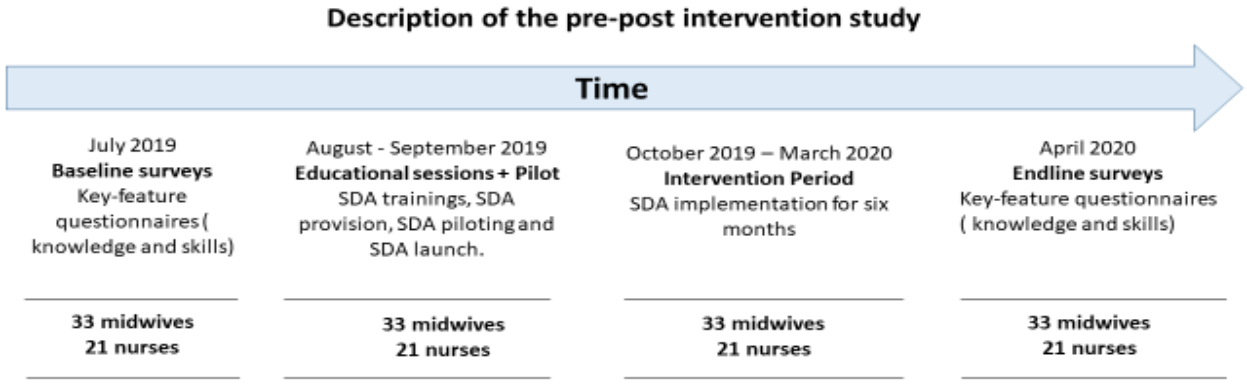

Figure 5.1: Description of the pre-post intervention study

5.3.4. Description of the SDA intervention

The SDA is an mLearning application designed to provide training for health care providers in low-income countries on how to manage obstetric and neonatal emergencies. The SDA conveys knowledge and skills, such as how to ventilate a newborn in need of resuscitation or how to remove a retained placenta by means of visual guidance using animated instructional videos and a self-explanatory learning platform. The SDA also contains a catalog with essential obstetric drugs and equipment. The content of the SDA is based on WHO clinical guidelines on BEmONC and has been validated by an international group of global health experts [78]. All features and functions in the SDA are designed for low-literacy and low-income settings and work off-line once downloaded. It can thus, be adapted to local contexts and policies. The SDA can be downloaded free of charge for iPhone at https://itunes.apple.com/dk/app/safe-delivery/id985603707?mt=8 and for Android at https://play.google.com/store/apps/details?id=dk.maternity.safedelivery&hl=en .

Smartphones with the SDA were implemented at two district hospitals for a six months' period. Nurses and midwives working in the maternity departments of the selected hospitals received a half-day SDA introduction training. The training encompassed a description of the SDA features and modules and an explanation of how to use the smartphone and SDA with joint video viewing and interactive exercises in small groups on using the SDA as a learning tool. Each of the study hospitals (Masaka and Nyamata) was allocated three smartphones, with pre-installed English and French versions of the SDA. Participants who owned smartphones, were encouraged to download the SDA for use during the training. The majority of participants (n = 47) downloaded the SDA on their personal smartphones for the training. During the six months' SDA intervention, nurses and midwives used the SDA in a personalized learning journey to train their knowledge and skills on how to manage obstetric and neonatal emergencies with the assistance of the SDA installed on their personal smartphones or the smartphones provided by the researcher. The research team ensured that the provided smartphones were available to the team on duty at all times. Since it was a pilot study, the intervention also entailed two visits per week by the researcher and four research assistants to each of the study hospitals. During the visits, the researcher and the research assistants observed how the participants were using the SDA and encouraged them to watch the videos while they were there, they also provided guidance on how to start their learning journeys and made sure that each participant started learning for the PPH and NR modules.

5.3.5. Measurement and data collection

The primary outcomes of the study were knowledge scores and skills scores of nurses and midwives. Self-administered key feature questionnaires developed and tested by Maternity foundation were adopted, only questions regarding PPH and NR were considered. Knowledge and skills scores were measured for 2 BEmONC services, PPH management and neonatal resuscitation. The research instrument included questions on PPH management and NR knowledge and skills, demographic information, as well as exposure to in-service education on the topics under study. The knowledge questionnaire consisted of clinical content questions on causes, consequences, prevention, treatment and management of PPH and NR. The knowledge questionnaire includes 36 knowledge questions for PPH management and 37 knowledge questions for NR with single and multiple responses options. The skills were evaluated by means of a self-administered questionnaire with simulated clinical cases due to technical difficulties of evaluating skills by change in real practice. The skills questionnaire comprised of six clinical scenarios simulating PPH cases for PPH management and four clinical scenarios simulating NR cases for NR with single and multiples responses options. The collected demographic data of the participants included age, gender, education level, years of experience in obstetric care, hours spent per week in providing obstetric care, and number of deliveries participated in monthly. In addition, we asked participants if they have received any in-service training about PPH management and/ or neonatal resuscitation during the 6 months prior or during the SDA intervention period. This question helped the researcher to understand more about the influence of the SDA or other available in-service training. We also asked participants if they have previously used smartphones to capture their experience with smartphones.

A total of 54 nurses and midwives completed either the English or the French form of self-administered questionnaires at baseline and at 6 months' post-intervention. English and French languages are both professionally used in Rwanda. Baseline measures were taken prior to the training of nurses and midwives on the use of the SDA and included: demographic data; knowledge of nurses and midwives in the management of PPH and NR; and skills of nurses and midwives in managing PPH and NR. All data were collected on paper in a classroom setting. Six months after the SDA introduction, knowledge and skills were measured a second time in the classroom setting using the same data collection instruments.

5.3.6. Data management and analysis

The data were entered and checked for errors in Microsoft Excel and subsequently transferred and analyzed in Stata version 16 (StataCorp LLC). Descriptive summary statistics were computed on demographic data including age, gender, education level, years of experience, hours spent per week in providing obstetric care, delivery participated in monthly, previous use of smartphone, and in-service training for six months prior and during SDA intervention. Since the study targeted all nurses and midwives working in the maternity department of the selected hospitals, all the eligible participants in the maternity department, a sample of more than 30 participants was required to support the use of parametric statistical tests.

Knowledge and skills scoring were calculated by dividing the number of questions answered correctly by the total number of questions times a hundred. Respondents who scored 50% and above were considered knowledgeable. Further, mean scores across all knowledge and skills scores were computed. A paired-sample t-test was used to measure the pre-post intervention, mean knowledge and skills scores differences (where the dependent variable was the mean difference in change on scores for the two measurements, baseline and endline). Confidence intervals (CIs) and effect size were calculated. To test for potential confounding, using a t-test, pre-post intervention mean knowledge and skills scores were compared and between group differences were calculated to examine the role of in-service training and previous smartphone use on test scores. One-way analysis of variance (ANOVA) was used to compare means scores across the three categories of experience in obstetric care (group 1: 1 year to 5 years, group 2: 6 years to 10 years, group 3: Above 10 years) for pre and post intervention results. Significance level was set at $p<0.05$.

5.3.7. Ethics approval

This study has been approved by the Human Research Ethics Committee of the University of the Witwatersrand (M190258) and the University of Rwanda, College of Medicine and Health Sciences' Institutional Review Board (No.377/CMHS IRB/2018). Written consent was obtained from each participant. Confidentiality of the participants was maintained at all times. Questionnaires were number-coded thereby keeping the identity of the participants coded.

5.4. Results

5.4.1. Demographic characteristics of study participants

A total of 54 participants, 33 midwives and 21 nurses completed the surveys. More than a half were from Masaka district hospital (n=30, 56%), the majority were female (n=33, 61%), their

average age was 33 years (SD = 7.1). The level of education was predominantly the advanced diploma (A1) in midwifery with 27 of 54 (50%) participants having A1 level in midwifery. The least represented level of education was the secondary school level (A2) in nursing with only one participant with A2 level in nursing. The majority of the participants had less than 6 years of experience in obstetric care (n=32, 59%), spent more than 10 hours per week providing obstetric care (n=40, 74%) and participated in more than 10 deliveries per month (n=41,76%). Three participants have received BEmONC in-service training during the 6 months of the SDA intervention. Four participants had never used a smartphone before the study. More details are shown in Table 5.1.

Table 5. 1. Demographic Characteristics of study participants (N=54)

	n (%)
Hospital Affiliation	
Masaka District Hospital	30 (56)
Nyamata District Hospital	24 (44)
Gender	
Male	21 (39)
Female	33 (61)
Education Level	
Midwife A0	6 (11)
Midwife A1	27 (50)
Nurse A0	5 (9)
Nurse A1	15 (28)
Nurse A2	1 (2)
Years of experience in obstetrical care	
1–5	32 (59)
6–10	15 (28)
>10	7 (13)
Weekly workload in obstetrical care (hours)	
0–5	4 (7)
6–10	10 (19)
>10	40 (74)
Number of deliveries past month	
0–5	8 (15)
6–10	5 (9)
>10	41 (76)
In-service trainings past six months	
No	51 (94)
Yes	3 (6)
Experience with smartphone	
Tried using one	50 (93)
Never tried using one	4 (7)
Age, years, Mean (SD)	33(7.1)

Abbreviations: % : Weighted percent, SD: Standard deviation

5.4.2. Pre-Post SDA Intervention Differences in Knowledge Scores for PPH management and NR

The mean difference in PPH knowledge from pre- to post-test was statistically significant; mean difference = 17.1% (SD = 8.8, 95% CI :14.7 - 19.5); P<.001. The findings suggest a large effect size for PPH knowledge scores differences, Cohen's d score = 1.8. Similarly, the mean difference in NR knowledge from pre- to post-test was statistically significant; mean difference = 19.1% (SD = 9.9; 95% CI: 16.3 - 21,8); P<.001. The findings suggest a large effect size for NR knowledge scores differences, Cohen's d score = 1.7. We found a significant association between the SDA

intervention and nurses' and midwives' knowledge on both PPH and NR knowledge, 6 months after baseline (Table 5.2).

Table 5.2. Differences in mean knowledge scores Pre-and-Post SDA Intervention (n=54)

	Mean, SD	95% CI	P value	Cohen's d
PPH Knowledge scores (out of 100)				
Pre, mean (SD)	45.8 (9.2)	(43.4 , 48.3)	**<.001**	1.8
Post, mean (SD)	62.9 (9.4)	(60.4 , 65.5)		
Pre - post difference, mean(SD)	17.1 (8.8)	(14.7 , 19.5)		
NR Knowledge scores (out of 100)				
Pre, mean (SD)	48.6 (12.3)	(45.3 , 51.9)	**<.001**	1.7
Post, mean (SD)	67.7 (10.2)	(64.9 , 70.4)		
Pre - post difference, mean(SD)	19.1 (9.9)	(16.3 , 21.8)		

Abbreviations: Wt.% : Weighted percent; NR : neonatal resuscitation; PPH: postpartum hemorrhage

5.4.3. Pre-Post SDA Intervention Differences in Skills Scores for PPH management and NR

The mean difference in PPH skills from pre- to post-test was statistically significant; mean difference = 2.6% (SD = 5.9, 95% CI: 1.1, 4.3); P = .002. The findings suggest a small effect size for PPH skills scores differences, Cohen's d score = 0.3. Similarly, the mean difference in NR skills from pre- to post-test was statistically significant; mean difference = 5.5% (SD = 6.9; 95% CI: 3.7, 7.4); P<.001. The findings suggest a medium effect size for NR skills scores differences, Cohen's d score = 0.7. We found a significant association between the SDA intervention and nurses' and midwives' skills on both PPH and NR skills, 6 months after baseline (Table 5.3).

Table 5.3. Differences in mean skills scores Pre-and-Post SDA Intervention (n=54)

	Mean, SD	95% CI	P value	Cohen's d
PPH Skills scores (out of 100)				
Pre, mean (SD)	63.4 (9.8)	(60.8 , 66.2)	**0.002**	0.3
Post, mean (SD)	66.1 (11.2)	(63.1 , 69.2)		
Pre - post difference, mean(SD)	2.6 (5.9)	(1.1 , 4.3)		
NR Skills scores (out of 100)				
Pre, mean (SD)	56.5 (7.1)	(54.6 , 58.5)	**<.001**	0.7
Post, mean (SD)	62.1 (8.4)	(59.8 , 64.4)		
Pre - post difference, mean(SD)	5.5(6.9)	(3.7 , 7.4)		

Abbreviations: Wt.% : Weighted percent; NR : neonatal resuscitation; PPH: postpartum hemorrhage

Potential Confounders

The comparisons of PPH and NR mean knowledge and skills scores by in –services training (6 months' prior the intervention and 6 months during the intervention period) across the baseline and endline groups showed that there were no significant differences along in –service training lines in the pre and post-test for both PPH and NR (Table 5.4). Analysis of knowledge and skills scores by previous smartphone experience did not show a significant difference for PPH and NR scores on both pre- and post-tests (Table 5.4). Although participants who had smartphone experience scored slightly higher on the PPH skills post-test, there was no significant difference. Similarly, there was no significant difference in mean change in PPH and NR knowledge from pre- to post-test among those experienced with smartphones and those who had never used them. Moreover, Participants were classified into three groups according to their years of experience in obstetric care: group 1 (1 year to 5 years, n = 32); group 2 (6 years to 10 years, n = 15), group 3 (above 10 years, n = 7). The ANOVAs indicated significant group mean differences only for the NR skills pre- test ($F(2,51) = 5.31$, $p = .008$) and for the NR skills post- test ($F(2,51) = 4.83$, $p = .012$) (Table 5.5). As shown in Table 5.6, a tukey post-hoc test revealed that pre- test NR skills scores were statistically significantly higher in the group 1 compared to the group 3 ($p = .006$). Similarly, post- test NR skills scores were statistically significantly higher in the group 1 compared to the group 3 ($p = .011$). Also, post- test NR skills scores were statistically significantly higher in the group 2 compared to the group 3 ($p = .023$). However, there were no statistically significant differences between the pre- and post- test NR skills scores in the group 2 compared to the group

1 (p = .641 and .999 respectively). Also, there were no statistically significant differences between the pre- test NR skills scores in the group 3 compared to the group 2 (p = .058).

Table 5.4. Differences in Knowledge and Skills Scores Pre- and Post-Intervention , Analyzed by in-service training and Smartphone Experience

	In - service training				Smartphone Experience			
	Yes	No	Mean diff	P value	Yes	No	Mean diff	P value
PPH Knowledge scores (out of 100)								
Pre, mean (SD)	49.7 (2.5)	45.7 (9.4)	4	0.468	46 (9.4)	44.5 (6.1)	1.5	0.756
Post, mean (SD)	61.6 (6.4)	63.1 (9.6)	1.5	0.805	63 (9.4)	63.3 (10.9)	0.3	0.953
PPH Skills scores (out of 100)								
Pre, mean (SD)	54 (13.7)	59.3 (10.9)	5.3	0.424	59.1 (11.4)	58 (7.6)	1.1	0.851
Post, mean (SD)	60.6 (10.1)	66.4 (11.3)	5.8	0.392	66.9 (11.2)	56.8 (6.4)	10.1	0.083
NR Knowledge scores (out of 100)								
Pre, mean (SD)	61.3 (6.4)	47.9 (12.2)	13.4	0.065	48.7 (12.3)	48 (14.3)	0.7	0.916
Post, mean (SD)	75 (8.2)	67.2 (10.2)	7.8	0.202	67.8 (10.3)	66.5 (10.3)	1.3	0.814
NR Skills scores (out of 100)								
Pre, mean (SD)	53 (10)	56.7 (6.9)	3.7	0.379	56.4 (7.2)	58.3 (6.1)	1.9	0.615
Post, mean (SD)	59 (8.5)	62.2 (8.4)	3.2	0.522	61.8 (8.7)	65.3 (3.5)	3.5	0.435

Abbreviations: Wt.% : Weighted percent; NR : neonatal resuscitation; PPH: postpartum hemorrhage

Table 5.5. Differences in Knowledge and Skills Scores Pre- and Post-Intervention, Analyzed by Years of experience

	Group 1 (n = 32)	Group 2 (n = 15)	Group 3 (n = 7)	Df	F	P value
PPH Knowledge scores (out of 100)						
Pre, mean (SD)	46.8 (9.5)	46.2 (9.4)	41.1 (6.7)	(2 , 51)	1,10	0.341
Post, mean (SD)	64.1 (9.4)	63.5 (10.1)	56.6 (5.9)	(2 , 51)	1.96	0.151
PPH Skills scores (out of 100)						
Pre, mean (SD)	59.9 (12.2)	57.4 (10.1)	58.4 (7.7)	(2 , 51)	0.27	0.767
Post, mean (SD)	66.9 (11.2)	66 (12.3)	62.6 (9.3)	(2 , 51)	0.43	0.655
NR Knowledge scores (out of 100)						
Pre, mean (SD)	48.7 (13.4)	49.3 (10.7)	46.7 (11.9)	(2 , 51)	0.11	0.899
Post, mean (SD)	67.8 (10.9)	68.5 (10.1)	65.6 (7.6)	(2 , 51)	0.19	0.827
NR Skills scores (out of 100)						
Pre, mean (SD)	58.2 (6.7)	56.3 (6.5)	49.3 (6.2)	(2 , 51)	5.31	**0.008**
Post, mean (SD)	63.4 (7.2)	63.3 (8.4)	53.4 (9.9)	(2 , 51)	4.83	**0.012**

Abbreviations: Wt.% : Weighted percent; NR : neonatal resuscitation; PPH: postpartum hemorrhage

Table 5.6. Paired comparisons for Skills Scores Pre- and Post-Intervention, Analyzed by Years of experience

	P Value for Paired Comparisons with Turkey's HSD		
	Group2 vs Group1	Group3 vs Group1	Group3 vs Group2
NR Skills scores (out of 100)			
Pre - test	0.641	**0.006**	0.058
Post - test	0.999	**0.011**	**0.023**

Abbreviations: Wt.% : Weighted percent; NR : neonatal resuscitation; PPH: postpartum hemorrhage HSD (honestly significant test)

5.5. Discussion

The current study assessed the effect of the SDA mLearning application on nurses 'and midwives' knowledge and skills in postpartum hemorrhage management and neonatal resuscitation in two district hospitals in Rwanda. A statistically significant increase, of the mean knowledge scores, was found post SDA intervention, recording 17.1% for PPH management and 19.1% for NR. The increase of the mean skills scores for PPH management and NR was also statistically significant, at 2.6% and 5.5% respectively. The significant increase in knowledge is further supported by Cohen d large effect size. On the other hand, for skills scores, NR had a medium effect size and PPH Management had a small effect size. The difference in the effect size between knowledge and skills could be associated with measurements tools utilized to evaluate skills because we did not assess skills in real practice rather used simulated clinical cases. The analysis of knowledge and skills scores by potential confounders (in-service training 6 months prior and during intervention and smartphone experience) did not show a significant difference for PPH and NR scores on both pre- and post-tests. However, the analysis of skills scores by years of experience in obstetric care has shown a significant difference in skills scores for both pre- and post-measurements in different categories of years of experience. This study is important because it addresses the need of a potential solution to nurses and midwives' problems of accessing up-to-date learning resources in low and middle income countries including Rwanda.

Our findings mirror those of other studies in two ways. First, the revelation that mhealth learning tools are essential for facilitating continuous learning and upgrading knowledge and skills of different health professional cadres is consistent with findings of a study conducted in Senegal that documented the association of a mLearning tool with sustained knowledge gains for family

planning content [228]. The study highlighted the usefulness of mLearning to provide in-service training without interrupting health services [228]. Secondly, the potential of mLearning tools to improve healthcare workers' knowledge and skills which results in improvement of maternal and neonatal healthcare services in LMICs is corroborated by systematic reviews that demonstrated the effectiveness of mhealth interventions in maternal and child healthcare [37,229]. These findings together underline the importance of mLearning tools for facilitating in-service training particularly in low resources settings where continuous training opportunities are scarce and the costs of training are unaffordable.

The SDA mLearning application was associated with an increase in knowledge mean scores among nurses and midwives on PPH management and NR following the six month SDA implementation. Likewise, a mixed-methods feasibility and pilot cluster randomized trial using the safe delivery app study conducted in the democratic republic of Congo revealed a similar increase in PPH and NR knowledge scores among health workers at 3 months post-SDA intervention [77]. Several studies have shown that mhealth interventions can improve healthcare services delivery processes which lead to improved outcomes [38,127,230]. A study in Tanzania assessed performance and adoption of an eLearning system utilized by healthcare providers to enhance maternal and perinatal health care for a period of 18 – 21 months [231]. The study reported that healthcare providers had acquired and utilized new knowledge and skills in clinical practice at 89% level at the end of the intervention [231]. Another study in Nigeria provided health care workers with mhealth tutorial application for changing the knowledge and attitude on Ebola virus disease and reported an 11% significant improvement in average knowledge levels between pre- and post-intervention scores [232]. Our findings support those of other studies [77,231] that the use of mhealth is perceived as an opportunity for personalized continuous learning with effects on health care workers' knowledge update. Therefore, it is important to highlight that mLearning tools such as the SDA could be considered as integrated parts of other efforts to support nurses and midwives continuous learning thus improving the quality of delivery care.

Moreover, the current study has found a significant association between the SDA mLearning application and skills of PPH management and NR among nurses and midwives. Similar findings were documented in a randomized clinical trial conducted in Ethiopia which determined the association between the safe delivery app and health care workers' knowledge and skills in

neonatal resuscitation [78]. The trial reported a more than 2-fold significant increase in health care workers' skills and knowledge scores for neonatal resuscitation, 6 months following the SDA intervention [78]. It is noteworthy that in our study, improvements in average knowledge and skills of PPH management and NR occurred across all cadres irrespective of their access to other available in-service trainings. However, the years of experience played a significant role in different skills scores for both pre- and post-tests in neonatal resuscitation. This can be partly explained by the fact that nurses and midwives might have been used to routine procedures in neonatal resuscitation. The effectiveness of the SDA mLearning application in changing nurses' and midwives' knowledge and skills of PPH management and NR may be attributed to disseminating educational materials in real time combined with the convenience of unrestricted access to online learning materials by nurses and midwives over an unlimited time period. This underlines the potential benefits of mLearning tools to enhance nurses' and midwives learning. mHealth tools in general present an opportunity for improving maternal health care services in underserved remote areas of low-resource settings by broadening knowledge and skills of healthcare workers.

The implications of this study are that the SDA intervention increases the knowledge and skills of nurses and midwives in managing obstetric and neonatal emergencies. Evolving efforts for continuing education in Rwanda and similar contexts should consider the integration of mLearning as an approach for training and as a job aid for BEmONC in order to reduce maternal and newborn mortality, as well as considering the integration of mLearning tools for other priority and emergent health problems. Challenges to implementation of quality BEmONC care, posed by gaps in the environmental context and resources, as well as the regulatory and accountability environment, must be considered and addressed alongside other programmatic measures such as quality improvement initiatives to target health system weaknesses.

5.6. Strengths and limitations of this study

The study has three limitations. First, it is limited by the small sample of 54 nurses and midwives, which reflects the fact that the SDA intervention was implemented only in two district hospitals due to economic barriers. Therefore, the current study will not generalize findings. Second, we acknowledge the limitation of findings when assessing skills using a self-administered questionnaire with simulated clinical cases. This was due to technical difficulties of evaluating skills by change in real practice. Third, we acknowledge that some of the improvements in

knowledge and skills observed in this study may arise from exposure to other learning materials other than the SDA during the intervention period. Also, the increase in knowledge and skills does not necessarily equal better outcomes for mothers and newborns which is the ultimate goal. The findings in the current paper are part of a large study evaluating the feasibility of the SDA in Rwanda. Findings of the effect of the SDA on maternal and newborn outcomes will be discussed in another paper.

Nevertheless, the evidence that the SDA intervention is effective in improving knowledge and skills of nurses and midwives in the management of PPH and NR sets the stage for expanding coverage and further testing of the SDA intervention to other hospitals in Rwanda. Additionally, the accuracy of our findings is increased by supporting the knowledge and skills surveys with focus group discussions with nurses and midwives, to provide context to and clarify reasons behind some participant responses. The findings of the focus group discussions will be presented in a separate paper.

5.7. Conclusion

In conclusion, the SDA mLearning application appears to be effective for improving nurses' and midwives' knowledge and skills in the management of PPH and NR. The changes in knowledge and skills recorded from the evaluation of this SDA mLearning intervention suggest that mLearning tools have potential for facilitating continuous training of nurses and midwives without interrupting healthcare services. The user-friendly nature of this SDA and regular access to updated learning materials via visual guidance using animated videos and a self-explanatory learning platform, streamed in real time to nurses and midwives, is a strong selling point of this SDA mLearning application. Using mLearning tools as a means of sustaining the knowledge and skills of nurses and midwives to manage delivery complications and improving maternal and newborn healthcare in LMICs should be explored further, especially given the increased global utilization of mobile technology and corresponding economic benefit.

Chapter six: The effect of a decision-support mHealth application on maternal and neonatal outcomes in two district hospitals in Rwanda: pre – post intervention study.

6.1. Abstract

Globally, mobile health (mHealth) applications are known for their potential to improve healthcare providers' access to relevant and reliable health information. Besides, electronic decision support tools, such as the Safe Delivery mHealth Application (SDA), may help to reduce clinical errors and to ensure quality care at the point of service delivery. The current study investigated the use of the SDA and its relationship to basic emergency obstetric and newborn care (BEmONC) outcomes for the most frequent complications in Rwanda; post-partum hemorrhage (PPH) and newborn asphyxia.

The study adopted a pre–post intervention design. A pre-intervention record review of BEmONC outcomes: Apgar score and PPH progressions, was conducted for six months' period (February 2019 - July 2019). The intervention took place in two district hospitals in Rwanda and entails the implementation of the SDA for six months (October 2019- March 2020), and included 54 nurses and midwives using the SDA to manage PPH and neonatal resuscitation. Six months' post-SDA intervention, the effect of the SDA on BEmONC outcomes was evaluated. The study included 327 participants (114 cases of PPH and 213 cases of neonatal complications). The analysis compared the outcome variables between the baseline and the endline data. Fisher's exact test was used to compare the proportions and test between-group differences and significance level set at $p<0.05$.

Unstable newborn outcomes following neonatal resuscitation were recorded in 62% newborns cases at baseline and 28% newborns cases at endline, P-value = 0.000. Unstable maternal outcomes following PPH management were recorded in 19% maternal cases at baseline and 6% maternal cases at endline, P-value = 0.048. There was a significant association between the SDA intervention and newborns' and maternal' outcomes following neonatal resuscitation and PPH management, 6 months after baseline.

The use of the SDA supported nurses and midwives in the management of PPH and neonatal resuscitation which may have contributed to improved maternal and neonatal outcomes during 6 months of the SDA intervention. The findings of this study are promising as they contribute to a broader knowledge about the effectiveness of SDA in low and middle income hospital settings.

Adapted from **Nishimwe, A**., Ibisomi, L., Nyssen, M. et al. The effect of a decision-support mHealth application on maternal and neonatal outcomes in two district hospitals in Rwanda: pre-post intervention study. *BMC Pregnancy Childbirth* 22, 52 (2022). https://doi.org/10.1186/s12884-022-04393-9 _See Appendix 17.

6.2. Background

Mhealth refers to the practice of medicine and public health, supported by mobile devices (mobile phones, smartphones, tablets, smartwatches) [27]. Evidence suggests that mHealth applications are innovative approaches to improve the delivery of health care services [38]. Further, mhealth tools can help to reduce clinical errors and ensure quality care at the point of service delivery. There is growing evidence of the effectiveness of mHealth interventions in maternal and newborn health programs in low and middle-income countries (LMICs), particularly to improve adherence to treatment, meeting appointments, facilitate data collection, and the development of supportive networks for health professionals [110,122,147,233].

Among the many interventions currently being implemented to support maternal and newborn healthcare services, mHealth applications have been widely used in low-resources settings [110,234–236] as a potential solution to maximize health providers' efficiency, health outcomes [9, 10, 11] and improve service utilization [120]. Common areas of application of mHealth tools include point-of-care decision-making support; provider-to-provider communication; and data collection [75,239]. Though mHealth interventions are well received by healthcare providers [147,150,240] information about their effectiveness with regards to patient outcomes is limited [233,236,241].

Many interventions on the use of mHealth for improving maternal and newborns' health outcomes in sub-Saharan Africa mainly focused on timely access to health facilities including reminders for antenatal appointments and referrals of mothers [227]. For instance, the CommCare mHealth technology is a digital solution that has shown promising results in assisting community health workers (CHWs) in data collection, decision support, communications with clients and health centres, and access to educational training materials [242]. Few mHealth applications are addressing the support of healthcare providers at the point of care with the main focus on clinical decision support in order to improve maternal and newborns outcomes

[125,145,233,236,238,243,244]. The Safe Delivery mHealth Application (SDA) is one of the recent mHealth applications (loaded in smartphones) which avails BEmONC clinical guidelines to support nurses and midwives' clinical decisions [28].

Rwanda, a sub-Saharan African country, reports high maternal and neonatal deaths. In 2015, Rwanda's maternal mortality was estimated at 290 deaths per 100000 live births and its neonatal mortality rate was 20 deaths per 1000 live births, respectively [40] despite 90% of deliveries taking place in healthcare facilities attended by health professionals [44,46]. Common causes of these deaths are preventable including postpartum hemorrhage (22.7% of all documented cases) and newborn asphyxia and its complications (38%) [141,142,149]. Challenges faced by healthcare providers include poor access to clinical guidelines and the lack of timely response to pregnancy complications during delivery care [105,168]. It is in this context that a mHealth application - a clinical decision support tool (SDA) to facilitate easy access to maternal and neonatal guidelines for routine and emergency obstetric and neonatal care was introduced. The SDA has been tested for its effectiveness through a randomized controlled trial conducted in Ethiopia [78]. The SDA has also shown a positive effect on nurses and midwives' knowledge and skills in the management of PPH and neonatal resuscitation in Rwanda [169]. This study investigated the use of the SDA and its relationship to BEmONC outcomes for the most frequent birth-related complications of PPH and newborn asphyxia in Rwanda. The current paper addresses one objective of a broad study about implementation of the SDA in Rwanda.

6.3. Methods

6.3.1. Study design

This was a pre–post intervention study done over a 14-month period. The study was conducted in three phases. The first phase was the pre-SDA intervention baseline study over a period of six months (February 2019 - July 2019). During this phase, a record review was conducted to document maternal and neonatal outcomes, PPH and Apgar score progressions, at baseline. The second phase, the SDA intervention (August 2019 - September 2019) comprised of the capacity building of nurses and midwives on the usage of the SDA; the SDA provision; the SDA piloting, and the launch of the SDA which marked the start of the SDA implementation. More details on the SDA training are documented in the protocol paper for this study [160].The last phase was the six months of post-SDA intervention (October 2019- March 2020). Phase three encompassed the

implementation of the SDA and another record review was conducted to document maternal and neonatal outcomes, PPH and Apgar score progressions, at endline. The data were collected from the delivery registries using data extraction forms. The collected data included patients' characteristics and information on maternal and newborn outcomes, Apgar scores and PPH progressions, following NR and PPH management. The data were collected by the researcher and four research assistants. Data accuracy and transcription were checked by the researcher before analysis.

6.3.2. Study Setting

The study was conducted in two district hospitals in Rwanda: Masaka hospital in Kigali, an urban province; and Nyamata hospital located in the eastern rural province [44]. The two hospitals were chosen out of 12 district hospitals in the two provinces because both recorded a high number of deliveries per year [40]. Compared to other rural-based district hospitals, Nyamata reported the highest maternal and neonatal mortality rates [105].

6.3.3. Study Participants

The study participants included records on neonatal complication cases and PPH cases. The inclusion criteria for the cases of neonatal complications were set as babies born with asphyxia (Apgar score ≤ 7) and were subject to neonatal resuscitation. We excluded preterm births (≤ 36 completed weeks of gestation) and births with major congenital malformations because prematurity and congenital complications other than the newborn asphyxia could influence the newborn outcome after resuscitation [245]. We have also excluded records with missing data on Apgar scores and neonatal outcome. On the other hand, the inclusion criteria for PPH cases were set as women who had a recorded amount of blood loss more than or equal to 500 mls and were subjected to PPH management. The records with missing data on PPH progression and maternal outcomes were also excluded. The study was conducted in three phases. Phase one, pre-intervention, included 126 cases of newborns asphyxia and 67 cases of PPH. Phase two, intervention, involved 33 midwives and 21 nurses who used the SDA in both Masaka and Nyamata district hospitals. Nurses and midwives were chosen because they are the frontline healthcare providers in childbirth care in district hospitals of Rwanda. The inclusion criteria for nurses and midwives were set as follows: having a work experience of at least 6 months in obstetric care and willing to participate in the study. All nurses and midwives (n=54) working in the maternity departments of the selected hospitals volunteered to participate in the study and they were trained

on the use of SDA. Phase three, post-intervention, comprised 87 cases of newborns asphyxia and 47 cases of PPH. The flowchart in Figure 6.1 shows the number of neonatal complication cases and PPH cases considered in the pre-intervention group (before the introduction of SDA) and the post-intervention group (after SDA).

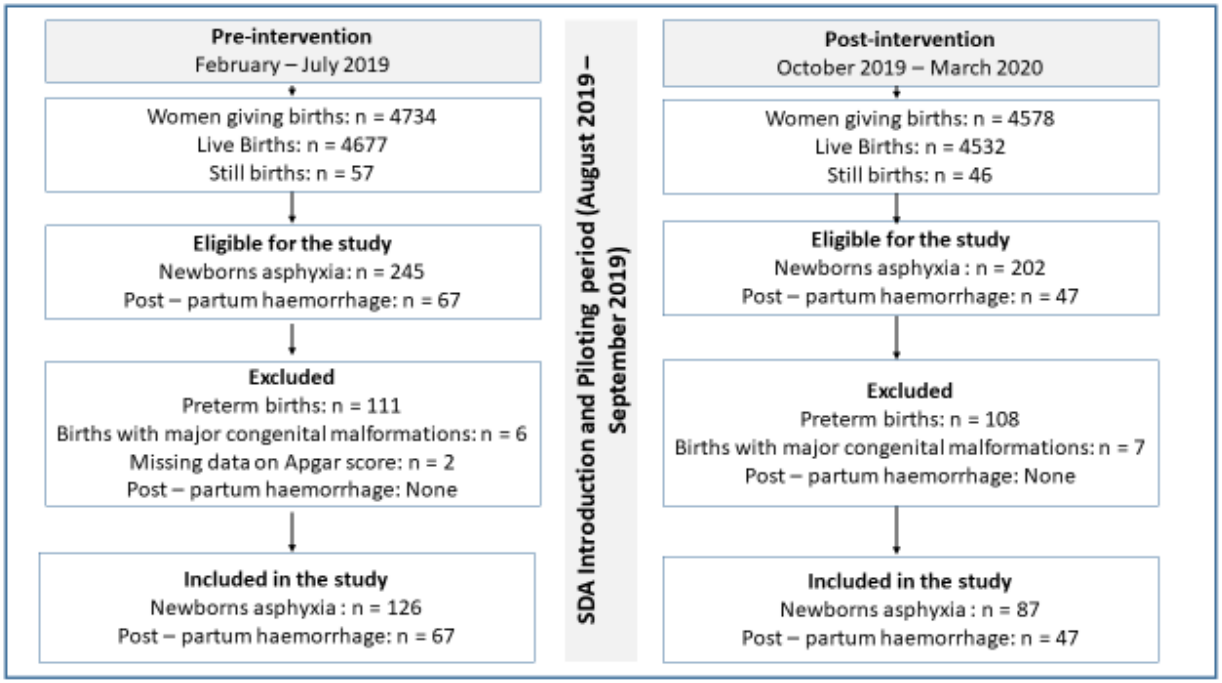

Figure 6.1: Records review flow chart

Description of the intervention: Implementation of the Safe Delivery mhealth Application (SDA)

The SDA is a smartphone application developed by the Maternity Foundation, Copenhagen University, and the University of Southern Denmark. It is designed to support nurses and midwives in clinical decision making, by providing them with instant access to evidence-based BEmONC clinical guidelines and a selection of essential preventive protocols in a user-friendly format. The content of the SDA is primarily based on WHO clinical BEmONC guidelines and has been validated by an international group of global health experts [246]. The clinical guidelines used by the Rwanda Ministry of Health are also primarily based on WHO guidelines except in some instances where clarifications/examples are given in line with the context-specific practices and available equipment. The SDA contains easy to understand animated instruction videos, action cards with validated clinical guidelines, essential drugs lists with their indications, practical procedures guidelines, and a learning platform [78]. All features and functions in the SDA are designed for low-literacy and low-income settings and work offline once downloaded. The SDA

can be used as a job aid and as an instructive aid in emergencies. While practicing, the skilled birth attendant (SBA) can consult action cards and drug lists to be helped in his/her clinical decision making. In the free time, the SBA can again play animated instruction videos, consult procedures descriptions and use the learning platform to update his/her knowledge and skills. The SDA can be downloaded free of charge for iPhone at https://itunes.apple.com/dk/app/safe-delivery/id985603707?mt=8 and for Android at https://play.google.com/store/apps/details?id=dk.maternity.safedelivery&hl=en.

The nurses and midwives in both hospitals received an explanation of the nature and purpose of the research and half-day training session on the use of the SDA. The majority of participants have downloaded the SDA on their personal smartphones during the training. The training session encompassed: an introduction to the research project; an overview of the SDA development and global outreach; description of the SDA features and modules; and hands-on practice on using the SDA as a job-aid and as a learning tool. Each of the study hospitals (Masaka and Nyamata) received three smartphones, with pre-installed English and French versions of the SDA. This was followed by the six months' intervention period, during which nurses and midwives provided BEmONC services with the assistance of the SDA installed on their personal smartphones or the smartphones provided by the researcher. During this period, the provided six smartphones were made available to the team on duty (three staffs per shift per hospital) at all times for use as a backup in case the participants experienced problems with their own smartphones. Nurses and midwives were expected to use the SDA as often as they wished. The intervention also entailed two visits per week by two research assistants to each of the study hospitals. During the visits, the research assistants monitored the SDA use by nurses and midwives.

6.3.4. Data collection

Data extraction forms were used to retrieve information on all cases of PPH and neonatal complications recorded in delivery registers. These were extracted and reviewed six months' pre-SDA intervention and six months' post-SDA intervention. The delivery registers contain information on obstetric and neonatal care including the Apgar scores and PPH progressions following neonatal resuscitation and PPH management. Newborn deaths or admission to the neonatal intensive care unit (NICU) or to neonatologist's service due to an unstable outcome (Apgar score < 7) after neonatal resuscitation was used as the primary outcome measure to determine the failure of neonatal resuscitation. The mothers' referral to a higher-level facility

(referral hospital) following an unstable outcome (persistent bleeding) after PPH management was considered as the primary outcome to measure the failure of PPH management at the district hospital. On the newborn side, we obtained data on Apgar scores progression and neonatal outcome following 10 minutes' neonatal resuscitation before and after the use of the SDA. While on the mother's side, we obtained data on maternal outcomes following PPH management before and after the use of the SDA.

6.3.5. Ethics approval

This study has been approved by the Human Research Ethics Committee of the University of the Witwatersrand (M190258) and the University of Rwanda, College of Medicine and Health Sciences' Institutional Review Board (No.377/CMHS IRB/2018). Permission to collect data has been granted by the hospitals which have authorization of using aggregated patient data in research. Consents to track the SDA usage were obtained from nurses and midwives. This study was carried out in accordance with relevant guidelines and regulations in the Ethical Declarations.

6.3.6. Statistical analysis

The data were checked for errors and exported from Microsoft Excel (Microsoft Corporation) to Stata version 16 (StataCorp LLC) for cleaning and analysis. Descriptive summary statistics were computed on data including the hospital, age of the mother at childbirth, the weight of the newborn at birth, sex of the newborn, mode of delivery, the leading clinician during delivery, Apgar scores at 1, 5 and 10 minutes and the resuscitation action taken for the newborns. For the maternal outcome, descriptive statistics included the hospital, age of the mother at delivery, gestational age in weeks, Mode of delivery, the leading clinician during delivery, Blood loss in milliliters, causes of PPH, the resuscitation action taken, mother outcome and cause of maternal death if dead. Further, the neonatal outcomes and maternal outcomes were compared at baseline and endline using Fisher's exact test. significance level was set at $p<0.05$.

6.4. Results

6.4.1. Demographic characteristics of end-users of the SDA

In total, 54 healthcare providers, 21 nurses and 33 midwives used the SDA during the intervention period. More than a half of the participants were from Masaka district hospital (56%), the majority of them were female (61%), the participants had an average age of 33 years (SD = 7.1). In terms of their level of education, most participants hold an advanced diploma (A1) in midwifery (50%). Only one participant had the secondary school level (A2) in nursing. The majority of the nurses

and midwives had less than six years of experience in the obstetric care (59%), spent more than ten hours per week providing services in obstetric care (74%), and participated in the care of more than ten deliveries per month (76%). Four participants acknowledged having never used a smartphone before the study. Additional details are shown in Table 6.1.

Table 6.1. The demographic characteristics of end-users of the SDA (N=54)

		n (%)
Hospital Affiliation		
	Masaka District Hospital	30 (56)
	Nyamata District Hospital	24 (44)
Sex		
	Male	21 (39)
	Female	33 (61)
Level of Education		
	Midwife A0	6 (11)
	Midwife A1	27 (50)
	Nurse A0	5 (9)
	Nurse A1	15 (28)
	Nurse A2	1 (2)
Experience in obstetrical care (years)		
	1–5	32 (59)
	6–10	15 (28)
	>10	7 (13)
Weekly workload in obstetric care (hours)		
	0–5	4 (7)
	6–10	10 (19)
	>10	40 (74)
Number of deliveries past month		
	0–5	8 (15)
	6–10	5 (9)
	>10	41 (76)
Experience with the smartphone		
	Tried using one	50 (93)
	Never tried using one	4 (7)
Age, years, Mean (SD)		33 (7.1)

Abbreviations: % : Weighted percent, SD: Standard deviation

6.4.2. SDA usage tracking

The SDA usage by nurses and midwives was tracked through the server of Maternity Foundation (table 6.2). We found that the most frequently accessed feature was the action cards, which was

used 199 times and 128 times in the midterm (at 3 months' intervention period) and endpoint (at 6 months' intervention period) respectively. The duration of time spent in the action cards by users varied from 282 minutes at midterm to 371 minutes at endpoint. The action cards were used by 66 users at mid-term and 80 users at endpoint. The number of users is higher than the study sample (n=54) because some participants have downloaded the SDA on their own smartphones in addition to the phones provided by the researcher and they were using both phones at different occasions. The least accessed feature was the essential drugs, which was used 26 times and 87 times in the midterm and endpoint respectively. The duration of time spent in the essential drugs by users varied from 14 minutes at midterm to 33 minutes at endpoint. The essential drugs were consulted by 14 participants at midterm and 23 participants at endpoint. For some features (action cards and essential drugs) the number of participants using the feature and the times spent in the SDA increased from midterm to endpoint. While for other features (practical procedures and videos), the number of participants using the feature and the session counts decreased from midterm to endpoint.

With regards to 'MyLearning feature', table 6.2 shows that a good portion of study participants (n=44, 85%) had started the familiar learning process in the midterm and by the endpoint 92% of the study participants had passed the familiar questionnaire. Similarly, a good portion of study participants (n=43, 83%) had started the proficient learning process in the midterm and by the endpoint 73% of the study participants had passed the proficient questionnaire. Finally, at endpoint, 75% of the study participants had passed the expert questionnaire. At the end of the intervention period, we had two SDA champions. The maternity foundation's server had also recorded 179 SDA users in Rwanda up to March 2020, meaning that our study participants in addition to downloading the SDA app on their own phones, they could have also shared the SDA to their colleagues in other hospitals apart from the hospitals included in the study. An exploration of the SDA acceptability was done at endline using surveys and focus group discussions with nurses and midwives. The findings of the SDA acceptability will be documented in a separate paper.

Table 6.2. SDA use by nurses and midwives

	Midterm		End-Point	
SDA App Features	Session Count	Session duration	Session Count	Session duration
	No. (number of times)	No. (duration in minutes)	No. (number of times)	No. (duration in minutes)
Action Cards	66 (199)	66 (282)	80 (128)	80 (371)
Essential drugs	14 (26)	14 (14)	23 (87)	23 (33)
Practical Procedures	37 (87)	37 (195)	17 (26)	17 (64)
Videos	53 (104)	53 (50)	33 (62)	32 (47)

My Learning	**Started the learning process , No. (%)**	**Passed the 'MyLearning' surveys , No. (%)**
Familiar	44 (85)	48 (92)
Proficient	43 (83)	40 (77)
Expert	39 (75)	39 (75)
SDA champions		**2 (3.85)**

Global Total SDA downloads_by March 2020, No. (%)	**126444 (100)**
Total SDA downloads in Rwanda_by March 2020, No. (%)	**179 (0.14)**

Abbreviations: No : number of content users, % : Weighted percent

Cases of newborns asphyxia

The analysis included 126 cases of newborns asphyxia in the baseline and 87 in endline groups over the study period. Table 6.3 shows that the majority of cases were from Masaka district hospital in the baseline group (55%) while in the endline group more cases were from Nyamata district hospital (56%). There were more male newborns for the baseline group (n=79, 63%) and the endline group (n=54, 62%). The most frequent mode of delivery was the spontaneous vaginal delivery in both the baseline group (n=77, 61%) and the endline groups (n=45, 52%). The leading clinicians during delivery, also in charge of neonatal resuscitation were mainly midwives (n=71, 56%) in the baseline group and (n=44, 51%) in the endline group. The average age of the mother was similar, 28 years and 27 years in the baseline and endline groups, respectively. The average weight of the newborn was similar, 2900 grams, and 2800 grams in the baseline and endline

groups, respectively. The average Apgar score at birth was the same, 6/10 in both the baseline and endline groups. However, the average Apgar score after 10 minutes of resuscitation was lower in the baseline group (8/10) than the endline group (9/10). The resuscitation actions taken were mostly dominated by aspiration and ventilation with Ambu bag in both groups, baseline (82%), and endline (79%). The endline group had higher numbers of newborns with stable outcome after resuscitation (n=64, 74%) than the baseline group (n=40, 32%). Overall, the endline group had fewer newborns transferred to NICU or neonatology service (n=24, 28%) than the baseline group (n=78, 62%).

Table 6.3. Participants characteristics_ Newborns asphyxia (N=213)

	Baseline n (%)	Endline n (%)
Hospital Affiliation		
Masaka District Hospital	69 (55)	38 (44)
Nyamata District Hospital	57 (45)	49 (56)
Sex		
Male	79 (63)	54 (62)
Female	47 (37)	38 (38)
Mode of Delivery		
Caesarean Section	49 (39)	42 (48)
Spontaneous Vaginal Delivery	77 (61)	45 (52)
Leading Clinician of the Delivery		
Doctor	49 (39)	42 (48)
Midwife	71 (56)	44 (51)
Nurse	6 (5)	1 (1)
Resuscitation Actions		
Aspiration, Ventilation with Ambu bag	103 (82)	69 (79)
Aspiration, Ventilation, Oxygenotherapy	12 (9)	6 (7)
CPR, Ventilation, Oxygenation	11 (9)	12 (14)
Outcome after 10 minutes Resuscitation		
Transferred to NICU or Neonatology Service	78 (62)	24 (28)
Skin to skin bonding with mother	39 (31)	63 (72)
Dead	9 (7)	0 (0)
Weight of the newborn, grams, Median (IQR)	2900(880)	2800(800)
Mother's age, years, Median (IQR)	28(7)	27(7)
Apgar Scores, Median (IQR)		
At 1 minute	6(2)	6(2)
At 5 minutes	7(2)	7(1)
At 10 minutes	8(2)	9(2)

Abbreviations: %: Weighted percent, IQR: Interquartile range

Cases of Postpartum hemorrhage (PPH)

The analysis included 114 cases of Post-partum hemorrhage (PPH): 67 in baseline and 47 in endline groups for both Masaka and Nyamata district hospitals over the study period. Table 6.4 shows that the majority of cases were from Masaka district hospital in the baseline group (54%) while in the endline group more cases were from Nyamata district hospital (55%). The most frequent mode of delivery was the spontaneous vaginal delivery in both the baseline group (n=47, 70%) and the endline groups (n=34, 72%). The leading clinicians of the delivery, also in charge of PPH management were mainly midwives (n=36, 54%) in the baseline group and (n=25, 53%) in the endline group. The average age of the mother was similar, 28 years in the baseline and endline groups, respectively. The average gestational age was similar, 39 weeks in the baseline and endline groups, respectively. The mean estimated amount of blood loss was 1167.2 mls in the baseline group and 1178.7 mls in the endline group. The most frequent cause of PPH was the uterine atony in both the baseline (72%) and the endline group (70%). The resuscitation actions taken were mostly dominated by administering oxytocin, IV fluids, and blood transfusion in both groups, baseline (37%), and endline (55%). The endline group had higher numbers of women with stable outcomes after PPH management (n= 44, 94%) than the baseline group (n= 55, 78%). Overall, the endline group had fewer women transferred to referral hospitals after PPH management (n= 3, 6%) than the baseline group (n= 13, 19%).

Table 6.4. Participants characteristics_ PPH (N=114)

	Baseline n (%)	Endline n (%)
Hospital Affiliation		
Masaka District Hospital	36 (54)	21 (45)
Nyamata District Hospital	31 (46)	26 (55)
Mode of Delivery		
Caesarean Section	20 (30)	13 (28)
Spontaneous Vaginal Delivery	47 (70)	34 (72)
Leading Clinicians of the Delivery		
Doctor	20 (30)	13 (28)
Midwife	36 (54)	25 (53)
Nurse	11 (16)	9 (19)
Causes of PPH		
Uterine atony	48 (72)	33 (70)
Cervical tear	11 (16)	7 (15)
Retention of Placenta	8 (12)	7 (15)
Resuscitation Actions		
Oxytocin, IV fluids	23 (34)	7 (15)
Oxytocin, IV fluids, Transfusion	25 (38)	26 (55)
Repair of tear, IV fluids	11 (16)	7 (15)
Removal of Placenta, IV fluids	8 (12)	7 (15)
Maternal outcome after PPH Management		
Transferred to Referral Hospital	13 (19)	3 (6)
Stable	52 (78)	44 (94)
Dead	2 (3)	0 (0)
Mother's age, years, Median(IQR)	28(5)	28(5)
Gestational age, weeks, Median(IQR)	39(0)	39(0)
Blood loss in Mls, Mean (SD)	1167.2 (276.6)	1178.7 (257.1)

Abbreviations: % : Weighted percent, IQR: Interquartile range, SD: Standard deviation

6.4.3. Pre-Post Differences in Newborns outcomes following neonatal resuscitation

We found a statistically significant association between the SDA intervention and newborns' outcomes following neonatal resuscitation, 6 months after baseline (Table 6.5). Among 213 cases of newborns complications who were included in the study, stable outcomes following neonatal resuscitation were recorded in 31% of newborns cases at baseline and 72% at endline. The transferred (unstable) newborns were 62% and 28% at baseline and endline respectively. While death following neonatal resuscitation appeared in 7% for the baseline group only. No death was recorded in the endline group. There was a significant difference between baseline and endline in

the outcome (stable, transferred, and dead) for newborns who underwent neonatal resuscitation (p=0.000, Fisher's exact test).

Table 6.5. Newborns Outcomes following neonatal Resuscitation (N=213)

	Before SDA (N=126), n(Wt.%)	After SDA(N=87), n(Wt.%)	P-Value (Fisher' exact test)
Newborns Outcome			
Stable	39 (31)	63 (72)	P(Fisher) = 0.000
Unstable(Transferred)	78 (62)	24 (28)	
Dead	9 (7)	0 (0)	

Abbreviations: Wt.%: Weighted percent

6.4.4. Pre-Post Differences in Maternal outcomes following PPH Management

We found a statistically significant association between the SDA intervention and maternal' outcomes following PPH management, 6 months after baseline (Table 6.6). Among 114 cases of PPH who took part in the study, stable outcomes following PPH management were recorded in 78% PPH cases at baseline and 94% at endline. Transferred (unstable) women were 19 % and 6% at baseline and endline respectively. While death attributed to PPH appeared in 3% women for the baseline group only. No death was recorded in the endline group. There was a significant difference between baseline and endline in the maternal outcome (stable, transferred, and dead) following PPH management (p=0.048, Fisher's exact test).

Table 6.6. Maternal Outcomes following PPH Management (N=114)

	Before SDA (N=67), n(Wt.%)	After SDA(N=47), n(Wt.%)	P-Value (Fisher' exact test)
Maternal outcome			
Stable	52 (78)	44 (94)	P(Fisher) = 0.048
Unstable(Transferred)	13(19)	3 (6)	
Dead	2 (3)	0 (0)	

Abbreviations: Wt.%: Weighted percent

6.5. Discussion

Main findings

The current study investigated the use of the SDA and its relationship to BEmONC outcomes for the most frequent birth-related complications in Rwanda; PPH and newborn asphyxia. Apgar scores and PPH progressions were considered in the investigation of newborn and maternal outcomes following neonatal resuscitation and PPH management.

The findings from this study are consistent with SDA having the potential to improve clinical outcomes. These results are encouraging: nurses and midwives were willing to use SDA and the intervention was engaged with throughout the intervention period. Clinical data show a correlation between SDA implementation and improved maternal and newborn outcomes. However, the improved maternal and newborn outcomes may have been influenced by other factors in addition to the SDA intervention. Nevertheless, the findings of this study contribute to the broader knowledge about the SDA effectiveness and provide promising evidence to support the need for more rigorous and expensive research on the SDA.

Comparison with other studies

As was noted in the present study, Lund et al. [78] also reported a significant effect of the use of the SDA particularly on skilled birth attendants in terms of significantly increased knowledge and skills scores in neonatal resuscitation in Ethiopia [78]. Our previous study also found a significant association between the SDA uptake/use and change in knowledge and skills of nurses and midwives in PPH management and NR [169]. Another study conducted in DRC Congo to determine the feasibility, acceptability, and potential effect of the SDA on health workers' practices in BEmONC reported a significant increase of health worker knowledge and self-confidence in the management of obstetric and newborn emergencies after 3 months SDA intervention [77]. In addition to the previous studies on the SDA, the present study provided evidence on the SDA implementation, use, and clinical outcomes. However, the implicit theory of change for the SDA may follow a logical sequence of (a) the SDA implemented and used; (b) the use of SDA supports skilled birth attendants' continuous learning and decision making; the use of the SDA changes clinical response behaviors and practices; (c) the changes in practices leads to improved clinical outcomes. Therefore, future research using a theory of change or a logical framework over a long period is needed to understand the dynamics and change processes of skilled birth attendants' clinical practices when using the SDA.

Moreover, mHealth programs have shown promising results for newborn outcomes. A study which looked at antenatal messaging services using a mobile phone intervention in Zanzibar reported a significant reduction in perinatal mortality [247]. This could be explained by the fact that mHealth applications have the potentiality to put relevant and reliable healthcare information into the hands of healthcare workers thus helping them in the management of maternal and neonatal cases. But also, that health professionals need continuous access to updated healthcare information and clinical guidelines to support their decision-making during practices. The same opinion was reported in a similar study done by Grol et al. [107] about the effective implementation of mHealth interventions [107]. However, Tamrat et al. [248] in their systematic review which analyzed mHealth interventions in maternal and newborn health programs and their outcomes around the world reported that few trials have been conducted and most maternal mHealth programs have not been evaluated, and the evidence is still weak [248]. Thus, the need for more evidence on maternal and newborn mHealth programs.

Maternal outcome following PPH management was another significant predictor in the present study. Our findings are in agreement with other studies that documented mHealth interventions which have been tested in a variety of health services delivery including decision support and clinical management [249–251]. These studies found promising findings for the mhealth technology in general and for maternal healthcare services in particular. Then again, other studies have shown that the evidence of maternal mHealth interventions is supportive but weak. A 2017 systematic review on mHealth interventions in low-income countries demonstrated good promise for the use of mHealth interventions in maternal health, but the evidence is limited [244]. This review suggested more research on the relationship between mHealth and clinical outcomes because the majority of mHealth trials focused on very distinct mHealth applications (i.e., appointment reminders and data collection). Another review which identified 51 RCTs, documented that nearly half of the reviewed RCTs (n=22) showed negative or unclear results, thus the need for better evidence; and for caution with new interventions [123]. Another study which assessed the impact of the SDA on the incidence of PPH in Ghana reported that the SDA was associated with an insignificant lower incidence of PPH [22]. Hence, the need for more evidence and higher-quality research in this field. The current study adds to much-needed evidence as to how a decision-support mHealth application functioned in a low-resource setting. Future research

that analyze event-event correlation between SDA use and maternal and newborn outcomes would be important.

6.6. Strength and Limitations

Though our study documents important patterns of use of a mHealth to inform clinical decisions, the quantity of information accessed for the care of individual patients is limited in the current study. We acknowledge the limitations of our study design, pre-post intervention, which partly permitted us to demonstrate the effects of the SDA on maternal and newborn outcomes. The observed maternal and newborn outcomes may have been influenced by other factors in addition to the SDA intervention. Also, nurses and midwives may have consulted other sources rather than the SDA to inform their decision-making during the intervention. Although this limitation is inherent in the design of the study, the current study contributes to the broader evidence about the effectiveness of the SDA and provides much-needed insights as to how a decision-support mHealth application functioned in a low-resource setting.

6.7. Conclusion

The use of the SDA supported nurses and midwives in the management of PPH and neonatal resuscitation which may have contributed to improved maternal and neonatal outcomes during 6 months of the SDA intervention. Mhealth interventions that focus on the clinical decision support process in maternal and newborn care may contribute to improved services delivery and should be considered by policymakers in resource-limited settings, like Rwanda. Overall, there is limited evidence on the effects of mHealth interventions on clinical outcomes on a large scale and further research is necessary to draw holistic conclusions, particularly for developing countries within the field of maternal and newborn care.

Chapter seven: A mixed-method study exploring experiences, perceptions, and acceptability of using a Safe Delivery mHealth Application in two district hospitals in Rwanda.

7.1. Abstract

Innovative use of mobile health (mHealth) technology in timely management of childbirth complications is a promising strategy, but its evidence base is limited. The Safe Delivery mHealth Application (SDA) is one of the recent mhealth applications (loaded in smartphones) which is a clinical decision support and training tool for basic emergency obstetric and newborn care (BEmONC). This paper describes, the health providers' experiences, perceptions, and acceptability of using the SDA, as well as the perceptions of key stakeholders.

A mixed-methods approach was utilized. Quantitative methods consisted of a self-reported acceptability survey, administered to 54 nurses and midwives, including questions on their usage and perceptions of the SDA. Descriptive statistics were employed to analyze the survey data. Qualitative methods included two focus group discussions with 24 nurses and midwives, and six key informant interviews with stakeholders (maternity matrons, responsible for maternal and child health, and district hospital managers). Thematic analysis was performed and selected quotations used to illustrate themes. The study took place in two district hospitals in Rwanda.

Quantitative results found that 31 (57.4%) participants used the SDA four to six times per week. Many participants felt more confident (53.7%) and better at their job (40.7%) since having the SDA. Likert scale survey responses (1-5, 1 =Strongly Disagree, 5 =Strongly Agree) indicated general agreement that SDA is easy to use (Mean =4.46), is an effective decision support tool (4.63), and training tool (4.65). Qualitative results included themes on perceived usefulness; professional growth acquired through the use of the SDA; SDA, an empowering, intuitive, and user-friendly technology; desired SDA features and functions; benefits of SDA as perceived by key informants, and future use of the SDA.

The nurses and midwives perceive the SDA as having improved their ability to manage childbirth complications. Key stakeholders also perceive the SDA as a useful tool with a reasonable cost and recommend its implementation in routine practices. This study deepens the understanding of the potential benefits of mHealth such as the SDA in low-income settings, like Rwanda. It also provides more evidence on the impact of mHealth in assuring quality BEmONC.

Adapted from Nishimwe, Aurore*, Latifat Ibisomi, Marc Nyssen, and Daphney Nozizwe Conco. A mixed-method study exploring acceptability, perceptions, and experiences of using a Safe Delivery mHealth Application in two district hospitals in Rwanda. *Under review at BMC Nursing_See Appendix 18*

7.2. Background

Globally, maternal and newborn deaths remain a public health concern despite several efforts that have been/are being made to reduce the deaths. It is estimated that 295,000 maternal deaths, 2 million stillbirths and 2.5 million early newborn deaths occur annually in the world [79,80]. More than 90% of these deaths happen in low- and middle-income countries, like Rwanda [34,173]. Most of these deaths are attributable to preventable causes such as post-partum haemorrhage (PPH), newborn asphyxia, pre-eclampsia, obstructed labor, infections, and hypertensive disorders [174]. The WHO, UNICEF, and UNFPA have identified essential interventions known as Basic Emergency Obstetric and Newborn Care (BEmONC) for prevention and treatment of the preventable causes of maternal and newborn deaths [1,84]. The BEmONC package includes the management of PPH, the removal of a retained placenta, the management of maternal sepsis, the management of hypertensive disorders, the management of prolonged labor, the management of complications of abortion, and neonatal resuscitation (NR) [1]. These services can be provided by nurses and midwives. There is evidence that BEmONC is a key intervention to reduce death and disability of mothers and newborns [84]. However, the available literature remains characterized by gaps in assuring the quality of BEmONC.

The quality of BEmONC services is important to improving maternal and newborn health [88]. The research evidence suggests that barriers to instituting quality BEmONC are complex and are often linked to limited knowledge and skills among health care providers, lack of access and adherence to evidence-based clinical guidelines, insufficient monitoring to inform appropriate responses, and lack of some essential materials [34]. Besides, research recommends the use of mobile health (mHealth) to improve health systems, as a solution that could potentially support in addressing some of the health systems challenges and improve service delivery [74,148].

The safe delivery mHealth application (SDA) is a novel mHealth application which is a decision support and training tool for BEmONC that was developed by the Maternity Foundation [28]. The main purpose of the SDA is to make a healthcare provider better prepared to prevent, detect, and

manage life threatening complications to mothers and newborn via offering evidence-based BEmONC [28]. The SDA contains animated videos with instructions on management of PPH and NR. The SDA offers the opportunity to watch the entire instructional animated video (8–15 min long) as well as choosing to see a specific procedural step of each video (1-3 min long). Besides, the SDA contains a catalogue of action cards with essential recommendations to support clinical decision making in an emergency situation when the user does not have time to review a video. The SDA also include a comprehensive drug list which contains useful information on the various essential drugs needed to perform PPH management and NR. Further, the SDA describes certain essential procedures step-by-step and required equipments. In addition, the SDA has a self-explanatory learning platform 'My Learning' that provides learning and assessment strategies based on key elements within the clinical content found in the SDA. To stimulate use, the SDA sends weekly notifications with quiz questions and a direct link to the films where the information to answer the question is found. The clinical content of the SDA was developed following international WHO guidelines but focusing on key essential lifesaving interventions of BEmONC [246].

The SDA can be downloaded free of charge for iPhone at: https://itunes.apple.com/dk/app/safe-delivery/id985603707?mt=8 and for Android at: https://play.google.com/store/apps/details?id=dk.maternity.safedelivery&hl=en

The present paper, was derived from a broader study about the implementation of the SDA in handling two elements of the BEmONC: PPH and NR in two district hospitals in Rwanda. Such focus was informed by evidence that indicated PPH and newborn asphyxia as the priority challenges in Rwanda [141,252]. In 2019, Rwanda's maternal mortality was estimated at 203 deaths per 100,000 live births and its neonatal mortality rate was 19 deaths per 1000 live births [178] despite 91% of births taking place in healthcare facilities and attended by healthcare professionals [175]. Therefore, more efforts are still needed to reduce the numbers of deaths. The SDA was piloted in two district hospitals in Rwanda. This pilot implementation process was divided into three phases (pre-intervention, intervention, and post-intervention). The first phase (pre-intervention) involved the presentation of the research to different stakeholders and the baseline study (surveys, records review, and focus group discussions). The second phase (intervention) included the capacity building in the usage of the SDA among nurses and midwives;

the SDA provision and piloting; and the SDA implementation for a period of six months. The third phase (post-intervention) included the implementation evaluation and encompassed the endline study (surveys, records reviews, focus group discussions, and key informant interviews). More details are provided in the protocol paper for this research [160]. The present paper explores the end-users' experiences, perceptions and acceptability of the SDA and key stakeholders' perspectives.

7.3. Methods

7.3.1. Study design

This paper describes part of a larger study about the implementation of the SDA in BEmONC services in two district hospitals in Rwanda. The larger study methodology and the evaluation of initial outcomes have been reported elsewhere [160,168–170]. The part of the study presented in this paper, used mixed research methods to explore end-users' experiences, perceptions, and acceptability, and explore the key stakeholders' perceptions of the SDA. Mixed-methods is defined as a research design that involve the combination of quantitative and qualitative research approaches in order to obtain a comprehensive understanding of the research question [152,164].

7.3.2. Study setting

The study took place in two district hospitals in Rwanda: Masaka hospital in Kigali, an urban province; and Nyamata hospital located in the eastern rural province [44].The two hospitals were selected out of 12 district hospitals in the two provinces because both had a high number of deliveries per year [40] and had been offering BEmONC services for more than five years.

7.3.3. Study Participants

The study adopted a purposive sampling and included 60 participants, the nurses and midwives (n=54) and stakeholders (n=6). Nurses and midwives who deal with childbirth in the maternity departments of the two district hospitals were introduced to the study and invited to participate in the study during the face-to-face morning staff meetings. The inclusion criteria were as follows: having work experience of at least six months in obstetric care; being full-time employed in the selected hospitals; and willing to participate in the study. The selected stakeholders (key informants in the management position at the district hospital level) were approached individually and consented to participate in the study. They included maternity matrons (n=2), managers responsible for maternal and child health (n=2), and district hospital directors (n=2).

7.3.4. Data collection and analysis

Quantitative data

The quantitative part of the research entailed asking all nurses and midwives who were part of implementation of the SDA to complete a self-administered questionnaire (Additional file 1) evaluating usage of the SDA, as well as their perception and acceptability. A pilot test of the self-administered questionnaire was conducted with 2 nurses and 3 midwives in a different district hospital prior to the survey. The survey was conducted at endpoint once users had used the SDA for six months. Responses were analysed descriptively using Stata version 16 (StataCorp LLC).

Qualitative data

Two methods were used to collect qualitative data - focus group discussions (FGDs) and key informant interviews (KIIs).

Focus groups discussions explored in depth the participants' experiences and views on the functionality of the SDA. Two FGDs were conducted, one in each of the study hospitals. In each hospital, 12 participants were recruited and total number of FGD participants is 24. The participants included in the FGDs were selected based on their interest and availability. We sought perspective diversity in terms of age, gender, and experience [253] and these criteria were considered in both groups.

The Key Informant Interviews were conducted with six participants (three from each hospital), who were selected because of their leadership/management portfolios in the participating hospitals. The purpose was to get their views on the feasibility of adopting the SDA for wider implementation with the focus on its costs, possible scalability and sustainability. The interviews with key stakeholders started with an introduction of the SDA to the key informant including an explanation of the features and modules of the SDA, and a demonstration of how the SDA functions using a smartphone. After the introduction of the SDA, the key informant was invited to ask questions and comment on the SDA. Once their concerns were addressed, the researcher presented the estimated total cost that was used for piloting the SDA in two district hospitals (Masaka and Nyamata) in Rwanda. The estimated total cost was 10.076.410 Rwf ($10000) including the technology cost =4.504.000 Rwf ($4470.56), the training cost =2.083.410 Rwf ($2067.94) and the intervention cost =3.489.000 Rwf ($3463.09). Then, participants were asked

to provide their perceptions of the SDA and their opinions on its cost, scalability, and sustainability.

The interview guides (Additional file 2) were developed in English, translated to Kinyarwanda, and translated back to English in a blinded manner to ensure accuracy and equivalence [165]. To ensure the quality and adequacy of the interview guides, they were pretested with two participants at a different district hospital. The interviews were conducted face to face in March 2020 and were held in private rooms at both Masaka and Nyamata district hospitals to ensure confidentiality. Interviews were conducted in the language of the participants' preference, which was Kinyarwanda. The first author conducted the interviews with assistance of an experienced research assistant who assisted in taking notes and supervising the tape recording. FGDs lasted between 60 and 90 minutes and KII interviews between 30 and 45 minutes. All FGDs and KIIs were digitally recorded and transcribed in Kinyarwanda by two research assistants. Transcriptions were done following the true verbatim method to accurately capture meanings, perceptions, and context [254]. Then, transcripts were translated from Kinyarwanda to English by a professional translator. In order to ensure that everything was translated as correctly as possible, all transcriptions were compared with the audio files and field notes. The data were analyzed using thematic analysis with a hybrid approach (inductive and deductive) [165]. Two authors (AN and DNC) first read all transcripts independently, then jointly developed a codebook. Disagreements were resolved by discussion. The final list of codes was applied to all transcripts using Nvivo 11 Plus software. Coded output was then read, merged into major themes, and illustrative quotations were identified. The consolidated criteria for reporting qualitative research [185] guided reporting for the qualitative data (Additional file 3).

Findings from both quantitative and qualitative data were integrated during the data-interpretation stage. The goal was to obtain different but complementary data that validate the overall results about the SDA acceptability.

7.3.5. Ethical considerations

Ethical approvals were obtained from the Human Research Ethics Committee of the University of the Witwatersrand (M190258) and the University of Rwanda, College of Medicine and Health Sciences' Institutional Review Board (No. 377/CMHS IRB/2018). All participants gave written informed consent and consents for recording the interviews prior to their participation. Participants

were assured that their identities would remain anonymous in all reporting of the study and that their personal information would be kept confidential. All methods in this study were carried out in accordance with relevant guidelines and regulations in the Ethical Declarations.

7.4. Results

7.4.1. Characteristics of quantitative study participants

A total of 54 nurses and midwives completed the acceptability survey. The majority of participants were midwives (n=33). More than half were from Masaka district hospital (n = 30, 56%), the majority were female (n = 33, 61%), their average age was 33 years (SD = 7.1). The level of education was predominantly the advanced diploma (A1) in midwifery with 27 of 54 (50%) participants having advanced diploma (A1 level) in midwifery. The least represented level of education was the secondary school level (A2) in nursing with only one participant with A2 level in nursing. A detailed description of the survey respondents is provided in Table 7.1.

Table 7.1. Demographic characteristics of the acceptability survey respondents (N=54)

	n (%)
Hospital Affiliation	
Masaka District Hospital	30 (55.6)
Nyamata District Hospital	24 (44.4)
Sex	
Male	21 (38.9)
Female	33 (61.1)
Education Level	
Midwife A0	6 (11.1)
Midwife A1	27 (50)
Nurse A0	5 (9.3)
Nurse A1	15 (27.8)
Nurse A2	1 (1.8)
Age, years, Mean (SD)	33 (7.12)

Abbreviations: %: Weighted percent, A0 = bachelor's degree, A1 = Advanced Diploma, A2 = Secondary school level.

7.4.2. The nurses' and midwives' experiences of the SDA during the study implementation.

The utilization of the SDA by nurses and midwives

The majority of participants (n=31) reported using the SDA four to six times per week. Features of the SDA that were most consulted include; the action cards (n=15), my learning (n=14) and the drug list (n=10). A half of the participants used the SDA to revise their knowledge. Other

participants used the SDA in emergency situations (n=14), in a normal work situation (n=5) and to discuss with co-workers (n=8). Nurses and midwives predominantly accessed the SDA on both their own smartphones and on the smartphones provided by the researcher (n=28). A large number of participants (n=35) often used the SDA with a co-worker. Participants reported having access to most of the equipments and drugs seen in the SDA (n=40). More details on the SDA use and evaluation by end-users are shown in Table 7.2.

Table 7.2. SDA access and evaluation by nurses and midwives (N=54)

	n (%)
Frequency of SDA use in a week	
I used it almost every day	15 (27.8)
I used it 4-6 times	31 (57.4)
I used it 1-3 times	8 (14.8)
I didn't use it at all	0 (0)
Features of the SDA most consulted	
Videos	9 (16.7)
Action cards	15 (27.8)
Drug list	10 (18.5)
Procedures	6 (11.1)
My Learning	14 (25.9)
Most often quoted reasons for using the SDA	
To revise my knowledge	27 (50)
During an emergency	14 (25.9)
In a normal work situation	5 (9.3)
To discuss with co-workers	8 (14.8)
The device often used to access the SDA	
Own phone	7 (13)
The phone provided by the researcher	19 (35.2)
Both	28 (51.8)
With who do you often use the SDA?	
By myself	19 (35.2)
With a co-worker	35 (64.8)
Access to the equipment and/or drugs seen in the SDA.	
All	14 (25.9)
Most	40 (74.1)
None	0 (0)

Abbreviations: Wt.% : Weighted percent; SDA: Safe Delivery mHealth Application

When rating their experiences of using the SDA particularly, half of respondents (n=27) indicated that it was very easy to the SDA, however one participant reported that it was very difficult to use

a smartphone. SDA features that were most appreciated included: the action cards (33%), the drug list (22%), and my learning (19%). They also reported feeling more confident (53.7%) and becoming better (40.7%) at doing their jobs at work. Few participants (n=5) reported what they liked least about the SDA, three participants stated that they did not understand instructions, and the other two said that it was difficult to navigate the smartphone. More details on the experiences with the SDA and its added value are displayed in Table 7.3.

Table 7.3. Experiences with the SDA and its added value (N=54)

	n (%)
Experience with the smartphone and the SDA	
Very easy	27 (50)
Somewhat easy	23 (42.6)
Somewhat difficult	3 (5.6)
Very difficult	1 (1.8)
Features of the SDA most appreciated	
Action cards	18 (33.3)
Videos	10 (18.5)
Drug list	5 (9.3)
Procedures	12 (22.2)
My Learning	9 (16.7)
Added value from the SDA	
I have become better at doing my job.	22 (40.7)
I feel more confident at work.	29 (53.7)
Fewer mortalities/fatal cases	3 (5.6)
I did not notice any change.	0 (0)
What do you like least about the SDA?	
I do not understand the instructions.	3 (5.6)
I think it is difficult to navigate the smartphone.	2 (3.7)
The app does not add to my existing knowledge.	0 (0)
None applicable.	49 (90.7)

Abbreviations: Wt.% : Weighted percent; SDA: Safe Delivery mHealth Application

7.4.3. Acceptability of the SDA as rated by nurses and midwives.

Nurses and midwives were asked to rate their acceptance of the SDA in a Likert scale. They were asked whether they "strongly disagree", "disagree", were "undecided", "agree", or "strongly agree" to a series of statements relating to the SDA acceptability. Responses were assigned point values as follows; strongly disagree =1, disagree =2, undecided =3, agree =4, strongly agree =5. Likert scale survey results showed that the SDA was: well understood (Mean=4.00); easy (4.46) and

comfortable (4.31) to use; an effective decision support (4.63) and training (4.65) tool; and useful in improving efficiency in BEmONC (4.59). Most participants reported that they intended to continue using the SDA in daily practices (4.68). On the other hand, a lower rating was given to using the SDA when seeing notifications (2.48), implying that most participants did not only use the SDA when they saw notifications. The notifications are push messages that appear occasionally on the phones of the SDA users to remind them to revisit the SDA. The messages mainly guide the users to interesting parts that they may want to explore in the SDA. Overall participants reported good acceptability of the SDA. Likert scale responses are highlighted in Table 7.4.

Table 7.4. Likert scale survey responses of nurses and midwives about SDA acceptance

Statement	N	Mean (SD) [Range]
I have a good understanding of what the SDA is	54	4.00 (0.71) [3-5]
The SDA is easy to use	54	4.46 (0.50) [4-5]
I am comfortable using the SDA	54	4.31 (0.57) [4-5]
The SDA is an effective decision support tool for BEmONC	54	4.63 (0.69) [4-5]
The SDA is an effective training tool for BEmONC	54	4.65 (0.48) [4-5]
The SDA is useful in improving efficiency in BEmONC	54	4.59 (0.56) [3-5]
I intend to continue using the SDA in my daily practices	54	4.68 (0.50) [4-5]
I use the SDA when I see notifications	54	2.48 (0.40) [1-3]

Note: Likert scale response options were as follows: 1Strongly Disagree, 2Disagree, 3Neutral, 4Agree, and 5Strongly Agree

7.4.4. Perceptions about the usefulness and acceptability of the SDA

The results of the interviews with end-users of the SDA emerged into four main themes: (1) the perceived usefulness of the SDA; (2) professional growth acquired through the use of the SDA; (3) SDA, an empowering, intuitive and user-friendly technology; and (4) the desired SDA features and functions. The results of the interviews with key stakeholders revealed two main themes (1) benefits of the SDA as perceived by the key informants, and (2) future use of the SDA. These identified themes are shown in Figure 1. More details on the main themes and sub-themes are presented in the discussion of results, and are illustrated by verbatim quotations from the two FGDs and six KIIs.

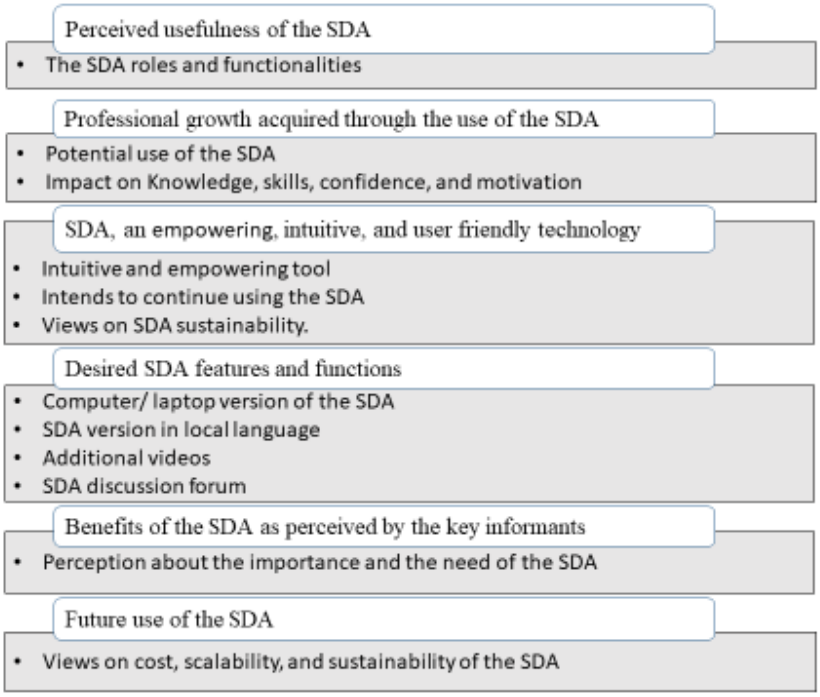

Figure 7.1: Thematic framework

Interviews with SDA end-users (nurses and midwives)

Perceived usefulness of the SDA

Participants described the SDA as a useful, intuitive, empowering and practical tool that supported their daily practices. They described how it provided important information and guidelines on management of obstetric emergencies, and thus, increases their knowledge and skills on how to manage normal childbirth as well as birth complications.

> *"This application came as a golden opportunity for us …normally, it is very hard to go to a library all the time to read; but the library, I am hereby talking about is that SDA application we have received…It provides very useful information and guidelines that upgrade our knowledge and skills in delivery care"* **Midwife, FGD1.**

In addition, nurses and midwives reported using the SDA both as a decision support tool while managing birth complications including PPH or NR, and as a debriefing tool for reflections on performed care to identify if essential procedures had been missed.

> *"When you have an emergency case to manage, you don't have difficulties figuring out how to handle it…all the steps are clearly outlined in this application and so well summarized that you immediately find what you need whenever you refer to it…The SDA support our clinical decisions in emergency situations…Sometimes, when I go home from*

a night duty, on the bus, I consult the SDA to see if I have performed well during the night" **Nurse, FGD2.**

Participants also described the SDA as a practical and easy to use tool that helps strengthen their theoretical knowledge. They articulated how the SDA helped them remember the management of rare clinical cases. Procedures for those rare cases are easy to forget as they rarely had to apply the theory learnt from school into practice.

> *"Before SDA, you could sometimes start wondering what management was appropriate for a case which is not so frequent after you had forgotten…Now, we refer to the SDA when there is a doubt about anything… With this new application, we have become all fresh and we can easily remember the essential procedures step by step as per international standards"* **Midwife, FGD1.**

Other participants expressed appreciation of the SDA as a training tool, highlighting the ingenuity of the visuals when dealing with life threatening complications of mothers and their newborns. They considered the SDA to be a kind of simulated clinical training that continuously enhances their knowledge and practical skills, contributing to their professional growth. They also reported improved performance when managing childbirth complications. Such improvement was attributed to continuous learning, facilitated by the SDA and the fact that learning could take place anywhere.

> *This application has been an important learning tool…I consider it as a training manual with all clinical guidelines accompanied by video materials… we learn a lot from the SDA in addition to what we learned at school…You can learn from this application from anywhere: at the hospital, on the bus, at home or anywhere. So, having your telephone means being able to learn more anywhere."* **Midwife, FGD2.**

Then again, participants revealed that they used to consult other internet sources for learning like YouTube. They found such sources not so easy to use, as it was hard to get concise updated information and guidance in a timely manner, the way the SDA does.

> *"We used to visit YouTube to learn something about the services we deliver, but most materials in there are not so clear as in this app. When you consult the SDA, you find that everything is easy to understand. You quickly get information on which medication is good for which case…"* **Midwife, FGD1.**

"Some of us are mentors in health centers and we have been consulting this application while preparing training materials" **Midwife, FGD1.**

Some found the SDA notifications useful as reminders for them to continue learning. The notifications that appeared intermittently on their phones, reminded them to revisit the SDA that also pointed them to other interesting parts of the SDA that they may want to explore.

"We have posters displayed in maternity telling us what to always bear in mind. Some of the information on them is "remember to close the door to keep the newborn warm" ... I compare this with the SDA notifications that I frequently get on my smartphone…these are very nice reminders that I have to keep learning" **Midwife, FGD2.**

"I would come back to what a colleague said about SDA notifications. This is a way of alerting you and I like that… There exists a wrong belief that nurses don't like reading. Maybe, it is true but this application is not too demanding. It doesn't consume your time as if you go to a library… This app is a good source and we need to regularly use it" **Nurse, FGD1.**

Professional growth acquired through the use of the SDA

The perceived usefulness of the SDA described by the participants was associated with substantial improvements in their childbirth care practices. Nurses and midwives narrated experiencing an increase in their knowledge, skills, and confidence after using the SDA and how such professional growth has been reflected in the quality service they offer.

"The reason number one I like this app is that it upgrades my knowledge and skills, and makes me confident than before…it is a kind of continuous professional development…It is so good in a way that if you fail to understand the text when reading, you have an option to search for more explanation using videos. It is really very useful…" **Nurse, FGD2.**

"The biggest difference for me when I compare now and the past experience is service delivery which has so positively improved. The special aspect of the application is that the content therein has everything we theoretically studied at school" **Midwife, FGD2.**

The study participants indicated that the SDA has helped them to recollect and revise their skills, which have made them more capable at managing childbirth complications in accordance with the

recommended essential procedures. One of the significant changes expressed by participants was that they had learned the lifesaving steps of how to stop a bleeding by applying bimanual compression.

> *"This application has been helping us refresh our memories and equipping us with techniques that we use to handle obstetric emergencies.… My colleagues have talked about bimanual compression…You may even not know anything about it … Then, when you try to familiarize with it on the SDA, you get to know about it and perform it correctly"* **Midwife, FGD1.**

Other participants explained how the SDA supported them during practice. They described the before SDA childbirth care experience and compared it with after SDA experience by highlighting the specific instances in which the SDA supported them. Previously, in situations where nurses and midwives were struggling to assist a mother or a newborn, they would immediately call upon a medical doctor to come and help. And, sometimes the doctor assigned to maternity department was busy with caesarean surgery which would delay his assistance to attend to the complicated case. But, now with the support of the SDA, nurses and midwives have been able to provide essential assistance to mothers and newborns while waiting for the doctors.

> *"I agree that BEmONC services were also delivered before we started using SDA but the situation was not the same. For example, when there was a complication with a patient, the only thing we would do was to ask a colleague or to call a medical doctor. This was time consuming and would delay service delivery and could complicate the situation even cause maternal deaths... However, when there is a problem nowadays, you just take your phone, go to the application and get a quick solution. As a result, our patients get quick and more efficient service"* **Midwife, FGD2.**

Both nurses and midwives revealed that they used to fear occurrence of birth complications, because of the limited skills and experience on how to manage such events. They noted that the SDA had reduced this fear and had led them to have more confidence in their work.

> *"In using this app, you are always aware of what might happen in a given case. So, when you have a real case, you don't panic much…For instance, when it comes to PPH management, with the SDA you can easily figure out the steps to follow*" **Nurse, FGD1.**

"This application can help you when you are stressed. You may have had a lot of cases to manage in a day and end up in confusion somewhere. When this happens, you take your phone and see what should be done to handle a particular case with confidence." **Midwife, FGD2.**

Some participants described how solving problems using the SDA motivated and enabled them to be more efficient in providing care at work.

"when you have a problem and you find a way to solve it, that is self-explanatory; you feel motivated automatically. As we get support from the application, our job becomes easier and more efficient" **Midwife, FGD1.**

Further, nurses and midwives explained that they used the SDA either at home to update knowledge or while they were at work, either before a delivery when the woman is in labor or when complication arises in the course of a delivery. Some participants described using the SDA to guide co-workers when they work in pairs in order to follow the necessary steps during a delivery. In emergency situations, the SDA was often used as a decision support tool to see how to manage e.g. PPH and neonatal resuscitation or as a reminder of drug dosages and administration. Participants also acknowledged having access to most of the equipments and drugs seen in the SDA.

"We have most of the materials we need to perform well. But, the SDA has been there to support us in upgrading our knowledge wherever we are - at home, before assisting a delivery or during an emergency…You may forget something like medication dosage, even though you learned it at school… but since we got this app, it helps us to remember the dosages in emergencies, we use it as a job aid in a simple way" **Nurse, FGD2.**

SDA an empowering, intuitive and user friendly technology

The study participants also voiced that the SDA is easy to use, intuitive, user friendly, and enabled them to provide first aid to patients before calling upon doctors.

This application is special in that it is so focused and shows you clear sequences…For example, you can easily find what specifically refers to steps for removing a retained placenta when you have such a case. We really like it because it is easy to use" **Midwife, FGD2.**

"I would say something additional. With this application, we have learnt how at least one can provide first aid for a mother or do resuscitation for a newborn… That is so important because you don't need to call upon a doctor for everything" **Midwife, FGD2.**

Likewise, participants indicated that the SDA has helped them to get a common understanding with medical doctors about managing birth complications. They explained on how consulting the SDA helped them to have informed recommendations and they were happy to contribute with confidence to care plans and sometimes supporting doctors.

"I would say that when I have a special case, I first consult the application, see how I can myself manage it before I talk to a medical doctor. Even when I have to talk to the doctor, at least I provide an informed suggestion and contribute to further treatment steps. We are supporting our doctors much more." **Midwife, FGD1.**

Then again, nurses and midwives described how the SDA has helped them to get updated information and to have a common understanding among themselves during practice.

"I can easily remember what I studied in school and when I tell my colleague X, he sometimes tells me a different story. This is due to the fact that he studied so recently, let's say three years ago, while I studied the similar subject 12 years ago…There is a need for all of us to have the same updates. This application is a solution because it keeps getting updated" **Nurse, FGD1.**

When asked if they will continue using the SDA in their future practice. Both nurses and midwives stated that due to the SDA benefits, it is their own advantage to continue using it in their routine practice for efficient provision of care.

"I would say that we have been lucky to be the champions of this application. I agree that we have a lot of work to do in maternity but we can't forget that we also need updates in our career…We will always need to refer to the app in our routine practices and find some time to learn new things from the SDA. We shall keep using it and it is for our own interest" **Midwife, FGD2.**

"This application is user friendly, affordable, covers a lot of areas, and does not take your internet megabytes when using… It is not like a book or a computer that would be heavy for you to carry…It is in a mobile phone that you always carry in your hands…You can

check up anything, anywhere and anytime.… Unless something unexpected happens, I don't see how people can stop using the SDA" **Midwife, FGD1.**

When asked how they perceive the SDA sustainability in district hospitals in Rwanda, all nurses and midwives indicated that the SDA will be likely sustained.

"This application will be maintained because it is an important tool for us to deliver good service to the patients. When you use it properly, you deal with various cases with confidence and you perform your duties with success" **Midwife, FGD1.**

"I am also confident that SDA will be sustained for two main reasons. The first reason is that it is easy to use and provides text content accompanied by video materials. Secondly, SDA is so relevant in that it is equipped with modules that reflect our day to day clinical practices" **Midwife, FGD2.**

Furthermore, participants requested the SDA scalability to the whole country of Rwanda in consideration of the present country's agenda to support the adoption of technology in healthcare service delivery.

"Personally, I would say that this is the most appealing application on my phone…When we are discussing with colleagues on social media (WhatsApp), there may be some questions raised in relation to our career. When there is a confusion, I immediately take my phone, get reliable information from the SDA and in a fast way I share with them… Is it possible to implement this app in all hospitals in Rwanda? …Since most people have smartphones, this should not be a problem, also our country is currently promoting application of technology in healthcare. I think this would make a lot of difference" **Midwife, FGD1.**

"I have to tell you that this is a very good application, those using the application have already started seeing the benefits and they gain a lot from it. I wish it could have been shared with other hospitals too. It should be scaled up to national level. I wish to see all midwives in Rwanda using this app… It is easy to use, once you have it installed, you don't need much guidance on how to use it, then we will be able to save more maternal and newborn lives" **Midwife, FGD2.**

"I remember I was in Musanze some time back and when I talked about this application to my friends, they were surprised. They started asking me how they can access it too. I just showed them and they became very interested. I am inviting everyone to have this spirit of sharing so that it reaches more people" **Nurse, FGD1.**

Other participants recommended that the SDA should be part of learning materials used at University.

"Ever since I started using the SDA, there has been no single case that I have failed to get information about in this application. I think this application should be part of tools that midwifery students use at University before they graduate. If this is done, using it at workplace would be easier. I am confident that if you once saw something at school and you need to use it in your job, it becomes easily implementable" **Midwife, FGD1.**

Desired SDA features and functions

The study participants were asked if there might be any other information or functionalities they would want to be added to the SDA for improving the application. Most participants stated that the SDA is useful as it is. However, some participants suggested features and functions they wish to be added to the SDA. Firstly, participants requested if the SDA could have a version for desktop and laptop computers so that it could be installed in computers available at their respective hospitals or if they could access the SDA using a desktop/laptop browser.

"I wonder if this application can't be installed in our office computers because sometimes one's phone might not be available maybe because it is not charged, it is stolen or broken or the owner simply doesn't have it with him/her. Having the application available in various devices would be much better and *accessing it might be easier for everyone"* **Midwife, FGD1.**

Other participants expressed their need for locally appropriate clinical decision support tools and emphasized their wish to have a version of the SDA available in the local language 'Kinyarwanda'.

"I would like to add that it would be great to have this application in Kinyarwanda like I saw it having other language versions including Swahili, Hindi…. I guess this is a process, but we will be grateful if this is expedited. That will really be helpful. Thanks" **Nurse, FGD2.**

In addition, nurses and midwives requested additional animated videos to be added to the SDA. These include; videos on antenatal care in line with the new WHO antenatal care models with a minimum of eight contacts as well as guidance on the identification of risk factors for birth complications before delivery.

> *''I think this application can be very helpful if they add some videos on antenatal care or how one could identify a woman in labor who would probably get a complication"* **Midwife, FGD2.**

Also important was the suggestion that the SDA application could have a discussion forum window or platform for the users across different hospitals and countries to share experiences about managing obstetric emergencies.

> *"I wish that this application can have a kind of worldwide discussion forum where we can put comments and share experiences and views. For example, a midwife from X hospital in Rwanda can discuss and share her experience with midwives in other hospitals across multiple countries…Sharing like this can upgrade levels of knowledge for everyone. I think this would be very beneficial"* **Midwife, FGD1.**

Interviews with key stakeholders

The analysis revealed two main themes: (1) benefits of the SDA as perceived by the key informants, and (2) future use of the SDA. These identified themes are shown in Figure 1. The details on the main themes and sub-themes are presented, and are illustrated by quotations from the six KIIs.

Benefits of the SDA as perceived by the key informants

The key informants described the SDA as a useful tool and recommended its implementation in routine practices, specifically for the purpose of continuous learning without interrupting health services. Such benefit was depicted as fitting for the work environment in the context of Rwanda where numbers of healthcare providers were insufficient. Clinical staff require periodic training to stay on track with the knowledge and skills necessary for their practice. For their annual practice license renewal, they need evidence of continuous professional development in addition to corresponding academic credits. SDA was therefore seen as a valuable solution as it offers on-the-job learning opportunities, assessment strategies, and possibilities of getting certificates.

> *"This application is useful as it allows on-job continuous learning. We have been facing challenges for getting continuous learning opportunities for all staffs, now the SDA comes with this advantage. I recommend that it should be incorporated in routine practices"* **Respondent, KII 3.**

While the SDA was recommended for staff, because it captures the essential topics for BEmONC, key informants felt that this should in addition to the other sources of information including formal books and Ministry of Health guidelines that gives a broader view of obstetric care.

> *"The SDA is good particularly for BEmONC but the SDA alone cannot solve all maternity care problems. Our staff need to use this application together with other sources of reliable information like the guidelines from the Ministry of Health"* **Respondent, KII 1.**

Another benefit highlighted was that the SDA is applicable in clinical practices by providing guidance on essential procedures that are needed to save maternal and newborn lives.

> *"…We need safety in all we do, so this application is welcomed. I was happy to note that it provides concise information that will help nurses and midwives to take good decisions when dealing with childbirth complications"* **Respondent, KII 6.**

Future use of the SDA

When KII participants were asked their opinions about the SDA cost, scalability, and sustainability, opinions on the future use of the SDA in Rwanda were apparent, along with the aspect of technology application in healthcare and its support in continuous learning. Participants perceived the estimated cost of piloting the SDA as affordable compared to physical training opportunities or online learning resources. They recommended the SDA implementation in consideration of its benefits, particularly the mLearning opportunity.

> *"The cost is reasonable compared to other online learning tools…Also physical training has a double cost of time and resources. This application can train many people at the same time depending on individuals' needs…I think this mLearning approach should be promoted in Rwanda as the country is looking to making healthcare services electronic-based…This application will be one of the solutions"* **Respondent, KII 5.**

One participant was concerned about the technology cost. But, he indicated that this cost could be alleviated by the fact that many healthcare providers own a smartphone. He suggested that they could use their own smartphone for future use of the SDA.

> *"The technology cost is a bit high but as many people have smartphones and access to good internet, this might not be a problem. They could download the SDA on their own smartphones"* **Respondent, KII 6.**

In addition, participants expressed their wish to see the SDA implemented at a large scale, in all hospitals in Rwanda. However, they recommended that the SDA scalability needs to be preceded by a proper assessment and approvals by all required bodies.

> *"Technology is in everything we do in healthcare and this application is useful…For future implementation, you need more sensitization and to involve all key stakeholders like MOH (Ministry of Health), RAM (Rwanda association of midwives), association of gynecologists and pediatricians…"* **Respondent, KII 2.**

> *"I think after in-depth assessment and approval by MOH (Ministry of Health), the whole country (all hospitals) could use this application and it could help us to promote continuous learning while at work"* **Respondent, KII 3.**

Another participant highlighted the need for possible monitoring and follow-up programs to evaluate if the acquired knowledge and skills are translated into real clinical practices. He also suggested that the monitoring programs could be connected with the existing annual performance contracts and evaluation.

> *"…Some mechanisms of monitoring could be put in place to assess if what has been learnt in the SDA is being practiced…Why not link this monitoring with imihigo (performance contracts)? People should think about it"* **Respondent, KII 4.**

Then again, participants indicated that the SDA could benefit a large variety of healthcare cadres like medical doctors.

> *"…Not only nurses and midwives would benefit from the application, medical doctors can use it …Everyone needs to know how it works and its importance.* **Respondent, KII 2.**

Moreover, KII participants perceived the SDA as an easy to use tool with well explained topics. They indicated that the SDA could be sustained because it supports healthcare providers to manage childbirth complications. They also acknowledged the fact that the SDA provides useful information needed in routine clinical practices.

> *"I think this application will be sustained…When you see the topics and how they are explained…This information is what our staff need every day for managing birth complications"* **Respondent, KII 1.**

Furthermore, participants suggested additional topics other than topics of BEmONC that could be added to the SDA to make it more useful and sustainable.

> *"We have seen some additional topic like COVID 19 and infection prevention in this application. Other topics that are generally relevant for healthcare providers could be added…I am thinking of topics like: medical bio safety and bio security, patient centered care and quality improvement, ethics in clinical practice…all these topics could be tied to maternity care"* **Respondent, KII 3.**

7.5. Discussion

The present study findings indicate that the SDA was acceptable to both the end-users and the key informants. End-users, nurses and midwives, used the SDA frequently, and viewed it as a useful tool that contributes to their professional growth and improve their practice. They frequently used it for education to revise and improve knowledge and skills, and as a decision support tool when immediate guidance was required to manage birth-related complications. Users felt that the SDA has improved their confidence and ability to manage childbirth complications, which they were previously insecure about. These findings are supported by a pre-post intervention study conducted with the same population, which found that the SDA in Rwanda led to a significant increase in nurses and midwives' knowledge and skills scores for PPH and NR management six months after SDA introduction [169]. Other researchers similarly indicated that the SDA, when used as a training tool, has shown significant increases in knowledge and skills of different healthcare professionals [77,78].

The perceived usefulness of the SDA seems to be related to its functionalities when applied to the clinical context of low resource settings [28]. This study emphasized the fact that the SDA offers continuous training opportunity without interrupting health services which is very beneficial due to the shortage of staffs. These findings mirror those of other studies that mHealth applications are increasingly being used in LMICs to improve health professionals' access to evidenced and up to date information and training. In maternal and newborn healthcare services, mHealth application are being used as both training tools [255] and decision support tools [125]. The adoption of these applications in resources poor settings depend on their functions that need to be tailored to contexts of interest [256]. Other studies have similarly shown that mLearning are potential solutions to support continuous learning among health professionals in LMICs [257,258].

Also, in the current study, the SDA was reported to be practical by helping nurses and midwives translate theoretical knowledge into practice with the support of visual instructions in the animated videos. Then again, with mLearning, the user has the opportunity to study/read multiple times and master the subject. A study in Kenya compared hands-on and video training for PPH management and reported that video training appeared to be as effective as hands-on training [225]. Thus, mHealth applications providing visual instructions via animated videos such as the SDA are potential solutions to improve knowledge and skills of nurses and midwives.

In addition, nurses and midwives had a positive experience with the SDA, they felt confident and better at their job when using the SDA, and reported it as an easy to use, intuitive and empowering tool. Participants were motivated to use the SDA in providing better services and suggested additional features and functions. These findings are in agreement with other studies which reported that the use of mHealth application is perceived as an opportunity for improving the quality of healthcare services with an effect on staff confidence [259], motivation [260], and self-efficacy [261]. Likewise, a realistic review about mHealth and the performance of maternal health care workers in low- and middle-income countries, revealed that health workers can be empowered to adopt and utilize mHealth in contexts where it is aligned to their needs, workload, training, and skills [262]. The review also noted that mHealth can empower health workers with skills and confidence when it is perceived as useful and easy to use [262]. Consequently, the SDA like other mHealth applications is considered an empowering tool that has a positive impact on healthcare delivery processes.

Moreover, in this study, the SDA was highly acceptable by nurses and midwives who admitted to continue using the SDA in their daily clinical practices. This level of user acceptance combined with the documented impact of the SDA is interesting considering the existing gap of ensuring access and adherence to BEmONC evidence-based clinical guidelines in low- and middle-income countries. Several studies have found a low adherence to evidence-based standards for maternal and newborn care particularly in low resource settings [263,264]. Other studies have suggested the use of mHealth to improve the access and adherence to evidence-based guidelines [125,265,266]. Therefore, mHealth tools such as the SDA, which ensures access to the most recent BEmONC evidence-based clinical guidelines, and is demonstrably well accepted by its end-users, may help to improve the adoption of guidelines. The advantages of the SDA are that it is self-explanatory, available in many languages, is open source and free for download, and, once installed on the smartphone, does not require internet to function.

Furthermore, the SDA was appreciated by key informants in the management position at the district hospital level. On the other hand, those key stakeholders acknowledged the benefits of the SDA and were willing to advocate for its scalability for future use in Rwanda. They noted that the cost of piloting the SDA in two district hospitals was reasonable and predicted the possible sustainability of the SDA. However, they recommended a large scale research on the SDA and involvement of the required bodies. Likewise, Eze et al [267] used a stakeholder perspective to analyze existing research on the mHealth process in developing countries, and reported that interactions between system developers and stakeholder groups are important for sustainability of mHealth [267]. Another research documented that in order to realize the potential benefits of mHealth, it is important to identify the relevant stakeholders and how they might be affected [268]. Other studies similarly found that the complexity of introducing mHealth into health care calls for strategies encouraging collaboration between multiple stakeholders to enhance successful implementation [269–272].

The implications of this study are that the SDA was accepted by both end-users and key stakeholders due to its functions tailored to the Rwandan context. Among the beneficial functionalities of the SDA, there is the capacity of the SDA to function as a training tool and a decision support tool. This increases the confidence and the ability of nurses and midwives in

providing quality care during obstetric and neonatal emergencies as well as improved routine obstetric and newborn care. The acceptability and the positive perceptions of the SDA in two district hospitals reflect a possible adoption of the SDA even on a large scale in Rwanda like in other low-resources settings. Evolving efforts for quality maternal and newborn care in Rwanda and similar contexts should consider the integration of SDA as an approach for training and as a clinical decision support tool for BEmONC in order to reduce maternal and newborn mortality. Future work could consider large scale studies of the SDA with maternal and newborn outcomes as primary outcomes.

7.6. Implications for Research and Clinical Practice

The implications of this study are that the SDA was accepted by both end-users and key stakeholders due to its functions tailored to the Rwandan context. Among the beneficial functionalities of the SDA, there is the capacity of the SDA to function as a training tool and a decision support tool. This increases the confidence and the ability of nurses and midwives in providing quality care during obstetric and neonatal emergencies as well as improved routine obstetric and newborn care. The acceptability and the positive perceptions of the SDA in two district hospitals reflect a possible adoption of the SDA even on a large scale in Rwanda like in other low-resources settings. Evolving efforts for quality maternal and newborn care in Rwanda and similar contexts should consider the integration of SDA as an approach for training and as a clinical decision support tool for BEmONC in order to reduce maternal and newborn mortality. Future work could consider large scale studies of the SDA with maternal and newborn outcomes as primary outcomes.

7.7. Strength and limitations of the study

The study is limited by the small sample size, which reflects the fact that the SDA was implemented only in two district hospitals due to funding limitations. Therefore, the findings of the current study cannot be generalized. Nevertheless, the evidence that the SDA was acceptable and perceived useful by both end-users and key stakeholders at the piloting settings sets the stage for expanding coverage and further testing of the SDA intervention to other hospitals in Rwanda. Additionally, the accuracy of our findings is increased by supporting the acceptability survey with focus group discussions to provide context to and clarify reasons behind some participant responses.

7.8. Conclusion

The nurses and midwives perceived the SDA as an easy to use, useful, intuitive and empowering tool, which helps them update and revise their knowledge and skills, improves their confidence and makes them feel better to deliver quality obstetric care. Key stakeholders also perceived the SDA as a relevant and useful tool with a reasonable cost and recommended its implementation in routine practices. Overall, both end-users and key informants think that the SDA is beneficial and could be sustained. End-users suggested additional features that would improve the usability of the SDA. These included: a computer/ laptop version of the SDA, a SDA version in Kinyarwanda language, some additional videos, and a SDA discussion forum. Key informants also suggested additional topics that could be added to the SDA such as; medical bio-safety and bio-security, patient centered care and quality improvement, and ethics in clinical practice. The positive perceptions of the SDA in Rwanda suggest that mLearning and mHealth decision support tools such as the SDA may be a potential way to improve knowledge and skills of nurses and midwives. The mHealth applications like the SDA have the potential to further improve patient care, as they avail evidence-based clinical guidelines and can be easily adapted to contextual needs. Thus, credible, evidence-based, affordable mHealth applications like the SDA are needed to support clinical decision making and provide a platform for updates and continuous learning for nurses and midwives in Rwanda and other limited resource settings. The present study also adds to existing evidence about the benefits of mHealth applications in assuring quality BEmONC.

SECTION C: DISCUSSION, CONCLUSION AND RECOMMENDATIONS

Chapter eight: Integrated discussion

8.1. Introduction

The present study provides an understanding of three implementation outcomes (effectiveness, symptomatology, and acceptability) of the SDA in the context of Rwanda. These implementation outcomes were chosen because they fall under three categories of outcomes namely service, client, and intervention outcomes for the evaluation of a new innovation in a new setting as recommended by Proctor et al (2011) [30]. Implementation outcomes are important at each level of change, for the pilot stage of our intervention, we choose to evaluate one outcome under each category (service, client, and intervention). In this chapter, I revisit the aim and objectives of the overall thesis against what was found. This begins with a brief summary of how each publication answered the thesis research objectives. The chapter also summarizes the key findings of the present study and discusses them at length to answer the questions raised in the beginning of this PhD study. While discussing the findings of the present study, the researcher has examined their consistency with findings presented in previous literature. I therefore present a synthesis of evidence from my research, drawing on previous scholarship and conceptual and theoretical frameworks to illuminate the implications, limitations and conclusions of the study. In addition, the chapter also includes separate sections on the scholarly contribution of this PhD work focusing on implications of findings on policy, practice, research, and public health. The strengths and limitations of the study are also discussed in this chapter.

8.2. Summary of Key Findings

The research conducted for this thesis provides new evidence on the use of an innovative mHealth technology, the SDA, in the management of the most frequent birth-related complications of postpartum hemorrhage (PPH) and newborn asphyxia in Rwanda. There is documented evidence that the delays in accessing skilled care when birth-related complications arise significantly affect outcomes for both the mother and the newborn in Rwanda [64,252,273]. Therefore, skilled childbirth attendance is among the key targets of the Ministry of Health in order to reduce maternal and newborn deaths from preventable causes [43]. In response to this need by Rwanda's MOH, this study tested an mHealth application, the SDA, which is an aid for skilled birth attendants to manage birth-related complications. MHealth applications are classified into three categories

according to three components of end-users, namely health systems; healthcare providers; and clients/patients [75]. The SDA which is the focus of the current study belongs to the healthcare providers' category. The present study sought to investigate the effect of the SDA in supporting clinical decisions of nurses and midwives on handling two elements of the BEmONC: PPH management and neonatal resuscitation (NR) by measuring, combining, and theoretically interpreting three implementation outcomes: the effectiveness, the symptomatology, and the acceptability of the SDA. The study findings discuss the effect of the SDA with regards to the two BEmONC interventions (PPH management and NR), that when successfully implemented, play an important role in enhancing the safety of the mother and her newborn. The study was conducted in three major phases (pre-intervention, intervention, and post-intervention). It was a pre – post intervention study with a convergent parallel mixed-methods approach starting with baseline surveys and FGDs, followed by the SDA implementation for six months, and ending with endline surveys, FGDs and KIIs. Each phase of the study produced important findings which were combined together to provide a comprehensible and reliable understanding of the use of the SDA in the context of Rwanda. As shown in Table 8.1, the research objectives were addressed through the following four manuscripts.

Table 8.1. PhD manuscript alignment with objectives

Objectives	**Article references**	**Summary of findings**
1 - Exploring nurses' and midwives' reflections on knowledge and skills surveys data and the baseline records review findings. - Exploring perceptions of nurses and midwives on the management of BEmONC with a particular focus on PPH and NR.	Paper 1 (See Chapter 4)	• About reflecting on the baseline knowledge and skills surveys data and the record review findings, nurses and midwives survey identified inadequate knowledge and skills in PPH management and NR (the average knowledge score was 47.2% and the average skills score was 59.9%). The baseline records review revealed 62% unstable newborn cases and 19% unstable maternal cases following PPH management and NR). Nurses and midwives validated the findings and felt that they were a true reflection of the reality and offered diverse explanations for the results. The provided explanation included: staff shortage, limited in-service training, lack of clinical guidelines, and lack of some essential materials. • The participants' narratives of lived experiences of managing PPH and NR revealed two broad themes: (1) Self-reflections on their current practices with insights on team work, commitment to professional ethics, insufficient skills, learning opportunities and evidence-based clinical guidelines. (2) Contextual factors influencing the delivery of BEmONC services which included: leadership and management, the staff shortage and heavy workload, the limited resources, the profile of their clients in relation to their socio-economic status as well as their socio-cultural beliefs and behaviors.

		These findings provided insights into challenges faced by nurses and midwives when managing PPH and NR. Some of the key challenges like insufficient skills, lack of continuous learning opportunities, and limited access to evidence-based clinical guidelines to support their daily clinical decisions could be solved by the use of the SDA in routine practices.
2 - Assessing the effects of the SDA on knowledge and skills of nurses and midwives.	Paper 2 (See Chapter 5)	• Effectiveness outcome Pre-post SDA surveys revealed a significant increase of knowledge scores and skills scores on PPH management and NR. Increases were unaffected by participants' attendance to in-service training six months prior and during SDA intervention and previous smartphone use. However, pre- and post-intervention skills scores were significantly different by years of experience in obstetric care. These findings highlighted the effectiveness of the mLearning feature of the SDA in the context of Rwanda.
3&4 - Assessing the effects of the SDA on nurses and midwives' clinical decision making with regards to maternal and newborn outcomes in two district hospitals in Rwanda	Paper 3 (See Chapter 6)	• Symptomatology outcome - The SDA utilization by nurses and midwives was tracked through the server of Maternity Foundation which revealed multiple session counts and duration across all modules of the SDA. -Pre-post SDA records review analysis revealed a significant association between the SDA intervention and newborns' and maternal' outcomes following neonatal resuscitation and PPH management. These findings widen our understanding of the effect of the decision support feature of the SDA in the context of Rwanda.
5&6 - Describing the nurses' and midwives' experiences, stakeholders' perceptions and the implementation process of using the SDA. - Exploring the acceptability of the SDA among end-users (nurses and midwives) and key stakeholders (key informants in the management position at the facility level) with views on the SDA scalability, costs and sustainability.	Paper 4 (See Chapter 7)	• Acceptability outcome Overall, SDA was acceptable with potential for scalability. Views on costs and sustainability arose. -The nurses and midwives perceived the SDA as having improved their ability to manage childbirth complications. They indicated general agreement that the SDA is easy to use, is an effective decision support tool, and training tool. They also suggested additional features and functions to the SDA developers such as computer/laptop version of the SDA, additional videos, SDA version in the local language, and a discussion forum in the SDA. They also reflected on future use of the SDA in Rwanda. -Key stakeholders also perceived the SDA as a useful tool with a reasonable cost and recommended its implementation in routine practices. They were optimistic that the SDA could be scaled up and be sustained in the whole country. These findings provide an understanding of the acceptability of the SDA and multiple views on its scalability, cost, and sustainability.

8.3. Discussion

In this integrated discussion, I acknowledge the critical role of nurses and midwives in maternal and newborn healthcare services, and discuss their real-life experiences in BEmONC with a particular focus on PPH management and NR. I then discuss the required knowledge and skills in order to perform this critical role as well as their sources of information such as evidence-based clinical guidelines. I address a series of questions with regards to nurses and midwives' clinical decision making in BEmONC and the implications of the SDA. For instance; (1) What clinical decisions are to be taken when dealing with birth-related complications (PPH and NR), (2) How does clinical decisions affect maternal and newborn outcomes following PPH management and NR, (3) What is the impact of the SDA on the delivery care process (PPH and NR), and (4) How is the SDA judged and received by key stakeholders. The distinguitive features of the two district hospitals (urban and rural) under the current study in terms of study findings are also discussed.

The study findings were categorized under three implementation outcomes evaluated in this study, effectiveness, symptomatology and acceptability of the SDA informed by proctor framework. These characterizations inform the implementation approaches that were critical for understanding how an mLearning and mHealth decision support tool functioned in a resource-poor setting and its implication on patient care, clinical practice and policy. Four manuscripts were derived from the study findings. In the discussion, the individual manuscript findings are not repeated, but rather built upon in line with the broader literature through the presentation of the theoretical orientation of this PhD and the adopted implementation research model. Three research questions were raised at the beginning of the study and the research was designed in a way to get answers of all the questions sufficiently. Below is the discussion on the answer of these questions, as obtained after the analysis of data collected through research. Table 8.2. highlights the cross-cutting themes of the research covered under the evaluated implementation outcomes and these are checked across the four results chapters.

Table 8.2. The cross-cutting themes of the research aligned with the results chapters.

S/N	Cross-cutting themes of the research	Chapter 4: PaperI (Objective 1)	Chapter 5: Paper II (Objective 2)	Chapter 6: Paper III (Objectives 3&4)	Chapter 7: Paper IV (Objectives 5&6)
1	Effectiveness of the SDA	X	X		
2	Symptomatology of the SDA			X	
3	Acceptability of the SDA				X

8.3.1. What is the effectiveness of the SDA in district hospitals in Rwanda?

The evaluation of the effectiveness of the SDA was preceded by baseline knowledge and skills surveys of nurses and midwives as well as baseline six-month records review about maternal and newborns outcomes following PPH management and NR. The study included all nurses and midwives working in the selected district hospitals and the reviewed maternal and newborn outcomes were the results of the clinical work performed by those nurses and midwives. This first step also involved the validation of the surveys' results and the records review findings through focus group discussions with nurses and midwives. This was followed by an exploration of perceptions and lived experiences of nurses and midwives about offering BEmONC services in the selected district hospitals. The researcher wanted to understand the real-life experiences when managing birth-related complications and the main challenges faced by nurses and midwives when offering BEmONC services with a special focus on PPH and NR at the district hospital level. This first exploratory qualitative study was done to confirm the fitness of the SDA in the context of Rwanda, matching the SDA benefits to the current-practices challenges.

Participants' reflections on the baseline research results

The nurses and midwives were requested to reflect on the key findings from the knowledge and skills surveys and record review findings done in the maternity departments. Overall, there were low knowledge and skills scores, and big numbers of unstable maternal and newborns outcomes following PPH management and newborn resuscitation. Nurses and midwives were shocked and surprised by their scores and the realities of the performance of their departments. However, they validated the findings and felt that they were a true reflection of the reality and offered diverse

explanations for the results. The provided explanation included: staff shortage, limited in-service training, lack of clinical guidelines, and lack of some essential materials. Similarly, a number of studies has explored the barriers to and facilitators of emergency obstetric care provision [143,186–188] and reported similar challenges in multiple health facilities in low and middle income countries. Therefore, engaging nurses and midwives on how they reflect on their knowledge, skills, and performance in obstetric care reveals realities of practice that could guide policymakers when tailoring contexts-specific interventions that are applied to particular challenges in order to improve obstetric care.

In addition, a particular strength of this study was our approach to make the participants first reflect on their actual knowledge and skills and on their performance as a departmental team. And then, exploring their lived experiences in managing PPH and NR. This triggered a longue conversation that opened the discussion on the realities of practices at the same time participants gave explanation of the reasons for their low knowledge and skills scores as well as the unstable patient outcomes. This allowed us to get an overview of knowledge and skills of nurses and midwives and the reality of their performance looking at the patients' outcomes using both quantitative and qualitative methods. This methodological approach is supported by the pragmatism theory which considers both the subjective and objective knowledge [152]. This approach helped to have full information on context specific realities and experiences of nurses and midwives in BEmONC in the context of Rwanda. The following section discusses the real-life experiences of nurses and midwives when managing PPH and NR.

Lived experiences in managing PPH and NR

The nurses and midwives play a vital role in the management of PPH and NR, particularly in low-resource settings of SSA [89]. The realities of practices of nurses and midwives when managing PPH and NR differ in different context due to multiple factors. The present study identified some insights into nurses and midwives' current practices towards the management of birth-related complications with a particular focus on PPH management and NR. Among the identified enablers to better service provision, the team work and the commitment to professional ethics were highlighted as supporting factors in the delivery of quality care. Similarly, Berlin et al (2012) [274] studied models of teamwork and found a linkage between team work and team performance [274]. Their study highlighted five types of analytical teamwork models in consideration of team

members' disciplines; team members' ways of organizing and coordinating the assignments; roles and responsibilities of team members; the development of team work from forming up to storming; and goal-orientation and collaborative skills within the team. The study concluded that a synchronous, complementary or mature team is not necessarily optimal, what is important is collaboration between team members that will make the team grow as relationships extend [274]. As per our findings, the present teamwork spirit influenced the commitment of nurses and midwives and made the management of PPH and NR possible. This encourages the reinforcement of the team work environment with its required necessities in the district hospital of Rwanda.

In the present study, nurses and midwives also indicated a number of context specific factors that influence the quality of care in BEmONC, particularly in the management of PPH and NR. A surprising finding was that the nurses and midwives admitted to have the full support of the leadership and management of the hospital which they think led to most of the positive maternal and newborn outcomes [168]. Contrary to other studies in SSA which have shown a lack of support from the hospital leadership and the health system failure towards saving mothers and newborns [190,275,276]. Other contextual factors were similar to those in the identical LMICs settings, and included human resources constraints, limited medical suppliers, financial barriers for patients, and use of traditional healers and medicines [143,187,211,213,216]. Identical challenges were also reported by a scoping review on human resources for health-related challenges to ensuring quality newborn care [197]. These challenges contributed to negative maternal and newborn outcomes [205,206]. Therefore, there is an urgent need to address these challenges.

Moreover, our study participants acknowledged getting minor support from the few available learning opportunities such as in-service training and staff meetings. They also expressed the challenges they face when managing PPH and NR. The stated challenges included: insufficient skills, limited access to learning opportunities, and to evidence-based clinical guidelines. These findings are similar to other researches' results that indicated limited knowledge and skills among health care providers in LMICs as well as limited access to continuous learning opportunities [197,198]. These challenges are crucial to address as they are directly linked to healthcare providers' clinical decisions that predict maternal and newborn outcomes [186]. Another study which investigated the pre-service and in-service education and training for maternal and newborn

care providers in LMICs revealed an existing gap in educational programs abiding to international standards, and called for a continuous investment in midwifery in-service trainings [277]. This is in line with our study contribution to maternal and newborn healthcare particularly to the management of birth-related complications via supporting continuous learning and decision making for the provision of evidence-based care towards PPH management and NR.

Overall, these findings provided the insights of nurses and midwives regarding their real-life experiences and main challenges they face when managing PPH and NR. Some of the key challenges like limited knowledge and skills, lack of continuous learning opportunities, and limited access to evidence-based clinical guidelines to support their daily clinical decisions could be solved by the use of the SDA in routine practices. This confirmed our research hypothesis that the SDA could contribute to continuous learning and clinical decision making of nurses and midwives thus improving obstetric care services in district hospitals of Rwanda. Therefore, with consideration of the critical role of nurses and midwives in PPH management and NR, we needed to understand if they have the required knowledge and skills in order to perform this critical role. We also needed to understand their continuous learning opportunities as well as their sources of information such as evidence-based clinical guidelines. Our findings have an important meaning to the management of birth-related complications as well as on maternal healthcare implementation research for LMICs settings, like Rwanda. The next section discusses the effectiveness outcome basing on the effects of the SDA on knowledge and skills of nurses and midwives.

Effects of the SDA on knowledge and skills of nurses and midwives

The current study has comprehensively examined the effects of the SDA on knowledge and skills of nurses and midwives in managing PPH and NR. We found that the SDA intervention was associated with improved knowledge and skills scores, irrespective of their attendance to in-service training six months prior and during SDA intervention and previous smartphone use [169]. These findings highlight the effectiveness of the mLearning feature of the SDA in the context of Rwanda [169]. Our study findings mirror those of other studies that investigated the effects of the SDA on healthcare provider's knowledge in Ethiopia and Democratic Republic of Congo [77,78]. Our findings also support those of other studies that the use of mLearning tools is perceived as an opportunity for improving healthcare providers' quality with effects on their knowledge, skills,

motivation, self-efficacy and enthusiasm [259,261]. Other researchers have indicated that mHealth applications facilitate continuous learning [77,228,232]. The effectiveness of an evidence-based solution in a new setting as discussed by Proctor et al (2011) [30] concentrates on the degree to which the solution is successful in bringing change and achieving desired outcomes [30]. In the present study we opted to test if the SDA could facilitate continuous learning and improve knowledge and skills as one of the challenges raised by nurses and midwives. Besides, it is worthwhile to note that the implementation strategies used in this study played a crucial role in achieving the positive results about SDA effectiveness.

The implementation strategies in the present study were informed by Proctor's model [278,279] that provides a classification of multi-level implementation strategies. The model specifies four levels of change; larger system; organization; group/team; and individual level; when assessing performance improvement [278]. At the large system level, the legal and regulatory policies are key; at the organization level, the structure of the system is important; at the group/ team level, the cooperation, coordination, and shared knowledge are key; while at individual level, knowledge, skill, and expertise are key. In the current study, the implementation strategies incorporated all levels of change (large system, organization, group, and individual) and their attributes. This was done by involving key stakeholders and end-users of the SDA, with consideration of the Rwandan health system structure, in the early stages of the conceptualization of the study. Also, practical trainings were conducted on the use of SDA as an mLearning and decision support tool before the intervention [160]. The SDA implementation model focused on the mLearning and decision support features. During the implementation process, district hospitals' guidance, team meetings, outreach visits, audits and feedback were prioritized. Then, an assessment of knowledge and skills at the individual level was conducted before and after SDA intervention. In addition, the model by proctor accommodates theories of dissemination [280,281], implementation [282], and diffusion of innovation [71,283]. Hence, basing our implementation strategies on the Proctor's model [278] has a strength that brought a successful improvement in knowledge and skills among nurses and midwives, and would affect both the SDA implementation outcomes (service, client, and intervention) and its dissemination and diffusion in Rwanda.

Moreover, the knowledge and skills of healthcare providers are directly linked to their skilled clinical decision making when providing care [284]. A growing body of evidence has shown that health provider's competence and motivation interact with the work environment to give rise to the work effort that produces clinical performance [285–287]. Other researchers indicated that the main factors that influence clinical decision making include cognitive skills, acquired knowledge, and clinical experience [285,288]. Gillespie et al (2009) introduced a framework 'the Situated Clinical Decision-Making Framework' that indicates how the foundational knowledge and skills of an individual nurse influences his/her clinical decision making process [284]. Moreover, the framework stressed that effective clinical decision-making entails active and continuous acquisition of new knowledge pertinent to the specific patient and situation, along with thoughtful selection and use of existing knowledge [284]. Hence the need for continuous learning and the use of updated evidence-based clinical guidelines. Another researcher embraces the clinical decision making process as an approach that involves clinical reasoning for multiple problem solving and requires pertinent knowledge and skills of healthcare workers [287]. Another study explained how a healthcare provider combines both his/her knowledge and cognitive processes to make a decision in a particular situation [20]. The study emphasized the clinical decision making process as a line of reasoning that involve information processing, mainly from ones' knowledge and skills, to generate an argument or set of arguments leading to a conclusion towards clinical care [20].Therefore, knowledge and skills of healthcare providers are one of the key pillars of an effective clinical decision making.

However, the increases in knowledge and skills, even though they have straight influence, do not directly predict the changes in behaviors and practices as well as patient outcomes [261,289,290]. A growing body of evidence suggest that knowledge and skills acquisition are the first key steps towards improvement of clinical practices [291–293]. Other studies highlighted that skills are key to change behaviors and practices but individual attitudes play an important role in the process [102,260]. The knowledge to action cycle framework discusses the knowledge translation into practice basing on a social constructivism approach that privileges social interaction and adaptation of research evidence taking local context and culture into account [294]. Besides, Straus et al (2011) discusses the knowledge translation as the use of knowledge in health care decision making [295]. Helfrich et al (2018) further describes the knowledge translation into practices as

dual process that involves unlearning harmful routines clinical practices and substituting them with evidence-based practices with the consideration of the clinical decision process [296]. Therefore, the knowledge and skills translation into clinical practices is an emerging field that brought several scientific debates. One of them is how to determine if improved knowledge and skills are translated into best practices and associated with improved service delivery and better patients' outcomes.

Additionally, in this study, pre- and post-intervention skills scores in NR were significantly different by years of experience in obstetric care. The study participants with lower years of experience had higher scores in NR [169]. This suggests that recent graduate may do better on knowledge and skills tests or are more likely to adhere to practice guidelines, however the relationship to patient outcomes still need more explorations. Our findings are consistent with past studies, for instance a systematic review that investigated the relationship between clinical experience and quality of health care reported an inverse relationship between the number of years that a clinician has been in practice and the quality of care that the clinician provides [297]. Another study indicated that the clinical performance does not necessarily correlate with professional experience [298]. Contrary, another study demonstrated that the levels of nurses' competence increase through the course of their clinical experience [299]. But, Overall, the relationships between the levels of nursing competence and the length of clinical experience were illustrated by curves with a rapid increase in competence levels at the early stage of the nursing career and a slower increase later [299]. Therefore, there is a need to advocate for continuing professional education to keep up to date knowledge and skills of clinicians along their medical career.

In addition, Estabrooks (2008) discussed an emerging new domain 'Evidence-based Medicine (EBM)' in a bibliometric study that analysed knowledge utilization in healthcare [300]. Building on Rogers' diffusion of innovation theory [71], the study indicated that the growth of EBM considers knowledge utilization, technology transfer, and innovation diffusion [300]. Similarly, introduces evidence-based practice as a branch of EBM that uses current best evidence in making decisions about care of individual patients [301]. Another research emphasizes the use of evidence-based guidelines in the process of translating knowledge into practices and bridging the know-do gap [302]. This is in line with the design of the SDA which provides evidence-based clinical guidelines on BEmONC. Also, one of the challenges indicated by nurses and midwives was limited

access to evidence-based clinical guidelines. Therefore, having the required knowledge and skills and translating those into real practices while using evidence-based clinical guidelines is important. For that reason, we evaluated the maternal and newborn outcomes following clinical work of the nurses and midwives when using the SDA as an mLearning and decision support tool.

The literature suggests that implementation outcomes of a new innovation in a new healthcare setting could be assessed from six months after implementation [30,303]. Also, implementation in healthcare might be about system change but ultimately, it is the individuals that have to change [304]. In the current study, the effectiveness of the SDA was assessed at individual level looking at the change in knowledge and skills of nurses and midwives after using the SDA as an mLearning tool for six months. These knowledge and skills have a great influence on their clinical decision making that guide their daily practices and predict the patients' outcomes as indicated by different scholars. The next section discusses the symptomatology outcome and highlight the SDA effects on maternal and newborn outcomes.

8.3.2. What is the symptomatology of the SDA in district hospitals in Rwanda?

In this study, the symptomatology was defined as a set of symptoms characteristic of a medical condition or exhibited by a patient [30]. The symptomatology of the SDA was assessed through a pre-post intervention record review of the BEmONC outcomes: Apgar score and PPH progressions. Newborn death or admission to the neonatal intensive care unit (NICU) or to neonatologist's service due to an unstable outcome (Apgar score < 7) after NR was used as the primary outcome measure to determine the failure of NR. The mothers' referral to a higher-level facility (referral hospital) following an unstable outcome (persistent bleeding) after PPH management was considered as the primary outcome to measure the failure of PPH management at the district hospital. Under the symptomatology outcome, we assessed the effects of the SDA on nurses and midwives' clinical decision making with regards to pre-post SDA maternal and newborn outcomes following PPH management and NR. The SDA reflects current global evidence-based clinical guidelines for BEmONC, including PPH management and NR [28].

Quality health care is sometimes defined as care that delivers the best possible results by using the right clinical decisions made at the right time in the right way for the right patients [305]. Several researches indicated that making the right clinical decisions requires familiarity with the latest medical knowledge and use of good clinical judgment [286,306,307]. Cioffi et al (2012) [308] embraced the process of clinical decision making in nursing and midwifery as a naturalistic approach that recognizes and includes the underlying knowledge and skill of professional expertise embedded in clinical practice [308]. The naturalistic clinical decision-making approach involves the generation of all possible options for the clinical situation in order to satisfy a determined goal, either diagnosis, treatment or prevention [308,309]. The interest of the naturalistic decision-making is in how people use their knowledge, skill, experience, and available guidelines to take clinical decisions in emergent situations, under time pressure, and unclear goals [310,311]. Hence, the SDA is a practical tool to support clinical decision making as it facilitates continuous learning and provides an unlimited access to evidence-based clinical guidelines.

In the present study, the clinical decisions that were to be taken when dealing with PPH and NR included the identification of causes, symptoms and consequences of PPH and newborn asphyxia, and being able to provide prevention and treatment of those birth-related complications. The nurses and midwives used the SDA as a job-aid tool equipped with evidence-based clinical guidelines to inform their clinical decision making when managing PPH and NR. Overall, the use of the SDA supported nurses and midwives in the management of PPH and NR which may have contributed to improved maternal and neonatal outcomes during six months of the SDA intervention [170]. Likewise, other mHealth interventions tested in different contexts in LMICs were associated with positive patient outcomes [123,247,249,312]. However, another study which assessed the impact of the SDA on the incidence of PPH in Ghana reported that the SDA was associated with an insignificant lower incidence of PPH [22]. Therefore, innovative approaches that adapt technology to context to improve patients' outcomes need to be thoroughly evaluated as the results of the same innovative tool may differ in different contexts.

Moreover, several researches have shown that non-adherence to standard clinical guidelines is a potential contributor to maternal and neonatal mortality [82,243,313]. Other studies stressed the impact of using evidence-based clinical guidelines on positive maternal and newborn outcomes

[263]. But, previous studies have shown the absence of standard clinical guidelines at the point of service delivery, particularly in low income settings [314,315]. Also, the availability of clinical guidelines cannot change the patient outcomes unless health services and healthcare providers adopt them in practice [316]. The adoption of clinical guidelines involves health professionals' behavior change within healthcare systems [316]. Grol et al. [317] discusses the implementation of change in healthcare as a complex process that involve individual clinician behavior and practices change [317]. Therefore, ensuring the provision of evidence-based care using standard clinical guidelines requires behavior and practices change among healthcare providers which may lead to improved patient outcomes.

The improvements contributing to optimal patient care with consideration of new evidences and application of standard clinical guidelines have been shown to be an unpredictable, slow and haphazard process because of individual behaviors that need to be changed [317–319]. Rogers (2003) [71] highlighted that emotions, attitudes, beliefs and intentions are important for behavior change [71]. The normalization process theory addresses the factors needed for successful implementation and integration of interventions such as adoption of standard clinical guidelines into routine practices [320]. This theory suggests factors to consider when the researcher wish to maximize the use of a new innovation such cognitive participation looking at if the target user will be prepared to invest time, energy and work in the innovation [320,321]. Therefore, it is important to note that clinical practice guidelines are essential tools for embedding clinical evidence in practice. However, their use and positive results depend greatly on the change in behaviors of the end-users. In this study, even though improved maternal and newborn outcomes were observed following the SDA intervention, we could not evaluate the changes over time in nurses and midwives' behaviors and practices. Future research using a theory of change and/or a logical framework over a long period is needed to understand the dynamics and change processes within the larger health system and the impact of the SDA on the delivery care process with regards to the management of birth-related complications.

Furthermore, in the present study, our analysis took into consideration other interventions to improve obstetric care that happened in our study settings concurrently with our intervention and found non-significant differences. Our intervention may have contributed to the improved

maternal and newborn outcomes; however, we acknowledge other initiatives that strive to improve the quality of obstetric care in our study settings. Similarly, Hannah et al (2020) advocated for valuing other concurrent interventions in study contexts when looking at effectiveness of an intervention that addressed adherence to clinical guidelines [243]. Also, urban and rural settings may have different patient outcomes with the same intervention depending on the differences in the work environment [322]. However, in the current study, there were no significant differences in maternal and newborn outcomes within the urban and the rural district hospitals. In this study, we have also explored the acceptability of the SDA among end-users and key stakeholders. The following section discusses the acceptability outcome of the SDA in Rwanda.

8.3.3. What is the acceptability of the SDA among end-users and key stakeholders in Rwanda?

The acceptability of the SDA was assessed on one hand via a quantitative survey and focus group discussions with end-users (nurses and midwives). Overall, there was acceptability and positive perspectives about the SDA. The majority of nurses and midwives used the SDA four to six times per week and perceived the SDA as having improved their ability to manage PPH and NR. They acknowledged it as a useful tool for continuous learning and clinical decision support. Our study findings mirror those of other studies that mHealth solutions are adopted by healthcare providers depending on their benefits and perceived usefulness [133,323]. A recent study that evaluated the acceptability of mHealth solution underpinned by the diffusion of innovation theory reported a lower initial level of system acceptability and an improvement in overall mean acceptability after the pilot of the mHealth [324]. Similarly, consistent with Rogers' theory of the diffusion of innovation, the experiences and use of a new innovation may increase its acceptability [280]. He states that the characteristics of an innovation as perceived by the members of a social system determine its rate of adoption [280]. Hence the importance of exploring the acceptability of the SDA among end-users after they have experienced its use in real practices.

On the other hand, the acceptability of the SDA was explored through key informant interviews with stakeholders who directly influence policy at the district hospital level. The key stakeholders were also requested to provide their views on SDA scalability, costs and sustainability. Key stakeholders perceived the SDA as useful tool with a reasonable cost and recommended its

implementation in routine practices. They were optimistic that the SDA could be scaled up and be sustained in the whole country. Besides, there is an increasing recognition of the importance of stakeholder engagement to improve the acceptability and adoption of mHealth interventions in LMICs [324,325]. Effective stakeholder engagement is also recognized as one of the most crucial determinants of success of mHealth interventions as it influences the performance of the intervention and offers means to navigate social, economic, cultural, political and ethical issues [325]. This study explored perceptions of key stakeholders on the SDA as part of stakeholder engagement in the early phases of implementation of the SDA. The findings of this study add to available evidence about stakeholder engagement for the promotion of mHealth technology in LMICs.

In the same vein, Everet Rogers‘ diffusion of innovation theory [326] explains how new innovations are accepted and adopted among the intended audience. The theory elaborates that there are five attributes that can determine the acceptability and adoption of an innovation including relative advantage, observability, compatibility, complexity and triability [326]. Rogers explains relative advantage as the degree to which an innovation is perceived to be more beneficial than the situation it supersedes [283,326]. In this study, the SDA relative advantage was investigated using nurses’ and midwives’ knowledge and skills as well as maternal and newborn outcomes. Compatibility is defined as the degree to which an innovation fits within needs, values and experiences of the target audience [283,326]. In the present study, the SDA was shown to be a solution to challenges raised by nurses and midwives, including limited access to clinical guidelines and lack of continuous learning opportunities. Rogers refers to complexity as the degree to which an innovation is perceived as difficult to understand and use, proposing that the simpler the innovation is perceived the better the chances of adoption [283,326]. In this study, nurses and midwives perceived the SDA as an easy tool. Triability is defined as the degree to which an innovation can be experimented with on a limited basis [283,326]. This refers to the perceived ability of the target audience to have an input in the innovation, and in this study, nurses and midwives were able to propose desired features of the SDA that could be included for its additional benefit. Last, but not least, observability is the degree to which the results of an innovation are visible to the target audience [283,326]. In this study, the end-users experienced themselves the

benefit of using the SDA in real practices which was associated with improved knowledge and skills as well as maternal and newborn outcomes following PPH management and NR.

Although, the SDA acceptability was good in the present study, the uptake may be influenced by individual and context-specific factors. Other studies have documented poor uptake for some features of mHealth technology like text messaging despite high rates of acceptability [327–330]. Hannah et al [329] explained how individual health worker factors (demographics, personal and work-related needs, perceived timeliness of intervention, and tacit knowledge), organizational factors (resource availability, information flow, phone ownership), and technological factors (attrition of phones, network quality) play a crucial role in the uptake of mHealth technology [329]. Another research that investigated the use of mhealth to support clinical decision-making to improve maternal and neonatal health outcomes in Ghana found variations in the information needs for decision-making of different health workers which guided the use of different functions of the mHealth [331]. In the current study, the uptake of the SDA was found to be moderate with more than a half (57.4%) of participants using the SDA four to six times a week for an intervention period of six months. Therefore, further studies are needed to explore the factors influencing the uptake of the SDA in the context of Rwanda.

Additionally, Rogers (2003) indicated that in the course of diffusion of an innovation, in our case the SDA, there is a classification of end-users of the innovation on the basis of innovativeness [71]. This classification includes innovators, early adopters, early majority, late majority, and laggards [71]. For Rogers, innovativeness is “the degree to which an individual is relatively earlier in adopting new ideas than other members of a system”[326]. He states that the innovativeness helps in understanding the desired and main behavior in the innovation-decision process [71]. Also, Braak (2001) described innovativeness as “a relatively-stable, socially-constructed, innovation-dependent characteristic that indicates an individual’s willingness to change his or her familiar practices” [332]. Also, the normalization process theory discusses the factors needed for successful implemented interventions to be normalized into routine clinical practices [320]. The theory explains how the adoption of innovation is a process that involves coherence or sense making, cognitive participation or engagement, collective action and reflexive monitoring [138,320]. Thus the pace of adopting a new innovation will differ for different people composing

a health system. Other models have indicated that the adoption of a new innovation that involves the clinical behaviour change depends on multiple factors such as capability , opportunity, motivation, and behaviour [333]. Hence, future studies to explore the acceptability of SDA by digging dipper in the changes in behaviors and practices of end-users of the SDA guided by theories such as the diffusion of innovation theory and normalization process theory are needed.

Furthermore, the Theory of Diffusion highlights the importance of intermediary actors (opinion leaders, change agents and gate- keepers) for successful adoption and implementation of a new innovation [107]. In the current study, we explored the acceptability of the SDA among key stakeholders (key informants in the management position at the facility level). They perceived the SDA as useful tool and were willing to accept its implementation in routine practices. Our findings are congruent with other studies that have found high level of acceptability of mHealth interventions among stakeholders in relation to the intervention' perceived usefulness [325]. Likewise, research evidence has shown that policy makers in LMICs advocated to move from early stages of introduction and implementation of mHealth solutions to scalability and sustainability evaluation [334,335]. Also, the path dependence theory which discusses the implementation of new healthcare models aimed at improving the quality of healthcare [336] highlights the relevant influence of organizational culture, that considers the efforts of both managers and employees, in the adoption of new solutions [336,337]. Hence, the importance of exploring the views of managers as well as key stakeholders on a new innovation such as the SDA.

Moreover, in the current study, key stakeholders reflected on the possible scalability of the SDA, its costs and its possible sustainability in Rwanda. The findings are promising because stakeholders felt that the SDA pilot cost was reasonable and its scalability and sustainability is possible. Another research that investigated the cost-effectiveness of a clinical decision support system in improving maternal healthcare in Ghana, reported a decrease in the service costs with regards to pregnancy complications when using the new technology [338]. The study highlights that even though there are additional technology costs at the introduction of mHealth interventions, their implementation significantly support the detection of pregnancy complications and early management compared to routine care [338]. Other researchers have also advocated for scalability and sustainability of complex eHealth interventions in consideration of the lessons learnt from the pilot implementation

and the views of key stakeholders [268,271,306]. However, Proctor's model states that an evidence-based intervention may be highly effective but given its high cost, only mildly acceptable to key stakeholders and low in sustainability [30]. Therefore, our study findings provide insights into the SDA effectiveness and reasonable costs and set the baseline to the plan of the SDA scalability and sustainability evaluation in the context of Rwanda.

8.4. Methodological Innovation

The adoption of convergent parallel mixed-methods in this dissertation research, as reported in the papers, has illustrated the potential to use different approaches as part of data triangulation. This is a particular strength of this research. The study bases on pragmatism as a theoretical orientation and the pragmatic philosophy incorporates both the quantitative and qualitative methods (mixed-methods) [164]. In the pragmatic philosophy, the researcher focuses on the research problem rather than on the research methods hence uses a variety of relevant data collection and analysis approaches to get a deep understanding of the context, the problem, the actions, and their consequences and outcomes. The philosophy that the nature of knowledge and the ways of acquiring and discovering the knowledge are subjective and objective give pragmatic researchers the freedom to choose methods, procedures and techniques to use in their research projects from both quantitative and qualitative research [339]. Hence, the pragmatism philosophy assumes independence of methods drawing on the philosophy that " all knowledge is knowledge from some point of view"[340]. The present study considered both subjective and objective knowledge by using mixed-methods in order to investigate the use of the SDA in the context of Rwanda.

In addition, the most important feature of the pragmatic approach is the determination of outcomes and end-causes/results and not the identification of the ultimate cause. Morgan (2014) advocates for the use of pragmatism as a unique philosophical foundation for convergent parallel mixed-methods research [153]. Pragmatic approaches use value-neutral or naturalistic deductive methodology to identify causes that influence outcomes [153]. Also, pragmatic approaches use inductive methodology to understand events from individual perspectives as well as to conduct a directed interrogation of values and assumptions [152]. Also, Pragmatism offers an alternative end to the 'paradigms wars' since researchers have been in a dilemma as to which methods to use; quantitative or qualitative as described by Cameron (2011) [341]. Pragmatism has been considered as a bridge between the paradigms and the methodology in such a way that the nature of knowledge

and what constitutes realities can be explored from several perspectives using mixed methods approaches. In this study, we were interested in the evaluation of service, client, and intervention outcomes when using the SDA in the context of Rwanda. Three implementation outcomes; effectiveness, symptomatology, and acceptability were investigated using convergent parallel mixed-method approach with consideration of both deductive and inductive techniques. These implementation outcomes would predict the success or the failure of the pilot implementation of the SDA in Rwanda. Overall, the multi-methods approach helped to strengthen the research's contribution to evidence of how the SDA functions in low-resource settings of sub-Saharan Africa, like Rwanda.

8.5. Scholarly contribution of PhD

This PhD research is innovative and unique in that it is the first study in the country to investigate the effect of the SDA on nurses' and midwives' clinical decision-making for the management of the two top frequent birth-related complications (newborn asphyxia and postpartum hemorrhage) using a convergent parallel mixed-method approach. The choice of using implementation research to bring insight into the effectiveness, symptomatology, and acceptability of the Safe Delivery mHealth Application to manage specific life threatening adverse maternal and neonatal outcomes is novel in this setting and of public health and policy relevance.The unique contribution to knowledge is that the present research adds to much-needed evidence as to how a mHealth-based clinical decision support tool and mLearning functioned in a low-resource setting. The study also fully expands the depth of knowledge about the applicability of this inexpensive mHealth tool. More scholarly implications are outlined below:

8.5.1. Policy and practice Implications

- This work provides justification and practical lessons for the inclusion of mHealth decision support tools and mLearning solutions like the SDA in routine clinical practices such as obstetric care. This ultimately can lead to increased knowledge and skills among nurses and midwives and to improved maternal and newborn health outcomes.
- We partnered with key stakeholder's representative of the Ministry of Health (MOH) at the district hospital level to carry out this research. As a result, we believe that this partnership will promote inclusion of the study findings in future maternal and child health policy analysis.
- The study provides a framework for evidence-informed policy formulation which may be utilized by Rwanda's Ministry of Health in designing and implementing a carefully-laid

strategy towards reduction of maternal and newborn morbidity and mortality in consideration of specific needs of nurses and midwives who are the frontline workers in obstetric care.

- Evidence on the usage of the SDA in Rwanda will inform policy and planning of the BEmONC prevention strategies.

8.5.2. Research Implication

- This is the first study in Rwanda to investigate the effect of the SDA on clinical decision-making using a convergent parallel mixed-method approach.
- The first study to have used an evaluative implementation framework to evaluate the SDA implementation outcomes and it provides baseline for future studies.
- The study participants suggested additional features and functions of the SDA to be considered by SDA developers such as computer/laptop version of the SDA, additional videos, SDA version in the local language, and a discussion forum in the SDA. This information could guide future SDA improvements and updates as well as further SDA researches.
- The study also contributes to existing literature on the integration of ICT and maternal and child health for future researches in this domain.
- Our study also provides informed hypotheses for further research on maternal and newborn mHealth interventions in general, and the SDA in particular.
- This research will hopefully lead to future research and programming and contribute concretely to making a difference in maternal and newborn healthcare in Rwanda and to improving maternal and newborn outcomes.

8.5.3. Theoretical and conceptual implications

The pragmatism theoretical foundation and the adopted implementation research model were instrumental in supporting the conceptualization of the different pieces of research and in analyzing overall findings of this research. The implementation research model was critical to carrying out the fieldwork, in terms of guiding the choice of implementation outcomes to be investigated and the standard instruments to be used, and the crafting of the qualitative interview guides. Also, pragmatism informed this research by employing ‘what works’, using different approaches from different perspectives; the nurses’ and midwives’ perspectives and the key stakeholder’s perspectives. Further, pragmatism contributed to understanding the research question from different angles and to nurturing a complex relationship with the data, analyzing the results, and merging the qualitative and quantitative results. Pragmatists tend to view the nature of

reality as both singular and multiple [152,153]. As singular reality, there may be a theory that is helpful in explaining the research findings and a tendency to hypothesis testing. As multiple reality, there may be a tendency for assessing phenomena from multiple perspectives, hence the convergent parallel mixed-method approach. Therefore, the nature of reality in this research is both a singular and a multiple 'pragmatist view', but also with use of interpretation, in other words I can call it- interpretive pragmatist. Therefore, the research process used in this study inform future mHealth researches. Because the proctor framework is mainly focusing on implementation strategies and implementation outcomes of a new innovation, it was suitable for this pilot research of the SDA. But, future large scale research will need to revise the framework and include a theory of change and/or a logical framework in order to investigate the change in practices when using the SDA.

8.5.4. Public Health Impact

- The study adds to positive efforts ensuring that no woman/newborn dies during childbirth from causes that can be prevented by the use of the SDA mhealth technology.
- The present study used an innovative and unique research methodology that involved participants reflecting on their experiences of managing postpartum hemorrhage (PPH) and newborn asphyxia through a reflection on the baseline knowledge and skills results and records review findings. This process helped in gaining an in-depth understanding of the reality of practices from the perspective of nurses and midwives who are the frontline healthcare workers in obstetric care. This information is essential to enable the design of contextually-targeted interventions to improve facility-based childbirth care in LMICs, including Rwanda.
- This study offers more insights on how an mLearning and mHealth decision support tool could contribute to improved maternal and newborn outcomes in low-resource settings like Rwanda.
- This research also provides a good understanding on how mHealth interventions that focus on the clinical decision support processes in maternal and newborn care may contribute to improved and quality healthcare service delivery. Therefore, the mHealth decision support tools like the SDA should be considered by policymakers in resource-limited settings towards enhanced implementation of effective interventions.

8.6. Strengths and limitations of the research

The strengths and limitations of this study have been highlighted in the papers derived from this PhD work. We summarize them at a higher level in this section.

The study has multiple strengths and is highly relevant in low-income countries like Rwanda, where quality of childbirth care is challenged by a lack of in-service continuous training, limited knowledge and skills among healthcare providers, and poor access to clinical guidelines. Also, the methodology employed in this study, and the pragmatic approach that allowed the use of mixed – methods and the consideration of both objective and subjective knowledge with data triangulation, quantitative and qualitative data, from different data sources was a strength of the study. An understanding of implications of the SDA from an implementation research perspective guided by proctor' conceptual framework added value to this study. Given the complexity of implementing a new mHealth technology in delicate clinical services such as the management of PPH and NR in a new setting, a six-month pilot study permitted us to assess the future implications of use of the SDA from healthcare providers that denoted that it was something that they wanted to continue using to continuously improve their knowledge and skills as well as patient outcomes.

The present study utilized an evaluative implementation framework by proctor which provided results/findings that we believe are adding to the existing knowledge about the effect of the SDA and are comparable with previous researches on the SDA. However, a future longer duration (12 – 24 months) study will allow to measure the sustainability of the SDA over a longer period. Also, the implicit theory of change for SDA is that it changes skilled birth attendants' practices, leading to improved patients' outcomes. In future studies, the use of an evaluative implementation framework coupled with a theory of change and/or a logical framework over a long period will help to explore the dynamics and processes of change in practices towards best practice in the management of birth-related complications.

Then again, while the results of this study show improved knowledge and skills, acceptable and effective in management of PPH and NR, we cannot ascertain generalizability in settings beyond district hospitals. Availability of nurses and midwives with smartphones could have increased the success of the SDA implementation. We acknowledge the limitations of our study design, pre-post intervention, which only permitted us to investigate the relationship between the SDA intervention and study outcomes. The improved knowledge and skills and the observed maternal and newborn outcomes may have been influenced by other factors, such as other learning opportunities, in addition to the SDA intervention. But, we controlled for other learning opportunities in the analysis

and did not find any significant difference. We also acknowledge the limitation of findings when assessing skills using a self-administered questionnaire with simulated clinical cases. This was due to technical difficulties of evaluating skills by change in real practice. Both the study design and the methodological approach could have been improved (such as inclusion of control sites) without budget restrictions and limited research time. Also, nurses and midwives may have consulted other sources rather than the SDA to inform their decision-making during the intervention. Although this limitation is inherent in the design of the study, the current study contributes to the broader evidence about the effectiveness, symptomatology, and acceptability of the SDA and provides much-needed insights as to how an mLearning and a decision-support mHealth application functioned in a low-resource setting.

Chapter nine: Conclusion and Recommendations

9.1. Introduction

This is the last chapter of the thesis and contains the conclusion derived after analysis and discussion of the study findings. In addition, the chapter also includes the recommendations of the study on policy, practice, and research.

9.2. Conclusion

This study provides a comprehensive and detailed understanding of the effectiveness, symptomatology and acceptability of the SDA implementation in the context of district hospitals in Rwanda. The pragmatic approach together with the adopted implementation research model allowed us to investigate the use of SDA from different perspectives, both individual perspectives (end users) and key stakeholders. Prior to the SDA intervention, nurses and midwives reflected on the baseline survey results of their knowledge and skills in PPH management and NR, and on the records review findings about maternal and newborn outcomes following PPH management and NR. This was followed by an exploration of nurses and midwives' experiences in delivering obstetric care services, which revealed real practices challenges such as the lack of in-service continuous training, limited knowledge and skills, and poor access to clinical guidelines. The pilot testing of the SDA model that entailed a six-month implementation of the SDA (as an mHealth decision support tool and an mLearning solution) to avert these challenges showed increased knowledge and skills among nurses and midwives, and improved maternal and newborn outcomes. The SDA was also perceived by end-users and key stakeholders as an effective and useful tool. This suggests that the introduction of mHealth technologies like the SDA in routine obstetric care practices may constitute one response to the lack of continuous learning opportunities, and to limited access to standard clinical guidelines which could promote evidence-based obstetric care that lead to better maternal and newborn outcomes. The views of end-users and key stakeholders also highlighted that the SDA could be scaled up because it was beneficial and its cost was reasonable, and it could be sustained. The study, thus, concludes that the SDA intervention was associated with improved knowledge and skills as well as improved patient outcomes, and was highly acceptable among end-users and key stakeholders. The findings of the present study add to the broader knowledge about the feasibility and potential benefits of the SDA in low-income settings and set the baseline for future research on the SDA scalability, cost-effectiveness and sustainability in the context of Rwanda.

9.3. Recommendations

9.3.1. Recommendations for policy and practice

The findings of the present study suggest several courses of action for the Ministry of Health (MOH) in Rwanda and its partners. First, the study has identified that the use of the SDA has beneficial impact on both knowledge and skills of nurses and midwives, and on patient's outcomes. The SDA was also perceived by end-users and key stakeholders as an effective and useful tool with a reasonable cost and potentiality to be scaled up and sustained. The MOH is, therefore, recommended to take actions in this regard and support the inclusion of the SDA in routine clinical practice. Second, Important policy changes in improving the adoption of mHealth technology such as the SDA in clinical practice is particularly recommended. Third, the study recommends the use of evidence-based clinical guidelines to inform clinical decision making during childbirth care. Fourth recommendation is for the district hospital management for facilitating access to evidence-based clinical guidelines, and there is no better choice than the SDA to facilitate instant access to evidence-based clinical guidelines.

9.3.2. Recommendations for future research

The main recommendations for future research based on work from this thesis are summarized in the bullet points below:

- Carrying out a pilot study prior to doing a larger study is important for a variety of reasons notably, in the case of this study, as related to understanding the limitations linked with the research setting. The present study was an effort to extensively investigate the effectiveness, symptomatology, and acceptability of the SDA in the context of two district hospitals in Rwanda. Future researches can use more advanced methodology for conducting comprehensive research in other hospitals in Rwanda. The limitations of the present study, as highlighted above, needs to be taken into account while conducting any future study on the subject.
- Future researches should capture data on a time basis to allow analysis that reviews trends over months or years with regards to variability about patient outcomes.
- Future long duration research is suggested to clarify the dynamics of clinical decision making using the SDA and practices change processes guided by a theory of change and/or a logical framework. Further research is also needed to explore the scalability, cost-effectiveness and sustainability of the SDA in the context of Rwanda.

- Further researches are also needed to investigate the effectiveness of the SDA when used by other healthcare cadres whose responsibilities are directly linked with the management of childbirth complications, for instance, medical doctors and gynecologists, health centers staffs, ambulance workers and paramedics, and community health workers. An exploration of specific modules and functions of the SDA that would best inform those cadres depending on their respective responsibilities would be beneficial.

9.4. Research trajectory (candidate's next steps)

Our pilot study laid the groundwork for future research to test the hypothesis that the SDA mHealth decision support and mLearning intervention is effective in reducing maternal and newborn mortality in Rwanda. The findings of the current study inform future studies which should consider adopting the implementation research hybrid 1 design (testing a clinical intervention while gathering information on its potential for implementation in a real-world situation). The implementation research hybrid designs have been shown to be the most common approaches to speeding the translation of research findings into sustained routine practice [282]. Planned future research will measure patient outcomes on a larger scale with a longer follow-up period and integrate practice change assessments for instance a pre-and-post partogram completion research component for measuring provider behavior change. This type of research would necessitate the use of an electronic data collection instrument, given the concerns regarding accuracy and completeness of data in delivery registries on key maternal and neonatal indicators, as indicated by our record review findings. The local SDA version would be advocated for and if possible used for future SDA research. The SDA individual usage will be tracked for a longer follow-up period which would add useful data to sustainability evaluation. The researcher would ideally work with the Rwandan Ministry of Health and key in country partners to develop and put in place the informatics capacity for SDA use in a larger study on SDA scalability, cost-effectiveness and sustainability.

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Appendices

Appendix A. Co – Author Agreement

Appendices

Appendix A. Co – Author Agreement

Declaration: Student's contribution to article(s) and agreement of co-author(s)

I, Aurore Nishimwe, student number 1941393, declare that this Thesis/Dissertation/ Research Report is my own work and that I contributed adequately towards research findings published in the article(s) stated below which are included in my Thesis/Dissertation/Research Report.

Signature of Student: **Date:** 14th January 2022

Name of Primary Supervisor: Dr. Daphney Nozizwe Conco

Signature of Primary Supervisor ..... **Date**: 16 January 2022

Agreement by co-authors: By signing this declaration, the co-authors listed below agree to the use of the article by the student as part of his/her Thesis/Dissertation/ Research Report. In cases where the student is not the 1st author of a published article, the primary supervisor must explain (under comments) why the student is entitled to use the paper for his/her degree purposes.

Article 1: Title: Clinical decision making in basic emergency obstetric and newborn care among nurses and midwives: the role of the safe delivery mhealth application_pre-post-intervention study (research protocol)

Journal name, year, volume, and page numbers: *Informatics for Health and Social Care 46, no. 2 (2021): 126-135.* (Status: Published)

Authors	Names	Signatures	Dates
1st author	Aurore Nishimwe		14th January 2022
2nd author	Marc Nyssen		17th January 2022
3rd author	Latifat Ibisomi		17 January 2022
4th author	Daphney Nozizwe Conco		16 January 2022

Article 2: Title: Context specific realities and experiences of nurses and midwives in basic emergency obstetric and newborn care services in two district hospitals in Rwanda: a qualitative study.

Journal name, year: *BMC Nursing 21, no. 1 (2022): 1-16.* (Status: Published)

Authors	Names	Signatures	Dates
1st author	Aurore Nishimwe		14th January 2022
2nd author	Daphney Nozizwe Conco		16 January 2022
3rd author	Marc Nyssen		17th January 2022
4th author	Latifat Ibisomi		17 January 2022

Article 3: Title: The effect of an mLearning application on nurses' and midwives' knowledge and skills for the management of postpartum hemorrhage and neonatal resuscitation: pre–post intervention study.

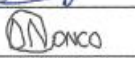
Journal name, year, volume, and page numbers: *BMC Human Resources for Health 19, no. 1 (2021): 1-10.* (Status: Published)

Authors	Names	Signatures	Dates
1st author	Aurore Nishimwe		14th January 2022
2nd author	Latifat Ibisomi		17 January 2022
3rd author	Marc Nyssen		17th January 2022
4th author	Daphney Nozizwe Conco		16 January 2022

Article 4: Title: The effect of a decision-support mHealth application on maternal and neonatal outcomes in two district hospitals in Rwanda: pre – post intervention study.

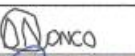
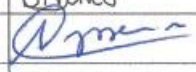
Journal name, year: *BMC Pregnancy and Childbirth. 2021* (Status: accepted for publication)

Authors	Names	Signatures	Dates
1st author	Aurore Nishimwe		14th January 2022
2nd author	Latifat Ibisomi		17 January 2022

3rd author	Marc Nyssen		17th January 2022
4th author	Daphney Nozizwe Conco		16 January 2022

Article 5: Title: A mixed-method study exploring experiences, perceptions, and acceptability of using a Safe Delivery mHealth Application in two district hospitals in Rwanda.

Journal name, year: *BMC Nursing, 2022* (Status: Under review)

Authors	Names	Signatures	Dates
1st author	Aurore Nishimwe		14th January 2022
2nd author	Daphney Nozizwe Conco		16 January 2022
3rd author	Marc Nyssen		17th January 2022
4th author	Latifat Ibisomi		17 January 2022

Appendix B. Ethical clearances

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

Office of the Deputy Vice-Chancellor (Research & Post Graduate Affairs)

TO: Ms A Nishimwe
School of Public Health
Medical School
University

E-mail: 1941393@students.wits.ac.za

CC: Supervisor: Dr DN Conco; Professors L Ibisomi & M Nyssen
<Daphney.Conco@wits.ac.za>
and <HREC-MedicalResearchOffice@wits.ac.za>

FROM: Iain Burns
Human Research Ethics Committee (Medical)
Tel: 011 717 1252

E-mail: Iain.Burns@wits.ac.za

DATE: 2019/04/24

REF: *R14/49*

PROTOCOL NO: **M190258** *(This is your ethics application study reference number. Please quote this reference number in all correspondence relating to this study)*

PROJECT TITLE: *Safe delivery mhealth application and clinical decision making among nurses and midwives on basic emergency obstetric and newborn care in district hospitals in Rwanda*

Please find attached the Clearance Certificate for the above project. I hope it goes well and that an article in a recognized publication comes out of it. This will reflect well on your professional standing and contribute to the Government funding of the University.

MSWorks2000/Iain0007/Clearscan.wps

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

R14/49 Ms A Nishimwe

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M190258

NAME: (Principal Investigator)	Ms A Nishimwe
DEPARTMENT:	School of Public Health Medical School University
PROJECT TITLE:	Safe delivery mhealth application and clinical decision making among nurses and midwives on basic emergency obstetric and newborn care in district hospitals in Rwanda
DATE CONSIDERED:	2019/02/22
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr DN Conco; Professors L Ibisomi & M Nyssen
APPROVED BY:	Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	2019/04/24

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on the 3rd Floor, Phillip Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.

I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to submit details to the Committee. **I agree to submit a yearly progress report.** When a funder requires annual re-certification, the application date will be one year after the date when the study was initially reviewed. In this case, the study was initially reviewed in **February** and will therefore reports and re-certification will be due early in the month of **February** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

25.4.2019
Date

UNIVERSITY OF RWANDA — COLLEGE OF MEDICINE AND HEALTH SCIENCES

CMHS INSTITUTIONAL REVIEW BOARD (IRB)

Kigali, 11th /12/2018

NISHIMWE Aurore
University of Witwatersrand

Approval Notice: No 377/CMHS IRB/2018

Your Project Title "**Safe delivery mhealth application and clinical decision making among nurses and midwives on basic emergency obstetric and newborn care in district hospitals in Rwanda**" has been evaluated by CMHS Institutional Review Board.

		Involved in the decision		
		Yes	No (Reason)	
Name of Members	**Institute**		**Absent**	**Withdrawn from the proceeding**
Prof Kato J. Njunwa	UR-CMHS	X		
Prof Jean Bosco Gahutu	UR-CMHS	X		
Dr. Brenda Asiimwe-Kateera	UR-CMHS	X		
Prof Ntaganira Joseph	UR-CMHS	X		
Dr. Tumusiime K. David	UR-CMHS	X		
Dr. Kayonga N. Egide	UR-CMHS	X		
Mr. Kanyoni Maurice	UR-CMHS	X		
Prof Munyanshongore Cyprien	UR-CMHS	X		
Mrs. Ruzindana Landrine	Kicukiro district		X	
Dr. Gishoma Darius	UR-CMHS	X		
Dr. Donatilla Mukamana	UR-CMHS	X		
Prof Kyamanywa Patrick	UR-CMHS		X	
Prof Condo Umutesi Jeannine	UR-CMHS		X	
Dr Nyirazinyoye Laetitia	UR-CMHS	X		
Dr Nkeramihigo Emmanuel	UR-CMHS		X	
Sr Maliboli Marie Josee	CHUK	X		

After reviewing your protocol during the IRB meeting of where quorum was met and revisions made on the advice of the CMHS IRB submitted on 12th November 2018, **Approval has been granted to your study**.

Please note that approval of the protocol and consent form is valid for **12 months**.

You are responsible for fulfilling the following requirements:

1. Changes, amendments, and addenda to the protocol or consent form must be submitted to the committee for review and approval, prior to activation of the changes.
2. Only approved consent forms are to be used in the enrolment of participants.
3. All consent forms signed by subjects should be retained on file. The IRB may conduct audits of all study records, and consent documentation may be part of such audits.
4. A continuing review application must be submitted to the IRB in a timely fashion and before expiry of this approval
5. Failure to submit a continuing review application will result in termination of the study
6. Notify the IRB committee once the study is finished

Sincerely,



Date of Approval: The 11th December 2018

Expiration date: The 11th December 2019

Professor GAHUTU Jean Bosco
Chairperson Institutional Review Board, College of Medicine and Health Sciences, UR

Cc:

- Principal College of Medicine and Health Sciences, UR
- University Director of Research and Postgraduate Studies, UR

Appendix C. Study sites permission letters

REPUBLIC OF RWANDA

Masaka 20/12/2018
REF 332/MSK/DH/2018

KIGALI CITY
DISTRICT KICUKIRO
HOPITAL MASAKA
B.P 3472 KIGALI
E-mail: masaka.hospital@moh.gov.rw

To: NISHIMWE Aurore
0788814121

Re: Permission to conduct a study in Masaka District Hospital

Dear Madam,

Refering to the letter written on 13th December 2018 requesting to conduct a study in Masaka District Hospital on **«The feasibility of the Safe Delivery Application in supporting clinical decisions for Basic Emergency Obstetric and Newborn Care among nurses and midwifes in district hospitals in Rwanda »**, the management of Masaka District Hospital is pleased to inform you that you have authorization to conduct that study in this hospital.

Sincerely

Dr. Marcel UWIZEYE
Director General Masaka Hospital

REPUBLIQUE DU RWANDA

03rd JANUARY 2019

ADEPR

HOPITAL NYAMATA
BP : 7112 Kigali
Tél : 0780637766
E-mail : nyamata.hospital@moh.gov.rw

Dear **NISHIMWE Aurore**

CMHS-UR, School of Health Sciences

RE: PERMISSION TO CONDUCT A STUDY

After reception of your request for permission to Conduct a Study in Nyamata Hospital and review of your Research Protocol on " **The feasibility of the Safe Delivery Application in Supporting Clinical Decisions for Basic Emergency Obstetric and New-born Care Among nurses and midwives in Districts Hospitals in Rwanda**", required for completion of your PHD studies, the Nyamata Hospital Ethics Committee has decided to give you permission to conduct your Study.

The Ethics Committee recommends you to:

a. Ensure that consent is guaranteed and signed before interview and administration of questionnaires to nurses and midwives,
b. Ensure confidentiality of individual information,
c. Submit a final copy of your Research findings after completion of the study,
d. Consult Nyamata Hospital administration in case you need to publish the findings.

Yours Sincerely.

Dr Cyrille NTAHOMPAGAZE
Chair Person of Ethics Committee

Approved by: **Dr William RUTAGENGWA**
Director General of Nyamata Hospital

Appendix D. Faculty Approval of PhD Thesis Title

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Private Bag 3 Wits, 2050
Fax: 027117172119
Tel: 02711 7172076

Reference: Mrs Sandra Benn
E-mail: sandra.benn@wits.ac.za

06 February 2019
Person No: 1941393
PAG

Mrs A Nishimwe
Kigali City
3286
Rwanda

Dear Mrs Aurore Nishimwe

Doctor of Philosophy: Approval of Title

We have pleasure in advising that your proposal entitled *Safe delivery mhealth application and clinical decision making among nurses and midwives on Basic Emergency Obstetric and Newborn Care in district hospitals in Rwanda* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

Appendix E. Data extraction sheets_Record reviews

CASES OF NEWBORN COMPLICATIONS (from the Delivery Register/ Registre d'accouchement):

- **Cases of newborns with fetal distress:**
  - Apgar score at birth below 7

Date of Delivery	Hospital Name	Patient ID number	Age of the mother	Weight of the newborn at birth in Kg	Sex of the newborn (M/F)	Mode of Delivery	Delivery led by (Nurse, Midwife, Doctor,...)	Apgar Score at 1 minute	Apgar Score at 5 minutes	Apgar Score at 10 minutes	Resuscitation Actions taken if Any	Newborn outcome (stable, fair , critical, dead, transferred to NCU)

CASES OF OBSTETRIC COMPLICATIONS (from the Delivery Register/ Registre d'accouchement):

- **Cases of Post-Partum Hemorrhage (PPH)**
  - Amount of blood loss superior to 500 ml

Date of Delivery	Hospital Name	Patient ID number	Age	Gestational age in weeks	Mode of Delivery	Delivery led by: (Nurse, Midwife, Doctor,...)	Blood loss in ml	Causes of PPH {Uterine atony(5a), Cervical tear(5b), retention of placenta(5c)}	Resuscitation Actions taken if Any	Mother outcome (stable, transferred, dead)	Cause of Maternal death if dead

Appendix 1. Information sheet

WITS UNIVERSITY

INFORMATION SHEET

Project Title: Safe Delivery mhealth Application and clinical decision making among nurses and midwives on Basic Emergency Obstetric and Newborn Care in district hospitals in Rwanda.

We would like to invite you to take part in a study and we would like to explain what we are doing before you decide whether or not to take part. Please take some time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Thank you for reading this.

What is the purpose of the study?

This research seeks to investigate the effect of the Safe Delivery Application on nurses' and midwives' clinical decision making in Basic Emergency Obstetric and Newborn Care in district hospitals in Rwanda. The data collected could inform planning for prevention strategies and improve best practices in basic emergency obstetric and newborn care.

Who is doing the study?

The study is done by Aurore Nishimwe, a student in the school of public health at the University of the Witwatersrand, South Africa. The study is part of what I have to do to earn a PhD degree.

Do I have to take part?

You do not have to take part if you do not want to. If you decide not to take part, this will not affect you in anyway. Even after you choose to participate, you are at liberty to opt out any time without giving a reason.
If you agree to take part, then you will need to sign a form.

What will I be asked to do?

You will be asked to complete questionnaires about your knowledge and skills in post – partum hemorrhage management and neonatal resuscitation.

How do I benefit?
There is nothing to offer to you directly in this study. However, the response you offer will be very useful in helping to understand how BEmONC services can be improved in Rwanda. This could be helpful for the reduction of maternal and newborn mortality in Rwanda.

How will I receive feedback?
I plan to write a book from these findings. The book will be ready by the end of 2020. This book will be open in the university library. I also plan to publish academic papers in online journals.

Contact details for further information:
Aurore NISHIMWE, Principal Investigator, telephone no: +250788814121, or by e-mail at 1941393@students.wits.ac.za,

Dr. Daphney Nozizwe Conco, Supervisor, on telephone no: +270832824320, or by e-mail at Daphney.Conco@wits.ac.za

Prof. Latifat IBISOMI, Supervisor, on telephone no. +270117172607, or by e-mail at Latifat.Ibisomi@wits.ac.za

Prof Marc NYSSEN, Supervisor, on telephone no: +3224774424, or by e-mail at marc@minf.vub.ac.be

Appendix 2: Consent form_quantitative surveys



PARTICIPANT CONSENT SHEET

Project Title: Safe Delivery mhealth Application and clinical decision making among nurses and midwives on Basic Emergency Obstetric and Newborn Care in district hospitals in Rwanda.

1. I have been given a Participant Information Sheet which explains the nature and processes involved in this study, which is attached hereto;
2. I was given time to read it, or had it read to me, in the language I best understand;
3. I was given time to ask any questions I wanted to and found any answers given to me to be reasonable and satisfactory;
4. I believe I fully understand why the study is being conducted and what the intended outcomes will be;
5. I understand that there will be no immediate benefit to me, should I agree to participate, nor will I receive any payment; conversely, participation will not cost me anything but my time;
6. I understand that, even if I initially consent to take part in the study, I may subsequently withdraw at any time and would not be required to give any reasons; if that happened, any data collected about me for the purposes of the study would immediately be destroyed, unless I give consent for it to be retained
7. I have been given a range of contact details, listed below. If I require further information or become concerned about any aspect of this study, I am free to speak to any of these contacts.

Contact details:

Aurore NISHIMWE, Principal Investigator, telephone no: +250788814121, or by e-mail at 1941393@students.wits.ac.za,

Dr. Daphney Nozizwe Conco, Supervisor, on telephone no: +270832824320, or by e-mail at Daphney.Conco@wits.ac.za
Prof. Latifat IBISOMI, Supervisor, on telephone no. +270117172607, or by e-mail at Latifat.Ibisomi@wits.ac.za
Prof Marc NYSSEN, Supervisor, on telephone no: +3224774424, or by e-mail at marc@minf.vub.ac.be

Dr CB Penny, Chairperson of the Human Research Ethics Committee (Medical) at the University of Witwatersrand, on telephone no. 011 717 2301, or by e-mail at Clement.Penny@wits.ac.za. Ms. Z Ndlovu or Mr. Rhulani Mkansi, Committee Secretariat, telephone nos.: 011 717 2700 or 1234, or by e-mail at: Zanele.Ndlovu@wits.ac.za or Rhulani.Mkansi@wits.ac.za

Name of Participant: _____
Date: _____
Place: _____
Signature or mark _____

Witnessed by:

Name of Witness: _____
Signature: _____
Date: _____

Appendix 3. Knowledge and Skills surveys questionnaires_English version

SAFE DELIVERY APP – KNOWLEDGE AND SKILLS SURVEY

Dear Participant, thank you for agreeing to participate in this study. You are about to answer questions regarding neonatal resuscitation. There is a mix of single response and multiple response questions. Kindly answer all questions honestly and completely. We assure you that your identity and the information you will provide will be kept confidential.
Please answer to the best of your ability.

BACKGROUND INFORMATION

Date: _____

Age: _____

Gender: ___M ___F

Hospital Name: _____

Title: ___A0 Midwife ___ A1 Midwife ___ A0 Nurse ___A1 Nurse ___A2 Nurse

Please enter your personal ID number: _ _ _ _ _ _ _ _ _ _ _

1. How many years have you been providing obstetrical care? ___ Years ___ Months

2. How many hours per week do you spend providing obstetrical care? ___<5hrs ___5-10hrs ___10-20hrs ___>20hrs

3. On average how many deliveries do you participate in monthly? ___0-5 ___5-10 ___10-20 ___20-30 ___>30

4. Have you received any in-service training about neonatal resuscitation during the last 6 months? ___Yes ___No, if yes please specify

   _____

5. Have you ever used a smartphone?

___Tried using one ___Never tried using one

KNOWLEDGE QUESTIONS REGARDING NEONATAL RESUSCITATION

1. Failure to initiate adequate breathing at birth is a common cause of: *Please select only **one** answer*. a. post-partum hemorrhage

b. Jaundice
c. Genital malformation
d. Neonatal death 2. The golden minute implies that all newborns should by one minute of age: *Select **all** answers that apply.* a. Breathe on their own

b. Move their arms and legs with a good tone
c. If not breathing be ventilated with a bag

d. Lie skin to skin with the mother 3. When do you assess the newborn after birth? *Please select only **one** answer.*

a. Immediately after delivery
b. After one minute
c. After the umbilical cord is cut
d. If he is not crying

4. Where do you place the newborn immediately after birth? *Please select only **one** answer.*
   a. On the mother with skin to skin contact
   b. Set it down in between the legs of the mother while you care for her
   c. On the weighing scale
   d. In a warm cloth away from the mother

5. What are the first steps you take after the baby is born? *Please select only **one** answer.*
   a. Assess the newborn's colour, tone and check if it is crying and breathing well
   b. Suction the baby's mouth and nose
   c. Start inflation breaths with a ventilation bag
   d. Call for help

6. Which statement is true? *Please select only **one** answer.*

   a. Only babies born with thick meconium need suction at birth
   b. Suction all newborns at births

7. If a baby is born with thick meconium and needs resuscitation, in what order would you act? ___; ___; ___.
   a. Suction
   b. Ventilate
   c. Dry thoroughly

8. What do you do within 5 seconds after the delivery of a vigorously crying newborn? *Select **all** answers that apply.* a. Dry the baby with a towel.
   b. Stimulate the baby by rubbing the back.
   c. Cut the umbilical cord
   d. Remove wet towels and cover the newborn to keep it warm.

9. Immediately after birth, you find that the newborn is not breathing well, what do you do next? *Please select only **one** answer.*

   a. Stimulate the baby by drying and rubbing the back with a dry cloth
   b. Suction the baby's mouth and nose
   c. Assess the baby's heart rate

10. Which of the following statements are true? The newborn needs resuscitation if: *Please select only **one** answer.*

   a. Within 30 seconds after delivery and after thorough stimulation he is gasping or not crying or breathing
   b. Within 2 minutes after delivery he is gasping or not crying or not breathing

11. The newborn is not responding to stimulation by drying and rubbing the back. Place the following four immediate actions in order: ___; ___; ___; ___.

a. Clamp and cut the umbilical cord
b. Open the airway or position the head in neutral position
c. Call for help
d. Give 5 inflation breaths

12. When performing resuscitation, you place the head in a neutral position. What is the neutral head position? *Please select only **one** answer.*

a. Head is extended backward to open the airway
b. Head is to the side to let fluids escape
c. Head is parallel to the surface

13. Where do you place the mask on the newborn? *Please select only **one** answer.*

a. On the mouth
b. On the mouth and nose
c. On the eyes, mouth and nose
d. On the nose

14. How do you ensure that ventilation is effective? *Please select only **one** answer.*

a. Make sure that the bag is emptied every breath
b. Make sure to ventilate very fast
c. Make sure that the chest rises with every ventilation
d. Make sure to press very hard on the bag

15. You start resuscitation by giving how many inflation breaths? *Please select only **one** answer.* a. 7

b. 10
c. 5
d. 15

16. How do you perform a jaw thrust? *Please select only **one** answer.*

a. Apply force on the mask on the newborn's jaw
b. Apply force on the mask on the newborn's jaw
c. Lift the baby's jaw forward with one hand

17. What are important actions to take in order to provide successful inflation breaths? *Select **all** answers that apply.* a. Sustain the breath for 2-3 seconds

b. Position the head in the neutral position
c. Make sure that chest moves with every breath
d. Assess the heart rate

18. The chest is not rising during your attempts to provide inflation breaths. What do you do? *Select **all** answers that apply.*

a. Reposition the head and lift the newborn's jaw forward

b. Give 5 inflation breaths again
c. Wait and see if the respiration is restored spontaneously
d. Stop resuscitation

19. What are inflation breaths? *Please select only **one** answer.*

a. The first 5 slow ventilations in neonatal resuscitation- each breath is sustained for 2-3 seconds while the chest move
b. Ventilating the newborn at a rate of 40 breaths per minute- with each you say "breathe-2-3"
c. The first spontaneous breaths the newborn takes unassisted on its own.

20. What are ventilation breaths? *Please select only **one** answer.*

a. Ventilating the newborn at a rate of 40 breaths per minute– with each breath you say "breathe-2-3"
b. The first 5 slow ventilations in neonatal resuscitation – each breath is sustained for 2-3 seconds while the chest moves.
c. The first spontaneous breaths the newborn takes unassisted on its own.

21. At what rate do you give ventilation breaths with? *Please select only **one** answer.*

a. Approximately 40 breaths per minute
b. Approximately 100 breaths per minute

22. After inflation breaths, the newborn is breathing less than 30 breaths/minute, or the heart rate is below 100 beats per min. What is your next action? *Please select only **one** answer.*

a. Stimulation by drying and rubbing the back.
b. Stop resuscitation and counsel the mother on her loss
c. You start ventilation breaths
d. Wait and see if the respiration is restored spontaneously

23. When do you continue with ventilation breaths? *Select **all** answers that apply.*

a. Respiratory rate less than 30 times/ minute
b. Heart rate below 100 beats per minute
c. Reduced tone
d. Respiratory rate more than 40 times/ minute

24. What is most important thing to keep in mind regarding ventilation breaths? *Please select only **one** answer.* a. That the rate is 40 breaths/min
b. That you know the ventilation technique is effective when you can see chest movements
c. That you apply force on the mask to ensure a good seal
d. That you wrap the newborn in a warm cloth

25. How do you ensure an even rhythm in ventilation breaths? *Select **all** answers that apply.*

a. Squeeze the bag as you say "breathe" and release the pressure on the bag as you say "two-three"

b. Count out loud: “Breathe – two – three” as you ventilate the newborn
c. Squeeze the bag three times every time you say “breathe-two-three”

26. How do you correctly ventilate a newborn? *Select **all** answers that apply.*

a. Make sure that the mask is well sealed to the newborn
b. Look for adequate chest rise
c. Allow the lungs to recover between each inflation
d. Make sure the newborn has a gastric tube

27. When do you assess the newborn during resuscitation? *Please select only **one** answer.* a. Every 5 minutes

b. Every 30 seconds
c. After 20 minutes
d. Every Minute

28. What do you assess during neonatal resuscitation? *Select **all** answers that apply.* a. Breathing

b. Heart rate
c. Colour and tone
d. If the newborn urinates

29. If the newborn has not established regular breathing or the pulse is below 100 what do you do? *Please select only **one** answer.*

a. Give chest compressions
b. Wait and see if the respiration is restored spontaneously
c. Continue ventilation breaths
d. Stop resuscitation

30. When the newborn is breathing well, it has normal colour, normal tone, and a heart rate above 100 bpm, in what order would you do the following actions? ___; ___; ___; ___.

a. Place the newborn skin by skin with the mother
b. Establish early breastfeeding
c. Stop ventilation and continue observation for 5 minutes.
d. Every 15 minutes for the first 2 hours, you check colour, tone, breathing, heart rate, and that the newborn is warm.

31. The respiratory rate is normal. But what do you do if the newborn’s colour is bluish or if the newborn is having difficulty breathing with in-drawings or grunting? *Please select only **one** answer.*

a. Give phenobarbital IV/IM
b. Wrap the newborn and give him/ her to the mother
c. Give oxygen by nasal catheter or prongs if available

32. When do you stop resuscitation? *Select **all** answers that apply.*

a. If the newborn is not breathing and has no heart rate after 10 minutes of effective ventilation

b. When the newborn is breathing well, has normal colour, normal tone, and a heart rate above 100bpm
c. If the newborn has a heart rate below 60 bpm for more than 20 minutes you take the difficult decision to stop the resuscitation.
d. If the newborn is not breathing and has no pulse after 2 min of effective ventilation

33. What do you do after you have decided to stop an unsuccessful resuscitation of a newborn? *Select **all** answers that apply.*

a. Explain gently to the mother, that the newborn unfortunately did not survive.
b. Provide emotional support to the family
c. You leave the woman alone to grieve
d. You continue with your other duties

34. The newborn is now crying with a good colour and tone. *Select two immediate actions.*

a. Place the newborn with mother skin-to-skin
b. Wrap the newborn and place it with a relative
c. Give antibiotics IV or IM
d. Early breastfeeding (within the first hour)

35. How do you prevent hypoglycemia if the newborn has been resuscitated for more than one minute? *Select **all** answers that apply.*

a. Establish breastfeeding within the first half hour
b. After breastfeeding give supplementary feeding in a cup
c. Give the newborn cow milk
d. Give the newborn exclusive formula milk

36. How should you resuscitate a preterm newborn? *Please select only **one** answer.*

a. With the same maneuvers as for full term newborns but with a smaller mask for ventilation
b. Avoid inflation breaths in a preterm newborn – otherwise resuscitate in the same way as you would do with a term newborn
c. You should use a smaller mask for ventilation

37. What are the greatest challenges with regards to the resuscitation of a small or preterm newborn? *Select **all** answers that apply.*

a. Airway and breathing
b. Adequate chest rise
c. Disability
d. Sepsis/infections
e. To ensure a correct seal of the mask and bag

SKILLS QUESTIONS REGARDING NEONATAL RESUSCITATION

1. In the last month, how many newborns have you resuscitated as the primary obstetric provider?

___Number of newborn resuscitations

2. Neonatal resuscitation case scenario:

You are assisting a delivery of a 39-week infant with an estimated weight of 4500 grams (4.5 kg). The mother is a G2 P1, 40-year-old, and her last delivery was a vaginal delivery. Mother has been in labor for 18 hours and within the last 20 minutes, fetal heart rate tracings have become concerning due to intermittent late decelerations. Amniotic fluid was clear. The infant required forceps assist at delivery. The baby is born with no tick meconium and is placed on the warmer limp, cyanotic, and apneic.

2.1. What is the first step you take after the baby is born? *Please select only **one** answer*

a. Suction the baby's mouth and nose
b. Call for help
c. Assess the newborn's color, tone and check if he is crying and breathing well
d. Start inflation breaths with a ventilation bag

At 1 minute and 30 seconds… you Check the heart rate and listen to breath sounds

HR = 70 bpm, newborn still limp, SpO2 = 50%

2.2. What would you do next? *Please select only **one** answer*

a. Continue with positive pressure ventilation for 30 seconds
b. Give oxygen by nasal catheter or prongs if available
c. Wrap the newborn and give him/ her to the mother

At 2 minutes and 30 seconds, you check again the heart rate and listen to breath sounds

HR = 130 bpm, the newborn is picking up gradually, muscle increasing in tone, newborn becoming more active, respirations regular in rate and rhythm, but weak, SpO2 = 85%.

2.3. What is the most appropriate plan of care? *Select **all** answers that apply.*

a. Continue with positive pressure ventilation for 30 seconds
b. Discontinue free flow oxygen when SpO2 reading remains above 85%
c. Explain to mom that newborn will go to NICU for post-resuscitation care; and for further management and care if any problems may arise later

SAFE DELIVERY APP – KNOWLEDGE AND SKILLS SURVEY

Dear Participant, thank you for agreeing to participate in this study. You are about to answer questions regarding postpartum hemorrhage management. There is a mix of single response and multiple response questions. Kindly answer all questions honestly and completely. We assure you that your identity and the information you will provide will be kept confidential.

Please answer to the best of your ability.

BACKGROUND INFORMATION

Date: _____

Age: _____

Gender: ___M ___F

Hospital Name: _____

Title: ___A0 Midwife ___ A1 Midwife ___ A0 Nurse ___A1 Nurse ___A2 Nurse

Please enter your personal ID number: _ _ _ _ _ _ _ _ _ _ _

1. How many years have you been providing obstetrical care?

___ Years ___ Months

2. How many hours per week do you spend providing obstetrical care?

___<5hrs ___5-10hrs ___10-20hrs ___>20hrs

3. On average how many deliveries do you participate in monthly?

___0-5 ___5-10 ___10-20 ___20-30 ___>30

4. Have you received any in-service training about PPH management during the last 6 months?
___Yes ___No, if yes please specify
_____

5. Have you ever used a smartphone?

___Tried using one ___Never tried using one

KNOWLEDGE QUESTIONS REGARDING POST-PARTUM HEMORRHAGE MANAGEMENT

1. What is correct regarding PPH? *Please select only **one** answer.*
   a. It rarely affects women with a normal delivery
   b. It is one of the major causes of maternal death
   c. It will appear within the first 10 minutes after delivery

2. Where does a postpartum bleeding most frequently originate from? *Please select only **one** answer.*
   a. From the placental attachment site inside the uterus due to loss of tone
   b. From retained tissue
   c. From a tear in the birth canal

3. Prioritize (Put in the correct order) the actions at strong bleeding until helpers arrive. ___; ___; ___. a. Stop the bleeding
   b. Resuscitate
   c. Call for help

4. A woman gets cold, sweaty, and feels dizzy after birth. What are the most important causes to rule out? *Select **all** answers that apply.*

   a. Exhaustion after a long delivery
   b. Maternal sepsis
   c. Low blood sugar due to stress, pain, exhaustion and lack of food
   d. Remarkable and dangerous blood loss

5. Is the amount of blood you can see the actual blood loss? *Please select only **one** answer.*

a. Yes, the uterus will always make the blood come out of the vagina. Just keep an eye on the bleeding
b. No, the uterus can have a remarkable of blood hidden. Palpate or massage the uterus to make sure it contracts.

6. What is the correct regarding moderate bleeding? *Please select only **one** answer.*
   a. It is not dangerous as long as the bleeding doesn't get excessive
   b. It will accumulate over time if it is not treated
   c. As long as vital signs are normal, wait for spontaneous recovery
   d. It is caused by a tear in the cervix

7. What would you do within 15 minutes at moderate bleeding directly after birth? *Select **all** answers that apply.* a. Empty the bladder
b. Apply uterus massage
c. Monitor vital signs and give IV fluids
d. Remove the placenta manually

8. Why is uterine massage recommended? *Please select only **one** answer.*
   a. It stimulates the brain to release oxytocin and the bleeding decreases
   b. It inhibits the blood supply to a bleeding tear and the bleeding decreases
   c. The wound where the placenta used to sit, is thereby minimized and bleeding decreases.

9. Why should the bladder be emptied at PPH? *Please select only **one** answer.*
   a. It is difficult to assess the bleeding if it is mixed with running urine
   b. A permanent urine catheter will minimize the risk of stitches in the urethra, when sewing a bleeding tear
   c. A full bladder makes it difficult for the uterus to contract properly

10. What is true regarding checking vital signs at strong bleeding? *Please select only **one** answer.*
   a. It is the first thing to do no matter what to know the starting point
   b. It is important_ because misoprostol must not be given to patients with the pulse above 100bpm
   c. It is a waste of valuable time as long as you are alone

11. At strong bleeding, why do you stop the bleeding before you resuscitate the woman? *Select **all** answers that apply.*
   a. The woman can bleed to death faster than you can resuscitate
   b. You cannot keep the pace with IV fluids if she is bleeding heavily and uncontrolled.
   c. Trick question, of course, you resuscitate immediately and manage the bleeding afterward.

12. What are the advantages of bimanual compression? *Select **all** answers that apply.*
   a. It provides pressure on the uterus so a bleeding due to lack of tone is controlled
   b. It can control the bleeding until helpers arrive

c. It can reduce the bleeding from a cervical tear while the assistant prepares for suturing
d. It cannot do any harm, but can on the other hand save lives

13. Bimanual compression: Are you allowed to enter your hand again after withdrawal? *Please select only **one** answer.*

a. Yes. You have to in order to check if the bleeding has halted – and to avoid acidification in your arms
b. No. It will add extra bacteria and increase the risk of uterine infection

14. What do you do if long sterile gloves for bimanual compression are not available? *Select **all** answers that apply.*

a. Alternatively, use whatever sort of gloves available at your facility
b. Use normal sterile gloves
c. Due to high risk of infection do not apply bimanual compression

15. How do you give tranexamic Acid at PPH? *Please select only **one** answer.*

a. 1g IV – can be repeated after half an hour
b. 0.5 g IV – can be repeated after half an hour
c. 1g IM – once
d. 0.5 g IM – once

16. How can Misoprostol be administrated? *Please select only **one** answer.*

a. Sublingually
b. Drip
c. IV
d. IM

17. What are the contraindications for Ergometrine IV? *Select **all** answers that apply.* a. Heart Diseases
b. Hypertension
c. Allergy to steroids
d. Diabetes

18. What is most effective in stopping a strong bleeding due to lack of tone? *Please select only **one** answer.* a. Manual manoeuvres
b. Uterotonics

19. It is bleeding from vaginal trauma. What will you do to be able to suture? *Please select only **one** answer.*

a. Compress with sterile gauze for 10 minutes to stop the bleeding for overview prior to suturing
b. Wait an hour patiently. Vaginal tears most likely stop bleeding spontaneously (and often do not require suturing)
c. Immediately suture the best you can despite bleeding

20. Why is a rectal exploration always indicated after birth? *Select **all** answers that apply.*

a. To assess the degree of perineal trauma
b. To identify trauma to the rectal sphincter
c. To assess the amount of bleeding from the intestine
d. To check if there are polyps or fistulas

21. What is the primary reason for checking the placenta quickly after birth? *Please select only **one** answer.* a. To check for missing tissue

b. To measure the length of the cord
c. To see if there are blood clots on the surface
d. To weigh the placenta

22. What is the treatment of retained tissue after birth? *Please select only **one** answer.*

a. Surgical removal of the tissue
b. Oxcytocin drip for 24 hours
c. Manual removal of the tissue
d. No treatment_the uterus rejects the tissue itself 23. Removal of tissue: List the following actions in correct order. ___; ___; ___; ___.

a. Support the uterus on top of the fundus with the external hand
b. Insert a flat hand up into the uterus
c. Carefully move the hand from side to side with fingers tightly together
d. Withdraw fragments and palpate cavity to ensure complete removal

24. In which situation must you be careful NOT to give IV fluids fast? *Select **all** answers that apply.*

a. At suspected pulmonary oedema
b. At hypertension
c. At sepsis
d. At low blood pressure

25. If possible, when is it appropriate to measure haemoglobin? *Please select only **one** answer.*

a. After infusion of the first Ringer's lactate or normal saline
b. When the woman is bleeding actively
c. The following day

26. Can the bleeding proceed after removal of tissue? *Please select only **one** answer.*

a. Probably not. It is rarely seen
b. Yes, keep a close eye on the uterus and the bleeding
c. No, empty cavity ensures good contractility

27. What are the indications for applying a condom balloon tamponade(CTB)? *Please select only **one** answer.*

a. A bleeding that doesn't stop despite all possible non-surgical actions
b. All women bleeding more that 1L must have a CTB for a minimum of 24 hours

28. What are the 4 T's? *Please select only **one** answer.*

    a. Tone, trauma, tissue, toxins
    b. Tone, trauma, tissue, tamponade
    c. Tone, trauma, tissue, thrombin
    d. Tone, trauma, tissue, tenderness

29. How do you position a bleeding woman correctly? *Please select only **one** answer.*

    a. On the back, legs up and head flat/down
    b. On the back with straight legs
    c. Recovery position on the left side
    d. On the back with slightly bent legs and a small pillow under the head

30. Why the legs up and head down position for PPH? *Please select only **one** answer.*

    a. In this way you ensure that the blood left in the body gets to the vital organs
    b. In this way the woman cannot see how much she is bleeding and it is easy to get an overview of the extent of the bleeding

31. You are in charge of the uterus. Two helpers arrive, what does the first helper do at the head? *Select **all** answers that apply.*

    a. Notes the time of relevant events
    b. Checks airway, breathing and ventilates if necessary
    c. Positions the head flat
    d. Reassures the woman

32. You are in charge of the uterus. Two helpers arrive, the first helper is at the head. What does the second helper do at the arm? *Select **all** answers that apply.* a. Give uterotonic drugs

    b. Check pulse and blood pressure
    c. Set up IV-access, X-match blood, IV fluids
    d. IV phenobarbital

33. What is the overall rule regarding PPH and referral to a higher level facility? *Please select only **one** answer.*

    a. You must stop the bleeding where you are. Referral is very risky
    b. Refer as soon as possible after diagnosing PPH – in case it gets severe you need assistance and an operating theatre

34. After stopping the bleeding how would you administer IV fluids? *Please select only **one** answer.*

    a. Give Dextrose 5% IV 2 liters' fast

    b. Give Normal Saline IV 2-3 liters' fast
    c. Give Normal Saline IV 1 liter slowly

35. How do you perform aorta compression? *Select **all** answers that apply.*

    a. One hand as a fist compresses the aorta above the umbilicus and slightly to the left
    b. The other hand is palpating the femoral artery to make sure the pulse stops

c. One hand as a fist compresses the aorta below the umbilicus
d. The other hand is in the vagina compressing from the inside

36. What would you expect to happen with the pulse and blood pressure, if the woman is affected by the blood loss? *Please select only **one** answer.*

a. Pulse will fall and blood pressure will rise simultaneously
b. Blood pressure will fall and pulse will fall simultaneously
c. Pulse will rise, late blood pressure will fall
d. Blood pressure will rise, later pulse will rise

SKILLS QUESTIONS REGARDING POST-PARTUM HEMORRHAGE MANAGEMENT

1. In the last month, how many postpartum hemorrhages have you managed as the primary obstetric provider? ___Number of postpartum hemorrhages

2. Management of post-partum hemorrhage case scenario:

Mrs. B is a 30-year-old G4 P3. She gave birth at the district hospital to a healthy, full-term baby weighing 3.2 kg. You gave Oxcytocin 10 units IM following the birth of the baby. The placenta was delivered 5 minutes later without complications. However, 10 minutes after the normal delivery, you notice that Mrs. B suddenly starts to bleed heavily. 2.1. What is the first action you will take? *Please select only **one** answer.*

a. Check the uterus to see whether it is contracted
b. Administer more oxytocin
c. Perform bimanual compression
d. Perform manual exploration of the uterus

You have completed your assessment of Mrs. B and your main findings include the following: Pulse 88/minute, Respiration rate 18/ minute, Blood pressure 110/80, Temperature 37^0 C.
Her Uterus is firm and well contracted. The placenta is complete. She has no perineal trauma. It is difficult to examine the vagina and the cervix because she continues to have heavy vaginal bleeding.

2.2. Based on those findings, what is your next step? *Please select only **one** answer.*

a. Pack the uterus and vagina
b. Begin a blood transfusion
c. Start antibiotics
d. Perform speculum examination of the vagina and cervix to identify and repair tears

2.3. What will you tell your assistant to do while you perform the exam? *Please select only **one** answer.*

a. Monitor vital signs and begin intravenous fluids
b. Reassure Mrs. B and her family
c. Draw blood for hemoglobin
d. All of the above

Your examination reveals that the bleeding is coming from a cervical tear. One hour following childbirth you repair Mrs.B's cervical tear.

2.4. What is the most appropriate manner to repair a cervical tear? *Please select only **one** answer.*

a. Perform interrupted sutures using silk
b. Perform continuous sutures using silk
c. Perform continuous sutures using chromic catgut or polyglycolic suture
d. Perform interrupted sutures using chromic catgut or polyglycolic suture

After repair of the cervical tear, Mrs. B's hemoglobin is found to be 10g/dl, and her vital signs are stable

2.5. What is the most appropriate plan of care? *Please select only **one** answer.*

a. Begin transfusing blood
b. Send her home
c. Monitor her vital signs for 24 hours and begin ferrous sulphate and folate supplementation; encourage breastfeeding
d. Continue administration of oxytocin for 24 hours

Appendix 4. Knowledge and Skills surveys questionnaires_French version

SAFE DELIVERY APP – ENQUÊTE SUR LES CONNAISSANCES ET LES COMPÉTENCES

Cher participant, merci d'avoir accepté de participer à cette étude. Vous êtes sur le point de répondre à des questions concernant la réanimation néonatale. Il y a un mélange de questions à réponse unique et à réponses multiples. Veuillez répondre à toutes les questions honnêtement et complètement. Nous vous assurons que votre identité et les informations que vous fournirez resteront confidentielles. S'il vous plaît répondez au mieux de votre capacité.

INFORMATIONS DEMOGRAPHIQUES

Date: _____

Age: _____

Sexe: ___M ___F

Nom de l'hôpital : _____

Title: ___Sage-femme A0 ___Sage-femme A1 ___Infirmier(e) A0___Infirmier(e) A1___Infirmier(e) A2

Veuillez entrer votre numéro d'identification personnel : _ _ _ _ _ _ _ _ _ _ _

1. Depuis combien de temps prodiguez-vous des soins obstétricaux? ___ Années ___ Mois

2. Combien d'heures par semaine consacrez-vous aux soins obstétricaux? ___<5hrs ___5-10hrs ___10-20hrs ___>20hrs

3. En moyenne, dans combien d'accouchements participez-vous mensuellement? ___0-5 ___5-10 ___10-20 ___20-30 ___>30

4. Avez-vous reçu une formation au travail sur la réanimation néonatale au cours des 6 derniers mois ? ___Oui ___Non Si oui, précisez _____

5. Avez-vous déjà utilisé un smartphone?

___J'ai utilisé un smartphone ___ Je n'ai jamais utilisé de smartphone

QUESTIONS DE CONNAISSIANCE CONCERNANT LA RÉANIMATION NÉONATALE

1. L'incapacité à pouvoir initier une respiration adéquate à la naissance est la cause commune de : *Veuillez sélectionner **une seule** réponse.*
    a. Jaunisse
    b. Malformation génitale
    c. L'hémorragie post-partum
    d. Mort néonatale
2. La « minutes d'or » implique que tous les nouveaux- nés doivent à leur première minutes d'âge : *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Respire d'eux-mêmes
b. Bouger les bras et les jambes avec un bon tonus
c. S'ils ne respirent pas, ils devraient être ventilés avec un ballon d'ambu et masque
d. Dormir peau contre peau avec la maman 3. Quand faut- il examiner un nouveau-né après accouchement ? *Veuillez sélectionner **une seule** réponse.* a. Après avoir coupé le cordon ombilical

b. S'il ne crie pas
c. Immédiatement après l'accouchement
d. Après une minute

4. Où placez-vous le nouveau-né immédiatement après l'accouchement ? *Veuillez sélectionner **une seule** réponse.*

a. Le placer entre les jambes de sa mère pendant qu'on prend soin de la mère b. Sur la balance
c. Dans un tissu chaud loin de sa mère
d. Sur la mère peau contre peau

5. Quels sont les premières étapes à poser quand le bébé est né ? *Veuillez sélectionner **une seule** réponse.*

a. Évaluer l'aspect du nouveau-né, le tonus, vérifier s'il crie et respire bien
b. Aspire le nez et la bouche du nouveau – né
c. Commencer la ventilation au ballon d'ambu
d. Appeler de l'aide

6. Quelle assertion est correcte ? *Veuillez sélectionner **une seule** réponse.*

a. Seuls les nouveau-nés, nés avec un liquide méconial ont besoin d'une aspiration à la naissance
b. Il faut aspirer tous les nouveau-nés à la naissance

7. Si un nouveau-né est né d'un liquide méconial épais et a besoin d'une aspiration, dans quel ordre le faisiez-vous ?

___; ___; ___.

a. Aspirer
b. Le sécher complètement
c. Ventiler

8. Que faites-vous dans les 5 secondes qui suivent la naissance d'un nouveau-né qui crie vigoureusement ? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Sécher le nouveau-né avec un tissu
b. Stimuler le bébé en frictionnant le dos
c. Couper le cordon ombilical
d. Enlever les tissus humides, couvrir le bébé et le garder au chaud

9. Immédiatement après la naissance, tu découvres que le nouveau-né ne respire pas bien, que faire à l'étape suivante? *Veuillez sélectionner **une seule** réponse.*

a. Aspirer le bébé par la bouche et le nez
b. Stimuler le bébé en le séchant et le frictionnant la peau avec un tissue sec
c. Evaluer la fréquence cardiaque du nouveau-né

10. Quelle est l'assertion correcte parmi les suivantes ? Le nouveau-né a besoin d'une réanimation si : *Veuillez sélectionner **une seule** réponse.*

a. Dans le 30 secondes après accouchement et après une stimulation complète, le bébé ne crie pas ou ne respire pas, ou continue à gasper
b. Dans le 2 minutes après accouchement, le bebe ne crie pas ou ne respire pas ou continue à gasper

11. Le nouveau-né ne répond pas à la stimulation en le séchant et en le frictionnant le dos. Placer les 4 gestes suivants en ordre : ___ ; ___ ; ___ ; ___.

a. Clamper et couper le cordon ombilical
b. Libérer les voies aériennes et placer la tète dans une position neutre
c. Appeler de l'aide
d. Donner 5 ventilations

12. Quand on fait la réanimation, on place la tête dans une position neutre. C'est quoi une position neutre ? *Veuillez sélectionner **une seule** réponse.*

a. La tête est en extension tournée en arrière pour libérer les voies aériennes
b. La tête est en latéral pour faciliter l'écoulement des liquides
c. La tête est parallèle à la surface

13. Où placez-vous le masque sur le nouveau-né ? *Veuillez sélectionner **une seule** réponse.*

a. Sur la bouche
b. Sur la bouche et le nez
c. Au nez
d. Sur les yeux, la bouche et le nez

14. Comment se rassurer que la ventilation est effective ? *Veuillez sélectionner **une seule** réponse*

a. S'assurer qu'on presse fort sur le ballon
b. Se rassurer que le ballon soit vidé pour chaque insufflation
c. Se rassurer qu'on ventile très rapidement
d. Se rassurer qu'à chaque ventilation il y a élévation de la poitrine

15. Vous commencez la réanimation en donnant combien de bouffée ? *Veuillez sélectionner **une seule** réponse* a. 7

b. 10
c. 5
d. 15

16. Comment relevez-vous la mâchoire? *Veuillez sélectionner **une seule** réponse*

a. Appliquer la force sur le masque placé sur la mâchoire du nouveau-né
b. Soulever la mâchoire du bébé tout en la propulsant en avant avec une main
c. Aspirer la bouche et le nez du nouveau-né

17. Quels sont les gestes à poser pour donner des inflations efficaces ? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Placer la tête dans une position neutre
b. Maintenir les insufflations pendant 2-3 secondes
c. Se rassurer qu'il y a un mouvement du thorax pour chaque insufflation

d. Evaluer la fréquence cardiaque

18. Il n'y a pas mouvement du poitrine quand vous essayez de donner des inflations respiratoires. Que faire ? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Arrêter la réanimation

b. Attendre et voir si la respiration se restore spontanément

c. Repositionner la tête et soulever la mâchoire du nouveau-né tout en la propulsant en avant d. Donner 5 insufflations encore

19. Quel sont les insufflations d'inflations ? *Veuillez sélectionner **une seule** réponse.*

a. Les 5 premières ventilations lentes en réanimation néonatale - chacune maintenue pendant 2-3 seconde pendant que la poitrine bouge

b. Ventiler le nouveau-né à une fréquence de 40 insufflations par minute et chaque insufflation dure 2-3

secondes

c. Les premières insufflations respiratoire spontanées par le nouveau –né sans assistance.

20. Quel sont les insufflations de ventilation ? *Veuillez sélectionner **une seule** réponse.*

a. Ventiler le nouveau-né à une fréquence de 40 insufflations par minute et chaque insufflation dure 2-3

secondes

b. Les 5 premières ventilations lentes en réanimation néonatale - chacune maintenue pendant 2-3 seconde pendant que la poitrine bouge

c. Les premières insufflations respiratoire spontanées par le nouveau –né sans assistance.

21. A quelle fréquence donnez-vous les insufflations de ventilation ? *Veuillez sélectionner **une seule** réponse.*

a. Approximativement 100 insufflations par minutes

b. Approximativement 40 insufflations par minutes

22. Après insufflations d'inflation, le nouveau-né respire à moins de 30 respirations par minutes ou la fréquence cardiaque <100 par minutes. Quelle est votre prochaine action ? *Veuillez sélectionner **une seule** réponse.*

a. Attendre pour voir si la respiration se restore spontanément

b. Tu commences la ventilation

c. Stimulation en séchant et en frictionnant le dos

d. Arrêter la réanimation et conseiller la mère sur la mort de son bébé

23. Quand faut-il continuer avec la ventilation assistée ? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. En cas de fréquence respiratoire moins que 30 respirations par minutes

b. En cas de tonus faible

c. En cas de fréquence respiratoire plus que 40 fois par minute

d. Si la fréquence cardiaque moins que 100 bpm

24. Quelle est la chose la plus importante à garder en esprit au cours d'une ventilation assistée ? *Veuillez sélectionner **une seule** réponse.*

a. Que le rythme est de 40 bouffées /minutes
b. Que tu dois appliquer de la force au masque pour assurer un bon contact
c. Que vous sachiez que la ventilation technique est efficace quand vous pouvez voir le mouvement de la poitrine.
d. Que tu couvres le nouveau-né d'un tissu chaud

25. Comment se rassurer qu'on anime un bon rythme ventilatoire ? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Presser le ballon d'ambu chaque fois en disant « respire- 2- 3 ».
b. Compter à haute voix « respire- 2 – 3 » en ventilant le nouveau-né en même temps
c. Presser le ballon d'ambu en disant « respire » et libérer la pression pendant que tu dis « 2-3 ».

26. Comment ventilez-vous un nouveau-né correctement ? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Assurez-vous que le masque est bien scellé au nouveau-né
b. Obtenir un mouvement adéquat de la poitrine
c. Permettre aux poumons de se relaxer entre deux inflations
d. Assurez-vous que le nouveau-né a une sonde nasogastrique

27. Quand faut-il réévaluer le nouveau-né au cours de la réanimation ? *Veuillez sélectionner **une seule** réponse* a. Toutes les 30 secondes

b. Après 20 minutes
c. Toutes les 5 minutes
d. Chaque minute

28. Qu'évaluez-vous au cours d'une réanimation néonatale ? *Sélectionnez **toutes** les réponses qui s'appliquent.* a. La respiration

b. L'aspect et le tonus
c. Si le nouveau-né urine
d. La fréquence cardiaque

29. Si le nouveau-né n'initie pas un mouvement respiratoire régulier ou la pulsation est moins que 100 bpm, que faire ? *Veuillez sélectionner **une seule** réponse.*

a. Continuer la ventilation assistée
b. Faire le massage cardiaque
c. Arrêter la réanimation
d. Attendre et voir si la respiration s'améliore spontanément.

30. Lorsque le nouveau-né respire normalement, a un aspect normal, et une fréquence cardiaque au-dessus de 100 bpm, dans quel ordre allez- vous exécuter les étapes suivantes ?___; ___; ___; ___.

a. Placer le nouveau-né peau contre peau de sa mère
b. Arrêter la ventilation et continuer l'observation pendant 5 minutes

c. Initier l'allaitement précoce

d. Toutes les 15 minutes et pendant 2hrs, vérifier l'aspect, le tonus, la respiration , la fréquence cardiaque, et que le nouveau-né est au chaud.

31. La fréquence respiratoire est normale, mais l'aspect du nouveau-né est bleuâtre et présente de difficultés respiratoires avec de tirage intercostal et grognement. Que faire ? *Veuillez sélectionner **une seule** réponse.*

a. Give oxygen by nasal catheter or prongs if available.

b. Give Phenobarbital IV/IM

c. Wrap the newborn and give it to the mother

32. Quand arrêtez-vous la réanimation ? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Quand le nouveau-né respire bien et qu'il a un bon aspect, un tonus normal, et une fréquence cardiaque au-dessus de 100 bpm.

b. Si le nouveau-né ne respire pas et la fréquence cardiaque est nulle après 10 minutes de ventilation efficace.

c. Si le nouveau-né a une fréquence cardiaque au-dessous de 60 bpm pendant plus de 20min, tu peux prendre une décision difficile d'arrêter la réanimation.

d. Si le nouveau-né ne respire pas et n'a pas de pulsation après 2 minutes de ventilation efficace

33. Que faire lorsque vous décidez d'arrêter la réanimation inefficace d'un nouveau-né ? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Expliquer doucement à la mère que le nouveau-né n'a pas malheureusement survécu.

b. Offrir un soutien émotionnel à la famille.

c. Il faut laisser la femme pleurer seule.

d. Il faut continuer avec le reste de vos taches.

34. Le nouveau-né crie bien avec un bon aspect et un bon tonus. *Sélectionner les 2 gestes à poser immédiatement :*

a. Placer le nouveau-né peau contre peau de sa mère

b. Envelopper le nouveau-né avec tissu et le remettre à un familier

c. Donner des antibiotiques IV ou IM

d. Initier l'allaitement précoce (dans la première heure qui suit l'accouchement)

35. Comment prévenir l'hypoglycémie chez un nouveau-né réanimé pendant plus d'une minute ? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Initier l'allaitement dans les 30 premières minutes.

b. Après avoir allaité, donner un supplément dans un tasse.

c. Donner du lait de vache au nouveau-né.

d. Donner exclusivement du lait artificiel au nouveau-né.

36. Comment réanimez-vous un nouveau –né prématuré ? *Veuillez sélectionner **une seule** réponse.*

a. Avec les même manœuvre que chez un nouveau-né à terme, mais avec un petit masque pour la ventilation.

b. Eviter l'insufflation d'inflation chez un prématuré, sinon la réanimation se fait de la même manière que chez un nouveau-né à terme

37. Quels sont les plus grands défis associés à la réanimation d'un petit ou nouveau-né prématuré ? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Voies aeriennes et respiration
b. Un mouvement adéquat de la poitrine
c. L'handicap
d. Le sepsis/ infections
e. Fixer correctement le masque et le ballon

QUESTIONS DE COMPÉTENCE CONCERNANT LA RÉANIMATION NÉONATALE

1. Au cours du dernier mois, combien de nouveau-nés avez-vous ressuscité en tant que prestataire obstétrique principal ?

___Nombre de réanimations néonatales

2. Scénario de réanimation néonatale :

Vous aidez dans l'accouchement d'un bébé de 39 semaines avec un poids estimé à 4 500 grammes (4,5 kg). La mère est une G2 P1 âgée de 40 ans et son dernier accouchement a eu lieu par voie vaginale. La mère est en travail depuis 18 heures et, au cours des 20 dernières minutes, le tracé de la fréquence cardiaque fœtale est devenu préoccupant en raison de décélérations tardives intermittentes. Le liquide amniotique était clair. Le forceps a été utilisé pour aider à l'accouchement du bébé. Le bébé est né sans méconium dans la bouche et est placé sous une lampe pédiatrique, le bébé est cyanosé et apnéique.

2.1. Quelle est la première étape que vous faites après la naissance du bébé ? *Veuillez sélectionner **une seule** réponse*

a. Aspirer la bouche et le nez du bébé
b. Appeler à l'aide
c. Évaluez la couleur et le ton du nouveau-né et vérifiez s'il pleure et respire bien
d. Commencez la ventilation avec un sac de ventilation

À 1 minute et 30 secondes… vous vérifiez la fréquence cardiaque et écoutez les bruits de

respiration HR = 70 bpm, le nouveau-né est toujours fragile, SpO2 = 50%

2.2. Que ferais-tu ensuite ? *Veuillez sélectionner **une seule** réponse*

a. Continuer avec ventilation à pression positive pendant 30 secondes
b. Donner de l'oxygène à l'aide d'une sonde nasale ou d'un cathéter nasal
c. Enveloppez le nouveau-né et donnez-le à la mère

À 2 minutes et 30 secondes, vous vérifiez à nouveau la fréquence cardiaque et écoutez les bruits de respiration

HR = 130 bpm, le nouveau-né se redresse progressivement, le tonus musculaire augmente, le nouveau-né devient plus actif, les respirations ont un rythme régulier, mais faible, SpO2 = 85%.

2.3. Quel est le plan de soins le plus approprié ? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Continuer avec ventilation à pression positive pendant 30 secondes
b. Cesser l'oxygène en écoulement libre lorsque la lecture de SpO2 reste supérieure à 85%

c. Expliquez à maman que le nouveau-né ira à NICU pour des soins post-réanimation ; et pour plus de gestion et de soins si des problèmes peuvent survenir plus tard

SAFE DELIVERY APP – ENQUÊTE SUR LES CONNAISSANCES ET LES COMPÉTENCES

Cher participant, merci d'avoir accepté de participer à cette étude. Vous êtes sur le point de répondre à des questions concernant la gestion des hémorragies post-partum. Il y a un mélange de questions à réponse unique et à réponses multiples. Veuillez répondre à toutes les questions honnêtement et complètement. Nous vous assurons que votre identité et les informations que vous fournirez resteront confidentielles. S'il vous plaît répondez au mieux de votre capacité.

INFORMATIONS DEMOGRAPHIQUES

Date: _____

Age: _____

Sexe: ___M ___F

Nom de l'hôpital : _____

Title: ___Sage-femme A0 ___Sage-femme A1 ___Infirmier(e) A0___Infirmier(e) A1___Infirmier(e) A2

Veuillez entrer votre numéro d'identification personnel : _ _ _ _ _ _ _ _ _ _ _

1. Depuis combien de temps prodiguez-vous des soins obstétricaux? ___ Années ___ Mois

2. Combien d'heures par semaine consacrez-vous aux soins obstétricaux? ___<5hrs ___5-10hrs ___10-20hrs ___>20hrs

3. En moyenne, dans combien d'accouchements participez-vous mensuellement? ___0-5 ___5-10 ___10-20 ___20-30 ___>30

4. Avez-vous reçu une formation au travail sur la gestion des hémorragies post-partum au cours des 6 derniers mois ? ___Oui ___Non , Si oui, précisez _____

5. Avez-vous déjà utilisé un smartphone?

___J'ai utilisé un smartphone ___ Je n'ai jamais utilisé de smartphone

QUESTIONS DE CONNAISSANCE CONCERNANT LA GESTION DE L'HÉMORRAGIE POST-PARTUM

1. Qu'est ce qui est correct en rapport avec l'hémorragie post-partum? *Veuillez sélectionner **une seule** réponse.*
   a. Ça affecte rarement les femmes qui ont un accouchement normal
   b. C'est l'une de causes majeures de décès maternel
   c. Ça se manifeste dans les 10 premières minutes suivant l'accouchement.

2. Quelle est le plus souvent l'origine de l'hémorragie ? *Veuillez sélectionner **une seule** réponse.*

a. Ça provient du site de détachement du placenta à l'intérieur de l'utérus à cause de l'atonie utérine b. D'une déchirure au niveau de la filière génitale

c. De rétention des tissus

3. Prioriser (mettez dans le bon ordre) les gestes à faire en cas de saignement forte, avant d'obtenir de l'aide:___; ___; ___.

a. Arrêter le saignement
b. Réanimer
c. Appeler de l'aide

4. Une femme devient froide avec de sueurs profuses et de vertiges après l'accouchement, quelles sont les causes importantes à exclure ? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. La fatigue après accouchement
b. Le sepsis maternel
c. L'hypoglycémie liée: au stress, à la douleur, à la fatigue et au manque de nourriture
d. Perte de sang dangereuse

5. Est -ce que la quantité de sang que vous voyez reflète les vraies pertes ? *Veuillez sélectionner **une seule** réponse.*

a. Oui, l'utérus expulse toujours le sang à travers le vagin, on doit toujours tenir à l'œil le saignement.
b. Non, l'utérus peut cacher une quantité importante du sang caché. Il faut procéder à la palpation ou au massage de l'utérus pour se rassurer qu'il se contracte.

6. Qu'est ce qui est correct en ce qui concerne un saignement modéré? *Veuillez sélectionner **une seule** réponse.*

a. Ce n'est pas dangereux aussi longtemps que le saignement n'est pas excessif.
b. Il peut s'accumuler au fil du temps aussi longtemps que rien n'est fait.
c. C'est dû à une déchirure au niveau cervical.
d. Aussi longtemps que les signes vitaux sont normaux, on peut attendre un rétablissement spontané

7. Que ferais-tu dans 15 minutes en cas de saignement modéré directement après la naissance? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Vider la vessie
b. Faire un massage de l'utérus
c. Prendre les signes vitaux et donner de liquides
d. Faire une délivrance manuelle du placenta

8. Pourquoi le massage de l'utérus est recommandé ? *Veuillez sélectionner **une seule** réponse.*

a. Ça permet de minimiser la plaie placentaire et réduire ainsi l'hémorragie
b. Ça inhibe l'irrigation de la déchirure qui saigne et diminue le saignement
c. Ça stimule le cerveau pour libérer l'ocytocine et diminuer le saignement

9. Pourquoi doit-on vider la vessie en cas d'hémorragie post partum ? *Veuillez sélectionner **une seule** réponse.*

a. Une vessie pleine empêche l'utérus de bien contracter

b. Il est difficile d'évaluer le saignement lorsqu'il est mélangé aux urines courantes

c. Une sonde urinaire permanent diminue le risque de suturer l'urètre lorsqu'il faut réparer un point qui saigne

10. Qu'est ce qui est correct en ce qui concerne la prise de signes vitaux au cours de saignement abondant? *Veuillez sélectionner **une seule** réponse.*

a. C'est la première chose à faire pour savoir l'état de départ

b. C'est important parce qu'on ne peut pas donner du misoprostol lorsque la pulsation est >100 bpm

c. C'est une perte du temps précieux si tu es seule

11. En cas de saignement abondante, pourquoi arrêter d'abord le saignement avant de passer à la réanimation ?

*Sélectionnez **toutes** les réponses qui s'appliquent.*

a. La femme peut saigner à mort plus vite que tu ne peux réanimer

b. Vous ne pouvez pas suivre les perfusions IV si la femme saigne beaucoup et de façon incontrôlable

c. Question de piège ! Bien sûr il faut d'abord réanimer et contrôler le saignement après.

12. Quels sont les avantages d'une compression bimanuelle ? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Ça procure une pression sur l'utérus de sorte que le saignement lié à une atonie est contrôlé

b. Ça peut contrôler le saignement en attendant que les aides arrivent

c. Ça peut réduire le saignent dû à une déchirure du col en même temps que l'assistant suture

d. Ça ne cause aucun problème, mais peut sauver des vies

13. Compression bimanuelle : Etes -vous permis de réintroduire votre main quand vous l'avez sortie ? *Veuillez sélectionner **une seule** réponse.*

a. Non, cela peut introduire des bactéries et accroitre le risque d'infections utérines.

b. Oui, tu dois le faire pour vérifier si le saignement s'est arrêté et pour éviter l'acidification de vos main.

14. Que faites-vous lorsque vous n'avez pas des gants gynécologiques pour faire la compression bimanuelle ? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Utiliser les gants stériles ordinaire

b. Utilise n'importe quels gants qui sont disponibles dans votre hôpital

c. A cause du risque élevé d'infection, ne fais jamais la compression bimanuelle

15. Comment donnez-vous de l'acide tranexamique en cas d'hémorragie post-partum? *Veuillez sélectionner **une seule** réponse.*

a. 0.5g IV – il peut être répéter après 30min
b. 0.5g IM dose unique
c. 1g IV – il peut être répéter après 30min
d. 1g IM dose unique

16. Comment peut-on donner du misoprostol ? *Veuillez sélectionner **une seule** réponse.* a. En sous-linguale
b. IV
c. IM
d. En infusion 17. Quelles sont les contre-indications de l'ergometrine en IV? *Sélectionnez **toutes** les réponses qui s'appliquent.* a. L'hypertension
b. Les maladies cardiaques
c. Allergie aux corticoïdes
d. Le diabète

18. Qu'est qui est plus efficace pour arrêter un saignement causé par l'atonie utérine? *Veuillez sélectionner **une seule** réponse.*

a. Les utérotoniques
b. Les manœuvres manuelles

19. Quand le saignement provient du vagin, que feras tu pour être en mesure de suturer ? *Veuillez sélectionner **une seule** réponse.*

a. Comprimer pendant 10 min avec des compresses pour arrêter le saignement pour bien visualiser avant de suture
b. Suturer immédiatement le mieux que tu peux quel que soit le saignement
c. Attendre au moins une heure. Les déchirures vaginales presque souvent s'arrêtent spontanément sans nécessiter de suture.

20. Pourquoi une exploration du rectum est toujours indiquée ? *Sélectionnez **toutes** les réponses qui s'appliquent.* a. Pour évaluer le degré de déchirure périnéale
b. Pour vérifier s'il y a des polypes ou une fistule
c. Pour évaluer la quantité de sang perdu à partir des intestins
d. Pour identifier le traumatisme sur le sphincter anal

21. Quelle est la raison primaire qui pousse à l'examen du placenta immédiatement après accouchement? *Veuillez sélectionner **une seule** réponse.*
a. Pour vérifier les tissus manquants
b. Pour peser le placenta
c. Pour mesurer la longueur du cordon
d. Pour voir s'il s'y trouve de caillots sanguins

22. Quel est le traitement de rétention de tissus après accouchement ? *Veuillez sélectionner*

***une seule** réponse.* a. Evacuation chirurgicale

b. Il ya pas de traitement, l'utérus expulse ces tissus soi-même
c. Donner de l'oxytocine en perfusion pendant 24h
d. Evacuation manuelle

23. Evacuation des tissus : Enumérer de manière correcte l'ordre de gestes à poser. ___; ___; ___; ___.

a. Enlever les fragments et palper la cavité pour se rassurer de l'évacuation complète
b. Appuyer le fond de l'utérus avec la main externe
c. Insérer une main plate dans l'utérus
d. Déplacez délicatement la main d'un côté à l'autre avec les doigts serrés

24. Dans quelle situation faut- il être prudent de ne pas donner des liquides IV? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. En cas de l'hypertension
b. En cas d'œdème pulmonaire suspecté
c. En cas de sepsis
d. En cas d'hypotension

25. Si possible, quand faut- il doser l'hémoglobine ? *Veuillez sélectionner **une seule** réponse.*

a. Quand la femme saigne activement
b. Le jour suivant
c. Après administration du premier Ringer lactate ou normale saline

26. Le saignement peut-il continuer après évacuation de tissus? *Veuillez sélectionner **une seule** réponse.*

a. Non, une cavité vide assure une bonne contractilité
b. Oui, il faut continuer à surveiller l'utérus et le saignement
c. Probablement non, ce cas apparait rarement

27. Quelles sont les indications de la tamponnade avec ballon de condom « condom balloon tamponade »? *Veuillez sélectionner **une seule** réponse.*

a. Un saignement qui ne s'arrête pas malgré tous les gestes non chirurgicaux.
b. Toutes les femmes qui saignent au-delà d'un litre doivent bénéficier du ballon tamponnade au condom pour un minimum de 24h.

28. Quels sont les 4 T ? *Veuillez sélectionner **une seule** réponse.*

a. Tonus, traumatisme, tissu, thrombine (trouble de coagulation)
b. Tonus, traumatisme, tissu, tamponnade
c. Tonus, traumatisme, tissu, toxins

29. Comment positionnez-vous correctement une femme qui saigne? *Veuillez sélectionner*

***une seule** réponse.* a. Une position latérale gauche de sécurité

b. En décubitus dorsal les jambes allongées
c. En décubitus dorsal avec les jambes légèrement fléchies et un petit oreiller en-dessous de la tète

d. En décubitus dorsal, les jambes surélevées et tète basse

30. Pourquoi les jambes surélevées et la tête basse en cas d'hémorragie post-partum? *Veuillez sélectionner **une seule** réponse.*

a. Dans cette position, la femme ne verra pas comment elle saigne et ça devient facile d'évaluer la gravité du saignement

b. Dans cette position, on a la chance que le peu de sang qui reste dans le corps profite aux organes nobles

31. Vous êtes responsable de l'utérus. Deux aides arrivent, que fait le premier aide au niveau de la tête ?

*Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Vérifie les voies aériennes, la respiration et ventile si nécessaire
b. Place la tête bas bien à plat
c. Rassure la femme
d. Note le temps des évènement importants

32. Pendant que tu t'occupes de l'utérus, un second aide arrive. Que fait-il au niveau du bras? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. Vérifie la pulsation et la tension arterielle
b. Place les abords veineux, fait la compatibilité sanguine, place les perfusions
c. Donne du phénobarbital en IV
d. Donne des uterotoniques

33. Quelle est la régle générale en ce qui concerne l'hémorragie post-partum et le transfert à un niveau supérieur ? *Veuillez sélectionner **une seule** réponse.*

a. Transférer aussi vite que possible après le diagnostic de l'hémorragie postpartum, parce que si ça s'aggrave on aura besoin d'un assistant et de la salle d'op

b. Tu dois arrêter le saignement à ton niveau. C'est très risquant de transférer.

34. Après avoir arrêté le saignement, comment faut-il administrer les liquides? *Veuillez sélectionner **une seule** réponse.*

a. Donner du normale saline 1L IV lentement
b. Donner du dextrose 5% IV 2L à couler rapidement
c. Donner du normale saline IV 2-3 L rapidement

35. Comment fait-on la compression de l'aorte? *Sélectionnez **toutes** les réponses qui s'appliquent.*

a. A l'aide d'un poing de main placé au-dessus de l'ombilic légèrement à gauche, comprimer l'aorte

b. En même temps l'autre main palpe l'artère fémorale pour se rassurer que la pulsation se soit arrêtée

c. Un poing de main en-dessous de l'ombilic comprime l'aorte
d. L'autre main est dans le vagin et se compresse de l'intérieur

36. Qu'attendriez-vous avec le pouls et la tension artérielle(TA) au cas où la femme saigne? *Veuillez sélectionner **une seule** réponse.*

a. Le pouls baisse et la TA est élevée simultanément
b. La TA chute ainsi que le pouls
c. Le pouls est élevé d'abord suivie d'une chute de la TA

QUESTIONS DE COMPÉTENCE CONCERNANT LA GESTION DE L'HÉMORRAGIE POST-PARTUM

1. Au cours du dernier mois, combien d'hémorragies post-partum avez-vous prises en charge en tant que prestataire obstétrique principal ?

___Nombre d'hémorragies postnatales

2. Scénario de gestion d'hémorragie post-partum :

Madame B. est une femme de 30 ans G4 P3. Elle a accouché à l'hôpital de district d'un bébé en bonne santé, né à terme et pesant 3,2 kg. Vous avez administré 10 unités d'ocytocine par voie IM après la naissance du bébé. Le placenta a été délivré 5 minutes plus tard sans complications. Cependant, 10 minutes après l'accouchement normal, vous remarquez que Mme B commence soudainement à saigner abondamment.

2.1. Quelle est la première action que vous allez entreprendre ? *Veuillez sélectionner **une seule** réponse.*

a. Vérifiez l'utérus pour voir s'il est contracté
b. Administrer plus d'ocytocine
c. Effectuer une compression bimanuelle
d. Effectuer une exploration manuelle de l'utérus

Vous avez terminé votre évaluation de Mme B et vos principales conclusions sont les suivantes : Pouls 88 battements / minute, respiration rate 18 / minute, Tension artérielle 110/80, Température 37^0 C.
Son utérus est ferme et bien contracté. Le placenta est complet. Elle n'a pas de traumatisme périnéal. Il est difficile d'examiner le vagin et le col de l'utérus car elle continue d'avoir des saignements vaginaux abondants.

2.2. Sur la base de ces résultats, quelle est votre prochaine étape ? *Veuillez sélectionner **une seule** réponse.*

a. Compresser l'utérus et le vagin en utilisant les compresses
b. Commencer une transfusion sanguine
c. Donner des antibiotiques
d. Effectuer un examen au spéculum du vagin et du col pour identifier et réparer les déchirures.

2.3. Qu'allez-vous dire à votre assistant pendant que vous effectuez l'examen? *Veuillez sélectionner **une seule** réponse.*

a. Surveiller les signes vitaux et commencer les fluides intraveineux
b. Rassurez Mme B et sa famille
c. Tirer du sang pour l'hémoglobine
d. Toutes les assertions precedentes sont vraies

Votre examen révèle que le saignement provient d'une déchirure cervicale. Une heure après l'accouchement, vous réparez la déchirure cervicale de Mme B.

2.4. Quelle est la manière la plus appropriée de réparer une déchirure cervicale ? *Veuillez sélectionner **<u>une seule</u>** réponse.*

a. Effectuer des sutures interrompues à l'aide de soie
b. Effectuer des sutures continues en soie
c. Effectuer des sutures continues en utilisant un catgut chromique ou une suture polyglycolique
d. Effectuer des sutures interrompues en utilisant un catgut chromique ou une suture polyglycolique

Après réparation de la déchirure cervicale, le taux d'hémoglobine de Mme B est de 10 g / dl et ses signes vitaux sont stables.

2.5. Quel est le plan de soins le plus approprié? *Veuillez sélectionner **<u>une seule</u>** réponse.*

a. Commencer à transfuser du sang
b. Envoyer Mme B a la maison
c. Surveillez ses signes vitaux pendant 24 heures et commencez la supplémentation en sulfate ferreux et en folate; encourager l'allaitement
d. Continuer l'administration d'oxytocine pendant 24 heures

Appendix 5. Acceptability survey_English version

SAFE DELIVERY APP - ACCEPTABILITY SURVEY

You are about to answer questions regarding your experience of the Safe Delivery App. Please be as honest as possible.

Background variables

1. **At which Hospital do you work?**
   a. Nyamata District Hospital
   b. Masaka District Hospital

2. **What is the highest level of education you have attained?**
   a. A0 Midwife b. A1 Midwife c. A0 Nurse
   d. A1 Nurse e. A2 Nurse f. Other _____

Questions regarding use of the Safe Delivery App

3. **If you think about the last week, how many times did you use the Safe Delivery App?**
   a. I didn't use it at all b. I used it 1-3 times
   c. I used it 4-6 times d. I used it almost every day

4. **Which of the following Safe Delivery App features have you looked at?**
   a. Videos b. Action cards c. Drug list d. Procedures

5. **In which of the following situations do you <u>most often</u> use the Safe Delivery App? Please select only one.**
   a. To revise my knowledge
   b. During an emergency
   c. In a normal work situation
   d. To discuss with co-workers
   e. To train clinical staff or assistants
   f. To inform and guide women
   g. Other

6. How do you most often access the Safe Delivery App? Please select only one option.

a. On my own phone b. The phone provided by the researcher c. Both

7. With who do you most often use the Safe Delivery App? Please select only one option.

a. By myself b. With a co-worker

8. Where have you used the Safe Delivery App? Select all the locations that apply.

a. At work b. At home c. Other: _____

9. How much of the equipment and/or drugs seen in the Safe Delivery App do you have access to?

a. All b. Most c. Little d. None

10. How was your experience using the smartphone?

a. Very easy b. Somewhat easy c. Somewhat difficult d. Very difficult

11. The SDA is easy to use:

Strongly disagree □ Disagree □ Undecided □ Agree □ Strongly Agree □

12. Which feature do you appreciate the most? Please select only one. a. Action cards b. Videos

c. Drug list

d. Procedures

e. My Learning

13. Do you think that the Safe Delivery App will be useful for you?

Strongly disagree □ Disagree □ Undecided □ Agree □ Strongly Agree □

14. Which video is most useful for you? Select the one video that you find most useful.

a. Infection prevention

b. Post Abortion Care (PAC)

c. Active Management of Third Stage Labour (AMTSL)

d. Hypertension

e. Prolonged labour

f. Post-partum Hemorrhage (PPH)

g. Maternal Sepsis

h. Manual Removal of Placenta

i.Neonatal Resuscitation

j. Newborn Management

15. Do you use the Safe Delivery App when you see the notifications? [Notifications are short reminder messages sent weekly by the App.]

a. Yes, most times b. Yes, sometimes c. No d. I did not see notifications

16. Have you logged in to My Learning?

a. Yes b. No

17. *If you have logged onto 'My Learning'* - Do you think My Learning will be useful for you?

Strongly disagree □ Disagree □ Undecided □ Agree □ Strongly Agree □

18. What do you like <u>least</u> about the Safe Delivery App? Select the one option that fits you best. a. I do not understand the instructions.

b. I think it is difficult to navigate the smartphone.

c. The app does not function correctly (technical issues).

d. The app does not improve my practical skills.

e. The app does not add to my existing knowledge.

d. None applicable.

19. In your opinion, what is the most important quality of the app? Select the one option that fits you best.

a. I have become better at doing my job.

b. I can advise my patients better.

c. I feel more confident at work.

d. Fewer emergencies

e. Fewer mortalities/fatal cases

f. I did not notice any change.

20. Please write down one word that best describes the app.

_____

Thank you for answering this questionnaire regarding your experience of the Safe Delivery App.

Appendix 6. Acceptability Survey_French version

Safe Delivery App : Enquête d'acceptabilité

Vous allez maintenant répondre aux questions sur votre expérience de l'application Safe Delivery.

Background variables

1. Dans quel hôpital travaillez-vous?

a. Hôpital de district Nyamata
b. Hôpital de district Masaka

2. Quelle est votre formation ?

a. Sage-femme Ao b. Sage-femme A1 c. Infirmièr(e) Ao d. Infirmièr(e) A1
e. Infirmièr(e) A2 f. Autre (veuillez préciser _____)

Questions regarding use of the Safe Delivery App

3. En vous référant à la semaine dernière, combien des fois avez-vous consulté l'application ?

a. Je n'ai pas consulté l'application la semaine dernière b. Je l'ai consulté 1-3 fois
c. Je l'ai consulté 4-6 fois d. Je l'ai consulté presque tous les jours

4. Lequel des fonctionnalités de l'application Safe Delivery avez-vous regardé ?

a. Vidéos b. Cartes d'action c. Liste des médicaments d. Modalités pratiques

5. Dans laquelle des situations suivantes utilisez-vous le plus souvent l'application ? *Veuillez en sélectionner une seule option*

a. Réviser mes connaissances
b. Pour la prise en charge lors d'une urgence
c. Pour la prise en charge dans une situation « normale »
d. Pour discuter avec mes collègues
e. Pour former et mettre à niveau mes aides-soignantes
f. Pour la sensibilisation des femmes – ex. lors de CPN
g. Autre (si autre, préciser _____)

6. Comment accédez-vous le plus souvent à l'application Safe Delivery? *Veuillez sélectionner une seule option*

a. sur mon propre téléphone b. sur l'appareil fourni par le chercheur c. tous les deux

7. Avec qui utilisez-vous premièrement l'application ? *Veuillez sélectionner une seule option*
a. Moi-même b. Avec des collègues c. autre _____

8. Où utilisez-vous l'application ? *Choisissez tous les lieux où vous avez utilisé l'application*
a. Sur mon lieu de travail b. À la maison c. Ailleurs (veuillez préciser le lieu_____)

9. Vous avez l'accès à combien de matériel médical montré dans les vidéos de l'application ?
a. Tout b. La plupart c. Peu d. Rien

10. Comment s'est passée votre expérience avec le smartphone ?
a. Très facile à utiliser b. Assez facile à utiliser c. Un peu difficile à utiliser d. Très difficile à utiliser

11. Le SDA est facile à utiliser :
Fortement en désaccord □ Désaccord□ Indécis □ D'accord □ Tout à fait d'accord □

12. Quelle est la fonction que vous aimez le plus ? *S'il vous plaît mettre en ordre* a. Vidéos
b. Cartes d'action
c. Liste des médicaments
d. Modalités pratiques
e. « MyLearning »

13. Pensez-vous que l'application Safe Delivery vous sera utile ?
Fortement en désaccord □ Désaccord□ Indécis □ D'accord □ Tout à fait d'accord □

14. Quel est la vidéo la plus utile pour vous dans votre structure ? Choisissez seulement une option. a. Prévention des infections
b. Soin post-avortement
c. Gestion active de la troisième phase du travail (GATPA)
d. Hypertension
e. Travail prolongé
f. Hémorragie post-partum
g. Septicémie maternelle
h. Délivrance artificielle du placenta

i. Réanimation néonatale
j. Prise en charge du nouveau-né

15. Utilisez-vous l'application Safe Delivery lorsque vous voyez les notifications? [Les notifications sont des messages de rappel courts envoyés chaque semaine par l'application.] a. Oui, la plupart du temps b. Oui, parfois c. Non d. Je n'ai vu aucune notification

16. Avez-vous utilisé « MyLearning »?

a. Oui b. Non

17.*Si vous avez utilisé MyLearning* - Pensez-vous que « MyLearning » vous sera utile?
Fortement en désaccord □ Désaccord□ Indécis □ D'accord □ Tout à fait d'accord □

18.Que-est ce que vous aimez *moins* sur l'application ? Choisissez seulement une option. a. Je ne comprends pas les instructions

b. L'application ne fonctionne pas correctement (problème technique)
c. L'application ne renforce pas mes capacités pratiques
d. L'application n'ajoute pas à mes connaissances existantes
e. Aucun n'est applicable
f. Autre :_____

19. A votre avis, quelle est la qualité la plus importante de l'application ? Choisissez seulement une option. a. Je me suis amélioré à faire mon travail. b. Je peux mieux conseiller mes patients.

c. Je me sens plus confiant au travail.
d. Je vois maintenant moins d'urgences.
e. Je vois maintenant moins de mortalités / cas mortels
f. Je n'ai remarqué aucun changement.

20. Un mot qui caractérise l'application pour vous ? _____

Merci de partager votre expérience en utilisant l'Application Safe Delivery!

Appendix 7. Consent Form_Audio recording

WITS UNIVERSITY

PARTICIPANT CONSENT SHEET - FGD

Project Title: Safe Delivery mhealth Application and clinical decision making among nurses and midwives on Basic Emergency Obstetric and Newborn Care in district hospitals in Rwanda.

1. I have been given a Participant Information Sheet which explains the nature and processes involved in this study, which is attached hereto;
2. I was given time to read it, or had it red to me, in the language I best understand;
3. I was given time to ask any questions I wanted to and found any answers given to me to be reasonable and satisfactory;
4. I believe I fully understand why the study is being conducted and what the intended outcomes will be;
5. I understand that there will be no immediate benefit to me, should I agree to participate, nor will I receive any payment; conversely, participation will not cost me anything but my time;
6. I understand that, even if I initially consent to take part in the study, I may subsequently withdraw at any time and would not be required to give any reasons; if that happened, any data collected about me for the purposes of the study would immediately be destroyed, unless I give consent for it to be retained;
7. I am aware that the focus group discussion will be tape-recorded and transcribed for data analysis purposes. I understand that these recordings will be preserved for two years after the study results have been published or three years if there is no publication, after which they will be destroyed.
8. I give permission for my contributions to the focus group discussion to be audio-recorded.
9. I have been given a range of contact details, listed below. If I require further information or become concerned about any aspect of this study, I am free to speak to any of these contacts.

Contact details:

Aurore NISHIMWE, Principal Investigator, telephone no: +250788814121, or by e-mail at 1941393@students.wits.ac.za,
Dr. Daphney Nozizwe Conco, Supervisor, on telephone no: +270832824320, or by e-mail at Daphney.Conco@wits.ac.za
Prof. Latifat IBISOMI, Supervisor, on telephone no. +270117172607, or by e-mail at Latifat.Ibisomi@wits.ac.za
Prof Marc NYSSEN, Supervisor, on telephone no: +3224774424, or by e-mail at marc@minf.vub.ac.be

Dr CB Penny, Chairperson of the Human Research Ethics Committee (Medical) at the University of Witwatersrand, on telephone no. 011 717 2301, or by e-mail at Clement.Penny@wits.ac.za. Ms. Z Ndlovu or Mr. Rhulani Mkansi, Committee Secretariat, telephone nos.: 011 717 2700 or 1234, or by e-mail at: Zanele.Ndlovu@wits.ac.za or Rhulani.Mkansi@wits.ac.za

Name of Participant: _____
Date: _____
Place: _____
Signature or mark _____
Witnessed by:

Name of Witness: _____
Signature: _____
Date: _____

Appendix 8. FGD Guide_Baseline study_English Version

Focus Group Discussion Guide _ Baseline Study (Masaka District Hospital)

- Reflections on baseline knowledge and skills surveys results and baseline record review findings

- Exploring nurses and midwives' perceptions on PPH management and neonatal resuscitation in district hospitals in Rwanda.

A. Focus Group Discussion Preparation Checklist

The following preparations should be completed and materials obtained before each FGD:

• 12 copies of study information sheets

• 12 copies of consent forms

• 12 copies of audio-recording consent forms

• Box of pens

• Digital audio-recording equipment (tested for working condition)

• Backup batteries for audio recorder(s)

• Notebooks for facilitator

• Private room with at least 13 seats and enough space to arrange seats in a (semi)circle

• Food and drinks for participants

Name and Signature of Study Staff: _____Date: _____

B. Checklist for Facilitator and Note taker

The FGD will only progress once the following are confirmed:

• All study consent forms have been signed and copies given to participants

• All participants have signed audio-recording consent form

• At least 6 participants in the group

• No more than 12 participants in the group

Note: Participants without the appropriate consent forms or not meeting the inclusion criteria will be excluded.

Name and Signature of Study Staff: _____Date: _____

C. The questions for Focus group discussions

1. Reflect on the key findings from the knowledge and skills survey and record review results done in this hospital (Masaka district hospital) for the purpose of this research in July 2019. Below half of the respondents (43%) reported good knowledge and skills in PPH management and neonatal resuscitation, 51 % of cases of newborns with newborn asphyxia did not have a stable outcome (some transferred to NCU, others dead) despite 10 minutes' neonatal resuscitation done. While 11% of cases with post-partum hemorrhage were transferred to referral hospitals for further management. Probe for:
    a. Whether Survey results reflect their understanding
    b. Whether Record review results reflect their expectations
    c. Possible explanations of the results
2. What are the factors influencing the management of post-partum hemorrhage in your hospital? Probe for:
    a. Barriers
    b. Enablers
    c. Clinical guidelines
    d. Resources available
    e. Possible peer-support in the work environment
3. What are the factors influencing the neonatal resuscitation in your hospital? Probe for: a. Barriers
    b. Enablers
    c. Clinical guidelines
    d. Resources available
    e. Possible peer-support in the work environment

End of the discussion, thank you.

Appendix 9. FGD Guide_Baseline study_Kinyarwanda version

Ibyo kwifashisha mu biganiro bigiranwa n'itsinda rigari- Uko ababyaza n' abaforomo bumva, bakanakira Safe Delivery Application

A. Urutonde rw'ibigomba kwifashishwa mu biganiro bigiranwa n'itsinda rigari

Dore ibintu bigomba kuba byatunganijwe n'ibikoresho bigomba kuba bihari mbere ya buri kiganiro gikoranwa n'itsinda rigari:

- Kopi 12 ku makuru arebana n'ubushakashatsi
- Kopi 12 zuzuzwamo umwirondoro ku bemera gufatwa amajwi mu biganiro
- Ipaki y'ikaramu
- Ibikoresho byo gufata amajwi (byabanje gusuzumwa ko bikora neza)
- Amabuye yo gushyira mu twuma dufata amajwi mu gihe andi yaba atagikora
- Amakaye yo kwandikamo ku bayoboye ibiganiro
- Icyumba kiri ahantu heza hihereye gifite imyanya 12 abantu bagomba kwicaraho ku buryo bicara bakoze igice cy'uruziga.

Amazina n'umukono by'ukora ubushakashatsi: _____

Itariki: _____

B. Ibyo uyoboye ibiganiro n'uwandika ibivugirwamo agomba kwitwararika

Ibiganiro bigiranwa n'itsinda rigari bigomba gutangira ari uko ibi bintu bikurikira byatunganijwe:

- Abatumiwe mu biganiro bamaze kuzuza amafishi ko bemera kugira uruhare mu biganiro kandi babonye amakopi yose ku bintu bakeneye
- Abatumiwe mu biganiro bamaze kuzuza amafishi ko bemera gufatwa amajwi
- Byibura abantu batandatu mu batumiwe kwitabira ibiganiro mu itsinda rigari bahageze.
- Abemerewe kwitabira ibiganiro bari aho batarenga abantu cumi na babiri.

Icyitonderwa: abantu bemerewe kugira uruhare mu biganiro ni abujuje amafishi ko bemera kubigiramo uruhare kandi bujuje ibisabwa byose bituma bemererwa kugira uruhare muri ibyo biganiro.

Amazina n'umukono by'ukora ubushakashatsi: _____

Itariki: _____

C. Ibibazo bigenderwaho mu biganiro bigiranwa n'amatsinda magari

1. Turifuza ko mutanga ibitekerezo ku bijyanye n'ibisubizo byavuye mu bushakashatsi bw'ubumenyi bw'ababyaza n'abaforomo ku bijyanye no kwita ku bana n'ababyeyi mu gihe cyo kubyara(BEmONC). Ndetse no kw'isuzumwa ryakozwe rigendeye ku byanditse (record review) bigendanye no kwita ku mubyeyi wagize ikibazo cyo kuva nyumwa yo kubyara(PPH) no kwita ku mwana wavutse ananiwe(neonatal resuscitation). Ubushakashatsi bwakozwe muri Nyakanga 2019. Muri rusange ubushakashatsi bwagaragaje ko: munsi y'icyakabiri (43% na 38%) cy'ababyaza n'abaforomo muri masaka na Nyamata aribo basubije neza, 51% na 52% by'abana bavutse bananiwe ntibabashije kumera neza nyuma yo kwitabwaho(neonatal rescucitation); bamwe muri bo boherejwe muri NCU, abandi barapfuye. Hanyuma 11% na 21% by'ababyeyi bagize ikibazo cyo kuva nyuma yo kubyara boherejwe mu bindi bitaro (referral hospitals) kugirango bitabweho neza. Mwibande kuri ibi bikurikira mu gusubiza:
    a. Ese ibisubizo byavuye mw'isuzumabumenyi(knowledge and skills survey) mwemeranywa nabyo, mutekereza ko ari iyihe mpamvu abantu bose batasubije neza
    b. Ese ibisubizo byavuye mw'isuzuma ry'ibyanditse(record review) mwemeranywa nabyo mutekereza ko ari iyihe mpamvu ibipimo byose bitaba byiza bigasaba transfert rimwe na rimwe nyuma yo kwita ku bana n'ababyeyi(neonatal resuscitation and PPH management).
    c. Ni izihe mbogamizi muhura nazo mu kuvura no kwita ku bana bavutse bananiwe n'ababyeyi bagize ikibazo cyo kuva nyuma yo kubyara?
2. Ni ibihe bintu bigenga cg bihindura imicungire cg imitangire ya service mu gihe umubyeyi yagize ikibazo cyo kuva kwa nyuma yo kubyara(PPH) mu bitaro by'akarere ka Nyamata / Masaka? mwibande kuri ibi bikurikira:
    a. Imbogamizi
    b. Ubufasha
    c. Amabwiriza y'ubuvuzi agendanye no kuva kwa nyuma yo kubyara (PPH)

d. Ibikoresho

e. Gushyigikirwa , gufashwa no kugirwa inama n’ abandi baganga mukorana

3. Ni ibihe bintu bigenga cg bihindura imicungire cg imitangire ya service mu gihe umwana ukivuka yagize ibibazo bigendanye n’ivuka rye (neonatal complications that lead to neonatal rescucitation) mu bitaro by’akarere ka Nyamata / Masaka? mwibande kuri ibi bikurikira:
    a. Imbogamizi
    b. Ubufasha
    c. Amabwiriza y’ubuvuzi agendanye n’ibibazo bibaho mu gihe cy’ivuka (neonatal complications that lead to neonatal rescucitation)
    d. Ibikoresho
    e. Gushyigikirwa , gufashwa no kugirwa inama n’ abandi baganga mukorana

Ikiganiro kirarangiye, Murakoze!

Appendix 10. FGD Guide_Endline study_English version

Focus Group Discussion Guide – Acceptability

A. Focus Group Discussion Preparation Checklist

The following preparations should be completed and materials obtained before each FGD:

• 12 copies of study information sheets

• 12 copies of consent forms

• 12 copies of audio-recording consent forms

• Box of pens

• Digital audio-recording equipment (tested for working condition)

• Backup batteries for audio recorder(s)

• Notebooks for facilitator

• Private room with at least 12 seats and enough space to arrange seats in a (semi)circle

• Food and drinks for participants

Name and Signature of Study Staff: _____Date: _____

B. Checklist for Facilitator and Note taker

The FGD will only progress once the following are confirmed:

• All study consent forms have been signed and copies were given to participants

• All participants have signed the audio-recording consent form

• At least 6 participants in the group

• No more than 12 participants in the group

Note: Participants without the appropriate consent/assent forms or not meeting the inclusion criteria will be excluded.

Name and Signature of Study Staff: _____Date: _____

C. The questions for Focus group discussions

Exploring the acceptability (and experiences) of the safe delivery application(SDA) among nurses and midwives in district hospitals in Rwanda

1. Share with me your experience in delivering BEmONC before and after the use of the SDA? Probe for:

a. The motivation for delivering BEmONC
b. Challenges you face when delivering BEmONC
c. Added value (if any) of using the SDA

2. After using the SDA, would you accept it in your routine practices? Probe for:

a. Does the SDA meet your approval?
b. Is the SDA appealing to you?
c. Is the SDA useful?
d. Is the SDA fitting your current work environment?
e. Do you like the SDA?
f. Are you welcoming the SDA?

3. After using the SDA, what do you think about its implementation in your daily practices? Probe for:

a. Is the SDA implementable?
b. Is the SDA possible in your daily practices?
c. Is the SDA doable?
d. Is the SDA easy to use?

4. After getting aware of the SDA and its roles and functionalities, what do you think about its sustainability (once implemented in your hospital)? Probe for:

a. Do you intend to continue using the SDA in the future?
b. Is the SDA durable?
c. Can the SDA be maintained?

5. If you think that the SDA is not really fitting your current work environment, what would you need to change for it to be more acceptable?

End of Interview, Thank you.

Appendix 11. FGD Guide_Endline study_Kinyarwanda version

Ibyo kwifashisha mu biganiro bigiranwa n'itsinda rigari- Uko ababyaza n' abaforomo bumva, bakanakira Safe Delivery Application

A. Urutonde rw'ibigomba kwifashishwa mu biganiro bigiranwa n'itsinda rigari

Dore ibintu bigomba kuba byatunganijwe n'ibikoresho bigomba kuba bihari mbere ya buri kiganiro gikoranwa n'itsinda rigari:

- Kopi 12 ku makuru arebana n'ubushakashatsi
- Kopi 12 zuzuzwamo umwirondoro ku bemera gufatwa amajwi mu biganiro
- Ipaki y'ikaramu
- Ibikoresho byo gufata amajwi (byabanje gusuzumwa ko bikora neza)
- Amabuye yo gushyira mu twuma dufata amajwi mu gihe andi yaba atagikora
- Amakaye yo kwandikamo ku bayoboye ibiganiro
- Icyumba kiri ahantu heza hihereye gifite imyanya 12 abantu bagomba kwicaraho ku buryo bicara bakoze igice cy'uruziga.

Amazina n'umukono by'ukora ubushakashatsi: _____

Itariki: _____

B. Ibyo uyoboye ibiganiro n'uwandika ibivugirwamo agomba kwitwararika

Ibiganiro bigiranwa n'itsinda rigari bigomba gutangira ari uko ibi bintu bikurikira byatunganijwe:

- Abatumiwe mu biganiro bamaze kuzuza amafishi ko bemera kugira uruhare mu biganiro kandi babonye amakopi yose ku bintu bakeneye
- Abatumiwe mu biganiro bamaze kuzuza amafishi ko bemera gufatwa amajwi
- Byibura abantu batandatu mu batumiwe kwitabira ibiganiro mu itsinda rigari bahageze.
- Abemerewe kwitabira ibiganiro bari aho batarenga abantu cumi na babiri.

Icyitonderwa: abantu bemerewe kugira uruhare mu biganiro ni abujuje amafishi ko bemera kubigiramo uruhare kandi bujuje ibisabwa byose bituma bemererwa kugira uruhare muri ibyo biganiro.

Amazina n'umukono by'ukora ubushakashatsi: _____

Itariki: _____

C. Ibibazo bigenderwaho mu biganiro bigiranwa n'amatsinda magari

Kugerageza gusobanukirwa uko abaforomo n'ababyaza bakorera mu bitaro by'uturere mu Rwanda bumva (banamenyereye gukoresha) Safe Delivery Application (SDA)

1. Mumbwire uko gutanga services za BEMONC bigenda/bimeze byaba mbere na nyuma yo gukoresha SDA?

Gerageza ubafashe ku buryo bavuga ku bintu bikurikira:

a. Ikibatera imbaraga mu gutanga services za BEmONC (Motivation)
b. Imbogamizi bahura nazo mu gutanga services za BEmONC
c. Icyo bumva bungutse (kiramutse gihari) mu gukoresha SDA

2. Nyuma yo gukoresha SDA, mwumva muzajya muyikoresha mu mirimo yanyu ya buri munsi? Gerageza kubafasha ku buryo bavuga ku bintu bikurikira:

a. Mwebwe ubwanyu SDA murayemera?
b. SDA mubona ibanogeye, SDA mwarayikunze?
c. Mubona SDA iberanye n'imiterere n'uburyo mukoramo akazi kanyu ka buri munsi?
d. SDA mubona ibafasha, SDA mwumva mwarayakiranye yombi?

3. Nyuma yo gukoresha SDA, ni gute mutekereza kuyishyira mu bikorwa mu mirimo yanyu ya buri munsi?

Gerageza kubafasha bavuge ku bintu bikurikira:

a. Babona SDA ari ikintu cyashyirwa mu bikorwa nta kibazo?
b. Babona SDA ishoboka mu mikorere yabo ya buri munsi?
c. Babona SDA ari ikintu gikoreka?
d. Babona SDA itagoye kuyikoresha?

4. Aho mumenyeye SDA, icyo ikora n'imikorere yayo, ni gute mubona uko yazakora mu buryo burambye (igihe izaba yinjijwe mu bikoresho bibafasha mu bitaro byanyu)? Gerageza kubafasha ku buryo bavuga ku bintu bikurikira:

a. Murumva mwifitemo kuzakomeza gukoresha SDA mu minsi iri imbere?
b. Mwumva SDA ari ikintu kizaramba?

c. Mwumva SDA ari ikintu kizabungwabungwa?

5. Niba mwumva SDA itaberanye n'imikorere yanyu muri iki gihe, ni iki mwumva cyahinduka kugira ngo ibe iboneye kurushaho?

Ikiganiro ni aha kirangiriye. Murakoze.

Appendix 12. KII Guide_Endline study_English version

Key Informant Interview Guide_ Acceptability

A. Key Informant Interview Preparation Checklist

The following preparations should be completed before each KII:

- 1 extra copy of study information sheets
- 1 extra copy of consent form
- 2 copies of audio-recording consent forms
- Digital audio-recording equipment (tested for working condition)
- Backup batteries for audio recorder(s)
- Notebooks for interviewer
- Private room
- Food and drinks for interviewee

Name and Signature of Study Staff: _____ Date: _____

B. Checklist for Facilitator and Note taker

The KII shall only progress once the following are confirmed:

- Study consent form has been signed and copy were given to interviewee
- Interviewee has signed the audio-recording consent form

Name and Signature of Study Staff: _____Date: _____

C. The questions for Key informant interviews

Exploring the acceptability of the safe delivery mHealth application(SDA) among stakeholders (district hospital managers, maternity matrons, head nursing, RAM responsible, MNCH responsible) in Rwanda.

The interview will start with an introduction of the SDA to the stakeholder. Explain its uses demonstrate how it functions and its implementation cost. After the introduction of the SDA, invite the participant to ask questions and comment on it. Once their concerns are addressed, explore the participant's perceptions and acceptability of the SDA.

1. Do you think nurses and midwives could benefit from the introduction of the SDA in district hospitals in Rwanda?
   a. Potential enablers
   b. Possible barriers
   c. Recommendations
2. After getting aware of the SDA and its roles and functionalities, what do you think about the implementation of the SDA in clinical practice? Probe for:
   a. Does the SDA meet your approval?
   b. Is the SDA appealing to you?
   c. Do you like the SDA?
   d. Are you welcoming the SDA?
   e. Is the SDA useful?
3. After getting aware of the SDA and its roles and functionalities, what do you think about the use of the SDA in clinical practices at district hospitals of Rwanda and other hospitals (scalability)? Probe for:
   a. Does the SDA seem implementable?
   b. Is the SDA possible?
   c. Is the SDA doable?
   d. Is the SDA easy to use?
4. After getting aware of the SDA costs in two district hospitals, do you think that it is affordable to the Rwandan context? Probe for:
   a. Technology cost
   b. Training cost
   c. Intervention cost
   d. Total cost
5. After getting aware of the SDA and its roles and functionalities, what do you think about its sustainability (once implemented in district hospitals in Rwanda)? Probe for:
   a. Can nurses and midwives continue to use the SDA in the future?
   b. Is the SDA durable?

End of Interview, Thank you.

Appendix 13. KII Guide_Endline study_Kinyarwanda version

Ibyo kwifashisha mu biganiro–baza bigiranwa n'umuntu umwe umwe mu batoranijwe gutanga amakuru mu bushakashatsi- Uko abantu bumva bakanakira Safe Delivery mHealth Application.

A. Urutonde rw'ibigomba kwifashishwa mu biganiro-baza bigiranwa n'umuntu umwe umwe

Ibintu bikurikira bigomba kuba byateganijwe mbere yo kugirana ibiganiro-baza n'umuntu umwe umwe mu bushakashatsi:

- Kopi 1 y' amakuru arebana n'ubushakashatsi
- Kopi 2 z'amafishi yo kwemera kugira uruhare mu bushakashatsi
- Kopi 2 zuzuzwamo umwirondoro ku bemera gufatwa amajwi mu biganiro-baza
- Ibikoresho byo gufata amajwi (byabanje gusuzumwa ko bikora neza)
- Amabuye yo gushyira mu twuma dufata amajwi mu gihe andi yaba atagikora
- Amakaye yo kwandikamo ku bayoboye ibiganiro-baza
- Icyumba kiri ahantu heza hihererereye

Amazina n'umukono by'ukora ubushakashatsi:_____Itariki: _____

B. Ibyo uyoboye ibiganiro n'uwandika ibivugirwamo bagomba kwitwararika

Ibiganiro-baza bigiranwa n'umuntu umwe umwe mu batoranijwe kugira uruhare mu bushakashatsi bigomba gutangira ari uko ibi bintu bikurikira byatunganye:

- Abatumiwe mu biganiro-baza bamaze kuzuza amafishi ko bemera kugira uruhare mu biganiro kandi buri wese yahawe kopi ye
- Buri wese mu babazwa amaze kuzuza ifishi ko yemera gufatwa amajwi

Amazina n'umukono by'ukora ubushakashatsi: _____Itariki: _____

C. Ibibazo birebana n'ibiganiro-baza bikoranwa n'umuntu umwe umwe mu batoranijwe gukorerwaho ubushakashatsi

Ibiganiro-baza bitangirana no gusobanura muri make icyo SDA ari cyo kugira ngo abagira uruhare mu biganiro-baza babisobanukirwe. Hagombwa gusobanurwa icyo imaze, n'uburyo ikora ndetse n'ibisabwa ngo ishyirwe mu bikorwa. Nyuma y'ibyo, abitabiriye ibiganiro basabwa kugira icyo babaza cyangwa babivugaho. Igihe baba bafite impungenge ariko zimaze kuvanwaho, gerageza gusobanukirwa neza uko bumva banemera iyo gahunda ya SDA.

6. Mutekereza ko ababyaza n'abaforomo bakorera mu bitaro by'uturere hari icyo SDA yabungura cg yabamarira?

   a. Ubufasha (potential enablers)
   b. Imbogamizi (possible barriers)
   c. Inama (recommendations)

7. Mumaze kumva icyo SDA ikora n'imikorere yayo, ni iki mutekereza ku kuyishyira mu ngiro mu bikorwa nyirizina by'ubuvuzi? Gerageza kubafasha ku buryo bavuga ku bintu bikurikira:

   e. Mwebwe ubwanyu SDA murayemera?
   f. SDA murabona ibanogeye?
   g. SDA murabona mwayikunda?
   h. SDA murumva mwayakirana yombi?
   i. Murabona SDA ifite akamaro?

8. Mumaze kumva icyo SDA ikora n'imikorere yayo, ni iki mutekereza ku kuyishyira mu ngiro mu bikorwa nyirizina by'ubuvuzi by'umwihariko mu bitaro by'uturere? Gerageza kubafasha ku buryo bavuga ku bintu bikurikira:

   e. Babona SDA ari ikintu cyashyirwa mu bikorwa nta kibazo?
   f. Babona SDA ishoboka?
   g. Babona SDA ishobora gukoreshwa mu bitaro by'uturere?
   h. Babona SDA itagoye kuyikoresha?

9. Mumaze gusobanukirwa n'ibyo SDA isaba byose, mwasobanuriwe ibijyanye n'ikiguzi cya SDA dufatiye ku bitaro bibiri byakorewemo igeragezwa rya SDA. Ese mubona SDA ari ikintu abantu babasha kwifashisha murebye imiterere y'u Rwanda? Gerageza kubafasha kugira ngo bavuge ku bintu bikurikira

   a. Ikiguzi mu rwego rw'ikoranabuhanga (technology cost)
   b. Ikiguzi mu rwego rw'amahugurwa (training cost)

c. Ikiguzi mu rwego rw’ ishyirwa mu bikorwa rya SDA (intervention cost)
d. Ikiguzi muri rusange (total cost)

10. Mumaze gusobanukirwa n’icyo SDA ikora n’imikorere yayo muri rusange, mutekerezako yazakoreshwa mu buryo burambye (igihe izaba itangiye gukoreshwa mu bitaro by’uturere)? Gerageza kubafasha ku buryo bavuga ku bintu bikurikira:

d. Murumva abaforomo n’ababyaza bazakomeza gukoresha SDA mu minsi iri imbere?
e. Mwumva SDA ari ikintu kizaramba?

Ikiganiro-baza ni aha kirangiriye, Murakoze.

Appendix 14. Original Paper I



Informatics for Health and Social Care

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Clinical decision making in basic emergency obstetric and newborn care among nurses and midwives: the role of the safe delivery mhealth application_pre-post-intervention study (research protocol)

Aurore Nishimwe , Marc Nyssen , Latifat Ibisomi & Daphney Nozizwe Conco

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Clinical decision making in basic emergency obstetric and newborn care among nurses and midwives: the role of the safe delivery mhealth application_pre-post-intervention study (research protocol)

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ABSTRACT

Most maternal and newborn deaths in low-income countries, including Rwanda, are attributable to preventable causes. Timely access to Basic Emergency Obstetric and Newborn Care (BEmONC) guidelines to support clinical decisions could lead to better obstetric care thus reduction of maternal and newborn deaths. Besides, innovative methods such as the usage and reference to healthcare guidelines using mobile devices (mhealth) may support clinical decision making. However, there is little evidence about mhealth that focuses on the clinical decision support process. This proposal aims to investigate the effect of the Safe Delivery mhealth Application(SDA) on nurses' and midwives' clinical decision making, so as to inform mhealth interventions for work in specific contexts. The study adopts a quasi-experimental design. Convergent parallel mixed – methods will be used to collect, analyze and interpret data. A pre-intervention assessment of the BEmONC outcomes: Apgar score and PPH progressions, and related knowledge, skills, and perceptions of nurses and midwives will be conducted. The intervention will take place in two district hospitals in Rwanda and entails the implementation of the SDA for six months. Six months' post-intervention, the effect of the SDA on BEmONC outcomes and the nurses' and midwives' knowledge and skills will be evaluated.

KEYWORDS
BEmONC; mhealth; safe delivery application; Rwanda

Introduction

It is estimated that 289,000 maternal deaths.[1] and 28 million neonatal deaths.[2] occur each year worldwide. More than 90% of these deaths happen in low- and middle-income countries.[1],2 Most maternal and newborn deaths are attributable to a handful of preventable causes.[3] The documented preventable causes include pre-eclampsia, obstructed labor, infections, postpartum hemorrhage, hypertensive disorders and newborn's failure to breathe.[4–6] United Nations agencies including WHO, UNICEF, and UNFPA have put forward seven key obstetric services as prevention and treatment strategies. These seven signal functions are referred to as Basic Emergency Obstetric and Newborn Care (BEmONC) and can be provided by nurses and midwives.[7] The BEmONC package includes the management of postpartum hemorrhage (PPH), the removal of a retained placenta, the management of maternal sepsis, the management of hypertensive disorders, the management of prolonged labor, the management of complications of abortion and neonatal resuscitation (NR).[8]

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Health outcomes in Rwanda have improved substantially in the last decade. Maternal deaths decreased by 77% between 2000 and 2013, while a 70% reduction in under-5 child mortality was documented.[1] Despite the remarkable reductions, maternal and neonatal mortalities in Rwanda remain high, at 290 maternal deaths/100.000 live births and 20 newborn deaths/1000 live births in 2015.[9] Literature suggests that most of these deaths are due to preventable causes including Postpartum hemorrhage (71.6%) and neonatal asphyxia (38%).[10,11] Evidence also revealed that limited knowledge and skills among nurses and midwives, poor access to clinical guidelines and lack of timely response to pregnancy complications during delivery care are significant predictors of maternal and neonatal mortality in Rwanda.[10]

Reducing maternal and neonatal deaths requires accessible, available and quality emergency obstetric care services for managing delivery complications.[12] Among the government strategies to bring down the numbers of maternal and newborn deaths in Rwanda, is ensuring quality BEmONC services.[13] Knowledge and skills of nurses and midwives in BEmONC have been found to influence the maternal and newborn clinical outcomes.[14] For instance, a study conducted in Kenya, Tanzania, and Zambia demonstrated that the knowledge and skills of nurses and midwives about BEmONC often do not meet the required standards.[15] Research conducted in Ethiopia found that midwives were more likely than nurses, to achieve knowledge-based mastery post-training.[16] In Rwanda, the majority of nurses and midwives expressed the need to improve their knowledge (60.6%) and skills confidence (72.2%) across fundamental topics of safe motherhood care.[17] Also, in-service trainings to keep them updated on better management of obstetric complications are few due to limited funds.[10] Yet, maternal and neonatal deaths could be prevented by quality obstetric and neonatal care services.

In low-resource settings, even with structures in place, equipment and consumables available, staff were unable to effectively deliver the BEmONC signal functions.[4] A study conducted in South Africa suggests that limited knowledge and skills are the primary reason the advantageous evidence-based BEmONC is still not widely adopted and effectively delivered.[18] On the other hand, Grol and Grimshaw[19] argued that health professionals need continuous access to updated healthcare information and clinical guidelines to support their decision making during practices.[19] In summary, BEmONC knowledge and skills of nurses and midwives combined with full access to clinical guidelines could lead to better obstetric care thus the reduction of maternal and newborn deaths. Furthermore, mhealth, including the use of mobile phone applications, improves health care services and effectively support nurses and midwives deliver better quality care.[20,21]

Mobile health applications are known for making relevant and reliable healthcare information available to healthcare providers.[22] Moreover, electronic decision support tools can help reduce clinical errors and ensure quality care at the point of service delivery.[23] There has been a considerable rise in the use of mhealth technology, in line with the increasing mobile phone subscriptions worldwide and this is associated with better data, better communication, and better information which in turn has the potential to improve health outcomes.[24] Mhealth applications are categorized according to three end-users: health systems; healthcare providers; and client/patient.[20] The Safe Delivery mhealth Application (SDA) belongs to the category of healthcare providers.

There is growing evidence of the effectiveness of mhealth interventions in low and middle-income countries(LMICs), particularly to improve adherence to treatment, meeting appointments, data collection and the development of supportive networks for health professionals.[26] For instance, Speciale and Freytsis[27] reviewed the usage of mhealth applications designed specifically for nurses and midwives and reported that most mhealth technologies for improving maternal and newborns' health outcomes mainly focused on accessing health care services.[27] A research study by Labrique[28] which examined twelve common mhealth applications, recommended more research for mhealth applications that address better service delivery with the primary focus on clinical decision support process.[28] The SDA is one of the recent mhealth application, designed to make BEmONC clinical guidelines available to nurses and midwives so as to support their clinical decisions.[29]

There are few published studies on the use of mhealth applications in BEmONC in Africa[30,31] and none in Rwanda. On the other hand, evidence suggests that mhealth technologies, such as the SDA

could improve the knowledge and skills of nurses and midwives while making reliable clinical guidelines easily available to them.[32] Even though the effectiveness of the SDA has been proven,[29] its implementation success depends on the context.[32] Therefore, this study will use a pre and post-intervention approach to investigate the effect of the SDA on nurses' and midwives' clinical decision making in the management of the two top frequent complications in Rwanda (newborn asphyxia with its complications and post-partum hemorrhage). More detail about the SDA is provided below. This manuscript outlines the research proposal used to meet the aim of the study.

Safe delivery mhealth application (SDA)

The development of the SDA was motivated by evident global inequalities. It is estimated that 99% of maternal and neonatal deaths occur in low-income countries, mostly in Africa.[32] In the search for an innovative solution to deal with this challenge, recognizing that Africa was the second-largest market for mobile phones,[29] the consideration was: what if mobile technology could be used to ensure safe births in Africa? The SDA – developed by the Maternity Foundation, Copenhagen University and the University of Southern Denmark – is a smartphone application that provides skilled birth attendants (SBA) with direct and instant access to the clinical guidelines on BEmONC.[29] It was developed to strengthen maternal healthcare by providing life-saving information and guidance to handle emergencies in pregnancy and childbirth even in the most remote settings.[32] The SDA contains easy to understand animated instruction videos, action cards, essential drugs, practical procedures guidelines and a learning platform.[29] All features and functions are designed for low-literacy, low-income settings and work offline once downloaded. The SDA can be used as on job reference tool, as a training tool and as an instructive aid in emergencies. While practicing, the SBA can consult action cards and drug lists to be helped in her decision in case of an emergency. In the free time, the SBA can again play animated instruction videos and consult procedures descriptions to improve on his/her knowledge and skills.[32]

The SDA can be downloaded for free: (https://play.google.com/store/apps/details?id=dk.maternity.safedelivery&hl=en).

Study justification

The rationale for this study is to seek solutions to the challenges encountered by nurses and midwives in providing BEmONC services in Rwanda. Challenges that are due to limited access to clinical guidelines to support their clinical decisions. On the other hand, evidence on the usage of the SDA in Rwanda will inform policy and planning of the BEmONC strategies. The results of the study will describe the effect of the SDA on supporting the nurses' and midwives' clinical decision making in two BEmONC signal functions; management of post-partum hemorrhage and neonatal resuscitation. Functions that when successfully delivered, enhance the safety of the mother and her newborn. The study is designed to produce evidence that will enable the adoption of mhealth technology in the provision of BEmONC services in Rwanda. The primary contribution of the SDA is to improve maternal and neonatal health outcomes. The study seeks to make a positive contribution to efforts ensuring that no woman/newborn dies during deliveries from preventable causes. Furthermore, the research should produce evidence that will contribute, not only to the limited body of knowledge on ICT applications in healthcare in Rwanda but to the broader literature on mhealth technology implementation outcomes.

Conceptual framework

The conceptual framework for this study (Figure 1) is embedded in the implementation research (IR) model by Proctor (2011). The IR model offers three different but interrelated types of processes.[33] These are:

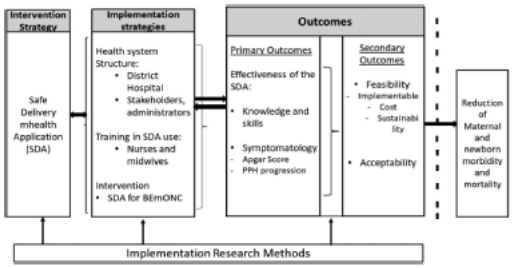

Figure 1. Conceptual framework adapted from the Implementation Research (IR) model by Proctor (2011).

- The What? (The intervention strategy or the evidence-based solution). In this study, the intervention strategy is the safe delivery mhealth application.
- The How? (The implementation strategies). For this research, these include matters that may influence the implementation outcomes. The health system structure; the organization (district hospitals); the stakeholders (who cares about the improvement effort, who will be affected, who can facilitate, service consumers, providers, administrators); and any aspect of the Rwandan context that may affect the SDA implementation and outcomes.
- The outcomes (primary and secondary outcomes). For the current study, they include; the effectiveness, symptomatology, and acceptability.

The current study assumes that the usage of the SDA will improve BEmONC outcomes and in the long run help reduce maternal and newborn morbidity and mortality. Proctor et al.[33] recommend methodological consideration of the specific context when planning to take an intervention from its efficacy under controlled settings to its effectiveness in a real-world setting. The implementation strategies are needed for the scale-up of the innovation, which may not work without an accurate assessment of implementation outcomes.[33] This study assumes that the SDA effectiveness would predict its symptomatology and acceptability.

Methods

This study design is a quasi-experimental research. It is three-phased research using convergent parallel mixed methods (Figure 2). Phase one, the pre-intervention study, is a mixed-method study using self-administered questionnaires and focus group guides to assess nurses' and midwives' knowledge and skills in NR and PPH management and their perceptions of PPH, NR and the SDA at baseline. Phase one also features a cross-sectional study using a record review to document BEmONC outcomes; PPH and Apgar score progression at baseline (records for six months' pre-intervention). Phase two is the intervention which comprises: the capacity building in the usage of the SDA among nurses and midwives; the SDA provision and piloting; and the SDA implementation for a period of six months in two district hospitals in Rwanda. Phase three, the post-intervention study, is a mixed-method study using self-administered questionnaires, focus group guides and key informant interview guides to assess the effects of the SDA on nurses and midwives' clinical decision making and their perceptions and acceptability of the SDA. Phase three also includes a cross-sectional study, using a record review to assess the effects of the SDA on BEmONC outcomes with regards to NR and PPH management. Table 1 provides a summary of the research methods across the three phases, outlining

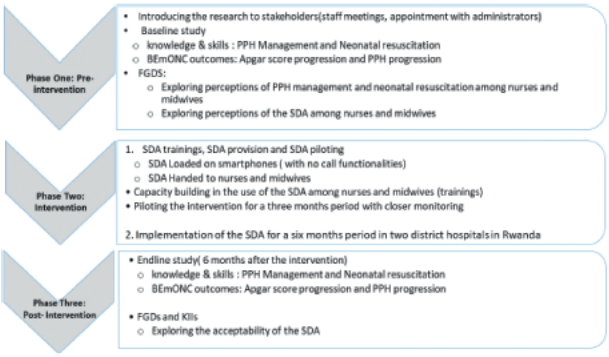

Figure 2. Phases of the study.

the study objectives; data needed; study design; location; sources of data; study population; procedures and data analysis.

The intervention: safe delivery mhealth application (SDA)

The SDA design is primarily based on WHO guidelines. It was validated by an international group of global health experts and can be adapted to local contexts and policies.[34] The SDA will be installed onto smartphones that will be provided to nurses and midwives in Masaka and Nyamata district hospitals. The SDA is designed to support nurses and midwives in clinical decision making, by providing them with instant access to evidence-based clinical guidelines on BEmONC and a selection of essential preventive protocols in a user-friendly format. Besides, the SDA offers an interactive learning platform that can be adapted for a personalized learning journey to further improve knowledge of the seven BEmONC signal functions. The intervention will run over a period of six months from enrollment into the study. Study participants will provide data on outcome measures at baseline, and at six months following recruitment.

Study setting and population

The study will be conducted in Rwanda. Rwanda is a small country (26.338 km^2) in East Africa sharing borders with Uganda, Burundi, Democratic Republic of Congo and Tanzania.[9] The country is divided into five provinces: Southern, Northern, Eastern, Western and Kigali. The country is further divided into 30 districts. Rwanda has a total population of 11.92 million,[9] and the human resources for health ration is one midwife per 18,790 inhabitants and one nurse per 1,227 inhabitants.[35]

The current study will be conducted in two provinces in Rwanda – the Eastern and Kigali City provinces. The Eastern province is rural and was chosen because of its high maternal and neonatal mortality rates.[36] While Kigali City province is urban and was chosen because of the high number of patients visiting its hospitals. Using purposive sampling, two district hospitals out of 12 district hospitals in the two provinces have been chosen; Masaka district hospital (located in Kigali province) and Nyamata district hospital (located in the Eastern province). The two hospitals were chosen

Table 1. Research protocol summary.

	Phase One		Phase Two	Phase Three			
	Pre - Intervention		Intervention	Post - Intervention			
	Objective 1	Objective 2		Objective 3	Objective 4	Objective 5	Objective 6
Objectives	To describe nurses' and midwives' knowledge, skills and their perceptions on PPH management, NR and the SDA	To document BEmONC outcomes: PPH and Apgar score progression at baseline.	Capacity building in the use of the SDA among nurses and midwives (trainings), SDA provision, SDA piloting and SDA implementation for a six months' period.	To assess the effects of the SDA on nurses and midwives' clinical decision making in the management of PPH and NR.	To assess the effects of the SDA on BEmONC outcomes with regards to PPH and NR.	To explore the acceptability of the SDA among stakeholders: managers, nurses, and midwives.	To describe the nurses' and midwives' experiences, stakeholders' perceptions and the implementation process of using the SDA
Data Needed	Knowledge & skills scores at baseline: PPH Management and NR; perceptions on PPH management, NR and the SDA	BEmONC outcomes: PPH progression (from minor to severe) and Apgar score progression (Apgar scores at 1 min, 5min, and 10 min after delivery) at baseline.		Knowledge & skills scores at endline: PPH Management and NR	BEmONC outcomes: PPH progression and Apgar score progression records when using the SDA.	PerceptionsAcceptability: (approval, likeliness, welcoming, perceived usefulness, intention to use), perceptions on the acceptability	Nurses and midwives' experiences of using the SDA, Stakeholders' perceptions of the SDA, Description of the implementation process of the SDA in two hospitals in Rwanda
Study Design	Mixed Methods (SAQs and FGDs)	Record Review		Quantitative (SAQs)	Record Review	Mixed Methods (SAQ, FGDs, KIIs)	Qualitative (FGDs and KIIs)
Location	Masaka and Nyamata district hospitals	Masaka and Nyamata district hospitals	Masaka and Nyamata district hospitals	Masaka and Nyamata district hospitals	Masaka and Nyamata district hospitals	Masaka and Nyamata district hospitals	Masaka and Nyamata district hospitals
Source of Data	Nurses and Midwives	Delivery Registries		Nurses and Midwives	Delivery registries	Nurses, Midwives, Managers, MNCH responsible	Nurses, Midwives and maternity matrons
Study Population	52 nurses and midwives (census method)	all cases of PPH and NR recorded in delivery registries six months' prior intervention		52 nurses and midwives (census method)	all cases of PPH and NR recorded in delivery registries six months during intervention	52 nurses and midwives, 2 maternity matrons, 2 directors of hospitals and 1 responsible of MNCH (census method)	52 nurses and midwives and 2 maternity matrons (census method)

(*Continued*)

Table 1. (Continued).

	Phase One		Phase Two	Phase Three			
	Pre - Intervention		Intervention	Post - Intervention			
	Objective 1	Objective 2		Objective 3	Objective 4	Objective 5	Objective 6
Procedure and Instrumentation	SAQs, FGD guide	Data extraction sheets		SAQs	Data extraction Sheets	SAQs, FGD guide, KII guide	FGD guide, KII guide
Data Analysis	Quantitative: descriptive statistics, Frequencies, percentages, Logistic regression analysis. Qualitative: thematic content analysis	Descriptive statistics		Paired t-test	Descriptive statistics	Quantitative data: descriptive statistics, Qualitative data: thematic content analysis	Thematic content analysis

because they have been offering BEmONC services for more than three years and for having a high average of deliveries per year in their respective provinces.[35] Using a census method, the study sample will be 52 nurses and midwives, working as full-time staffs and have a work experience above 6 months in obstetric care in Masaka and Nyamata district hospitals, two maternity matrons, two district hospital managers, the person in charge of maternal and newborn child health at the ministry of health level and delivery records in staff registries (delivery registries).

Outcomes measures

The primary outcomes of the study will be the effectiveness and the symptomatology, while the secondary outcome will be the acceptability of the SDA. For the effectiveness outcome, knowledge and skills scores for two key BEmONC services, NR and PPH at baseline and at six months' post-intervention will be assessed. The baseline and endline test scores will be compared. Knowledge and skills' data collection instruments were developed, tested (in English), and translated into French by the Maternity Foundation in Copenhagen. Reliability and validity measures have not yet been published for these measures; this study will contribute to the assessment of the measures. English and French languages are both professionally used in Rwanda.

Additionally, baseline demographic characteristics will be collected for nurses and midwives in the two district hospitals. For the symptomatology, cases of PPH and NR recorded in delivery registries will be reviewed at baseline and at six months' post-intervention using data extraction sheets. The PPH progression and the Apgar score progression will be observed. Cases recorded during the 6 months' intervention phase will be compared with the baseline cases recorded 6 months prior to the intervention.

The acceptability will be assessed through a quantitative survey among nurses and midwives and qualitative semi-structured interviews with nurses, midwives, maternity matrons, and district hospital managers. Key stakeholders' perspectives on the use of the SDA more broadly in Rwanda will also be assessed. The acceptability survey is a self-administered questionnaire developed and tested by Maternity Foundation and include Likert scale items with questions like; is the SDA easy to use or do you think that the SDA will be useful for you. The interview guides were developed and tested (in English) by the researcher and translated into French and Kinyarwanda by professional translators. A pilot survey will be conducted to pretest and strengthen the usability of the instruments. The interviews will be audio-recorded and transcribed verbatim.

This study has been approved by the Human Research Ethics Committee of the University of the Witwatersrand (M190258) and the University of Rwanda, College of Medicine and Health Sciences' Institutional Review Board (No.377/CMHS IRB/2018). Permission has been granted by the two district hospitals. Written, informed consent will be obtained from all the participants.

Data analysis

Data from the quantitative part of the study will be analyzed using STATA version 14. Mean scores across all knowledge and skills questions will be computed. Data will be summarized with descriptive statistics. A paired t-test will be used to test for means differences in the two groups (baseline and endline). Further, regression analysis will be done to assess the associations between knowledge and skills of nurses and midwives with their level of training, the number of years of experience in obstetric care and the kind of support they receive in the workplace. Significance will be set at p-value ≤ 0.05. Secondly, data from the record review will be analyzed for relative risk comparing the before and after intervention records. Thematic content analysis will be utilized to identify themes from the qualitative data: Data will be coded, similar foci will be categorized and sub-categorized, and thereafter themes will be identified. Coding will be done by the principal investigator and a second coder in two separate sessions and the results will be compared. To ensure the trustworthiness of data, an audit trail throughout the research process will be kept in a field journal; a detailed description of the data collection, analysis and interpretation will be outlined. Debriefing sessions will take place to discuss the

research process, findings and data analysis with the research supervisors. NVIVO software will be used to analyze and manage the qualitative data.

Limitations

Nurses and midwives may consult other sources rather than the SDA to inform their decision making during the intervention which might be a potential confounder to the study that will be adjusted for in the analysis. In terms of generalization, the current study will not generalize findings and it will recruit a relatively small sample (52 nurses and midwives) from two hospitals. Nevertheless, this study will give us evidence on the impact of implementation outcomes of the SDA in the context of Rwanda and will inform the planning of the BEmONC prevention strategies.

Abbreviations

BEmONC	Basic Emergency Obstetric and Newborn Care
mhealth	Mobile Health
SDA	Safe Delivery mhealth Application
PPH	Post-Partum Hemorrhage
NR	Neonatal Resuscitation
MNCH	Maternal Newborn and Child Health
WHO	World Health Organisation
UNICEF	United Nations International Children's Emergency Fund
UNFPA	United Nations Population Fund
LMICs	Low- and middle-income countries
ICT	Information, communication, technology
SAQs	Self-Administered questionnaires
FGD	Focus Group Discussion
KII	Key Informant Interview

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Authors' contributions

AN, DNC, MN and LI were involved in the conception and design of the study. AN drafted the manuscript. DNC, MN, and LI reviewed the manuscript. All authors read and approved the final manuscript.

Availability of data and materials

This article is a research proposal. The dataset generated for some of the phases of the study has not been analysed but will be made available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

Disclosure of interest

The authors report no conflict of interest.

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Ethics approval and consent to participate

This study has been approved by the Human Research Ethics Committee of the University of the Witwatersrand (M190258) and the University of Rwanda, College of Medicine and Health Sciences' Institutional Review Board (No.377/CMHS IRB/2018). Permission has been granted by the hospitals. Written, informed consent will be obtained from all the participants.

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Appendix 15. Original paper II

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Context specific realities and experiences of nurses and midwives in basic emergency obstetric and newborn care services in two district hospitals in Rwanda: a qualitative study

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Abstract

Background: In low and middle-income countries, nurses and midwives are the frontline healthcare workers in obstetric care. Insights into experiences of these healthcare workers in managing obstetric emergencies are critical for improving the quality of care. This article presents such insights, from the nurses and midwives working in Rwandan district hospitals, who reflected on their experiences of managing the most common birth-related complications; postpartum hemorrhage (PPH) and newborn asphyxia. Rwanda has made remarkable progress in obstetric care. However, challenges remain in the provision of high-quality basic emergency obstetric and newborn care (BEmONC). This study is a qualitative part of a broader research project about implementation of an mLearning and mHealth decision support tool in BEmONC services in Rwanda.

Methods: In this exploratory qualitative aspect of the research, four focus group discussions (FGDs) with 26 nurses and midwives from two district hospitals in Rwanda were conducted. Each FGD was made up of two parts. The first part focused on the participants' reflections on the research results (from the previous study), while the second part explored their experiences of delivering obstetric care services. The research results included: survey results reflecting their knowledge and skills of PPH management and of neonatal resuscitation (NR); and findings from a six-month record review of PPH management and NR outcomes, from the district hospitals under study. Data were analyzed using hybrid thematic analysis.

Results: The analysis revealed three main themes: (1) reflections to the baseline research results, (2) self-reflection on the current practices, and (3) contextual factors influencing the delivery of BEmONC services. Nurses and midwives felt that the presented findings were a true reflection of the reality and offered diverse explanations for the results. The participants' narratives of lived experiences of providing BEmONC services are also presented.

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Conclusion: The insights of nurses and midwives regarding the management of birth-related complications revealed multi-faceted factors that influence the quality of their obstetric care. Even though the study was focused on PPH management and NR, the resulting recommendations to improve quality of care could benefit the broader field of maternal and child health, particularly in low and middle-income countries.

Keywords: Basic emergency obstetric and newborn care, Post-partum haemorrhage, Neonatal resuscitation, Nurse, Midwife, Rwanda

Background

Globally, an estimated 295,000 maternal deaths (211/100,000 live births), 2 million stillbirths and 2.5 million early newborn deaths occurred in 2017 [1, 2]. More than 90% of these deaths happened in low and middle-income countries (LMICs), like Rwanda [3]. The risk of mortality is highest during labor, where 46% of maternal deaths and stillbirths and 36% of neonatal deaths occur [4]. Preventable causes such as pre-eclampsia, obstructed labor, infections, post-partum hemorrhage (PPH), hypertensive disorders and newborns failure to breathe are frequent [5, 6]. To help reduce preventable deaths during the childbirth critical period, the WHO, UNICEF, and UNFPA established a set of seven key obstetric services or "signal functions" referred to as Basic Emergency Obstetric and Newborn Care (BEmONC) [7]. These include the management of post-partum hemorrhage; the removal of a retained placenta; the management of maternal sepsis; the management of hypertensive disorders; the management of prolonged labor; the management of complications of abortion, and newborn resuscitation [8]. The BEmONC services are mostly provided by nurses and midwives in low-resource settings [9]. The WHO further, advocates for all births to be attended by a skilled birth attendant [10]. The BEmONC services were introduced in health facilities of Rwanda in 2004 with over 150 healthcare providers and community health workers trained in BEmONC from 2004 to 2009 [8].

The Rwandan health sector has remarkably evolved, since 2017, 91% of births take place in healthcare facilities and attended by healthcare professionals [11, 12]. The Rwandan public health care system has a pyramidal structure consisting of five levels: referral/ university teaching hospitals at the top followed by provincial hospitals, district hospitals, health centres and health posts [13]. An additional cadre of trained community health workers (CHWs) was introduced to link pregnant women in the community with the health facilities [14]. Normal births occur at health post or health center level. In the event of complications, the pregnant woman is transferred to the district hospital where advanced equipments and services are available. The obstetric care services are predominantly offered by nurses and midwives with the help of physicians in case of potentially fatal complications. The pre-service training of nurses and midwives in Rwanda varies widely with technical (A2); advanced diploma (A1); baccalaureate (A0) and graduate (masters) training available as pathways to entry to nursing and midwifery practice [15]. The work responsibilities vary depending on the level of education with nurses and midwives having A1 level and above, being responsible for managing normal deliveries and birth-related complications.

Efforts to reduce maternal mortality in Rwanda have included initiatives to encourage more women to deliver at health facilities with the free birth care advantage and health insurances affordability with 10% out of pocket payment of all received services [16]. Also, The public healthcare structure ensured that obstetric care services are delivered at different levels in line with the levels of expertise required and this contributed to a significant increase of births taking place in healthcare facilities [17–19]. However, maternal mortality and neonatal deaths remain high despite these initiatives. The maternal mortality ratio for the period 2014-2015 to 2019-2020 was 203/100,000 live births [20] and PPH at 22.7% was the leading direct cause [21]. The neonatal mortality ratio was 19 deaths/ 1000 live births [20] and newborn asphyxia and its complications was the leading cause, accounting for 38% of all neonatal deaths [22, 23]. This situation makes PPH and newborn asphyxia the priority challenges in Rwanda. This suggests that while the rate of heath facility deliveries has risen, the quality of care in health facilities might be suboptimal.

The current paper, was derived from a broader study about implementation of an mLearning and mHealth decision support tool (Safe Delivery Application) in basic emergency obstetric and newborn care services in Rwanda [24]. The aim of this aspect of the study was to explore the participating nurses and midwives' experiences and perceptions of obstetric care with a special focus on PPH management and NR. The objective of this aspect of the study was two-fold; one part was to elucidate from the participants' explanations of the research findings [25] from the quantitative part of the research. The second part was to explore context specific factors that influence their work as obstetric care givers in their respective hospitals.

Methods

Study setting

The study was conducted in two out of the 12 district hospitals in the Eastern and Kigali provinces in Rwanda [11]. The selected hospitals are: Nyamata district hospital from the rural eastern province and Masaka district hospital from the Kigali urban province. Both hospitals had been offering BEmONC services for more than 5 years and had a high number of deliveries per year, with more than 6000 deliveries per year in Nyamata hospital and 7200 deliveries per year in Masaka hospital [26].

Study participants

For the broader study, we invited nurses and midwives working in the maternity departments of the selected hospitals to participate in the study. Participants were selected using the following criteria: 1) having a work experience of at least 6 months in obstetric care, 2) being employed full-time in the selected hospital, and 3) willing to participate in the study. A total of 54 nurses and midwives participated in the baseline survey. For this qualitative study, 17 midwives and nine nurses were purposively sampled. The purpose was to select from participants who had participated in the survey and we were interested in having participants in line with the diverse roles in the maternity departments. Four focus group discussions were planned and the intended size of each focus group was a minimum of four and a maximum of six participants. According to Kitzinger and Barbour (1999), groups of this size are recommended for studies investigating health care systems and organization aspects [27]. In the present study, the number of participants who could attend on a given date per hospital determined the size of each group. Two groups in Nyamata district hospital consisted of six nurses and midwives each. While two groups in Masaka district hospital consisted of six and eight nurses and midwives respectively.

Study design

This exploratory qualitative study was embedded in a three phased pre – post intervention research, investigating the effect of the Safe Delivery mHealth Application on nurses' and midwives' clinical decision making in the management of the two top frequent births complications in Rwanda (newborn asphyxia with its complications and post-partum hemorrhage). The management of these two birth complications include neonatal resuscitation and PPH management [24]. The qualitative research sought to obtain an in depth insight into the nurses' and midwives' experiences about offering BEmONC services in the selected district hospitals. The study adopted an exploratory qualitative research design using moderated focus group discussions [28] to both explore and describe the nurses and midwives' reflections on the baseline survey results and their lived experiences in managing PPH and NR. The design was chosen as the nurses and midwives, who were delivering BEmONC services in the selected district hospitals, could offer a narrative explaining the baseline quantitative results and description of the phenomenon as they experienced it.

Data collection

The researcher moderated four FGDs, two in each study hospital, using a semi-structured guide. Each FGD session explored both the reflections of the participants to the baseline research results and their experiences of delivering BEmONC services. For the reflections, the researcher presented two sets of baseline findings on PPH management and NR - the survey results of nurses' and midwives' knowledge and skills; and the six-month record review on maternal and newborn outcomes (Apgar score and PPH progressions) following PPH management and NR. The researcher invited participants to reflect and discuss the baseline findings, probing for their reactions and explanations. The second part of the FGD explored nurses' and midwives' experiences in delivering obstetric care services with a special focus on PPH management and NR in their respective district hospitals.

FGDs were conducted in July 2019 at both hospitals. The duration of the interviews ranged from 45 to 60 min. The interview guide (Additional file 1) was developed in English, translated to Kinyarwanda, and translated back to English in a blinded manner to ensure accuracy and equivalence [29]. Interviews were conducted in the language of the participants' preference, which was Kinyarwanda. The first author conducted the FGDs with assistance of an experienced research assistant who assisted in taking notes and supervising the tape recording. To ensure the quality and adequacy of the FGD guide, it was pretested with one midwife and one nurse working in a similar department but at a different district hospital. Following the test, minor adjustments were made to the FGD guide. The minor adjustments included expanding one probe for more clarity, the probe was "peer-support" expanded to "possible peer-support in the work environment". Questions were open-ended to allow participants to expand upon topics they felt were important. Interviews were held in private rooms that adequately accommodate 12 people at both Masaka and Nyamata district hospitals to ensure anonymity and confidentiality.

Data analysis

Audio recordings of the FGDs were transcribed immediately following the discussions and then, translated from Kinyarwanda to English by a professional translator.

Transcriptions were done following the True Verbatim method to accurately capture meanings, perceptions, and context [30]. Field notes were incorporated in the written transcripts as additional data. To ensure data quality, two researchers independently double-checked all transcriptions and translations. Data were analyzed using thematic analysis with a hybrid approach (inductive and deductive) [30], consisting of six steps: 1) familiarization with data; 2) identifying initial codes; 3) generating themes; 4) reviewing and defining themes; 5) coding the data; 6) organizing themes and write up. The thematic analysis is broadly used in qualitative research and aims to present the main elements of the participants' descriptions [31]. The first author (AN) and one co-author (DNC) read all transcripts and developed the preliminary coding scheme together. Two interviews were double-coded by the first author (AN) and the co-author (DNC). Any inconsistencies were discussed and resolved to develop the final coding framework. The first author coded all remaining interviews transcripts. New themes, which could not be placed within the established coding framework, were also included in the analysis [32, 33]. Nvivo 11 Plus software was used in coding. The consolidated criteria for reporting qualitative research [34] guided reporting for this study (Additional file 2).

Results

Demographic information of the participants

A total of 26 nurses and midwives participated in the focus group discussions, 16 of whom were females and 10 males. More than a half were from Masaka district hospital ($n = 14$). The average age of participants was 32 years, ranging from 23 to 61 years. The level of education was predominantly the advanced diploma (A1) in midwifery with 14 of 26 participants having A1 level in midwifery. The majority of the participants had less than 10 years of experience in obstetric care ($n = 18$), and spent more than 10 h per week providing obstetric care ($n = 20$). Table 1 shows the demographic characteristics of the participants.

The analysis revealed three main themes: (1) reflections to the baseline research results, (2) self-reflection on the current practices, and (3) contextual factors influencing the delivery of BEmONC services. During the discussion of results, verbatim quotations were used to support the themes and provide evidence. More details on the main themes and sub-themes (Fig. 1) are presented in the text below, and are illustrated by quotations from the four FGDs.

Table 1 Participants characteristics ($N = 26$)

	n (%)
Hospital Affiliation	
Masaka District Hospital	14 (54)
Nyamata District Hospital	12 (46)
Gender	
Male	10 (38)
Female	16 (62)
Education Level	
Midwife A0	3 (11)
Midwife A1	14 (54)
Nurse A0	2 (8)
Nurse A1	5 (19)
Nurse A2	2 (8)
Years of experience in obstetrical care	
1–5	9 (35)
6–10	9 (35)
> 10	8 (30)
Weekly workload in obstetrical care (hours)	
0–5	2 (8)
6–10	4 (15)
> 10	20 (77)
Age, years, Mean (Range)	32 (23 - 61)

Abbreviations: % Percentage

Thematic framework

For each main theme, there were some associated key concepts that served as the sub - themes and resulted in the formation of the thematic framework shown in the Fig. 1.

Reflections to baseline research results

This was a reflection about the baseline survey findings on the knowledge and skills in the management of PPH and NR, and on a 6 months' record review of the BEmONC outcomes - Apgar score and PPH progressions. The survey results indicated that the average knowledge score was 47.2% and the average skills score was 59.9% among 33 midwives and 21 nurses interviewed for the survey [25]. The record review findings revealed an unstable newborn outcome (Apgar score < 7) following 10 min NR recorded in 62% ($n = 78$) newborn cases and an unstable maternal outcome (persistent bleeding ≥500mls) following PPH management recorded in 19% ($n = 13$) maternal cases. Under reflections to baseline research results, the sub-themes included reactions such as surprise, appreciation and shock, and explanations for the results which consisted of staff shortage, limited in-service training, lack of clinical guidelines, and lack of some essential materials.

Nurses and midwives admitted to being surprised by the survey and record review results. Some participants voiced appreciation of the research process, specifically

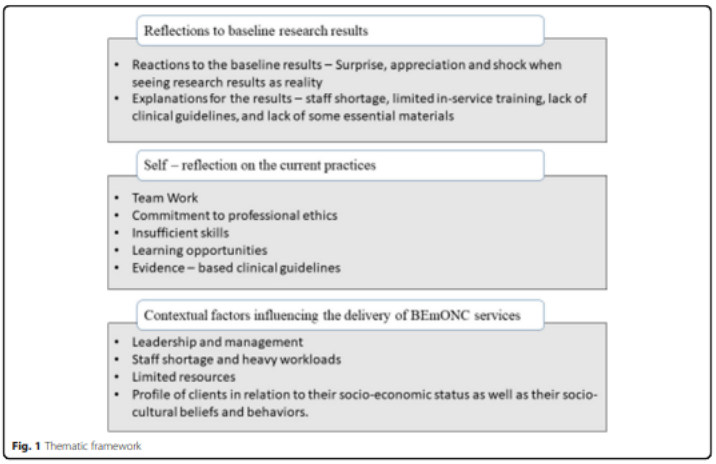

Fig. 1 Thematic framework

receiving feedback on the baseline research results. They indicated that the research results presented to them, helped them reflect on their usual practice and to consider ways of improving the services that they provide.

> *"It is the first time we get access to the findings from all the surveys that have been conducted here by the research people, this is good even though our performance was not good, I think we need to improve on our knowledge, get refresher courses or read a lot"***Midwife, Female-FGD1.**

Other participants said they were shocked by the realities of the performance of their departments, while others stated that they have always known that their performance was not optimum. The presented baseline results made some participants to consider ways to improve the situation.

> *"I know our department is not best performing due to some challenges we face here in district hospitals like the shortage of staff and lack of some essential materials, but these findings are not good at all. What can we do to address this issue? … I think the hospital administration need to take the lead to ensure safe environment of work here and help us get in-service trainings, it is really difficult to get them."-* **Midwife, Male-FGD4.**

Some participants thought that the reasons behind the low knowledge and skills scores was due to limited concentration while filling the survey questionnaires as they were thinking of the huge workload and this may have made them lose concentration.

> *"I think that the figures reflect the reality. But, I think the research was conducted while people were thinking of the work ahead. As a result of this, it is possible that some participants didn't take time to answer the questions properly with enough concentration. They might simply have ticked the answers without thinking about them. That is my opinion"-* **Midwife, Male-FGD1.**

Other possible explanations of the low knowledge and skills scores and the high records of unstable maternal and newborn outcomes, included staff related factors such as lack of skills where they describe the lack of in-service trainings as the main contributor.

> *"When we compare the knowledge and skills scores with the records, …. We can see that the figures from the records review also are too high* (62% unstable

newborn outcomes and 19% unstable maternal outcomes). *It is still a fact that there is a serious problem regarding lack of skills or experience"* **Nurse, Female-FGD2.**

Another participant said:

"I think that the main reason is lack of regular and continuous trainings for us, … Continuous professional development is always needed not only to refresh but also to upgrade what one learnt at school, in other words, staff members regularly need training to get updates" **Midwife, Female-FGD3.**

Another reason highlighted was the shortage of staff in the maternity department. According to nurses and midwives, the health system plays an important role in the provision of care which later affects patients' outcomes. The unstable maternal and newborn outcomes were attributed to the health system structure with the main highlight on the insufficiency of staff.

"The biggest challenge is insufficiency of staff. Sometimes, you may need some assistance when dealing with newborn resuscitation or PPH and you fail to get someone to assist. In this case, you need to do everything by yourself and as a result you may not succeed in everything as it could have been if there were two of you" **Nurse, Male-FGD2.**

Other participants voiced the need for adequate clinical guidelines that would be accessible and visible in the time of need, especially in case of emergencies, to help in decision making when dealing with birth complications such as PPH and NR.

"We need clinical guidelines to refer to regularly to provide better care to patients. The existing guidelines are not enough and not displayed in every labor room, … I think that the hospital should get more to have them displayed anywhere they may be needed" **Nurse, Female-FGD3.**

The lack of essential materials was mentioned as another reason why there were high records of unstable maternal and newborn outcomes.

We might be in a situation where some materials, equipment and medicines are not available. Sometimes, there is a possibility of providing good service but when you fail to get what you need (materials) to provide such a service on time, there is a problem and you can't succeed in your duties" **Nurse, Female-FGD4.**

Self – reflection on the current practices

The participants' narratives of lived experiences of providing obstetric care services in the study district hospitals revealed some insights into their current practices towards providing optimal BEmONC services. The discussions focused on team work, commitment to professional ethics, insufficient skills, learning opportunities and evidence-based clinical guidelines. Firstly, participants discussed the importance of peer-support for improved BEmONC services provision, particularly with regard to the management of PPH and NR. They acknowledged the presence of a team work spirit among nurses and midwives.

"I am happy with the teamwork spirit in this hospital and I find this as motivation and support here. Though we have different tasks to perform here, I appreciate the way we work together" **Nurse, Female-FGD3.**

Likewise, nurses and midwives indicated that sharing responsibilities is a significant enabler of good service provision. They link it to the issue of shortage of staff and high delivery loads. The mechanisms of supporting each other despite everyone's allocated daily responsibility make the work possible with the support of good and timely communication.

"I like the fact that people working in maternity ward are good at communicating. I am saying this because when several deliveries are to take place at the same time, they would always call upon the coordinator to send in more staff members for support." **Midwife, Female-FGD1.**

In addition, participants explained that their motivation which lead to their commitment to the professional ethics is a facilitator to better service provision. They discussed the value of wanting to save lives which keep them motivated to do whatever they can to care for women and newborns.

"I would like to say that we are motivated because we always wish to save lives. Of course, nobody would wish to experience newborn asphyxia. It is bad for any staff member. You would even get blamed for that. We are motivated and this has good impact on what we do. You can see that people like their job very much. You will see that we come not because we have to come but to save lives of mothers and newborns and to ensure that the work is properly done" **Nurse, Female-FGD2.**

However, participants acknowledged the presence of insufficient skills to deal with birth complications among some nurses and midwives coupled with the lack of up to date clinical guidelines, which pose barriers to patient care. This was expressed as follows:

"The challenge I would raise is limited skills. Maybe it is not an issue for everyone but it is there. Among five team members, you may only find two with the skills that are required for newborn resuscitation"- **Midwife, Female-FGD4.**

Another participant stated that:

*"Some nurses and midwives may not have enough skills to support the patients. For example, when it comes to cervical tear, they might fail to know how to suture the tear, thinking that it is only done by a doctor and remember that there is only one doctor assigned to maternity service"***Midwife, Female-FGD2.**

Furthermore, nurses and midwives described the factors in respect of their professional development as significant contributors to the quality of obstetric care. The lack of in-service professional development courses was mentioned as a crucial barrier to quality BEmONC service provision. Participants stated a need to get access to regular in-service trainings and continuous learning opportunities to improve on their knowledge and skills which would positively affect patient outcomes. There was also a recommendation to promote the culture of reading among nurses and midwives.

*"The big problem is that most of us do not have access to trainings and/or in -service professional development courses. Also, the culture of reading is not in us. We just keep doing things as we have always been doing."***Midwife, Male-FGD3.**

The study participants also mentioned the few learning opportunities that are available in the district hospitals which currently contribute to their continuous learning. These leaning opportunities include; mentorship sessions and clinical staff meetings. Participants agreed that those mentorship sessions improved their knowledge, skills and confidence, particularly with regard to maternal and child health care, and are key facilitators of evidence-based care provision.

*"We nowadays have mentors from Rwanda Association of Midwives (RAM) and Ingobyi Project who give training to clinical staff. Trainings are provided to doctors, nurses and midwives working in maternity. Trainees meet and work with these mentors every month. They give training in obstetric care. Their support is essential and it has improved our ability in providing better services to mothers and newborns. Those from Ingobyi have given training to four staff members so far, two of these four cascade the training to staff in health centres. Those from RAM together with Rwanda Pediatric Association come here every month to train three people per month."***Midwife, Male-FGD1.**

In addition, several participants felt that nurses and midwives who have not yet participated in the mentorship program should be included in training when possible. For this to happen, the training frequency might be increased to reach more staff. Other related suggestions included pairing already trained staff with non-trained staff during work shifts to improve both care provision and learning. Participants also suggested that the mentorship sessions could focus more on birth complications such as PPH management and NR.

*"I would also like to say that a big number of staff members in maternity department have not yet participated in the mentorship program. The number is still too low. If the days of mentorship could be increased, everyone will get a chance to be trained. We need that the sessions focus more on PPH and neonatal resuscitation. Remember, some staff members are fresh graduates who only have knowledge without experience. I think they need a lot of continuous professional development trainings. Also having them on day or night shifts with the more experienced staff who have benefited from the mentorship would make the situation better"***Midwife, Female-FGD4.**

Also, participants discussed the importance of clinical staff meetings that happen every morning to discuss obstetric care management. The meetings involve the presentation of cases of patients managed in the previous night as well as the hospitalized patients. The meetings also focus on the management of particular conditions in critical patients with senior staff advising junior staff. Nurses and midwives acknowledge these meetings as learning opportunities with real patient case presentations. Thus, helping them to improve the service provision. Participants also indicated that they have other educational meetings twice a week which are beneficial to their knowledge and skills refreshment.

"I think it is a good thing that we have staff meetings at hospital level to regularly discuss birth complications and related problems. We do not wait for these

*structured mentorship initiatives organized by external people. For example, in maternity ward, we also have educational meetings that are done on Wednesdays and Thursdays in addition to regular staff meetings that we have every morning. In these meetings, we talk about cases we have had and we thereafter have presentations about anything we think is useful. We often talk of PPH, eclampsia and helping baby breath. This is where emphasis is mostly laid to ensure that everyone working in maternity have basic skills in this. We also do some practices using the mannequins"***Midwife, Female-FGD2.**

Further, nurses and midwives discussed the role of evidence-based clinical guidelines in continuous learning and in the provision of evidence-based obstetric care. Participants stated that they need clinical guidelines to support their service provision. However, they pointed out the insufficiency of clinical guidelines as an important barrier to quality service provision. They indicated that the few clinical guidelines available are not displayed wherever needed.

"I would like to add that clinical guidelines are important for us. Clinical guidelines are there but not enough. I think there is a need to have them available in more places including emergency area where we also have PPH cases to deal with. Those working with ambulance should also have the guidelines because they are the ones to take care of the PPH patient while being transferred. They should also be displayed in maternity, emergency and out-patient and even in surgery room and this should be done in a sufficient quantity. I don't think they are available in health centres too. You may visit a place and notice that they don't have a PPH guideline while they may have had two or three PPH cases in a month." **Midwife, Female-FGD3.**

Other participants indicated that the available clinical guidelines are not updated. They stressed that the availability of enough and up to date clinical guidelines would help them in clinical decision making while dealing with birth complications such as PPH and NR.

"A staff member may not be in position to always remember what to do when there is a PPH or neonatal resuscitation. However, clinical guidelines are still few. Only one is displayed in the delivery room, it has been there for long ago and it is not updated." **Midwife, Female-FGD2.**

In addition, participants indicated the challenges with paper based clinical guidelines which are the only ones available. Participants cited the length, the difficulty to update and the deterioration with time as the main challenges of paper based clinical guidelines. They also stressed that it is hard for them to find time to read the non-summarized paper based clinical guidelines.

"There are few clinical guidelines: some are in file boxes and others are displayed on the walls..., it is hard to update these paper based-clinical guidelines and they could get deteriorated easily as time goes. The ones in file boxes are too long and it is unfortunate we do not read them- maybe reading is so difficult! People are too lazy to read or maybe don't have time to read. You will hardly see someone reading the clinical guidelines in files boxes" **Midwife, Male-FGD4.**

Finally, nurses and midwives, in consideration of the evolving digital age, proposed to have the summarized electronic clinical guidelines which could be easily accessible and regularly updated.

"I have read on internet that in developed countries' hospitals, there exist some form of electronic clinical guidelines that people consult on computers or smartphones. And, I think the easy way for us would be to have those electronic clinical guidelines that will be summarized, easily accessible for everyone and could be updated as science evolves." **Midwife, Female-FGD1.**

Contextual factors influencing the delivery of BEmONC services

Nurses and midwives indicated a number of context specific factors that influence the quality of care in BEmONC, particularly in the management of PPH and NR. Under contextual factors, the sub-themes included the realities of working in the context of district hospitals including the leadership and management, the staff shortage and heavy workload, the limited resources, the profile of clients in relation to their socio-economic status as well as their socio-cultural beliefs and behaviors.

The participants highlighted the contribution of the leadership and management in ensuring the quality of obstetric care in the hospitals. Participants described hands on leadership, provided by departmental managers, ensuring that services were well organized and that staff were assigned to where they were most needed. The good organization of service within the maternity department was perceived as key to better service provision.

"We actually have a kind of task distribution and daily organization of the work by the maternity matron. When there is an emergency, for example in delivery room, those people in charge of different units get in touch and they may get support from each other by sending some members to help. The number of members to support will depend on the size of work to be performed. Such movements often happen between delivery room and hospitalization unit depending on cases." **Midwife, Female-FGD2.**

The participants described the support provided by the hospital management as enabling the service provision for the management of PPH and NR. They felt that the managers of the hospitals give a particular attention to maternal and child care which translate into more resources and supplies to the maternity department. They verbalized that:

"The maternity heads in collaboration with the hospital managers do all they can to have all we need in stock. This include also PPH and NR emergency kits and all other kits. We organize a morbidity day event in which we discuss birth complications and the Director General also attends the event. They take into consideration all our challenges in the provision of maternity care" **Midwife, Male-FGD4.**

"What I can add is that we get a lot of support from the Hospital Management. Top management is very supportive and most importantly, the nursing leader is a midwife too. They are so sensitive about mothers. We usually get all equipments and drugs we need, even though sometimes, we run out of stock" **Midwife, Female-FGD1.**

However, participants described staffing shortages as a significant barrier to care provision. They explained it was common in district hospitals for two midwives or nurses to cover the waiting room, the emergency room, the labor room and the recovery room.

"There is a problem of workload. People here have too much to do. You may find two staff members in the maternity and when you have to attend to six mothers at once, you understand that it can't work. As soon as a delivery has taken place, you immediately go to another mother without considering subsequent stages as you should and then monitoring PPH becomes hard. As a result, sometimes there may be some complications and you may fail to handle them on time" **Midwife, Female-FGD2.**

Some participants stated that high number of deliveries per midwife made it difficult to perform well for every patient in need. They cited the poor staff/patient ratio, as an important barrier to good service provision in terms of dealing with birth-related complications. They stressed that the number of staff members is too low compared to the number of patients to take care of.

"I think there is a problem of staff/patient ratio. Monitoring also becomes very hard due to insufficient staff members. How can two midwives assist three deliveries at once? Who can meanwhile attend to those in the waiting room? Sometimes, you may end up finding the ones you left in waiting room suffering. The problem of insufficiency in staffing is crucial" **Midwife, Male-FGD3.**

Then again, nurses and midwives stated that the low number of doctors assigned to the maternity department is a challenge to better service delivery. This is partly linked to the shortage of staffs in district hospitals.

"I think that availability of medical doctors is also a requirement for these cases of PPH and NR, however they are still few, one allocated to Maternity service daily" **Nurse, Female-FGD1.**

Other participants felt that they need more specialist doctors like pediatricians when performing neonatal resuscitation and later for the recovery of the newborn.

"Another area to improve on is that we should also have a pediatrician to work with newborn resuscitation. The newborn resuscitation should not only be done by a midwife and a nurse. Sometimes, the newborn also needs antibiotics and a pediatrician would be in a better position to prescribe them. I think this is worth noting too" **Nurse, Female-FGD4.**

Furthermore, participants highlighted the issue of staff rotations in different services and staff turnover as barriers to better service provision. They expressed concerns about staff rotations that is implemented by the health system in district hospitals of Rwanda. Staff, particularly nurses, are rotated to different clinical services such as maternity, pediatric, surgery and sometimes rotating to or from maternity. As a result, the rotating nurses, like new staff may not be familiar with dealing with birth complications and they may take time to get used to the routine work. Also, staff turnover was indicated as an important barrier in consideration of staff moving from one hospital to another hospital. When staff turnover takes place the origin hospital loses an experienced staff.

"We know well that we sometimes have staff rotations and staff turnovers in hospital- for example fresh graduates who have no experience and moving back and forth in different services. These new staff members might proceed with a given management of the birth complications without following the standard clinical guidelines" **Nurse, Male-FGD3.**

Further, nurses and midwives discussed some of the resources challenge they face when dealing with obstetric emergencies. They cited lack of physical resources, including supplies and equipment, as a barrier to care provision. Resources such as oxygen cylinders, heating lamps for newborns, and suction bulbs were often unavailable or non-functional.

".... We only have one suction bulb here, imagine if we have more than one neonatal who fails to cry after birth, what can we do with one piece only? When this happens, we face a serious problem. For the time being, we only have three penguins and one lamp.... These materials are not sufficient" **Nurse, Female-FGD1.**

Another participant said:

"Another challenge is the problem related to availability and accessibility of some medications and materials. If I think of the number of deliveries we have here, they should match the quantity of equipment and materials needed for that purpose. I don't understand how you can assist in 15 deliveries with only one heating lamp at night.... Sometimes, you may even fail to get oxygen cylinders because they are not there or not in sufficient quantities...." **Midwife, Male-FGD4.**

Also, some participants described the persistent shortages of uterotonics, antibiotics and intravenous fluids. When medications were out of stock, patients or their family members were asked to purchase medications from outside pharmacies or, in emergency cases, nurses or midwives sometimes purchased medications for patients.

"We normally use oxytocin and cytotec. When we don't have these drugs in our hospital pharmacy, the patient attendants go out to buy them in private pharmacy and it might be a bit too late to provide good service by the time they get back to us with these drugs" **Nurse, Female-FGD1.**

Furthermore, nurses and midwives described the limited number of ambulances at the health centers level as an important barrier to better service provision. They highlighted that they receive some of the patients already in critical conditions due to travel delays related to the lack of transport/ambulances.

"The real problem starts at health centres because they may wish to transfer a mother with a complication but they fail to get transport for her. Some health centres do not have ambulances. You can see how much time it would then take for an ambulance to leave here and go to pick up that mother at a health centre. That ambulance will reach there when this mother is already in critical conditions"- **Midwife, Female-FGD2.**

Another contextual factor highlighted by nurses and midwives is the financial barrier among the patients. Participants described how financial barriers made service provision challenging for some patients. The lack of financial means for some mothers make them delay to present themselves to the hospital. And by the time they come, they are in a critical condition.

"Some patients are coming to hospital too late due to financial problems and in this case, both the mother and her baby have started to have some complications. It is a fact that sometimes, you fail to save a newborn's life not because you didn't have enough skills but because you started attending to the mother when the situation had gone beyond boundaries" **Nurse, Male-FGD1.**

Participants also indicated that some patients cannot afford drugs and nurses and midwives cannot assist all of them with the emergency kits available which contain few emergency medications and materials. Other patients also get issues in transfer when they cannot afford the transfer fee.

"Another thing is lack of financial means by some patients to afford drugs. It is a fact that we have emergency kits to assist such patients but you may not get everything in those kits that is required for all the cases" **Nurse, Female-FGD2.**

Another participant stated that:

"Sometimes we may have patients who cannot afford the services we provide. For instance, when we have a serious case to transfer, such a patient may not afford the transfer fee...When then time is being wasted discussing this, a patient might get in worse conditions" **Midwife, Female-FGD4.**

On the other hand, nurses and midwives described low literacy and social-cultural and beliefs behaviors among mothers who visit the hospitals as contributing factors to the outcomes of delivery. Participants indicated that the use of traditional medications was prevalent in local communities. They indicated that most of the mothers coming to the hospitals for delivery, first take traditional medicines and these traditional medicines make the newborn suffer. As a result, the baby is born very weak and subject to neonatal resuscitation which is mainly hard to manage because the newborn in most cases has inhaled these traditional medicines.

> *"Nowadays, based on my personal observation, some mothers come to hospital after taking some traditional medicines and this leads to aspiration syndrome and make the resuscitation of a newborn difficult"***Nurse, Female-FGD3**.

Another participant said that:

> *"I can add that there is a problem of literacy with the mothers we work with. They think that traditional healers help them to have live newborns. A large number of mothers who come here for delivery, they first take those traditional medicines. Such traditional drugs make the babies suffer a lot"***Midwife, Female-FGD3**.

Other participants described an overall lack of awareness about the value of medical care during childbirth among some mothers who think that medical care is not enough that it has to be supplemented by traditional healers. There are misconceptions surrounding childbirth that mothers should take traditional medicines before delivery if they want to come up with a live newborn. Further, nurses and midwives expressed the need of health programs to increase the awareness of value of medical care during childbirth among the population.

> *"I think there should be initiatives to tell the mothers to stop taking traditional medicines. They should let these mothers know about the negative effects of these medicines and ask them to stop such practices. This is a common practice with mothers who come here and it really has a negative effect on the newborns they give birth to"***Midwife, Female-FGD2.**

Discussion

Our research contributes to existing literature insights from in-depth exploration of the perceptions and experiences of nurses and midwives on obstetric care services particularly, with the management of birth related complications such as PPH and NR. The participants reflected on survey results and offered diverse explanations of the results. Participants also shared their lived experiences of managing PPH and NR and gave their opinions on what they believe is influencing their work as obstetric care givers in their respective hospital. Our findings illustrate the complexity of the process of managing birth-related complications in district hospitals of Rwanda. The three main themes from the FGDs with nurses and midwives were: reflections to baseline research results, self-reflections on the current practices, and contextual factors influencing the delivery of BEmONC services.

Reflections to baseline research results

The presented baseline research results were accepted as a true reflection of the reality of practice. Participants were shocked by the low knowledge and skills scores as well as the high number of unstable newborn and maternal outcomes. This made them reflect on their performance as a department and consequently provided possible explanations of the research results. Among the provided explanations, there were challenges such as staff shortages, limited in-service trainings, limited access to clinical guidelines, and lack of some essential materials. Similarly, a number of studies has explored the barriers to and facilitators of emergency obstetric care provision [35–38] and reported similar challenges in multiple health facilities in LMICs. Therefore, engaging nurses and midwives on how they perceive and reflect on obstetric care services reveals realities of practice that decision makers would consider when putting in place strategies to improve obstetric care particularly in low and middle income countries.

Moreover, other participants explained that their low scores in the knowledge and skills surveys were linked to their high workload. They indicate that their failure was due to the fact that they did not fully concentrate while filling the survey questionnaires because they were thinking of the huge work ahead. In the same vein, a study that explored perceptions of emergency obstetric care providers in Malawi on the critical factors of staff shortages and workload in their health facilities, reported the shortage of staff coupled with the unmanageable workloads that exceeded their capacity to cope as key contributors to the substandard provision of obstetric care [39].

Self-reflections on the current practices

Our findings revealed that effective teamwork is a key facilitator to better provision of care. The participants acknowledged mutual support when managing PPH and NR and valued their attitudes of sharing responsibilities. Comparable findings have been seen in a study which

focused on optimizing teamwork and leadership in reducing risk in maternity [40]. Another study which documented lessons from a series of research on teamwork, leadership and team training with regards to what makes maternity teams effective and safe [41] reported that teamwork is essential for managing complex pregnancies. Similarly, participants in the study perceived that peer support make a noticeable difference to team effectiveness and patient safety during obstetric emergencies [41]. Evidence of benefits of teamwork in maternal and newborn care have been indicated by several researchers [42–44]. Hence, teamwork is recommended when dealing with PPH and NR. Also, in the current study, the commitment to the professional ethics has been linked to teamwork and shown to promote staff motivation and improve obstetric care services.

Additionally, in the current study, on site mentorship sessions and clinical staff meetings, were identified as learning opportunities and key facilitators of evidence – based care provision. They helped nurses and midwives to update their knowledge and skills through critical discussions of specific cases and hands on practices with mentors. Other mentorship initiatives in partnership with the Human Resources for Health (HRH) Program have also been beneficial to the improvement of health service delivery in Rwanda [45, 46]. Similarly, a study in India found that a seven-month simulation-enhanced mentoring program for nurses and midwives from 320 primary health clinics improved their skills and confidence in managing common obstetric and neonatal complications [37]. Similar findings were documented in a prospective before-and-after study in Malawi, which evaluated the impact of a hospital-based mentoring program about EmONC on knowledge and skills among health providers [47]. The study has reported an increase of both short- and longer-term improvement in BEmONC knowledge and skills [47]. However, more research is required to assess whether the improvement in knowledge, skills and confidence leads to changes in practices that improve maternal and neonatal outcomes.

However, this study has identified barriers related to staff development. Study participants acknowledged having insufficient skills in PPH management and NR. They linked this challenge with the lack of professional development courses and the lack of culture of reading. Nurses and midwives emphasized on their need of continuous learning opportunities as the medical science evolves with new discoveries and approaches to deal with birth complications. They mainly highlighted how difficult it is to access continuous learning opportunities. Other studies have similarly noted that access to continuing professional development opportunities for nurses and midwives is often difficult, especially in LMICs [48, 49]. Filby et al. (2016) found that the lack of investment in continuing education prevents quality midwifery care [36]. Opportunities to address the in-service training challenges are available through short courses using competency-based learning curricula. However, context realities should be considered in terms of costs. The adoption of innovative methods of on job learning that utilize technology such as eLearning and mLearning could be adopted where face to face trainings are not accessible and less affordable.

In addition, the access to relevant and up-to-date clinical guidelines was another important point of discussion raised by nurses and midwives. Study participants acknowledged the importance of evidence-based clinical guidelines in continuous learning and its support in decision making at the point of care. However, the accessibility is still a challenge, as the available paper based clinical guidelines are few and not updated. Nurses and midwives also indicated that it is hard for them to find time to read the guidelines filed in cupboards. Likewise, a recent study mapped evidence on human resource-related challenges to quality facility-based newborn care provision by nurses and midwives [48] and reported the lack of access to current evidence-based guidelines as a common complaint in LMICs [48]. Other studies indicated that the care during labour and childbirth following evidence-informed clinical guidelines is associated with better patient outcomes [50–53]. Guidelines change regularly and thus dissemination and methods of updating nurses and midwives on new knowledge are essential. But, simple dissemination of paper-based clinical guidelines is ineffective as it was noted by our study participants. Electronic clinical guidelines and electronic decision support tools could be envisaged leveraging the rapidly increasing rates of smartphone access and mHealth technologies. Yet, additional research is needed on electronic clinical decision support tools, particularly in LMICs.

Contextual factors influencing the delivery of BEmONC services

The current study shown that the good leadership and management of the district hospitals is an essential facilitator of care provision for PPH management and NR. Participants referred to the good leadership in consideration of service organization (distribution of tasks and allocation of duties). The hospital support was an additional facilitator of care provision, particularly with regards to achieving sustainable improvements and the particular support in terms of resources and suppliers. Katie et al. (2013) similarly suggested that management practices coupled with leadership behaviours can make a huge difference to outcome and experience for women and their companions [40]. Other studies have also documented the benefits of hospital leadership on patients'

outcomes [54, 55]. Therefore, leadership is considered a core element for a well-coordinated and integrated provision of care.

However, the staff shortage was highlighted as a significant barrier to good service provision for PPH management and NR. Nurses and midwives indicated that the number of staff was very low compared to the number of patients to take care of. Similar findings have been reported in other LMICs [39, 56]. A study by Dani et al. (2020) found that healthy term infants' neonatal outcome is negatively associated with a low midwife-to-infant ratio [57]. Similarly, Christine et al. (2011) assessed the association between nursing staffing and patient outcomes and reported that inappropriate nursing staffing was linked to negative patient outcomes [58]. Other studies have also documented the effect of staff shortage on adverse events and increased medical costs [56, 59–61]. Moreover, Sosa et al. (2018) proposes the availability of a one midwife to one woman ratio for all women in labour [62]. Thus, an appropriate patient: staff ratio is revealed to be a determinant of quality obstetric and better maternal and newborn outcomes.

Also, the limited number of staff coupled with staff rotations and turnovers and a limited number of doctors posed significant barriers to PPH management and NR services in the two district hospitals under study. Similar human resource constraints have been reported in other LMICs [63]. Our study findings suggest that there is a problem of shortage of staff which leads to the fact that few nurses and midwives available work under pressure with less time spent with each woman leading sometimes to a lack of proper care. The resulting low quality of services is unpreventable. Therefore, one of the priorities is the need that policy makers put in place strategies that will help to increase the number of trained staff in obstetric care.

Other challenges identified in this study included the lack of some necessary medical supplies and problems related to the referral system such as few ambulances at the health center level. These findings were congruent with a report from a study conducted in India which revealed physical resource shortage as a barrier to the provision of optimal obstetric and neonatal emergency care [37]. Another study which identified barriers associated with the referral of emergency obstetric cases to a national referral centre in Ghana reported the problems with referral transportation system highlighting limited ambulances as a critical barrier to obstetric care service provision [64]. The quality of care of hospitals providing obstetric care has also been shown to be affected by a lack of required equipment and drugs as demonstrated by studies conducted in past [35]. Therefore, understanding these challenges from the healthcare providers' perspectives is important and informative to policy makers in order to put in place context specific strategies to improve obstetric care.

Additionally, in this study, financial barriers were found to play a crucial role in delaying the access to medical care when needed. Nurses and midwives discussed on how patients with low economic status were likely to reach the hospital late and in critical condition. Other patients were not able to afford drugs and got issues in transfers. Geleto et al. (2018) in his systematic review about access and utilization of emergency obstetric care (EmOC) at health facilities in sub-Saharan Africa [65] reported that financial barriers prevent mothers to access EmOC when needed. Other studies have also noted the burden of financial barriers to maternal care particularly in Sub-Saharan Africa [63, 66]. Initiatives to reduce maternal mortality in Rwanda have included the facilitation of access to health care services with the help of the national medical insurance scheme [67]. The current hospital delivery rate in Rwanda is 91% [11]. However, some women still face financial barriers to afford other required fees like transfer fees from health centers to district hospitals which delay the care they receive for instance in case of PPH. There is need for more support to the very poor patients for healthcare services.

Moreover, the current study identified barriers related to patient challenges such as social-cultural beliefs and behaviors. With regards to cultural beliefs and behaviors, nurses and midwives were referring to the use of traditional medicines by women while these traditional drugs have a negative impact on the newborn health outcome. Similar findings were documented in a study conducted in Zambia which revealed multiple interconnecting factors linked with cultural beliefs that influence traditional medicine use among pregnant women [68]. Women believed that traditional medicines help them with labour induction, and prevention of childbirth complications [68]. From the modern medical profession perspective, these traditional medicines are always associated with adverse health outcomes, specifically for the newborn [68]. A lack of awareness about the value of medical care during childbirth among some mothers was also mentioned. It is noteworthy, that in this study, we did not have the perspectives of patients on how they value medical care during childbirth. However, nurses and midwives based on their experience testify that the level of awareness on the benefits of medical care during childbirth is still low in the population, that is why they come to hospital after taking traditional medicines. Nyeko et al. (2016) explored the factors associated with herbal medicine use during pregnancy in Ugandan women [69] and reported an association of cultural beliefs with the use of those drugs. This therefore calls for population sensitization programs

on the dangers of use of traditional medicines in pregnancy, as well as the benefits of medical care during childbirth.

Strength and limitations of the study

The limitation of this study was that nurses and midwives were recruited from only two district hospitals. Therefore, the current study will not generalize findings. However, we believe our findings contribute to an increased understanding of the complexity of PPH management and NR services provision in Rwanda. The strength of this study was a comprehensive sampling of the nurses and midwives with different level of specialization. Both young and more experienced nurses and midwives were represented in the focus group discussions. The interviews were thoroughly analysed to define the three overarching themes and the subthemes. Recruitment was continued until saturation of the data and until any new information was obtained. One FGD included an additional two members who were the maternity matrons and their contribution increased the strength of findings.

Conclusion

Nurses and midwives were concerned with the survey results and the records review findings. Among possible explanations of the results, the discussions focused on limited in-service trainings, staff shortage, limited clinical guidelines and the lack of some essential materials. Participants also reflected on their current practices focusing on team work, commitment to professional ethics, insufficient skills, learning opportunities, and evidence-based clinical guidelines. Additionally, the study has revealed numerous contextual factors influencing the delivery of BEmONC services in Rwanda with a particular focus on PPH management and NR. The identified factors included; leadership and management, the shortage of staff and heavy workloads, the limited resources, and the profile of clients in relation to their socio-economic status as well as their socio-cultural beliefs and behaviors. Both the self-reflections and the contextual factors are particularly important to recognize and to address when possible, as they significantly affect the quality of facility-based obstetric care. Moreover, our study participants emphasized the need for innovative technology approaches such as eLearning, mLearning, and electronic evidence-based clinical guidelines to help them in continuous learning and clinical decision making at the point of care when dealing with birth complications. Further, the study provides evidence on how nurses and midwives are better sources of context-specific information through situation based-analysis of practices. Our study findings could inform policy reviews to address real practice challenges and promote identified facilitators in order to improve maternal and newborn care services. Also, an in-depth understanding of the reality of practices from the perspective of nurses and midwives, who are the frontline healthcare workers in obstetric care, is essential to enable the design of contextually-targeted interventions to improve facility-based childbirth care in LMICs, including Rwanda.

Abbreviations

BEmONC: Basic Emergency Obstetric and Newborn Care; EmOC: Emergency obstetric and newborn care; LMICs: Low- and middle-income countries; PPH: Post-partum hemorrhage; NR: Neonatal resuscitation; WHO: World Health Organization; UNICEF: United Nations International Children's Emergency Fund; UNFPA: United Nations Population Fund; FGD: Focus group discussion; CHWs: Community health workers

Supplementary Information

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Additional file 1.
Additional file 2.

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Authors' contributions

AN, DNC, MN and, LI were involved in the conception and design of the study. AN drafted the manuscript. DNC assisted with data analysis and interpretation. DNC, MN, and LI reviewed the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The dataset generated for this study will be made available from the corresponding author on a reasonable request.

Declarations

Ethics approval and consent to participate

Ethical approvals were obtained from the Human Research Ethics Committee of the University of the Witwatersrand (M190258) and the University of Rwanda, College of Medicine and Health Sciences' Institutional Review Board (No. 377/CMHS IRB/2018). All participants gave written informed consent and consents for recording the interviews prior to their participation. Participants were assured that their identities would remain anonymous in all reporting of the study and that their personal information would be kept confidential. All methods in this study were carried out in accordance with relevant guidelines and regulations in the Ethical Declarations.

Consent for publication
Not applicable.

Competing interests
None declared.

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Appendix 16. Original Paper III

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Human Resources for Health

RESEARCH Open Access

The effect of an mLearning application on nurses' and midwives' knowledge and skills for the management of postpartum hemorrhage and neonatal resuscitation: pre–post intervention study

Aurore Nishimwe[1,2*], Latifat Ibisomi[1,3], Marc Nyssen[4] and Daphney Nozizwe Conco[1]

Abstract

Background: Globally, mobile learning (mLearning) tools have attracted considerable attention as a means of continuous training for healthcare workers. Rwanda like other low-resource settings with scarce in-service training opportunities requires innovative approaches that adapt technology to context to improve healthcare workers' knowledge and skills. One such innovation is the safe delivery application (SDA), a smartphone mLearning application for Basic Emergency Obstetric and Neonatal Care (BEmONC) content. This study assessed the effect of the SDA intervention on nurses' and midwives' knowledge and skills for the management of postpartum hemorrhage (PPH) and neonatal resuscitation (NR).

Methods: The study used a pre–post test design to compare knowledge and skills of nurses and midwives in the management of PPH and NR at two measurement points: immediately prior to SDA intervention and after 6 months of SDA intervention. The intervention took place in two district hospitals in Rwanda and included 54 participants. A paired-sample t-test was used to measure the pre–post intervention, mean knowledge and skills scores differences. Confidence intervals (CIs) and effect size were calculated. A t-test and a one-way Anova were used to test for potential confounders.

Results: The analysis included 54 participants. Knowledge scores and skills scores on PPH management and NR increased significantly from baseline to endline measurements. The mean difference for PPH knowledge is 17.1 out of 100; 95% CI 14.69 to 19.49 and 2.6% for PPH skills; 95% CI 1.01 to 4.25. The mean difference for NR knowledge is 19.1 out of 100; 95% CI 16.31 to 21.76 and 5.5% for NR skills; 95% CI 3.66 to 7.41. Increases were unaffected by participants' attendance to in-service training 6 months prior and during SDA intervention and previous smartphone use. However, pre- and post-intervention skills scores were significantly different by years of experience in obstetric care.

Conclusion: The SDA intervention improved the knowledge and skills of nurses and midwives on the management of PPH and NR as long as 6 months after SDA introduction. The results are highly relevant in low-income countries

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like Rwanda, where quality of delivery care is challenged by a lack of in-service continuous training for healthcare providers.

Keywords: Postpartum hemorrhage, Neonatal resuscitation, mHealth, Safe delivery application, Rwanda

Background

According to WHO, Global numbers from the year 2017 estimates show that 295,000 women die during pregnancy and childbirth [1]. It is also estimated that 2 million stillbirths and 2.5 million early newborn deaths occur each year worldwide [2, 3]. More than 90% of these deaths happen in low- and middle-income countries, like Rwanda [4]. Leading experts state that between 70 and 88% maternal and newborn deaths are preventable or have treatable causes [5–8]. In Rwanda, the most frequent birth complications are postpartum hemorrhage (71.6%) and newborn asphyxia and their complications (38%) [9]. Strategies for prevention and treatment of birth complications have been proposed by the WHO, UNICEF, and UNFPA in a set of seven signal functions referred to as Basic Emergency Obstetric and Newborn Care (BEmONC). The BEmONC services are mostly provided by nurses and midwives in low-resource settings [10].

Nurses and midwives, particularly in sub-Saharan hospitals, are the key clinicians in birth care. But, substandard performance of nurses and midwives in managing birth complications has been documented widely as a major cause of maternal and newborn deaths in hospital settings globally [11]. Several studies have documented that knowledge and skills of nurses and midwives in low-resources settings are not always at an acceptable level despite their previous education [10–16]. Hence, improving competency of nurses and midwives could improve maternal and newborn outcomes. One of the approaches to improve competency of nurses and midwives is to conduct regular in-service training courses. Hosey et al. (2016) documented that promoting continuous professional development of midwives presents a constant promise of more effective and safe birth care in low-resources settings [17]. However, different logistical and financial barriers can make this approach unachievable [18, 20]. Given the accessibility of mobile phones in Africa, it is suggested that mLearning applications that provide essential obstetric training through instructional videos and self-directed learning options, such as the Safe Delivery mHealth Application (SDA), can overcome these barriers and improve birth care outcomes [19–22].

A number of studies have investigated the effectiveness of mobile health (mHealth) interventions in maternal and newborn health initiatives in low-income countries [23, 24]. For instance, an mLearning pilot study about delivering family planning refresher training using interactive voice response and text messages revealed a substantial increase in knowledge of contraceptive side effects among nurses and midwives in Senegal [25]. On the other hand, Tomlinson el al. (2013) highlighted the fact that the enthusiasm for effective mHealth interventions in sub-Saharan Africa is high, but little is known about their efficacy or effectiveness in resource-limited settings [26]. Also, most of the studies examining mLearning tools are of poor methodological quality [21]. There is limited evidence on the contribution of mLearning applications on healthcare workers' knowledge and skills particularly in low-income countries [27]. Hence, there is a need for evidence of mLearning applications benefits as means of continuous training without interrupting healthcare services. Therefore, this study assessed the effects of the SDA mLearning application on nurses' and midwives' knowledge and skills in the management of the most frequent birth-related complications of postpartum hemorrhage (PPH) and newborn asphyxia in Rwanda.

The SDA is a BEmONC mLearning smartphone application developed by the Maternity Foundation, University of Copenhagen, and the University of Southern Denmark [28]. The SDA was designed to reinforce the professional competences of skilled birth attendants on how to manage BEmONC by means of an mLearning platform made of animated instructional videos and a self-explanatory learning platform called "MyLearning". The videos last about 7 to 15 min and can be viewed either in full or by chapter. While, the learning platform allows the user to enter into his/her personalized learning journey and further improve his/her knowledge of the content provided on the SDA. The learning platform offers an opportunity to the user to test his or her knowledge using the MyLearning questionnaires. The learner moves from the beginner, intermediate, expert levels and reaches the Safe Delivery Champion level and gain a certificate as he/she passes the quizzes. We investigated whether Rwandan nurses and midwives' use of SDA had an effect on their knowledge and skills with regards to PPH management and NR.

Methods

Study setting

The study took place in two district hospitals in Rwanda: Masaka hospital in Kigali, an urban province; and

Nyamata hospital located in the eastern rural province [29]. The two hospitals were selected out of 12 district hospitals in the two provinces because both had a high number of deliveries per year [30]. The two hospitals have been offering BEmONC services for more than 5 years.

Study participants

Nurses and midwives working in the maternity departments of the selected hospitals, who deal with birth care were invited to participate in the study. The inclusion criteria for nurses and midwives were set as follows: having a work experience of at least 6 months in obstetric care, being full-time employed in the selected hospital, and willing to participate in the study. The study participants included 33 midwives and 21 nurses.

Study design

The study adopted a pre–post test design to compare knowledge and skills of nurses and midwives in the management of PPH and NR at two measurement points: pre and post the SDA intervention. The study was carried out in four phases: establishing the baseline, the educational sessions, the intervention and the endline. The baseline and endline surveys were conducted pre and post the intervention, respectively. The 6-month intervention period was preceded by training of the participants on how to use the SDA. The study took place between July 2019 and April 2020. Figure 1 provides more details on this study design.

Description of the SDA intervention

The SDA is an mLearning application designed to provide training for health care providers in low-income countries on how to manage obstetric and neonatal emergencies. The SDA conveys knowledge and skills, such as how to ventilate a newborn in need of resuscitation or how to remove a retained placenta by means of visual guidance using animated instructional videos and a self-explanatory learning platform. The SDA also contains a catalog with essential obstetric drugs and equipment. The content of the SDA is based on WHO clinical guidelines on BEmONC and has been validated by an international group of global health experts [31]. All features and functions in the SDA are designed for low-literacy and low-income settings and work off-line once downloaded. It can thus be adapted to local contexts and policies. The SDA can be downloaded free of charge for iPhone at https://itunes.apple.com/dk/app/safe-delivery/id985603707?mt=8 and for Android at https://play.google.com/store/apps/details?id=dk.maternity.safedelivery&hl=en.

Smartphones with the SDA were implemented at two district hospitals for a 6-month period. Nurses and midwives working in the maternity departments of the selected hospitals received a half-day SDA introduction training. The training encompassed a description of the SDA features and modules and an explanation of how to use the smartphone and SDA with joint video viewing and interactive exercises in small groups on using the SDA as a learning tool. Each of the study hospitals (Masaka and Nyamata) was allocated three smartphones, with pre-installed English and French versions of the SDA. Participants who owned smartphones, were encouraged to download the SDA for use during the training. The majority of participants ($n=47$) downloaded the SDA on their personal smartphones for the training. During the 6-month SDA intervention, nurses and midwives used the SDA in a personalized learning journey to train their knowledge and skills on how to manage obstetric and neonatal emergencies with the assistance of the SDA installed on their personal smartphones or the smartphones provided by the researcher. The research team ensured that the provided smartphones were available to the team on duty at all times. The intervention also entailed two visits per week by the

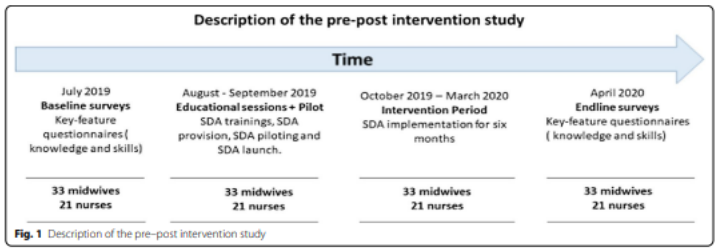

Fig. 1 Description of the pre–post intervention study

researcher and four research assistants to each of the study hospitals. During the visits, the researcher and the research assistants observed how the participants were using the SDA and encouraged them to watch the videos while they were there, they also provided guidance on how to start their learning journeys and made sure that each participant started learning for the PPH and NR modules.

Measurement and data collection

The primary outcomes of the study were knowledge scores and skills scores of nurses and midwives. Self-administered key feature questionnaires developed and tested by Maternity Foundation were adopted, only questions regarding PPH and NR were considered. Knowledge and skills scores were measured for 2 BEmONC services, PPH management and neonatal resuscitation. The research instrument included questions on PPH management and NR knowledge and skills, demographic information, as well as exposure to in-service education on the topics under study. The knowledge questionnaire consisted of clinical content questions on causes, consequences, prevention, treatment and management of PPH and NR. The knowledge questionnaire includes 36 knowledge questions for PPH management and 37 knowledge questions for NR with single and multiple responses options. The skills were evaluated by means of a self-administered questionnaire with simulated clinical cases due to technical difficulties of evaluating skills by change in real practice. The skills questionnaire comprised six clinical scenarios simulating PPH cases for PPH management and four clinical scenarios simulating NR cases for NR with single and multiples responses options. The collected demographic data of the participants included age, gender, education level, years of experience in obstetric care, hours spent per week in providing obstetric care, and number of deliveries participated in monthly. In addition, we asked participants if they have received any in-service training about PPH management and/or neonatal resuscitation during the 6 months prior or during the SDA intervention period. This question helped the researcher to understand more about the influence of the SDA or other available in-service training. We also asked participants if they have previously used smartphones to capture their experience with smartphones.

A total of 54 nurses and midwives completed either the English or the French form of self-administered questionnaires at baseline and at 6 months post-intervention. English and French languages are both professionally used in Rwanda. Baseline measures were taken prior to the training of nurses and midwives on the use of the SDA and included: demographic data; knowledge of nurses and midwives in the management of PPH and NR; and skills of nurses and midwives in managing PPH and NR. All data were collected on paper in a classroom setting. Six months after the SDA introduction, knowledge and skills were measured a second time in the classroom setting using the same data collection instruments.

Data management and analysis

The data were entered and checked for errors in Microsoft Excel and subsequently transferred and analyzed in Stata version 16 (StataCorp LLC). Descriptive summary statistics were computed on demographic data including age, gender, education level, years of experience, hours spent per week in providing obstetric care, delivery participated in monthly, previous use of smartphone, and in-service training for 6 months prior and during SDA intervention. Since the study targeted all nurses and midwives working in the maternity department of the selected hospitals, all the eligible participants in the maternity department, a sample of more than 30 participants was required to support the use of parametric statistical tests.

Knowledge and skills scoring were calculated by dividing the number of questions answered correctly by the total number of questions times a hundred. Respondents who scored 50% and above were considered knowledgeable. Further, Mean scores across all knowledge and skills scores were computed. A paired-sample t-test was used to measure the pre–post intervention, mean knowledge and skills scores differences (where the dependent variable was the mean difference in change on scores for the two measurements, baseline and endline). Confidence intervals (CIs) and effect size were calculated. To test for potential confounding, using a t-test, pre–post intervention mean knowledge and skills scores were compared and between group differences were calculated to examine the role of in-service training and previous smartphone use on test scores. One-way analysis of variance (ANOVA) was used to compare means scores across the three categories of experience in obstetric care (group 1: 1 year to 5 years, group 2: 6 years to 10 years, group 3: above 10 years) for pre- and post-intervention results. Significance level was set at $p < 0.05$.

Ethics approval

This study has been approved by the Human Research Ethics Committee of the University of the Witwatersrand (M190258) and the University of Rwanda, College of Medicine and Health Sciences' Institutional Review Board (No. 377/CMHS IRB/2018). Written consent was obtained from each participant. Confidentiality of the participants was maintained at all times. Questionnaires were number-coded thereby keeping the identity of the participants anonymous.

Results

Demographic characteristics of study participants

A total of 54 participants, 33 midwives and 21 nurses completed the surveys. More than a half were from Masaka district hospital ($n=30$, 56%), the majority were female ($n=33$, 61%), their average age was 33 years (SD = 7.1). The level of education was predominantly the advanced diploma (A1) in midwifery with 27 of 54 (50%) participants having A1 level in midwifery. The least represented level of education was the secondary school level (A2) in nursing with only one participant with A2 level in nursing. The majority of the participants had less than 6 years of experience in obstetric care ($n=32$, 59%), spent more than 10 h per week providing obstetric care ($n=40$, 74%) and participated in more than 10 deliveries per month ($n=41$, 76%). Three participants have received BEmONC in-service training during the 6 months of the SDA intervention. Four participants had never used a smartphone before the study. More details are shown in Table 1 below.

Table 1 Demographic characteristics of study participants ($n=54$)

	n (%)
Hospital affiliation	
Masaka District Hospital	30 (56)
Nyamata District Hospital	24 (44)
Gender	
Male	21 (39)
Female	33 (61)
Education level	
Midwife A0	6 (11)
Midwife A1	27 (50)
Nurse A0	5 (9)
Nurse A1	15 (28)
Nurse A2	1 (2)
Years of experience in obstetrical care	
1–5	32 (59)
6–10	15 (28)
> 10	7 (13)
Weekly workload in obstetrical care (h)	
0–5	4 (7)
6–10	10 (19)
> 10	40 (74)
Number of deliveries past month	
0–5	8 (15)
6–10	5 (9)
> 10	41 (76)
In-service trainings past 6 months	
No	51 (94)
Yes	3 (6)
Experience with smartphone	
Tried using one	50 (93)
Never tried using one	4 (7)
Age, years, mean (SD)	33 (7.1)

% weighted percent, *SD* standard deviation

Pre–post SDA intervention differences in knowledge scores for PPH management and NR

The mean difference in PPH knowledge from pre- to post-test was statistically significant; mean difference = 17.1% (SD = 8.8, 95% CI 14.7–19.5); $p<0.001$. The findings suggest a large effect size for PPH knowledge scores differences, Cohen's d score = 1.8. Similarly, the mean difference in NR knowledge from pre- to post-test was statistically significant; mean difference = 19.1% (SD = 9.9; 95% CI 16.3—21.8); $p<0.001$. The findings suggest a large effect size for NR knowledge scores differences, Cohen's d score = 1.7. We found a significant association between the SDA intervention and nurses' and midwives' knowledge on both PPH and NR knowledge, 6 months after baseline (Table 2).

Pre–post SDA intervention differences in skills scores for PPH management and NR

The mean difference in PPH skills from pre- to post-test was statistically significant; mean difference = 2.6% (SD = 5.9, 95% CI 1.1, 4.3); $p=0.002$. The findings suggest a small effect size for PPH skills scores differences, Cohen's d score = 0.3. Similarly, the mean difference in NR skills from pre- to post-test was statistically significant; mean difference = 5.5% (SD = 6.9; 95% CI 3.7, 7.4); $p<0.001$. The findings suggest a medium effect size for NR skills scores differences, Cohen's d score = 0.7. We found a significant association between the SDA intervention and nurses' and midwives' skills on both PPH and NR skills, 6 months after baseline (Table 3).

Potential confounders

The comparisons of PPH and NR mean knowledge and skills scores by in-services training (6 months prior the intervention and 6 months during the intervention period) across the baseline and endline groups showed that there were no significant differences along in-service training lines in the pre- and post-test for both PPH and NR (Table 4). Analysis of knowledge and skills scores by previous smartphone experience did not show a significant difference for PPH and NR scores on both pre- and post-tests (Table 4). Although participants who had smartphone experience scored slightly higher on the PPH skills post-test, there was no significant difference.

Table 2 Differences in mean knowledge scores pre- and post-SDA intervention ($n=54$)

	Mean, SD	95% CI	*P* value	Cohen's d
PPH knowledge scores (out of 100)				
Pre, mean (SD)	45.8 (9.2)	(43.4, 48.3)	*<.001*	1.8
Post, mean (SD)	62.9 (9.4)	(60.4, 65.5)		
Pre–post difference, mean (SD)	17.1 (8.8)	(14.7, 19.5)		
NR knowledge scores (out of 100)				
Pre, mean (SD)	48.6 (12.3)	(45.3, 51.9)	*<.001*	1.7
Post, mean (SD)	67.7 (10.2)	(64.9, 70.4)		
Pre–post difference, mean (SD)	19.1 (9.9)	(16.3, 21.8)		

Wt.% weighted percent, *NR* neonatal resuscitation, *PPH* postpartum hemorrhage

Table 3 Differences in mean skills scores pre- and post-SDA intervention ($n=54$)

	Mean, SD	95% CI	*P* value	Cohen's d
PPH skills scores (out of 100)				
Pre, mean (SD)	63.4 (9.8)	(60.8, 66.2)	*0.002*	0.3
Post, mean (SD)	66.1 (11.2)	(63.1, 69.2)		
Pre–post difference, mean (SD)	2.6 (5.9)	(1.1, 4.3)		
NR skills scores (out of 100)				
Pre, mean (SD)	56.5 (7.1)	(54.6, 58.5)	*<.001*	0.7
Post, mean (SD)	62.1 (8.4)	(59.8, 64.4)		
Pre–post difference, mean (SD)	5.5(6.9)	(3.7, 7.4)		

Wt.% weighted percent, *NR* neonatal resuscitation, *PPH* postpartum hemorrhage

Table 4 Differences in knowledge and skills scores pre- and post-intervention, analyzed by in-service training and smartphone experience

	In-service training				Smartphone experience			
	Yes	No	Mean diff	*P* value	Yes	No	Mean diff	*P* value
PPH knowledge scores (out of 100)								
Pre, mean (SD)	49.7 (2.5)	45.7 (9.4)	4	0.468	46 (9.4)	44.5 (6.1)	1.5	0.756
Post, mean (SD)	61.6 (6.4)	63.1 (9.6)	1.5	0.805	63 (9.4)	63.3 (10.9)	0.3	0.953
PPH skills scores (out of 100)								
Pre, mean (SD)	54 (13.7)	59.3 (10.9)	5.3	0.424	59.1 (11.4)	58 (7.6)	1.1	0.851
Post, mean (SD)	60.6 (10.1)	66.4 (11.3)	5.8	0.392	66.9 (11.2)	56.8 (6.4)	10.1	0.083
NR knowledge scores (out of 100)								
Pre, mean (SD)	61.3 (6.4)	47.9 (12.2)	13.4	0.065	48.7 (12.3)	48 (14.3)	0.7	0.916
Post, mean (SD)	75 (8.2)	67.2 (10.2)	7.8	0.202	67.8 (10.3)	66.5 (10.3)	1.3	0.814
NR skills scores (out of 100)								
Pre, mean (SD)	53 (10)	56.7 (6.9)	3.7	0.379	56.4 (7.2)	58.3 (6.1)	1.9	0.615
Post, mean (SD)	59 (8.5)	62.2 (8.4)	3.2	0.522	61.8 (8.7)	65.3 (3.5)	3.5	0.435

Wt.% weighted percent, *NR* neonatal resuscitation, *PPH* postpartum hemorrhage

Similarly, there was no significant difference in mean change in PPH and NR knowledge from pre- to post-test among those experienced with smartphones and those who had never used them. Moreover, participants were classified into three groups according to their years of experience in obstetric care: group 1 (1 year to 5 years, $n=32$); group 2 (6 years to 10 years, $n=15$), group 3 (above 10 years, $n=7$). The ANOVAs indicated significant group mean differences only for the NR skills pre-test ($F(2,51)=5.31$, $p=0.008$) and for the NR skills post-test ($F(2,51)=4.83$, $p=0.012$) (Table 5). As shown in Table 6, a Tukey post hoc test revealed that pre-test

NR skills scores were statistically significantly higher in the group 1 compared to the group 3 ($p=0.006$). Similarly, post-test NR skills scores were statistically significantly higher in the group 1 compared to the group 3 ($p=0.011$). Also, post-test NR skills scores were statistically significantly higher in the group 2 compared to the group 3 ($p=0.023$). However, there were no statistically significant differences between the pre- and post-test NR skills scores in the group 2 compared to the group 1 ($p=0.641$ and 0.999, respectively). Also, there were no statistically significant differences between the pre-test NR skills scores in the group 3 compared to the group 2 ($p=0.058$).

Table 6 Paired comparisons for skills scores pre- and post-intervention, analyzed by years of experience

	P value for Paired Comparisons with Turkey's HSD		
	Group2 vs Group1	Group3 vs Group1	Group3 vs Group2
NR Skills scores (out of 100)			
Pre-test	0.641	*0.006*	0.058
Post-test	0.999	*0.011*	*0.023*

Wt.% weighted percent, *NR* neonatal resuscitation, *PPH* postpartum hemorrhage, *HSD* honestly significant test

Discussion

The current study assessed the effect of the SDA mLearning application on nurses 'and midwives' knowledge and skills in postpartum hemorrhage management and neonatal resuscitation in two district hospitals in Rwanda. A statistically significant increase, of the mean knowledge scores, was found post-SDA intervention, recording 17.1% for PPH management and 19.1% for NR. The increase of the mean skills scores for PPH management and NR was also statistically significant, at 2.6% and 5.5%, respectively. The significant increase in knowledge is further supported by Cohen d large effect size. On the other hand, for skills scores, NR had a medium effect size and PPH Management had a small effect size. The difference in the effect size between knowledge and skills could be associated with measurements tools utilized to evaluate skills because we did not assess skills in real practice rather used simulated clinical cases. The analysis of knowledge and skills scores by potential confounders (in-service training 6 months prior and during intervention and smartphone experience) did not show a significant difference for PPH and NR scores on both pre- and post-tests. However, the analysis of skills scores by years of experience in obstetric care has shown a significant difference in skills scores for both pre- and post-measurements in different categories of years of experience. This study is important because it addresses the need of a potential solution to nurses and midwives' problems of accessing up-to-date learning resources in low- and middle-income countries including Rwanda.

Our findings mirror those of other studies in two ways. First, the revelation that mHealth learning tools are essential for facilitating continuous learning and upgrading knowledge and skills of different health professional cadres is consistent with findings of a study conducted in Senegal that documented the association of a mLearning tool with sustained knowledge gains for family planning content [25]. The study highlighted the usefulness of mLearning to provide in-service training without interrupting health services [25]. Secondly, the potential of mLearning tools to improve healthcare workers' knowledge and skills which results in improvement of maternal and neonatal healthcare services in LMICs is

Table 5 Differences in knowledge and skills scores pre- and post-intervention, analyzed by years of experience

	Group 1 ($n=32$)	Group 2 ($n=15$)	Group 3 ($n=7$)	*Df*	*F*	*P* value
PPH Knowledge scores (out of 100)						
Pre, mean (SD)	46.8 (9.5)	46.2 (9.4)	41.1 (6.7)	(2, 51)	1.10	0.341
Post, mean (SD)	64.1 (9.4)	63.5 (10.1)	56.6 (5.9)	(2, 51)	1.96	0.151
PPH Skills scores (out of 100)						
Pre, mean (SD)	59.9 (12.2)	57.4 (10.1)	58.4 (7.7)	(2, 51)	0.27	0.767
Post, mean (SD)	66.9 (11.2)	66 (12.3)	62.6 (9.3)	(2, 51)	0.43	0.655
NR Knowledge scores (out of 100)						
Pre, mean (SD)	48.7 (13.4)	49.3 (10.7)	46.7 (11.9)	(2, 51)	0.11	0.899
Post, mean (SD)	67.8 (10.9)	68.5 (10.1)	65.6 (7.6)	(2, 51)	0.19	0.827
NR Skills scores (out of 100)						
Pre, mean (SD)	58.2 (6.7)	56.3 (6.5)	49.3 (6.2)	(2, 51)	5.31	*0.008*
Post, mean (SD)	63.4 (7.2)	63.3 (8.4)	53.4 (9.9)	(2, 51)	4.83	*0.012*

Wt.% weighted percent, *NR* neonatal resuscitation, *PPH* postpartum hemorrhage

corroborated by systematic reviews that demonstrated the effectiveness of mHealth interventions in maternal and child healthcare [32, 33]. These findings together underline the importance of mLearning tools for facilitating in-service training particularly in low-resources settings where continuous training opportunities are scarce and the costs of training are unaffordable.

The SDA mLearning application was associated with an increase in knowledge mean scores among nurses and midwives on PPH management and NR following the 6-month SDA implementation. Likewise, a mixed-methods feasibility and pilot cluster randomized trial using the safe delivery app study conducted in the democratic republic of Congo revealed a similar increase in PPH and NR knowledge scores among health workers at 3 months post-SDA intervention [34]. Several studies have shown that mHealth interventions can improve healthcare services delivery processes which lead to improved outcomes [35–37]. A study in Tanzania assessed performance and adoption of an eLearning system utilized by healthcare providers to enhance maternal and perinatal health care for a period of 18–21 months [38]. The study reported that healthcare providers had acquired and utilized new knowledge and skills in clinical practice at 89% level at the end of the intervention [38]. Another study in Nigeria provided health care workers with mHealth tutorial application for changing the knowledge and attitude on Ebola virus disease and reported an 11% significant improvement in average knowledge levels between pre- and post-intervention scores [39]. Our findings support those of other studies [34, 38] that the use of mHealth is perceived as an opportunity for personalized continuous learning with effects on health care workers' knowledge update. Therefore, it is important to highlight that mLearning tools such as the SDA could be considered as integrated parts of other efforts to support nurses and midwives continuous learning thus improving the quality of delivery care.

Moreover, the current study has found a significant association between the SDA mLearning application and skills of PPH management and NR among nurses and midwives. Similar findings were documented in a randomized clinical trial conducted in Ethiopia which determined the association between the safe delivery app and health care workers' knowledge and skills in neonatal resuscitation [31]. The trial reported a more than two-fold significant increase in health care workers' skills and knowledge scores for neonatal resuscitation, 6 months following the SDA intervention [31]. It is noteworthy that in our study, improvements in average knowledge and skills of PPH management and NR occurred across all cadres irrespective of their access to other available in-service trainings. However, the years of experience played a significant role in different skills scores for both pre- and post-tests in neonatal resuscitation. This can be partly explained by the fact that nurses and midwives might have been used to routine procedures in neonatal resuscitation. The effectiveness of the SDA mLearning application in changing nurses' and midwives' knowledge and skills of PPH management and NR may be attributed to disseminating educational materials in real time combined with the convenience of unrestricted access to online learning materials by nurses and midwives over an unlimited time period. This underlines the potential benefits of mLearning tools to enhance nurses' and midwives learning. mHealth tools in general present an opportunity for improving maternal health care services in underserved remote areas of low-resource settings by broadening knowledge and skills of healthcare workers.

The implications of this study are that the SDA intervention increases the knowledge and skills of nurses and midwives in managing obstetric and neonatal emergencies. Evolving efforts for continuing education in Rwanda and similar contexts should consider the integration of mLearning as an approach for training and as a job aid for BEmONC in order to reduce maternal and newborn mortality, as well as considering the integration of mLearning tools for other priority and emergent health problems. Challenges to implementation of quality BEmONC care, posed by gaps in the environmental context and resources, as well as the regulatory and accountability environment, must be considered and addressed alongside other programmatic measures such as quality improvement initiatives to target health system weaknesses.

Strengths and limitations of this study

The study has three limitations. First, it is limited by the small sample of 54 nurses and midwives, which reflects the fact that the SDA intervention was implemented only in two district hospitals due to economic barriers. Therefore, the current study will not generalize findings. Second, we acknowledge the limitation of findings when assessing skills using a self-administered questionnaire with simulated clinical cases. This was due to technical difficulties of evaluating skills by change in real practice. Third, we acknowledge that some of the improvements in knowledge and skills observed in this study may arise from exposure to other learning materials other than the SDA during the intervention period. Also, the increase in knowledge and skills does not necessarily equal better outcomes for mothers and newborns which is the ultimate goal. The findings in the current paper are part of a large study evaluating the feasibility of the SDA in Rwanda. Findings of the effect of the SDA on maternal

and newborn outcomes will be discussed in another paper.

Nevertheless, the evidence that the SDA intervention is effective in improving knowledge and skills of nurses and midwives in the management of PPH and NR sets the stage for expanding coverage and further testing of the SDA intervention to other hospitals in Rwanda. Additionally, the accuracy of our findings is increased by supporting the knowledge and skills surveys with focus group discussions with nurses and midwives, to provide context to and clarify reasons behind some participant responses. The findings of the focus group discussions will be presented in a separate paper.

Conclusion

In conclusion, the SDA mLearning application appears to be effective for improving nurses' and midwives' knowledge and skills in the management of PPH and NR. The changes in knowledge and skills recorded from the evaluation of this SDA mLearning intervention suggest that mLearning tools have potential for facilitating continuous training of nurses and midwives without interrupting healthcare services. The user-friendly nature of this SDA and regular access to updated learning materials via visual guidance using animated videos and a self-explanatory learning platform, streamed in real time to nurses and midwives, is a strong selling point of this SDA mLearning application. Using mLearning tools as a means of sustaining the knowledge and skills of nurses and midwives to manage delivery complications and improving maternal and newborn healthcare in LMICs should be explored further, especially given the increased global utilization of mobile technology and the corresponding economic benefit.

Abbreviations

BEmONC: Basic emergency obstetric and newborn care; LMICs: Low- and middle-income countries; mLearning: Mobile learning; mHealth: Mobile Health; SDA: Safe Delivery mHealth application; PPH: Postpartum hemorrhage; NR: : Neonatal resuscitation; SBAs: Skilled birth attendants; WHO: World Health Organization; UNICEF: United Nations International Children's Emergency Fund; UNFPA: United Nations Population Fund.

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Authors' contributions

AN, LI, MN, and DNC were involved in the conception and design of the study. AN drafted the manuscript. LI, MN, and DNC reviewed the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The dataset generated for this study will be made available from the corresponding author on a reasonable request.

Ethics approval and consent to participate

This study has been approved by the Human Research Ethics Committee of the University of the Witwatersrand (M190258) and the University of Rwanda, College of Medicine and Health Sciences' Institutional Review Board (No. 377/CMHS IRB/2018). Written consent was obtained from each participant. Confidentiality of the participants was maintained at all times. Questionnaires were number-coded, thereby keeping the identity of the participants anonymous.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Appendix 17. Original Paper IV

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RESEARCH ARTICLE Open Access

The effect of a decision-support mHealth application on maternal and neonatal outcomes in two district hospitals in Rwanda: pre – post intervention study

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Abstract

Background: Globally, mobile health (mHealth) applications are known for their potential to improve healthcare providers' access to relevant and reliable health information. Besides, electronic decision support tools, such as the Safe Delivery mHealth Application (SDA), may help to reduce clinical errors and to ensure quality care at the point of service delivery. The current study investigated the use of the SDA and its relationship to basic emergency obstetric and newborn care (BEmONC) outcomes for the most frequent complications in Rwanda; post-partum haemorrhage (PPH) and newborn asphyxia.

Methods: The study adopted a pre–post intervention design. A pre-intervention record review of BEmONC outcomes: Apgar score and PPH progressions, was conducted for 6 months' period (February 2019 - July 2019). The intervention took place in two district hospitals in Rwanda and entails the implementation of the SDA for 6 months (October 2019- March 2020), and included 54 nurses and midwives using the SDA to manage PPH and neonatal resuscitation. Six months' post-SDA intervention, the effect of the SDA on BEmONC outcomes was evaluated. The study included 327 participants (114 cases of PPH and 213 cases of neonatal complications). The analysis compared the outcome variables between the baseline and the endline data. Fisher's exact test was used to compare the proportions and test between-group differences and significance level set at $p < 0.05$.

Results: Unstable newborn outcomes following neonatal resuscitation were recorded in 62% newborns cases at baseline and 28% newborns cases at endline, *P*-value = 0.000. Unstable maternal outcomes following PPH management were recorded in 19% maternal cases at baseline and 6% maternal cases at endline, *P*-value = 0.048. There was a significant association between the SDA intervention and newborns' and maternal' outcomes following neonatal resuscitation and PPH management, 6 months after baseline.

Conclusion: The use of the SDA supported nurses and midwives in the management of PPH and neonatal resuscitation which may have contributed to improved maternal and neonatal outcomes during 6 months of the SDA intervention. The findings of this study are promising as they contribute to a broader knowledge about the effectiveness of SDA in low and middle income hospital settings.

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Keywords: Maternal outcome, Neonatal outcome, BEmONC, mHealth, Safe delivery application, Rwanda

Background

Mhealth refers to the practice of medicine and public health, supported by mobile devices (mobile phones, smartphones, tablets, smartwatches) [1]. Evidence suggests that mHealth applications are innovative approaches to improve the delivery of health care services [2]. Further, mhealth tools can help to reduce clinical errors and ensure quality care at the point of service delivery. There is growing evidence of the effectiveness of mHealth interventions in maternal and newborn health programs in low and middle-income countries (LMICs), particularly to improve adherence to treatment, meeting appointments, facilitate data collection, and the development of supportive networks for health professionals [3–6].

Among the many interventions currently being implemented to support maternal and newborn healthcare services, mHealth applications have been widely used in low-resources settings [4, 7–9] as a potential solution to maximize health providers' efficiency, health outcomes [9–11] and improve service utilization [2]. Common areas of application of mHealth tools include point-of-care decision-making support; provider-to-provider communication; and data collection [12, 13]. Though mHealth interventions are well received by healthcare providers [6, 14, 15] information about their effectiveness with regards to patient outcomes is limited [5, 9, 16].

Many interventions on the use of mHealth for improving maternal and newborns' health outcomes in sub-Saharan Africa mainly focused on timely access to health facilities including reminders for antenatal appointments and referrals of mothers [17]. For instance, the CommCare mHealth technology is a digital solution that has shown promising results in assisting community health workers (CHWs) in data collection, decision support, communications with clients and health centres, and access to educational training materials [18]. Few mHealth applications are addressing the support of healthcare providers at the point of care with the main focus on clinical decision support in order to improve maternal and newborns outcomes [5, 9, 11, 19–22]. The Safe Delivery mHealth Application (SDA) is one of the recent mHealth applications (loaded in smartphones) which avails BEmONC clinical guidelines to support nurses and midwives' clinical decisions [23].

Rwanda, a sub-Saharan African country, reports high maternal and neonatal deaths. In 2015, Rwanda's maternal mortality was estimated at 290 deaths per 100,000 live births and its neonatal mortality rate was 20 deaths per 1000 live births, respectively [24] despite 90% of deliveries taking place in healthcare facilities attended by health professionals [25, 26]. Common causes of these deaths are preventable including postpartum hemorrhage (22.7% of all documented cases) and newborn asphyxia and its complications (38%) [27–29]. Challenges faced by healthcare providers in Rwanda include poor access to clinical guidelines and the lack of timely response to pregnancy complications during delivery care [30, 31]. It is in this context that a mHealth application - a clinical decision support tool (SDA) to facilitate easy access to maternal and neonatal guidelines for routine and emergency obstetric and neonatal care was introduced. The SDA has been tested for its effectiveness through a randomized controlled trial conducted in Ethiopia [32]. The SDA has also shown a positive effect on nurses and midwives' knowledge and skills in the management of PPH and neonatal resuscitation in Rwanda [33]. This study investigated the use of the SDA and its relationship to BEmONC outcomes for the most frequent birth-related complications of PPH and newborn asphyxia in Rwanda. The current paper addresses one objective of a broad study about implementation of the SDA in Rwanda.

Methods

Study design

This was a pre–post intervention study done over a 14-month period. The study was conducted in three phases. The first phase was the pre-SDA intervention baseline study over a period of 6 months (February 2019 - July 2019). During this phase, a record review was conducted to document maternal and neonatal outcomes, PPH and Apgar score progressions, at baseline. The second phase, the SDA intervention (August 2019 - September 2019) comprised of the capacity building of nurses and midwives on the usage of the SDA; the SDA provision; the SDA piloting, and the launch of the SDA which marked the start of the SDA implementation. More details on the SDA training are documented in the protocol paper for this study [34]. The last phase was the 6 months of post-SDA intervention (October 2019- March 2020). Phase three encompassed the implementation of the SDA and another record review was conducted to document maternal and neonatal outcomes, PPH and Apgar score progressions, at endline. The data were collected from the delivery registries using data extraction forms. The collected data included patients' characteristics and information on maternal and

newborn outcomes, Apgar scores and PPH progressions, following NR and PPH management. The data were collected by the researcher and four research assistants. Data accuracy and transcription were checked by the researcher before analysis.

Study setting

The study was conducted in two district hospitals in Rwanda: Masaka hospital in Kigali, an urban province; and Nyamata hospital located in the eastern rural province [26]. The two hospitals were chosen out of 12 district hospitals in the two provinces because both recorded a high number of deliveries per year [24]. Compared to other rural-based district hospitals, Nyamata reported the highest maternal and neonatal mortality rates [30].

Study participants

The study participants included records on neonatal complication cases and PPH cases. The inclusion criteria for the cases of neonatal complications were set as babies born with asphyxia (Apgar score ≤ 7) and were subject to neonatal resuscitation. We excluded preterm births ($\leq$ 36 completed weeks of gestation) and births with major congenital malformations because prematurity and congenital complications other than the newborn asphyxia could influence the newborn outcome after resuscitation [35]. We have also excluded records with missing data on Apgar scores and neonatal outcome. On the other hand, the inclusion criteria for PPH cases were set as women who had a recorded amount of blood loss more than or equal to 500 mls and were subjected to PPH management. The records with missing data on PPH progression and maternal outcomes were also excluded. The study was conducted in three phases. Phase one, pre-intervention, included 126 cases of newborns asphyxia and 67 cases of PPH. Phase two, intervention, involved 33 midwives and 21 nurses who used the SDA in both Masaka and Nyamata district hospitals. Nurses and midwives were chosen because they are the frontline healthcare providers in childbirth care in district hospitals of Rwanda. The inclusion criteria for nurses and midwives were set as follows: having a work experience of at least 6 months in obstetric care and willing to participate in the study. All nurses and midwives ($n=54$) working in the maternity departments of the selected hospitals volunteered to participate in the study and they were trained on the use of SDA. Phase three, post-intervention, comprised 87 cases of newborns asphyxia and 47 cases of PPH. The flowchart in Fig. 1 shows the number of neonatal complication cases and PPH cases considered in the pre-intervention group (before the introduction of SDA) and the post-intervention group (after SDA).

Description of the intervention: implementation of the safe delivery mhealth application (SDA)

The SDA is a smartphone application developed by the Maternity Foundation, Copenhagen University, and the University of Southern Denmark. It is designed to support nurses and midwives in clinical decision making, by providing them with instant access to evidence-based BEmONC clinical guidelines and a selection of essential preventive protocols in a user-friendly format. The content of the SDA is primarily based on WHO (World health organization) clinical BEmONC guidelines and has been validated by an international group of global health experts [36]. The SDA contains easy to understand animated instruction videos, action cards with validated clinical guidelines, essential drugs lists with their indications, practical procedures guidelines, and a learning platform [32]. All features and functions in the SDA are designed for low-literacy and low-income settings and work offline once downloaded. The SDA can be used as a job aid and as an instructive aid in emergencies. While practicing, the skilled birth attendant (SBA) can consult action cards and drug lists to be helped in his/her clinical decision making. In the free time, the SBA can again play animated instruction videos, consult procedures descriptions and use the learning platform to update his/her knowledge and skills. The SDA can be downloaded free of charge for iPhone at https://itunes.apple.com/dk/app/safe-delivery/id985603707?mt=8 and for Android at https://play.google.com/store/apps/details?id=dk.maternity.safedelivery&hl=en.

The nurses and midwives in both hospitals received an explanation of the nature and purpose of the research and half-day training session on the use of the SDA. The majority of participants have downloaded the SDA on their personal smartphones during the training. The training session encompassed: an introduction to the research project; an overview of the SDA development and global outreach; description of the SDA features and modules; and hands-on practice on using the SDA as a job-aid and as a learning tool. Each of the study settings (Masaka and Nyamata) received three smartphones, with pre-installed English and French versions of the SDA. This was followed by the 6 months' intervention period, during which nurses and midwives provided BEmONC services with the assistance of the SDA installed on their personal smartphones or the smartphones provided by the researcher. During this period, the provided six smartphones were made available to the team on duty (three staffs per shift per hospital) at all times for use as a backup in case the participants experienced problems

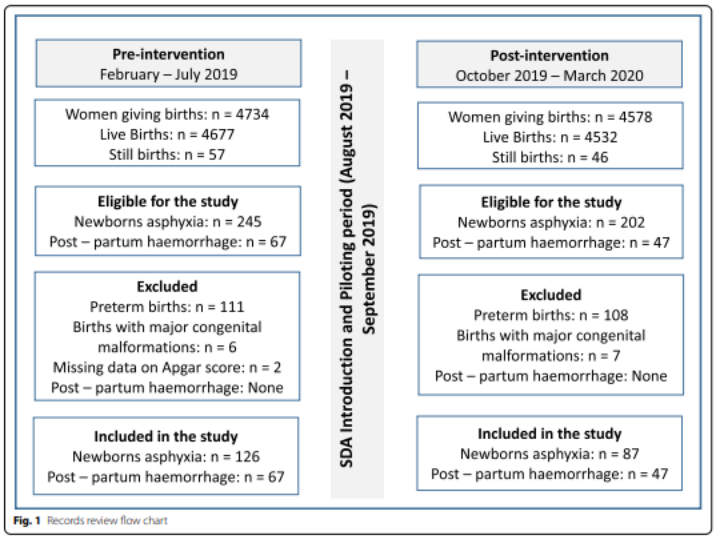

Fig. 1 Records review flow chart

with their own smartphones. Nurses and midwives were expected to use the SDA as often as they wished. The intervention also entailed two visits per week by two research assistants to each of the study hospitals. During the visits, the research assistants monitored the SDA use by nurses and midwives.

Data collection

Data extraction forms were used to retrieve information on all cases of PPH and neonatal complications recorded in delivery registers. These were extracted and reviewed 6 months' pre-SDA intervention and 6 months' post-SDA intervention. The delivery registers contain information on obstetric and neonatal care including the Apgar scores and PPH progressions following neonatal resuscitation and PPH management. Newborn deaths or admission to the neonatal intensive care unit (NICU) or to neonatologist's service due to an unstable outcome (Apgar score < 7) after neonatal resuscitation was used as the primary outcome measure to determine the failure of neonatal resuscitation. The mothers' referral to a higher-level facility (referral hospital) following an unstable outcome (persistent bleeding) after PPH management was considered as the primary outcome to measure the failure of PPH management at the district hospital. On the newborn side, we obtained data on Apgar scores progression and neonatal outcome following 10 min' neonatal resuscitation before and after the use of the SDA. While on the mother's side, we obtained data on maternal outcomes following PPH management before and after the use of the SDA.

Ethics approval

This study has been approved by the Human Research Ethics Committee of the University of the Witwatersrand (M190258) and the University of Rwanda, College of Medicine and Health Sciences' Institutional Review Board (No.377/CMHS IRB/2018). Permission to collect data has been granted by the hospitals which have authorization of using aggregated patient data in research. Consents to track the SDA usage were obtained from nurses and midwives. This study was carried out in

accordance with relevant guidelines and regulations in the Ethical Declarations.

Statistical analysis

The data were checked for errors and exported from Microsoft Excel (Microsoft Corporation) to Stata version 16 (StataCorp LLC) for cleaning and analysis. Descriptive summary statistics were computed on data including the hospital, age of the mother at childbirth, the weight of the newborn at birth, sex of the newborn, mode of delivery, the leading clinician during delivery, Apgar scores at 1, 5 and 10 min and the resuscitation action taken for the newborns. For the maternal outcome, descriptive statistics included the hospital, age of the mother at delivery, gestational age in weeks, Mode of delivery, the leading clinician during delivery, Blood loss in milliliters, causes of PPH, the resuscitation action taken, mother outcome and cause of maternal death if dead. Further, the neonatal outcomes and maternal outcomes were compared at baseline and endline using Fisher's exact test. Significance level was set at $p < 0.05$.

Results

Demographic characteristics of end-users of the SDA

In total, 54 healthcare providers, 21 nurses and 33 midwives used the SDA during the intervention period. More than a half of the participants were from Masaka district hospital (56%), the majority of them were female (61%), the participants had an average age of 33 years (SD = 7.1). In terms of their level of education, most participants hold an advanced diploma (A1) in midwifery (50%). Only one participant had the secondary school level (A2) in nursing. The majority of the nurses and midwives had less than 6 years of experience in the obstetric care (59%), spent more than 10 h per week providing services in obstetric care (74%), and participated in the care of more than ten deliveries per month (76%). Four participants acknowledged having never used a smartphone before the study. Additional details are shown in Table 1.

Table 1 The demographic characteristics of end-users of the SDA ($N = 54$)

	n (%)
Hospital Affiliation	
Masaka District Hospital	30 (56)
Nyamata District Hospital	24 (44)
Sex	
Male	21 (39)
Female	33 (61)
Level of Education	
Midwife A0	6 (11)
Midwife A1	27 (50)
Nurse A0	5 (9)
Nurse A1	15 (28)
Nurse A2	1 (2)
Experience in obstetrical care (years)	
1–5	32 (59)
6–10	15 (28)
> 10	7 (13)
Weekly workload in obstetric care (hours)	
0–5	4 (7)
6–10	10 (19)
> 10	40 (74)
Number of deliveries past month	
0–5	8 (15)
6–10	5 (9)
> 10	41 (76)
Experience with the smartphone	
Tried using one	50 (93)
Never tried using one	4 (7)
Age, years, Mean (SD)	33 (7.1)

Abbreviations: % Weighted percent, *SD* Standard deviation

SDA usage tracking

The SDA usage by nurses and midwives was tracked through the server of Maternity Foundation (Table 2). We found that the most frequently accessed feature was the action cards, which was used 199 times and 128 times in the midterm (at 3 months' intervention period) and endpoint (at 6 months' intervention period) respectively. The duration of time spent in the action cards by users varied from 282 min at midterm to 371 min at endpoint. The action cards were used by 66 users at mid-term and 80 users at endpoint. The number of users is higher than the study sample ($n = 54$) because some participants have downloaded the SDA on their own smartphones in addition to the phones provided by the researcher and they were using both phones at different occasions. The least accessed feature was the essential drugs, which was used 26 times and 87 times in the midterm and endpoint respectively. The duration of time spent in the essential drugs by users varied from 14 min at midterm to 33 min at endpoint. The essential drugs were consulted by 14 participants at midterm and 23 participants at endpoint. For some features (action cards and essential drugs) the number of participants using the feature and the times spent in the SDA increased from midterm to endpoint. While for other features (practical procedures and videos), the number of participants using the feature and the session counts decreased from midterm to endpoint.

With regards to 'MyLearning feature', Table 2 shows that a good portion of study participants ($n = 44$, 85%) had started the familiar learning process in the midterm and by the endpoint 92% of the study participants had

Table 2 SDA use by nurses and midwives

SDA App Features	Midterm		End-Point	
	Session Count	Session duration	Session Count	Session duration
	No. (number of times)	No. (duration in minutes)	No. (number of times)	No. (duration in minutes)
Action Cards	66 (199)	66 (282)	80 (128)	80 (371)
Essential drugs	14 (26)	14 (14)	23 (87)	23 (33)
Practical Procedures	37 (87)	37 (195)	17 (26)	17 (64)
Videos	53 (104)	53 (50)	33 (62)	32 (47)
My Learning	**Started the learning process, No. (%)**		**Passed the 'MyLearning' surveys, No. (%)**	
Familiar	44 (85)		48 (92)	
Proficient	43 (83)		40 (77)	
Expert	39 (75)		39 (75)	
SDA champions			**2 (3.85)**	
Global Total SDA downloads_by March 2020, No. (%)	126,444 (100)			
Total SDA downloads in Rwanda_by March 2020, No. (%)	179 (0.14)			

Abbreviations: No Number of content users, *%* Weighted percent

passed the familiar questionnaire. Similarly, a good portion of study participants ($n=43$, 83%) had started the proficient learning process in the midterm and by the endpoint 73% of the study participants had passed the proficient questionnaire. Finally, at endpoint, 75% of the study participants had passed the expert questionnaire. At the end of the intervention period, we had two SDA champions. The maternity foundation's server had also recorded 179 SDA users in Rwanda up to March 2020, meaning that our study participants in addition to downloading the SDA app on their own phones, they could have also shared the SDA to their colleagues in other hospitals apart from the hospitals included in the study. An exploration of the SDA acceptability was done at endline using surveys and focus group discussions with nurses and midwives. The findings of the SDA acceptability will be documented in a separate paper.

Cases of newborns asphyxia

The analysis included 126 cases of newborns asphyxia in the baseline and 87 in endline groups over the study period. Table 3 shows that the majority of cases were from Masaka district hospital in the baseline group (55%) while in the endline group more cases were from Nyamata district hospital (56%). There were more male newborns for the baseline group ($n=79$, 63%) and the endline group ($n=54$, 62%). The most frequent mode of delivery was the spontaneous vaginal delivery in both the baseline group ($n=77$, 61%) and the endline groups ($n=45$, 52%). The leading clinicians during delivery, also in charge of neonatal resuscitation were mainly midwives ($n=71$, 56%) in the baseline group and ($n=44$, 51%) in the endline group. The average age of the mother was similar, 28 years and 27 years in the baseline and endline groups, respectively. The average weight of the newborn was similar, 2900 g, and 2800 g in the baseline and endline groups, respectively. The average Apgar score at birth was the same, 6/10 in both the baseline and endline groups. However, the average Apgar score after 10 min of resuscitation was lower in the baseline group (8/10) than the endline group (9/10). The resuscitation actions taken were mostly dominated by aspiration and ventilation with Ambu bag in both groups, baseline (82%), and endline (79%). The endline group had higher numbers of newborns with stable outcome after resuscitation ($n=64$, 74%) than the baseline group ($n=40$, 32%). Overall, the endline group had fewer newborns transferred to NICU or neonatology service ($n=24$, 28%) than the baseline group ($n=78$, 62%).

Cases of postpartum haemorrhage (PPH)

The analysis included 114 cases of Post-partum haemorrhage (PPH): 67 in baseline and 47 in endline groups for both Masaka and Nyamata district hospitals over the study period. Table 4 shows that the majority of cases were from Masaka district hospital in the baseline group (54%) while in the endline group more cases were from Nyamata district hospital (55%). The most frequent mode of delivery was the spontaneous vaginal delivery in both the baseline group ($n=47$, 70%) and the endline groups

Table 3 Participants characteristics_ Newborns asphyxia ($N=213$)

	Baseline n (%)	Endline n (%)
Hospital Affiliation		
Masaka District Hospital	69 (55)	38 (44)
Nyamata District Hospital	57 (45)	49 (56)
Sex		
Male	79 (63)	54 (62)
Female	47 (37)	38 (38)
Mode of Delivery		
Caesarean Section	49 (39)	42 (48)
Spontaneous Vaginal Delivery	77 (61)	45 (52)
Leading Clinician of the Delivery		
Doctor	49 (39)	42 (48)
Midwife	71 (56)	44 (51)
Nurse	6 (5)	1 (1)
Resuscitation Actions		
Aspiration, Ventilation with Ambu bag	103 (82)	69 (79)
Aspiration, Ventilation, Oxgenotherapy	12 (9)	6 (7)
CPR, Ventilation, Oxygenation	11 (9)	12 (14)
Outcome after 10 min Resuscitation		
Transferred to NICU or Neonatology Service	78 (62)	24 (28)
Skin to skin bonding with mother	39 (31)	63 (72)
Dead	9 (7)	0 (0)
Weight of the newborn, grams, Median (IQR)	2900(880)	2800(800)
Mother's age, years, Median (IQR)	28(7)	27(7)
Apgar Scores, Median (IQR)		
At 1 min	6(2)	6(2)
At 5 min	7(2)	7(1)
At 10 min	8(2)	9(2)

Abbreviations: % Weighted percent, *IQR* Interquartile range

($n=34$, 72%). The leading clinicians of the delivery, also in charge of PPH management were mainly midwives ($n=36$, 54%) in the baseline group and ($n=25$, 53%) in the endline group. The average age of the mother was similar, 28 years in the baseline and endline groups, respectively. The average gestational age was similar, 39 weeks in the baseline and endline groups, respectively. The mean estimated amount of blood loss was 1167.2 mls in the baseline group and 1178.7 mls in the endline group. The most frequent cause of PPH was the uterine atony in both the baseline (72%) and the endline group (70%). The resuscitation actions taken were mostly dominated by administering oxytocin, IV fluids, and blood transfusion in both groups, baseline (37%), and endline (55%). The endline group had higher numbers of women with stable outcomes after PPH management ($n=44$, 94%) than the baseline group ($n=55$, 78%). Overall, the endline group had fewer women transferred to referral hospitals after PPH management ($n=3$, 6%) than the baseline group ($n=13$, 19%).

Pre-post differences in newborns outcomes following neonatal resuscitation

We found a statistically significant association between the SDA intervention and newborns' outcomes following neonatal resuscitation, 6 months after baseline (Table 5). Among 213 cases of newborns complications who were included in the study, stable outcomes following neonatal resuscitation were recorded in 31% of newborns cases at baseline and 72% at endline. The transferred (unstable) newborns were 62 and 28% at baseline and endline respectively. While death following neonatal resuscitation appeared in 7% for the baseline group only. No death was recorded in the endline group. There was a significant difference between baseline and endline in the outcome (stable, transferred, and dead) for newborns who underwent neonatal resuscitation ($p=0.000$, Fisher's exact test).

Pre-post differences in maternal outcomes following PPH management

We found a statistically significant association between the SDA intervention and maternal' outcomes following

Table 4 Participants characteristics_ PPH ($N=114$)

	Baseline n (%)	Endline n (%)
Hospital Affiliation		
Masaka District Hospital	36 (54)	21 (45)
Nyamata District Hospital	31 (46)	26 (55)
Mode of Delivery		
Caesarean Section	20 (30)	13 (28)
Spontaneous Vaginal Delivery	47 (70)	34 (72)
Leading Clinicians of the Delivery		
Doctor	20 (30)	13 (28)
Midwife	36 (54)	25 (53)
Nurse	11 (16)	9 (19)
Causes of PPH		
Uterine atony	48 (72)	33 (70)
Cervical tear	11 (16)	7 (15)
Retention of Placenta	8 (12)	7 (15)
Resuscitation Actions		
Oxytocin, IV fluids	23 (34)	7 (15)
Oxytocin, IV fluids, Transfusion	25 (38)	26 (55)
Repair of tear, IV fluids	11 (16)	7 (15)
Removal of Placenta, IV fluids	8 (12)	7 (15)
Maternal outcome after PPH Management		
Transferred to Referral Hospital	13 (19)	3 (6)
Stable	52 (78)	44 (94)
Dead	2 (3)	0 (0)
Mother's age, years, Median(IQR)	28(5)	28(5)
Gestational age, weeks, Median(IQR)	39(0)	39(0)
Blood loss in Mls, Mean (SD)	1167.2 (276.6)	1178.7 (257.1)

Abbreviations: % Weighted percent, *IQR* Interquartile range, *SD* Standard deviation

PPH management, 6 months after baseline (Table 6). Among 114 cases of PPH who took part in the study, stable outcomes following PPH management were recorded in 78% PPH cases at baseline and 94% at endline. Transferred (unstable) women were 19 and 6% at baseline and endline respectively. While death attributed to PPH appeared in 3% women for the baseline group only. No death was recorded in the endline group. There was a significant difference between baseline and endline in the maternal outcome (stable, transferred, and dead) following PPH management ($p=0.048$, Fisher's exact test).

Discussion

Main findings

The current study investigated the use of the SDA and its relationship to BEmONC outcomes for the most frequent birth-related complications in Rwanda; PPH and newborn asphyxia. Apgar scores and PPH progressions were considered in the investigation of newborn and maternal outcomes following neonatal resuscitation and PPH management.

The findings from this study are consistent with SDA having the potential to improve clinical outcomes. These results are encouraging: nurses and midwives were willing to use SDA and the intervention was engaged with throughout the intervention period. Clinical data show a correlation between SDA implementation and improved maternal and newborn outcomes. However, the improved maternal and newborn outcomes may have been influenced by other factors in addition to the SDA intervention. Nevertheless, the findings of this study contribute to the broader knowledge about the SDA effectiveness and provide promising evidence to support the need for more rigorous and expensive research on the SDA.

Comparison with other studies

As was noted in the present study, Lund et al. [32] also reported a significant effect of the use of the SDA particularly on skilled birth attendants in terms of significantly increased knowledge and skills scores in neonatal resuscitation in Ethiopia [32]. Our previous study also found a significant association between the SDA uptake/use and change in knowledge and skills of nurses and midwives in PPH management and NR [33]. Another study conducted in DRC Congo to determine the feasibility, acceptability, and potential effect of the SDA on health workers' practices in BEmONC reported a significant increase of health worker knowledge and self-confidence in the management of obstetric and newborn emergencies after 3 months SDA intervention [37]. In addition to the previous studies on the SDA, the present study provided evidence on the SDA implementation, use, and clinical outcomes. However, the implicit theory of change for the SDA may follow a logical sequence of (a) the SDA implemented and used; (b) the use of SDA supports

Table 5 Newborns outcomes following neonatal resuscitation ($N=213$)

	Before SDA ($N=126$), n(Wt.%)	After SDA ($N=87$), n(Wt.%)	*P*-Value (Fisher' exact test)
Newborns Outcome			
Stable	39 (31)	63 (72)	P(Fisher) = 0.000
Unstable(Transferred)	78 (62)	24 (28)	
Dead	9 (7)	0 (0)	

Abbreviations: *Wt.%* Weighted percent

Table 6 Maternal outcomes following PPH management ($N=114$)

	Before SDA ($N=67$), n(Wt.%)	After SDA ($N=47$), n(Wt.%)	*P*-Value (Fisher' exact test)
Maternal outcome			
Stable	52 (78)	44 (94)	*P*(Fisher) = 0.048
Unstable(Transferred)	13(19)	3 (6)	
Dead	2 (3)	0 (0)	

Abbreviations: Wt.% Weighted percent

skilled birth attendants' continuous learning and decision making; the use of the SDA changes clinical response behaviors and practices; (c) the changes in practices leads to improved clinical outcomes. Therefore, future research using a theory of change or a logical framework over a long period is needed to understand the dynamics and change processes of skilled birth attendants' clinical practices when using the SDA.

Moreover, mHealth programmes have shown promising results for newborn outcomes. A study which looked at antenatal messaging services using a mobile phone intervention in Zanzibar reported a significant reduction in perinatal mortality [38]. This could be explained by the fact that mhealth applications have the potentiality to put relevant and reliable healthcare information into the hands of healthcare workers thus helping them in the management of maternal and neonatal cases. But also, that health professionals need continuous access to updated healthcare information and clinical guidelines to support their decision making during practices. The same opinion was reported in a similar study done by Grol et al. [39] about the effective implementation of mHealth interventions [39]. However, Tamrat et al. [40] in their systematic review which analysed mHealth interventions in maternal and newborn health programs and their outcomes around the world reported that few trials have been conducted and most maternal mHealth programmes have not been evaluated, and the evidence is still weak [40]. Thus the need for more evidence on maternal and newborn mHealth programmes.

Maternal outcome following PPH management was another significant predictor in the present study. Our findings are in agreement with other studies that documented mHealth interventions which have been tested in a variety of health services delivery including decision support and clinical management [41–43]. These studies found promising findings for the mhealth technology in general and for maternal healthcare services in particular. Then again, other studies have shown that the evidence of maternal mHealth interventions is supportive but weak. A 2017 systematic review on mHealth interventions in low-income countries demonstrated good promise for the use of mHealth interventions in maternal health, but the evidence is limited [20]. This review suggested more research on the relationship between mHealth and clinical outcomes because the majority of mHealth trials focused on very distinct mhealth applications (i.e appointment reminders and data collection). Another review which identified 51 RCTs, documented that nearly half of the reviewed RCTs ($n=22$) showed negative or unclear results, thus the need for better evidence; and for caution with new interventions [44]. Another study which assessed the impact of the SDA on the incidence of PPH in Ghana reported that the SDA was associated with an insignificant lower incidence of PPH [45]. Hence, the need for more evidence and higher-quality research in this field. The current study adds to much-needed evidence as to how a decision-support mHealth application functioned in a low-resource setting. Future research that analyze event-event correlation between SDA use and maternal and newborn outcomes would be important.

Limitations

Though our study documents important patterns of use of a mHealth to inform clinical decisions, the quantity of information accessed for the care of individual patients is limited in the current study. We acknowledge the limitations of our study design, pre-post intervention, which partly permitted us to demonstrate the effects of the SDA on maternal and newborn outcomes. The observed maternal and newborn outcomes may have been influenced by other factors in addition to the SDA intervention. Also, nurses and midwives may have consulted other sources rather than the SDA to inform their decision-making during the intervention. Although this limitation is inherent in the design of the study, the current study contributes to the broader evidence about the effectiveness of the SDA and provides much-needed insights as to how a decision-support mHealth application functioned in a low-resource setting.

Conclusion

The use of the SDA supported nurses and midwives in the management of PPH and neonatal resuscitation which may have contributed to improved maternal and neonatal outcomes during 6 months of the SDA intervention. Mhealth interventions that focus on the clinical decision support process in maternal and newborn care

may contribute to improved services delivery and should be considered by policymakers in resource-limited settings, like Rwanda. Overall, there is limited evidence on the effects of mHealth interventions on clinical outcomes on a large scale and further research is necessary to draw holistic conclusions, particularly for developing countries within the field of maternal and newborn care.

Abbreviations

BEmONC: Basic Emergency Obstetric and Newborn Care; CHWs: Community health workers; CMHS IRB: College of Medicine and Health Sciences Institutional Review Board; IQR: Interquartile range; IV: Intravenous line; LMICs: Low- and middle-income countries; mHealth: Mobile Health; Mls: Millilitres; NICU: Neonatal intensive care unit; SDA: Safe Delivery mhealth Application; SD: Standard deviation; PPH: Post-Partum Hemorrhage; NR: Neonatal Resuscitation; SBA: Skilled Birth Attendants; WHO: World Health Organisation.

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Authors' contributions

AN, LI, MN, and DNC were involved in the conception and design of the study. AN drafted the manuscript. LI, MN, and DNC reviewed the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The dataset generated for this study will be made available from the corresponding author on a reasonable request.

Declarations

Ethics approval and consent to participate

This study has been approved by the Human Research Ethics Committee of the University of the Witwatersrand (M190258) and the University of Rwanda, College of Medicine and Health Sciences' Institutional Review Board (No.377/CMHS IRB/2018). Permission to collect data has been granted by the hospitals.

Consent for publication

Not applicable.

Competing interests

None declared.

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Appendix 18. Original Paper V

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RESEARCH Open Access

A mixed-method study exploring experiences, perceptions, and acceptability of using a safe delivery mHealth application in two district hospitals in Rwanda

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Abstract

Background: Innovative use of mobile health (mHealth) technology in timely management of childbirth complications is a promising strategy, but its evidence base is limited. The Safe Delivery mHealth Application (SDA) is one of the recent mhealth applications (loaded in smartphones) which is a clinical decision support and training tool for basic emergency obstetric and newborn care (BEmONC). This paper describes, the health providers' experiences, perceptions, and acceptability of using the SDA, as well as the perceptions of key stakeholders.

Methods: A mixed-methods approach was utilized. Quantitative methods consisted of a self-reported acceptability survey, administered to 54 nurses and midwives, including questions on their usage and perceptions of the SDA. Descriptive statistics were employed to analyze the survey data. Qualitative methods included two focus group discussions with 24 nurses and midwives, and six key informant interviews with stakeholders (maternity matrons, responsible for maternal and child health, and district hospital managers). Thematic analysis was performed and selected quotations used to illustrate themes. The study took place in two district hospitals in Rwanda.

Results: Quantitative results found that 31 (57.4%) participants used the SDA four to six times per week. Many participants felt more confident (53.7%) and better at their job (40.7%) since having the SDA. Likert scale survey responses (1–5, 1 = Strongly Disagree, 5 = Strongly Agree) indicated general agreement that SDA is easy to use (Mean = 4.46), is an effective decision support tool (4.63), and training tool (4.65). Qualitative results included themes on perceived usefulness; professional growth acquired through the use of the SDA; SDA, an empowering, intuitive, and user-friendly technology; desired SDA features and functions; benefits of SDA as perceived by key informants, and future use of the SDA.

Conclusions: The nurses and midwives perceive the SDA as having improved their ability to manage childbirth complications. Key stakeholders also perceive the SDA as a useful tool with a reasonable cost and recommend its implementation in routine practices. This study deepens the understanding of the potential benefits of mHealth such as the SDA in low-income settings, like Rwanda. It also provides more evidence on the impact of mHealth in assuring quality BEmONC.

Keywords: BEmONC, mHealth, Mixed-methods, Nurses and midwives, Safe delivery application, Rwanda

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Background

Globally, maternal and newborn deaths remain a public health concern despite several efforts that have been/are being made to reduce the deaths. It is estimated that 295,000 maternal deaths, 2 million stillbirths and 2.5 million early newborn deaths occur annually in the world [1, 2]. More than 90% of these deaths happen in low- and middle-income countries, like Rwanda [3, 4]. Most of these deaths are attributable to preventable causes such as post-partum haemorrhage (PPH), newborn asphyxia, pre-eclampsia, obstructed labor, infections, and hypertensive disorders [5]. The WHO, UNICEF, and UNFPA have identified essential interventions known as Basic Emergency Obstetric and Newborn Care (BEmONC) for prevention and treatment of the preventable causes of maternal and newborn deaths [6, 7]. The BEmONC package includes the management of PPH, the removal of a retained placenta, the management of maternal sepsis, the management of hypertensive disorders, the management of prolonged labor, the management of complications of abortion, and neonatal resuscitation (NR) [6]. These services can be provided by nurses and midwives. There is evidence that BEmONC is a key intervention to reduce death and disability of mothers and newborns [7]. However, the available literature remains characterized by gaps in assuring the quality of BEmONC.

The quality of BEmONC services is important to improving maternal and newborn health [8]. The research evidence suggests that barriers to instituting quality BEmONC are complex and are often linked to limited knowledge and skills among health care providers, lack of access and adherence to evidence-based clinical guidelines, insufficient monitoring to inform appropriate responses, and lack of some essential materials [3]. Besides, research recommends the use of mobile health (mHealth) to improve health systems, as a solution that could potentially support in addressing some of the health systems challenges and improve service delivery [9, 10].

The safe delivery mHealth application (SDA) is a novel mHealth application which is a decision support and training tool for BEmONC that was developed by the Maternity Foundation [11]. The main purpose of the SDA is to make a healthcare provider better prepared to prevent, detect, and manage life threatening complications to mothers and newborn via offering evidence-based BEmONC [11]. The SDA contains animated videos with instructions on management of PPH and NR. The SDA offers the opportunity to watch the entire instructional animated video (8–15 min long) as well as choosing to see a specific procedural step of each video (1–3 min long). Besides, the SDA contains a catalogue of action cards with essential recommendations to support clinical decision making in an emergency situation when the user does not have time to review a video. The SDA also include a comprehensive drug list which contains useful information on the various essential drugs needed to perform PPH management and NR. Further, the SDA describes certain essential procedures step-by-step and required equipments. In addition, the SDA has a self-explanatory learning platform 'My Learning' that provides learning and assessment strategies based on key elements within the clinical content found in the SDA. To stimulate use, the SDA sends weekly notifications with quiz questions and a direct link to the films where the information to answer the question is found. The clinical content of the SDA was developed following international WHO guidelines but focusing on key essential lifesaving interventions of BEmONC [12].

The SDA can be downloaded free of charge for iPhone at: https://itunes.apple.com/dk/app/safe-delivery/id985603707?mt=8 and for Android at: https://play.google.com/store/apps/details?id=dk.maternity.safedelivery&hl=en.

The present paper, was derived from a broader study about the implementation of the SDA in handling two elements of the BEmONC: PPH and NR in two district hospitals in Rwanda. Such focus was informed by evidence that indicated PPH and newborn asphyxia as the priority challenges in Rwanda [13, 14]. In 2019, Rwanda's maternal mortality was estimated at 203 deaths per 100,000 live births and its neonatal mortality rate was 19 deaths per 1000 live births [15] despite 91% of births taking place in healthcare facilities and attended by healthcare professionals [16]. Therefore, more efforts are still needed to reduce the numbers of deaths. The SDA was piloted in two district hospitals in Rwanda. This pilot implementation process was divided into three phases (pre-intervention, intervention, and post-intervention). The first phase (pre-intervention) involved the presentation of the research to different stakeholders and the baseline study (surveys, records review, and focus group discussions). The second phase (intervention) included the capacity building in the usage of the SDA among nurses and midwives; the SDA provision and piloting; and the SDA implementation for a period of six months. The third phase (post-intervention) included the implementation evaluation and encompassed the endline study (surveys, records reviews, focus group discussions, and key informant interviews). More details are provided in the protocol paper for this research [17]. The present paper explores the end-users' experiences, perceptions and acceptability of the SDA and key stakeholders' perspectives.

Methods

Study design

This paper describes part of a larger study about the implementation of the SDA in BEmONC services in two district

hospitals in Rwanda. The larger study methodology and the evaluation of initial outcomes have been reported elsewhere [17–20]. The part of the study presented in this paper, used mixed research methods to explore end-users' experiences, perceptions, and acceptability, and explore the key stakeholders' perceptions of the SDA. Mixed-methods is defined as a research design that involve the combination of quantitative and qualitative research approaches in order to obtain a comprehensive understanding of the research question [21, 22].

Study setting

The study took place in two district hospitals in Rwanda: Masaka hospital in Kigali, an urban province; and Nyamata hospital located in the eastern rural province [23].The two hospitals were selected out of 12 district hospitals in the two provinces because both had a high number of deliveries per year [24] and had been offering BEmONC services for more than five years.

Study participants

The study adopted a purposive sampling and included 60 participants, the nurses and midwives ($n=54$) and stakeholders ($n=6$). Nurses and midwives who deal with childbirth in the maternity departments of the two district hospitals were introduced to the study and invited to participate in the study during the face-to-face morning staff meetings. The inclusion criteria were as follows: having work experience of at least six months in obstetric care; being full-time employed in the selected hospitals; and willing to participate in the study. The selected stakeholders (key informants in the management position at the district hospital level) were approached individually and consented to participate in the study. They included maternity matrons ($n=2$), managers responsible for maternal and child health ($n=2$), and district hospital directors ($n=2$).

Data collection and analysis

Quantitative data

The quantitative part of the research entailed asking all nurses and midwives who were part of implementation of the SDA to complete a self-administered questionnaire (Additional file 1) evaluating usage of the SDA, as well as their perception and acceptability. A pilot test of the self-administered questionnaire was conducted with 2 nurses and 3 midwives in a different district hospital prior to the survey. The survey was conducted at endpoint once users had used the SDA for six months. Responses were analysed descriptively using Stata version 16 (StataCorp LLC).

Qualitative data

Two methods were used to collect qualitative data - focus group discussions (FGDs) and key informant interviews (KIIs).

Focus groups discussions explored in depth the participants' experiences and views on the functionality of the SDA. Two FGDs were conducted, one in each of the study hospitals. In each hospital, 12 participants were recruited and total number of FGD participants is 24. The participants included in the FGDs were selected based on their interest and availability. We sought perspective diversity in terms of age, gender, and experience [25] and these criteria were considered in both groups.

The Key Informant Interviews were conducted with six participants (three from each hospital), who were selected because of their leadership/management portfolios in the participating hospitals. The purpose was to get their views on the feasibility of adopting the SDA for wider implementation with the focus on its costs, possible scalability and sustainability. The interviews with key stakeholders started with an introduction of the SDA to the key informant including an explanation of the features and modules of the SDA, and a demonstration of how the SDA functions using a smartphone. After the introduction of the SDA, the key informant was invited to ask questions and comment on the SDA. Once their concerns were addressed, the researcher presented the estimated total cost that was used for piloting the SDA in two district hospitals (Masaka and Nyamata) in Rwanda. The estimated total cost was 10.076.410 Rwf ($10,000) including the technology cost = 4.504.000 Rwf ($4470.56), the training cost = 2.083.410 Rwf ($2067.94) and the intervention cost = 3.489.000 Rwf ($3463.09). Then, participants were asked to provide their perceptions of the SDA and their opinions on its cost, scalability, and sustainability.

The interview guides (Additional file 2) were developed in English, translated to Kinyarwanda, and translated back to English in a blinded manner to ensure accuracy and equivalence [26]. To ensure the quality and adequacy of the interview guides, they were pretested with two participants at a different district hospital. The interviews were conducted face to face in March 2020 and were held in private rooms at both Masaka and Nyamata district hospitals to ensure confidentiality. Interviews were conducted in the language of the participants' preference, which was Kinyarwanda. The first author conducted the interviews with assistance of an experienced research assistant who assisted in taking notes and supervising the tape recording. FGDs lasted between 60 and 0 min and KII interviews between 30 and 45 min. All FGDs and KIIs were digitally recorded and transcribed in Kinyarwanda by two research assistants. Transcriptions were done following the true verbatim method to accurately capture meanings, perceptions, and context [27]. Then, transcripts were translated from Kinyarwanda to English by a professional translator. In order to ensure that everything

was translated as correctly as possible, all transcriptions were compared with the audio files and field notes. The data were analyzed using thematic analysis with a hybrid approach (inductive and deductive) [26]. Two authors (AN and DNC) first read all transcripts independently, then jointly developed a codebook. Disagreements were resolved by discussion. The final list of codes was applied to all transcripts using Nvivo 11 Plus software. Coded output was then read, merged into major themes, and illustrative quotations were identified. The consolidated criteria for reporting qualitative research [28] guided reporting for the qualitative data (Additional file 3).

Findings from both quantitative and qualitative data were integrated during the data-interpretation stage. The goal was to obtain different but complementary data that validate the overall results about the SDA acceptability.

Ethical considerations

Ethical approvals were obtained from the Human Research Ethics Committee of the University of the Witwatersrand (M190258) and the University of Rwanda, College of Medicine and Health Sciences' Institutional Review Board (No. 377/CMHS IRB/2018). All participants gave written informed consent and consents for recording the interviews prior to their participation. Participants were assured that their identities would remain anonymous in all reporting of the study and that their personal information would be kept confidential. All methods in this study were carried out in accordance with relevant guidelines and regulations in the Ethical Declarations.

Results

Characteristics of quantitative study participants

A total of 54 nurses and midwives completed the acceptability survey. The majority of participants were midwives ($n=33$). More than half were from Masaka district hospital ($n=30$, 56%), the majority were female ($n=33$, 61%), their average age was 33 years (SD = 7.1). The level of education was predominantly the advanced diploma (A1) in midwifery with 27 of 54 (50%) participants having advanced diploma (A1 level) in midwifery. The least represented level of education was the secondary school level (A2) in nursing with only one participant with A2 level in nursing. A detailed description of the survey respondents is provided in Table 1.

The nurses' and midwives' experiences of the SDA during the study implementation

The utilization of the SDA by nurses and midwives

The majority of participants ($n=31$) reported using the SDA four to six times per week. Features of the SDA that were most consulted include; the action cards ($n=15$), my learning ($n=14$) and the drug list ($n=10$). A half of the participants used the SDA to revise their knowledge. Other participants used the SDA in emergency situations ($n=14$), in a normal work situation ($n=5$) and to discuss with co-workers ($n=8$). Nurses and midwives predominantly accessed the SDA on both their own smartphones and on the smartphones provided by the researcher ($n=28$). A large number of participants ($n=35$) often used the SDA with a co-worker. Participants reported having access to most of the equipments and drugs seen in the SDA ($n=40$). More details on the SDA use and evaluation by end-users are shown in Table 2.

When rating their experiences of using the SDA particularly, half of respondents ($n=27$) indicated that it was very easy to the SDA, however one participant reported that it was very difficult to use a smartphone. SDA features that were most appreciated included: the action cards (33%), the drug list (22%), and my learning (19%). They also reported feeling more confident (53.7%) and becoming better (40.7%) at doing their jobs at work. Few participants ($n=5$) reported what they liked least about the SDA, three participants stated that they did not understand instructions, and the other two said that it was difficult to navigate the smartphone. More details on the experiences with the SDA and its added value are displayed in Table 3.

Acceptability of the SDA as rated by nurses and midwives

Nurses and midwives were asked to rate their acceptance of the SDA in a Likert scale. They were asked whether they "strongly disagree", "disagree", were "undecided", "agree", or "strongly agree" to a series of statements relating to the SDA acceptability. Responses were

Table 1 Demographic characteristics of the acceptability survey respondents ($N=54$)

	n (%)
Hospital Affiliation	
Masaka District Hospital	30 (55.6)
Nyamata District Hospital	24 (44.4)
Sex	
Male	21 (38.9)
Female	33 (61.1)
Education Level	
Midwife A0	6 (11.1)
Midwife A1	27 (50)
Nurse A0	5 (9.3)
Nurse A1	15 (27.8)
Nurse A2	1 (1.8)
Age, years, Mean (SD)	33 (7.12)

Abbreviations: % Weighted percent, *A0* bachelor's degree, A1 Advanced Diploma, *A2* Secondary school level

Table 2 SDA access and evaluation by nurses and midwives (*N* = 54)

	n (%)
Frequency of SDA use in a week	
I used it almost every day	15 (27.8)
I used it 4–6 times	31 (57.4)
I used it 1–3 times	8 (14.8)
I didn't use it at all	0 (0)
Features of the SDA most consulted	
Videos	9 (16.7)
Action cards	15 (27.8)
Drug list	10 (18.5)
Procedures	6 (11.1)
My Learning	14 (25.9)
Most often quoted reasons for using the SDA	
To revise my knowledge	27 (50)
During an emergency	14 (25.9)
In a normal work situation	5 (9.3)
To discuss with co-workers	8 (14.8)
The device often used to access the SDA	
Own phone	7 (13)
The phone provided by the researcher	19 (35.2)
Both	28 (51.8)
With who do you often use the SDA?	
By myself	19 (35.2)
With a co-worker	35 (64.8)
Access to the equipment and/or drugs seen in the SDA	
All	14 (25.9)
Most	40 (74.1)
None	0 (0)

Abbreviations: Wt. % Weighted percent, SDA Safe Delivery mHealth Application

assigned point values as follows; strongly disagree = 1, disagree = 2, undecided = 3, agree = 4, strongly agree = 5. Likert scale survey results showed that the SDA was: well understood (Mean = 4.00); easy (4.46) and comfortable (4.31) to use; an effective decision support (4.63) and training (4.65) tool; and useful in improving efficiency in BEmONC (4.59). Most participants reported that they intended to continue using the SDA in daily practices (4.68). On the other hand, a lower rating was given to using the SDA when seeing notifications (2.48), implying that most participants did not only use the SDA when they saw notifications. The notifications are push messages that appear occasionally on the phones of the SDA users to remind them to revisit the SDA. The messages mainly guide the users to interesting parts that they may want to explore in the SDA. Overall participants reported good acceptability of the SDA. Likert scale responses are highlighted in Table 4.

Table 3 Experiences with the SDA and its added value (*N* = 54)

	n (%)
Experience with the smartphone and the SDA	
Very easy	27 (50)
Somewhat easy	23 (42.6)
Somewhat difficult	3 (5.6)
Very difficult	1 (1.8)
Features of the SDA most appreciated	
Action cards	18 (33.3)
Videos	10 (18.5)
Drug list	5 (9.3)
Procedures	12 (22.2)
My Learning	9 (16.7)
Added value from the SDA	
I have become better at doing my job.	22 (40.7)
I feel more confident at work.	29 (53.7)
Fewer mortalities/fatal cases	3 (5.6)
I did not notice any change.	0 (0)
What do you like least about the SDA?	
I do not understand the instructions.	3 (5.6)
I think it is difficult to navigate the smartphone.	2 (3.7)
The app does not add to my existing knowledge.	0 (0)
None applicable.	49 (90.7)

Abbreviations: Wt. % Weighted percent, SDA Safe Delivery mHealth Application

Perceptions about the usefulness and acceptability of the SDA

The results of the interviews with end-users of the SDA emerged into four main themes: (1) the perceived usefulness of the SDA; (2) professional growth acquired through the use of the SDA; (3) SDA, an empowering, intuitive and user-friendly technology; and (4) the desired SDA features and functions. The results of the interviews with key stakeholders revealed two main themes (1) benefits of the SDA as perceived by the key informants, and (2) future use of the SDA. These identified themes are shown in Fig. 1. More details on the main themes and sub-themes are presented in the discussion of results, and are illustrated by verbatim quotations from the two FGDs and six KIIs.

Interviews with end-users of the SDA

Perceived usefulness of the SDA

Participants described the SDA as a useful, intuitive, empowering and practical tool that supported their daily practices. They described how it provided important information and guidelines on management of obstetric emergencies, and thus, increases their knowledge and skills on how to manage normal childbirth as well as birth complications.

"This application came as a golden opportunity for us …normally, it is very hard to go to a library all the time to read; but the library, I am hereby talking about is that SDA application we have received… It provides very useful information and guidelines that upgrade our knowledge and skills in delivery care" Midwife, FGD1.

In addition, nurses and midwives reported using the SDA both as a decision support tool while managing birth complications including PPH or NR, and as a debriefing tool for reflections on performed care to identify if essential procedures had been missed.

"When you have an emergency case to manage, you don't have difficulties figuring out how to handle it…all the steps are clearly outlined in this application and so well summarized that you immediately find what you need whenever you refer to it…The SDA support our clinical decisions in emergency situations…Sometimes, when I go home from a night duty, on the bus, I consult the SDA to see if I have performed well during the night" Nurse, FGD2.

Participants also described the SDA as a practical and easy to use tool that helps strengthen their theoretical knowledge. They articulated how the SDA helped them remember the management of rare clinical cases. Procedures for those rare cases are easy to forget as they rarely had to apply the theory learnt from school into practice.

"Before SDA, you could sometimes start wondering what management was appropriate for a case which is not so frequent after you had forgotten…Now, we refer to the SDA when there is a doubt about anything… With this new application, we have become all fresh and we can easily remember the essential procedures step by step as per international standards" Midwife, FGD1.

Other participants expressed appreciation of the SDA as a training tool, highlighting the ingenuity of the visuals when dealing with life threatening complications of mothers and their newborns. They considered the SDA to be a kind of simulated clinical training that continuously enhances their knowledge and practical skills, contributing to their professional growth. They also reported improved performance when managing childbirth complications. Such improvement was attributed to continuous learning, facilitated by the SDA and the fact that learning could take place anywhere.

This application has been an important learning tool…I consider it as a training manual with all clinical guidelines accompanied by video materials… we learn a lot from the SDA in addition to what we learned at school…You can learn from this application from anywhere: at the hospital, on the bus, at home or anywhere. So, having your telephone means being able to learn more anywhere." Midwife, FGD2.

Then again, participants revealed that they used to consult other internet sources for learning like youtube. They found such sources not so easy to use, as it was hard to get concise updated information and guidance in a timely manner, the way the SDA does.

"We used to visit youtube to learn something about the services we deliver, but most materials in there are not so clear as in this app. When you consult the SDA, you find that everything is easy to understand. You quickly get information on which medication is good for which case…" Midwife, FGD1.

"Some of us are mentors in health centers and we have been consulting this application while preparing training materials" Midwife, FGD1.

Some found the SDA notifications useful as reminders for them to continue learning. The notifications that appeared intermittently on their phones, reminded them to revisit the SDA that also pointed them to other interesting parts of the SDA that they may want to explore.

"We have posters displayed in maternity telling us what to always bear in mind. Some of the information on them is "remember to close the door to keep the newborn warm" … I compare this with the SDA notifications that I frequently get on my smartphone…these are very nice reminders that I have to keep learning" Midwife, FGD2.

"I would come back to what a colleague said about SDA notifications. This is a way of alerting you and I like that… There exists a wrong belief that nurses don't like reading. Maybe, it is true but this application is not too demanding. It doesn't consume your time as if you go to a library… This app is a good source and we need to regularly use it" Nurse, FGD1.

Professional growth acquired through the use of the SDA

The perceived usefulness of the SDA described by the participants was associated with substantial improvements in their childbirth care practices. Nurses and midwives narrated experiencing an increase in their knowledge, skills, and confidence after using the SDA and how such professional growth has been reflected in the quality service they offer.

"The reason number one I like this app is that it upgrades my knowledge and skills, and makes me

confident than before…it is a kind of continuous professional development…It is so good in a way that if you fail to understand the text when reading, you have an option to search for more explanation using videos. It is really very useful…" Nurse, FGD2.

"The biggest difference for me when I compare now and the past experience is service delivery which has so positively improved. The special aspect of the application is that the content therein has everything we theoretically studied at school" Midwife, FGD2.

The study participants indicated that the SDA has helped them to recollect and revise their skills, which have made them more capable at managing childbirth complications in accordance with the recommended essential procedures. One of the significant changes expressed by participants was that they had learned the lifesaving steps of how to stop a bleeding by applying bimanual compression.

"This application has been helping us refresh our memories and equipping us with techniques that we use to handle obstetric emergencies.... My colleagues have talked about bimanual compression…You may even not know anything about it … Then, when you try to familiarize with it on the SDA, you get to know about it and perform it correctly" Midwife, FGD1.

Other participants explained how the SDA supported them during practice. They described the before SDA childbirth care experience and compared it with after SDA experience by highlighting the specific instances in which the SDA supported them. Previously, in situations where nurses and midwives were struggling to assist a mother or a newborn, they would immediately call upon a medical doctor to come and help. And, sometimes the doctor assigned to maternity department was busy with caesarean surgery which would delay his assistance to attend to the complicated case. But, now with the support of the SDA, nurses and midwives have been able to provide essential assistance to mothers and newborns while waiting for the doctors.

"I agree that BEmONC services were also delivered before we started using SDA but the situation was not the same. For example, when there was a complication with a patient, the only thing we would do was to ask a colleague or to call a medical doctor. This was time consuming and would delay service delivery and could complicate the situation even cause maternal deaths... However, when there is a problem nowadays, you just take your phone, go to the application and get a quick solution. As a result, our patients get quick and more efficient service" Midwife, FGD2.

Both nurses and midwives revealed that they used to fear occurrence of birth complications, because of the limited skills and experience on how to manage such events. They noted that the SDA had reduced this fear and had led them to have more confidence in their work.

"In using this app, you are always aware of what might happen in a given case. So, when you have a real case, you don't panic much…For instance, when it comes to PPH management, with the SDA you can easily figure out the steps to follow" Nurse, FGD1.

"This application can help you when you are stressed. You may have had a lot of cases to manage in a day and end up in confusion somewhere. When this happens, you take your phone and see what should be done to handle a particular case with confidence." Midwife, FGD2.

Some participants described how solving problems using the SDA motivated and enabled them to be more efficient in providing care at work.

"when you have a problem and you find a way to solve it, that is self-explanatory; you feel motivated automatically. As we get support from the application, our job becomes easier and more efficient" Midwife, FGD1.

Further, nurses and midwives explained that they used the SDA either at home to update knowledge or while they were at work, either before a delivery when the woman is in labor or when complication arises in the course of a delivery. Some participants described using the SDA to guide co-workers when they work in pairs in order to follow the necessary steps during a delivery. In emergency situations, the SDA was often used as a decision support tool to see how to manage e.g. PPH and neonatal resuscitation or as a reminder of drug dosages and administration. Participants also acknowledged having access to most of the equipments and drugs seen in the SDA.

"We have most of the materials we need to perform well. But, the SDA has been there to support us in upgrading our knowledge wherever we are - at home, before assisting a delivery or during an emergency... You may forget something like medication dosage, even though you learned it at school… but since we got this app, it helps us to remember the dosages in emergencies, we use it as a job aid in a simple way" Nurse, FGD2.

Table 4 Likert scale survey responses of nurses and midwives about SDA acceptance

Statement	N	Mean (SD) [Range]
I have a good understanding of what the SDA is	54	4.00 (0.71) [3-5]
The SDA is easy to use	54	4.46 (0.50) [4-5]
I am comfortable using the SDA	54	4.31 (0.57) [4-5]
The SDA is an effective decision support tool for BEmONC	54	4.63 (0.69) [4-5]
The SDA is an effective training tool for BEmONC	54	4.65 (0.48) [4-5]
The SDA is useful in improving efficiency in BEmONC	54	4.59 (0.56) [3-5]
I intend to continue using the SDA in my daily practices	54	4.68 (0.50) [4-5]
I use the SDA when I see notifications	54	2.48 (0.40) [1-3]

Likert scale response options were as follows: 1Strongly Disagree, 2Disagree, 3Neutral, 4Agree, and 5Strongly Agree

SDA an empowering, intuitive and user friendly technology

The study participants also voiced that the SDA is easy to use, intuitive, user friendly, and enabled them to provide first aid to patients before calling upon doctors.

> *This application is special in that it is so focused and shows you clear sequences…For example, you can easily find what specifically refers to steps for removing a retained placenta when you have such a case. We really like it because it is easy to use" Midwife, FGD2.*

> *"I would say something additional. With this application, we have learnt how at least one can provide first aid for a mother or do resuscitation for a newborn… That is so important because you don't need to call upon a doctor for everything" Midwife, FGD2.*

Likewise, participants indicated that the SDA has helped them to get a common understanding with medical doctors about managing birth complications. They explained on how consulting the SDA helped them to have informed recommendations and they were happy to contribute with confidence to care plans and sometimes supporting doctors.

> *"I would say that when I have a special case, I first consult the application, see how I can myself manage it before I talk to a medical doctor. Even when I have to talk to the doctor, at least I provide an informed suggestion and contribute to further treatment steps. We are supporting our doctors much more." Midwife, FGD1.*

Then again, nurses and midwives described how the SDA has helped them to get updated information and to have a common understanding among themselves during practice.

> *"I can easily remember what I studied in school and when I tell my colleague X, he sometimes tells me a different story. This is due to the fact that he studied so recently, let's say three years ago, while I studied the similar subject 12 years ago…There is a need for all of us to have the same updates. This application is a solution because it keeps getting updated" Nurse, FGD1.*

When asked if they will continue using the SDA in their future practice. Both nurses and midwives stated that due to the SDA benefits, it is their own advantage to continue using it in their routine practice for efficient provision of care.

> *"I would say that we have been lucky to be the champions of this application. I agree that we have a lot of work to do in maternity but we can't forget that we also need updates in our career…We will always need to refer to the app in our routine practices and find some time to learn new things from the SDA. We shall keep using it and it is for our own interest" Midwife, FGD2.*

> *"This application is user friendly, affordable, covers a lot of areas, and does not take your internet megabytes when using… It is not like a book or a computer that would be heavy for you to carry…It is in a mobile phone that you always carry in your hands…You can check up anything, anywhere and anytime…. Unless something unexpected happens, I don't see how people can stop using the SDA" Midwife, FGD1.*

When asked how they perceive the SDA sustainability in district hospitals in Rwanda, all nurses and midwives indicated that the SDA will be likely sustained.

> *"This application will be maintained because it is an important tool for us to deliver good service to the patients. When you use it properly, you deal with*

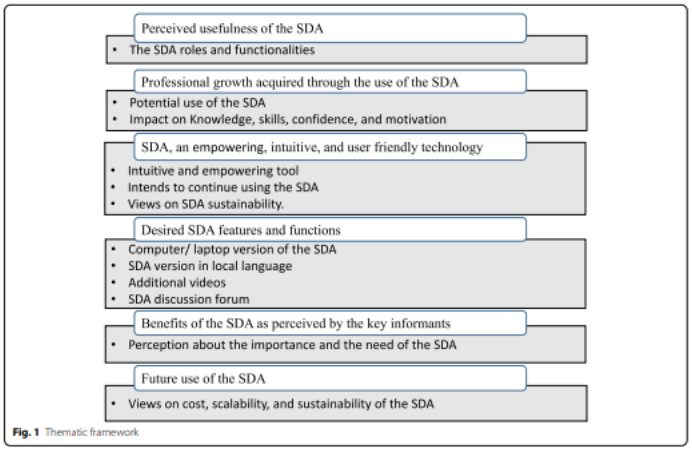

Fig. 1 Thematic framework

various cases with confidence and you perform your duties with success" Midwife, FGD1.

"I am also confident that SDA will be sustained for two main reasons. The first reason is that it is easy to use and provides text content accompanied by video materials. Secondly, SDA is so relevant in that it is equipped with modules that reflect our day to day clinical practices" Midwife, FGD2.

Furthermore, participants requested the SDA scalability to the whole country of Rwanda in consideration of the present country's agenda to support the adoption of technology in healthcare service delivery.

"Personally, I would say that this is the most appealing application on my phone…When we are discussing with colleagues on social media (WhatsApp), there may be some questions raised in relation to our career. When there is a confusion, I immediately take my phone, get reliable information from the SDA and in a fast way I share with them… Is it possible to implement this app in all hospitals in Rwanda? …Since most people have smartphones, this should not be a problem, also our country is currently promoting application of technology in healthcare. I think this would make a lot of difference" Midwife, FGD1.

"I have to tell you that this is a very good application, those using the application have already started seeing the benefits and they gain a lot from it. I wish it could have been shared with other hospitals too. It should be scaled up to national level. I wish to see all midwives in Rwanda using this app… It is easy to use, once you have it installed, you don't need much guidance on how to use it, then we will be able to save more maternal and newborn lives" Midwife, FGD2.

"I remember I was in Musanze some time back and when I talked about this application to my friends, they were surprised. They started asking me how they can access it too. I just showed them and they became very interested. I am inviting everyone to have this spirit of sharing so that it reaches more people" Nurse, FGD1.

Other participants recommended that the SDA should be part of learning materials used at University.

> *"Ever since I started using the SDA, there has been no single case that I have failed to get information about in this application. I think this application should be part of tools that midwifery students use at University before they graduate. If this is done, using it at workplace would be easier. I am confident that if you once saw something at school and you need to use it in your job, it becomes easily implementable" Midwife, FGD1.*

Desired SDA features and functions

The study participants were asked if there might be any other information or functionalities they would want to be added to the SDA for improving the application. Most participants stated that the SDA is useful as it is. However, some participants suggested features and functions they wish to be added to the SDA. Firstly, participants requested if the SDA could have a version for desktop and laptop computers so that it could be installed in computers available at their respective hospitals or if they could access the SDA using a desktop/laptop browser.

> *"I wonder if this application can't be installed in our office computers because sometimes one's phone might not be available maybe because it is not charged, it is stolen or broken or the owner simply doesn't have it with him/her. Having the application available in various devices would be much better and accessing it might be easier for everyone" Midwife, FGD1.*

Other participants expressed their need for locally appropriate clinical decision support tools and emphasized their wish to have a version of the SDA available in the local language 'Kinyarwanda.'

> *"I would like to add that it would be great to have this application in Kinyarwanda like I saw it having other language versions including Swahili, Hindi.... I guess this is a process, but we will be grateful if this is expedited. That will really be helpful. Thanks" Nurse, FGD2.*

In addition, nurses and midwives requested additional animated videos to be added to the SDA. These include; videos on antenatal care in line with the new WHO antenatal care models with a minimum of eight contacts as well as guidance on the identification of risk factors for birth complications before delivery.

> *"I think this application can be very helpful if they add some videos on antenatal care or how one could identify a woman in labor who would probably get a complication" Midwife, FGD2.*

Also important was the suggestion that the SDA application could have a discussion forum window or platform for the users across different hospitals and countries to share experiences about managing obstetric emergencies.

> *"I wish that this application can have a kind of worldwide discussion forum where we can put comments and share experiences and views. For example, a midwife from X hospital in Rwanda can discuss and share her experience with midwives in other hospitals across multiple countries....Sharing like this can upgrade levels of knowledge for everyone. I think this would be very beneficial" Midwife, FGD1.*

Interviews with key stakeholders

The analysis revealed two main themes: (1) benefits of the SDA as perceived by the key informants, and (2) future use of the SDA. These identified themes are shown in Fig. 1. The details on the main themes and sub-themes are presented, and are illustrated by quotations from the six KIIs.

Benefits of the SDA as perceived by the key informants

The key informants described the SDA as a useful tool and recommended its implementation in routine practices, specifically for the purpose of continuous learning without interrupting health services. Such benefit was depicted as fitting for the work environment in the context of Rwanda where numbers of healthcare providers were insufficient. Clinical staff require periodic training to stay on track with the knowledge and skills necessary for their practice. For their annual practice licence renewal, they need evidence of continuous professional development in addition to corresponding academic credits. SDA was therefore seen as a valuable solution as it offers on-the-job learning opportunities, assessment strategies, and possibilities of getting certificates.

> *"This application is useful as it allows on-job continuous learning. We have been facing challenges for getting continuous learning opportunities for all staffs, now the SDA comes with this advantage. I recommend that it should be incorporated in routine practices" Respondent, KII 3.*

While the SDA was recommended for staff, because it captures the essential topics for BEmONC, key informants felt that this should in addition to the other sources of information including formal books and Ministry of Health guidelines that gives a broader view of obstetric care.

"The SDA is good particularly for BEmONC but the SDA alone cannot solve all maternity care problems. Our staff need to use this application together with other sources of reliable information like the guidelines from the Ministry of Health" Respondent, KII 1.

Another benefit highlighted was that the SDA is applicable in clinical practices by providing guidance on essential procedures that are needed to save maternal and newborn lives.

"...We need safety in all we do, so this application is welcomed. I was happy to note that it provides concise information that will help nurses and midwives to take good decisions when dealing with childbirth complications" Respondent, KII 6.

Future use of the SDA

When KII participants were asked their opinions about the SDA cost, scalability, and sustainability, opinions on the future use of the SDA in Rwanda were apparent, along with the aspect of technology application in healthcare and its support in continuous learning. Participants perceived the estimated cost of piloting the SDA as affordable compared to physical training opportunities or online learning resources. They recommended the SDA implementation in consideration of its benefits, particularly the mLearning opportunity.

"The cost is reasonable compared to other online learning tools....Also physical training has a double cost of time and resources. This application can train many people at the same time depending on individuals' needs....I think this mLearning approach should be promoted in Rwanda as the country is looking to making healthcare services electronic-based...This application will be one of the solutions" Respondent, KII 5.

One participant was concerned about the technology cost. But, he indicated that this cost could be alleviated by the fact that many healthcare providers own a smartphone. He suggested that they could use their own smartphone for future use of the SDA.

"The technology cost is a bit high but as many people have smartphones and access to good internet, this might not be a problem. They could download the SDA on their own smartphones" Respondent, KII 6.

In addition, participants expressed their wish to see the SDA implemented at a large scale, in all hospitals in Rwanda. However, they recommended that the SDA scalability needs to be preceded by a proper assessment and approvals by all required bodies.

"Technology is in everything we do in healthcare and this application is useful...For future implementation, you need more sensitization and to involve all key stakeholders like MOH (Ministry of Health), RAM (Rwanda association of midwives), association of gynecologists and pediatricians..." Respondent, KII 2.

"I think after in-depth assessment and approval by MOH (Ministry of Health), the whole country (all hospitals) could use this application and it could help us to promote continuous learning while at work" Respondent, KII 3.

Another participant highlighted the need for possible monitoring and follow-up programs to evaluate if the acquired knowledge and skills are translated into real clinical practices. He also suggested that the monitoring programs could be connected with the existing annual performance contracts and evaluation.

"...Some mechanisms of monitoring could be put in place to assess if what has been learnt in the SDA is being practiced...Why not link this monitoring with imihigo (performance contracts)? People should think about it" Respondent, KII 4.

Then again, participants indicated that the SDA could benefit a large variety of healthcare cadres like medical doctors.

"...Not only nurses and midwives would benefit from the application, medical doctors can use it ... Everyone needs to know how it works and its importance. Respondent, KII 2.

Moreover, KII participants perceived the SDA as an easy to use tool with well explained topics. They indicated that the SDA could be sustained because it supports healthcare providers to manage childbirth complications. They also acknowledged the fact that the SDA provides useful information needed in routine clinical practices.

"I think this application will be sustained...When you see the topics and how they are explained... This information is what our staff need every day for managing birth complications" Respondent, KII 1.

Furthermore, participants suggested additional topics other than topics of BEmONC that could be added to the SDA to make it more useful and sustainable.

"We have seen some additional topic like COVID 19 and infection prevention in this application. Other topics that are generally relevant for healthcare providers could be added....I am thinking of topics like: medical bio safety and bio security, patient centered care and quality improvement, ethics in clinical

practice…all these topics could be tied to maternity care" Respondent, KII 3.

Discussion

The present study findings indicate that the SDA was acceptable to both the end-users and the key informants. End-users, nurses and midwives, used the SDA frequently, and viewed it as a useful tool that contributes to their professional growth and improve their practice. They frequently used it for education to revise and improve knowledge and skills, and as a decision support tool when immediate guidance was required to manage birth-related complications. Users felt that the SDA has improved their confidence and ability to manage childbirth complications, which they were previously insecure about. These findings are supported by a pre-post intervention study conducted with the same population, which found that the SDA in Rwanda led to a significant increase in nurses and midwives' knowledge and skills scores for PPH and NR management six months after SDA introduction [19]. Other researchers similarly indicated that the SDA, when used as a training tool, has shown significant increases in knowledge and skills of different healthcare professionals [29, 30].

The perceived usefulness of the SDA seems to be related to its functionalities when applied to the clinical context of low resource settings [11]. This study emphasized the fact that the SDA offers continuous training opportunity without interrupting health services which is very beneficial due to the shortage of staffs. These findings mirror those of other studies that mHealth applications are increasingly being used in LMICs to improve health professionals' access to evidenced and up to date information and training. In maternal and newborn healthcare services, mHealth application are being used as both training tools [31] and decision support tools [32]. The adoption of these applications in resources poor settings depend on their functions that need to be tailored to contexts of interest [33]. Other studies have similarly shown that mLearning are potential solutions to support continuous learning among health professionals in LMICs [34, 35].

Also, in the current study, the SDA was reported to be practical by helping nurses and midwives translate theoretical knowledge into practice with the support of visual instructions in the animated videos. Then again, with mLearning, the user has the opportunity to study/read multiple times and master the subject. A study in Kenya compared hands-on and video training for PPH management and reported that video training appeared to be as effective as hands-on training [36]. Thus, mHealth applications providing visual instructions via animated videos such as the SDA are potential solutions to improve knowledge and skills of nurses and midwives.

In addition, nurses and midwives had a positive experience with the SDA, they felt confident and better at their job when using the SDA, and reported it as an easy to use, intuitive and empowering tool. Participants were motivated to use the SDA in providing better services and suggested additional features and functions. These findings are in agreement with other studies which reported that the use of mHealth application is perceived as an opportunity for improving the quality of healthcare services with an effect on staff confidence [37], motivation [38], and self-efficacy [39]. Likewise, a realistic review about mHealth and the performance of maternal health care workers in low- and middle-income countries, revealed that health workers can be empowered to adopt and utilize mHealth in contexts where it is aligned to their needs, workload, training, and skills [40]. The review also noted that mHealth can empower health workers with skills and confidence when it is perceived as useful and easy to use [40]. Consequently, the SDA like other mHealth applications is considered an empowering tool that has a positive impact on healthcare delivery processes.

Moreover, in this study, the SDA was highly acceptable by nurses and midwives who admitted to continue using the SDA in their daily clinical practices. This level of user acceptance combined with the documented impact of the SDA is interesting considering the existing gap of ensuring access and adherence to BEmONC evidence-based clinical guidelines in low- and middle-income countries. Several studies have found a low adherence to evidence-based standards for maternal and newborn care particularly in low resource settings [41, 42]. Other studies have suggested the use of mHealth to improve the access and adherence to evidence-based guidelines [32, 43, 44]. Therefore, mHealth tools such as the SDA, which ensures access to the most recent BEmONC evidence-based clinical guidelines, and is demonstrably well accepted by its end-users, may help to improve the adoption of guidelines. The advantages of the SDA are that it is self-explanatory, available in many languages, is open source and free for download, and, once installed on the smartphone, does not require internet to function.

Furthermore, the SDA was appreciated by key informants in the management position at the district hospital level. On the other hand, those key stakeholders acknowledged the benefits of the SDA and were willing to advocate for its scalability for future use in Rwanda. They noted that the cost of piloting the SDA in two district hospitals was reasonable and predicted the possible sustainability of the SDA. However, they recommended a large scale research on the SDA and involvement of the

required bodies. Likewise, Eze et al. [45] used a stakeholder perspective to analyze existing research on the mHealth process in developing countries, and reported that interactions between system developers and stakeholder groups are important for sustainability of mHealth [45]. Another research documented that in order to realize the potential benefits of mHealth, it is important to identify the relevant stakeholders and how they might be affected [46]. Other studies similarly found that the complexity of introducing mHealth into health care calls for strategies encouraging collaboration between multiple stakeholders to enhance successful implementation [47–50].

Implications for research and clinical practice

The implications of this study are that the SDA was accepted by both end-users and key stakeholders due to its functions tailored to the Rwandan context. Among the beneficial functionalities of the SDA, there is the capacity of the SDA to function as a training tool and a decision support tool. This increases the confidence and the ability of nurses and midwives in providing quality care during obstetric and neonatal emergencies as well as improved routine obstetric and newborn care. The acceptability and the positive perceptions of the SDA in two district hospitals reflect a possible adoption of the SDA even on a large scale in Rwanda like in other low-resources settings. Evolving efforts for quality maternal and newborn care in Rwanda and similar contexts should consider the integration of SDA as an approach for training and as a clinical decision support tool for BEmONC in order to reduce maternal and newborn mortality. Future work could consider large scale studies of the SDA with maternal and newborn outcomes as primary outcomes.

Strength and limitations of the study

The study is limited by the small sample size, which reflects the fact that the SDA was implemented only in two district hospitals due to funding limitations. Therefore, the findings of the current study cannot be generalized. Nevertheless, the evidence that the SDA was acceptable and perceived useful by both end-users and key stakeholders at the piloting settings sets the stage for expanding coverage and further testing of the SDA intervention to other hospitals in Rwanda. Additionally, the accuracy of our findings is increased by supporting the acceptability survey with focus group discussions to provide context to and clarify reasons behind some participant responses.

Conclusions

The nurses and midwives perceived the SDA as an easy to use, useful, intuitive and empowering tool, which helps them update and revise their knowledge and skills, improves their confidence and makes them feel better to deliver quality obstetric care. Key stakeholders also perceived the SDA as a relevant and useful tool with a reasonable cost and recommended its implementation in routine practices. Overall, both end-users and key informants think that the SDA is beneficial and could be sustained. End-users suggested additional features that would improve the usability of the SDA. These included: a computer/ laptop version of the SDA, a SDA version in Kinyarwanda language, some additional videos, and a SDA discussion forum. Key informants also suggested additional topics that could be added to the SDA such as; medical bio-safety and bio-security, patient centered care and quality improvement, and ethics in clinical practice. The positive perceptions of the SDA in Rwanda is an indication that similar mLearning and mHealth decision making tools could be adopted as a means to improve knowledge and skills of nurses and midwives. The mHealth applications like the SDA have the potential to improve patient care, as they avail evidence-based clinical guidelines and can be easily adapted to contextual needs. Thus, credible, evidence-based, affordable mHealth applications like the SDA are needed to support clinical decision making and provide a platform for updates and continuous learning for nurses and midwives in Rwanda and other limited resource settings. The present study also adds to existing evidence about the benefits of mHealth applications in assuring quality BEmONC.

Abbreviations

BEmONC: Basic Emergency Obstetric and Newborn Care; FGD: Focus Group Discussion; KII: Key informant interview; mHealth: mobile health; mLearning: mobile learning; LMICs: Low- and middle-income countries; NR: Neonatal Resuscitation; PPH: Post-Partum Hemorrhage; RAM: Rwanda Association of midwives; UNICEF: United Nations International Children's Emergency Fund; UNFPA: United Nations Population Fund; WHO: World Health Organization.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12912-022-00951-w.

Additional file 1.
Additional file 2.
Additional file 3.

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Authors' contributions

AN, DNC, MN and, LI were involved in the conception and design of the study. AN drafted the manuscript. DNC and LI assisted with data analysis and interpretation. DNC, MN, and LI reviewed the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets generated for this study will be made available from the corresponding author on a reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approvals were obtained from the Human Research Ethics Committee of the University of the Witwatersrand (M190258) and the University of Rwanda, College of Medicine and Health Sciences' Institutional Review Board (No. 377/CMHS IRB/2018). All participants gave written informed consent and consents for recording the interviews prior to their participation. Participants were assured that their identities would remain anonymous in all reporting of the study and that their personal information would be kept confidential.

Consent for publication
Not applicable.

Competing interests
None declared.

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Appendix 19. Originality Report



Draft thesis

ORIGINALITY REPORT

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SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Aurore Nishimwe, Daphney Nozizwe Conco, Marc Nyssen, Latifat Ibisomi. "Context Specific Realities and Experiences of Nurses and Midwives in Basic Emergency Obstetric and Newborn Care Services in Two District Hospitals in Rwanda", Research Square Platform LLC, 2021 Publication	14%

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