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Health Systems Factors Influencing the Delivery of Emergency Obstetric Care in a South African District

By:

Siphiwe Bridget Pearl Thwala

Thesis submitted in fulfilment of Doctor of Philosophy

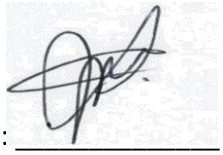
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Candidate Declaration

I Siphiwe Bridget Pearl Thwala, solemnly declare that this thesis is my own and original work. It has not been copied or reproduced in part or whole from elsewhere. This thesis is being submitted for the doctor of Philosophy Degree at the University of the Witwatersrand in Johannesburg, South Africa and has not been submitted for any other degree elsewhere.

Signature: 

Date: 20/10/2020

Dedication

To my son Wamukelwe, my mother, my second mom -Phindile, and my family.

Acknowledgements

The Almighty God: None of this work would have been possible without him. He literally held my hand throughout the PhD.

Dr Duane Blaauw: My supervisor of note, thank you for all your support and mentoring throughout this journey.

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Sakhile Thwala: My sister for real. You have been there the whole time. You saw the tears, and helped wipe them away

Keith Khaweka: You have been more than a brother-in-law. Your friendship, faith, support, and love has been extraordinary.

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5. **Thwala SBP**, Biljmakers L, Blaauw, D, Sayinzoga F, Mathole T, Zsarowsky C, Jackson D, Penn-Kekana L. (30th September -3rd October 2014). Preliminary findings on Emergency obstetric care and the health system in a South African District. (Oral presentation in an interactive session). *3rd Global Symposium on Health Systems Research*. Cape Town: South Africa

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Definition of terms

Maternal death: A woman that dies during pregnancy, labour, or the postnatal period up to 42 days after the end of the pregnancy but not from accidental or incidental causes.

Pregnancy related death: A woman that dies during pregnancy, labour, up to 42 days after the end of the pregnancy regardless of the cause of death.

Near miss: A woman who almost dies, but survives during pregnancy, childbirth, or up to 42 days after giving birth

Skilled health providers: Health providers who have formal training in maternity care during pregnancy, labour, and the postnatal period.

Abbreviations

ANC	Antenatal care
BEmOC	Basic emergency obstetric care
CEmOC	Comprehensive emergency obstetric care
DHIS	District health information system
DoH	Department of Health
EmOC	Emergency obstetric care
ESMOE	Essential steps in the management of obstetric emergencies
HIC	High-income country
HIV	Human immunodeficiency virus
HR	Human resources
HRH	Human resources for health
HS	Health system
HSS	Health system strengthening
iMMR	Institutional maternal mortality ratio
LG	Local government
LMIC	Low- and middle-income country
MD	Maternal death
MDGs	Millennium development goals
MH	Maternal health
MMR	Maternal mortality ratio
MOU	Midwife obstetric unit
NCCEMD	National committee for confidential enquiry into maternal deaths
NHI	National health insurance
NM	Near-miss
PMTCT	Prevention of mother-to-child transmission
PNC	Post-natal care
SA	South Africa
SAQ	Self-administered questionnaire
SDG	Sustainable development goal
SMO	Severe maternal outcome
UHC	Universal health coverage
UN	United nations
WHO	World health organisation
SDGs	Sustainable development goals

Abstract

Background

Ekurhuleni District has an unacceptably high maternal mortality ratio (MMR) that is persistently greater than the provincial average. The Gauteng Province identified Ekurhuleni as a high priority district, requiring heightened focus to reduce the MMR and end preventable maternal deaths. Most of these deaths are due to direct pregnancy related causes that can be effectively reduced by the emergency obstetric care (EmOC) intervention. The national committee for confidential enquiry into maternal death (NCCEMD) identified health system strengthening (HSS) as one of South Africa's key focus areas to decrease maternal mortality. Strategies for health system strengthening are not clear however. This PhD work sought to investigate health systems weaknesses, which if addressed could strengthen the health system of Ekurhuleni district, in order to reduce the MMR.

Purpose

To identify health system factors that influence the delivery of EmOC, and understand how these factors translate to severe maternal outcomes (SMOs) in the delivery of EmOC.

Methods

A mixed-methods study design was used. EmOC was used to trace the health system's support of maternal health using the WHO health systems building blocks. The extent to which EmOC services were available in the district was assessed. A rapid health system audit was performed in 15 public health facilities that offered EmOC services to the public in the district. To measure the impact of health system factors to maternal outcomes, a comparative near-miss audit was conducted over 12 months in two regional hospitals with contrasting performances in maternal outcomes. Lastly, a qualitative study was performed to explore in-depth, heath system governance issues that impacted on EmOC delivery and subsequent outcomes of the district. Analysis was methods specific. Descriptive statistics reported in proportions and frequencies of key indicators in the assessment of the availability of EmOC and the rapid health systems audit. Firth adjusted penalised conditional logistic regressions were used to establish associations of socio-demographic, obstetric and health system factors with

severe maternal outcomes (SMOs). Relationships were confirmed by multiple regression analyses. Thematic analysis was performed for qualitative data to determine governance and leadership issues explaining the reasons behind the health system performance measured by maternal outcomes.

Results

All 7 hospitals were classified EmOC facilities and none of the 8 community health centres (CHCs) qualified to be classified. There was a shortfall of at least 18 EmOC facilities to meet the current population need in the district. Midwives in hospitals had a significantly higher workload than in CHCs ($p<0{\cdot}0001$). Skilled health providers were not always available for women requiring EmOC in CHCs. None of the health facilities (0.0%, N=15) scored 100% on any checklists measuring drugs, equipment, supplies, or EmOC guidelines.

Health system effect on quality of EmOC and corresponding outcomes

The overall hospital MMR was high at 139.8 per 100 000 live births. Haemorrhage (35.4%) and hypertension (32.5%) were the most common underlying causes of SMOs. Anaemia was an important contributing factor as it was present in 21% of women. Antenatal care (ANC) was protective against SMOs ($p<0{\cdot}001$). Poor overall quality of EmOC, administrative problems, and health provider related problems had the highest odds for severe maternal outcomes (SMOs). EmOC facilities were often inadequate to meet need and could not therefore deliver care adequately.

Impact of health system factors on SMOs

The likelihood for SMOs from lack of access into the operating theatre (OT) was 17 fold (OR=17.4; 95%CI=4·28-70.56). Women were nearly 71 times more likely to have SMOs from lack of access into the intensive care unit (ICU) (OR=70.6; 95%CI=4.39-1135.35) when required. Ambulances (OR=4.0; 95%CI=0.73 - 22.11) were often unreliable and this predicted SMOs. Health providers sometimes gave substandard care (OR=10.0; 95%CI=1.24-80.48) or delayed to give care (OR=15.2; 95%CI=4·87-47·72) and this significantly raised the risk for SMOs. EmOC health providers were sometimes fewer than the need for EmOC by women, raising the risk for SMOs significantly (OR=3.1; 95%CI=0.51-6.33). Important patient factors were women delaying to present for care in hospitals ($p<0.01$) and lack of

information on pregnancy danger signs (p<0.05).Patient factors also had a high odds for SMOs in bivariate analysis, but were less significant (p=0.12) in the multivariate analysis where health provider (p<0.001) and administrative factors (p<0.001) were included.

Management experiences of the health system

In the interviews, district managers identified important health system weakness in relation to all six building blocks. Senior management posts were often vacant or manned by acting managers with a high turnover. Other important health systems issues included segmented EmOC services with suboptimal coordination between them; inadequate health providers to administer EmOC; insufficient numbers of ambulances available for EmOC; overwhelmed health facility infrastructure; inadequate routine health system indicators to rapidly reflect performance on EmOC; and insufficient overall funding for EmOC delivery.

Conclusions

The overall state of the health system is indeed weak in Ekurhuleni district, and results in poor quality of EmOC given, which corresponds to the occurrence of SMOs. EmOC medicines and supplies were not always available in health facilities and this limited the availability of EmOC in the district. Health system factors have a significant impact on SMOs, and therefore need to be addressed in order to prevent avoidable SMOs. To strengthen the health system, more EmOC facilities are needed to have EmOC readily available for women and decentralise EmOC. The organisation of EmOC services also needs revisiting to improve coordination by managers and subsequent service delivery. Furthermore, ANC is effective in protecting women from SMOs, and is a strength of the health system. More needs to be done to improve ANC attendance to 100% and to assure more than 4 visits by all women in the district. This PhD also contributes methodological innovations in measuring the size of the impact of health system factors on SMOs.

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Chapter 1: Background and Literature Review

This chapter introduces the thesis and sets the scene for the methods and discussion section. It details the literature review and the context in which this study was made.

Background

Millennium developmental goal (MDG) evaluations have shown that the world has made positive strides in reducing preventable maternal deaths. The overall global maternal mortality ratio (MMR) has reduced by 49% in the MDG era [1]. However, 99% of maternal mortality is localised in low- and middle-income countries (LMICs), and 66% is in sub-Saharan Africa [1]. Maternal mortality is mostly preventable, and the low maternal mortality rate (MMR) in high income countries is indisputable evidence in support of this claim [2-8]. Persistent high mortality rates are therefore unacceptable, and justify concerted efforts to reduce them. UN sustainable developmental goals (SDGs) are now in place of the MDGs and carry on the goal to reduce the global MMR has been sustained. It now targets to reduce the global MMR to less than 70 per 100 000 live births by the year 2030 [9].Maternal health programmes around the world promote interventions that target ending preventable deaths of women from pregnancy related causes. These maternal health interventions include family planning antenatal care (ANC), post-natal care (PNC), emergency obstetric care (EmOC), neonatal care, and life-longanti-retroviral therapy to pregnant mothers. However, interventions have been characterised mostly by vertical programme approaches, with limited recognition of the underlying health system weaknesses or additional support needed to implement them. A systems approach is needed, to identify the system components that influence implementation of maternal health services, both at the facility and community level [10, 11].

Pregnancy-related deaths are defined as deaths of women while pregnant or within 42 days after the end of pregnancy regardless of the cause of death [12, 13]. Maternal deaths are defined as deaths of women during pregnancy up to 42 days post pregnancy but not from accidental or incidental causes

[14]. Maternal mortality is commonly estimated by pregnancy related deaths, because of uncertainty over the cause of death, particularly in LMIC settings [13]. SA records women who die in health facilities exclusively, and is therefore able to report maternal deaths. Pregnancy related deaths are attributed to either direct or indirect causes of pregnancy. Indirect causes include deaths from non-pregnancy related infections (e.g. HIV, respiratory infections), traffic accidents, and gender-based violence. The most prevalent of these in many LMICs including South Africa is HIV. Direct pregnancy related deaths include obstetric sepsis, obstetric haemorrhage, pregnancy induced hypertension, and anaemia [15]. There are effective interventions in place, proven to be effective against direct and indirect causes of maternal deaths. Antiretroviral therapy introduced during pregnancy in the programme 'prevention of mother to child transmission of HIV' is an example, and has reduced HIV related maternal deaths considerably in South Africa [16, 17]. While effective interventions exist, the MMR of countries particularly in sub-Saharan Africa has persisted at unacceptable levels. This has prompted more detailed investigation, including the introduction of confidential maternal death audits in many countries. These and other types of enquiries (e.g. near miss studies) consistently identify the health system as one of the key weaknesses responsible for poor maternal health [18-21].

While differences in MMR by level of development suggest that poverty (and other social determinants) are associated with more maternal deaths, achievement of MMR reduction by some LMICs, such as Rwanda and Mozambique, indicates that other factors are also important [4]. Frenk [22] states that health systems strengthening globally, is what is required to achieve health goals and sustainably improve health. van Lerberghe and de Brouwere [23] were among the first to identify strategies that historically had worked in reducing maternal mortality to very low levels in high income countries (HICs). Interventions that worked included political will of countries evidenced in their policies and norms; childbirth professionals who were skilled, respected, accepted, and accountable; improved access to care; all in combination with technological advances in maternal health [23]. de Brouwere, *et al* [24] observe that policy, obstetrics care (which includes EmOC), and accountability of maternal care providers were among the most responsible for successful overall reduction of the

MMR in HICs. Since high income countries have managed to sustain these MMR reductions, LIMCs can possibly learn from these strategies to reduce maternal deaths, which remain common in these developmental regions.

Literature review

The case for emergency obstetric care

Direct obstetric causes are responsible for the majority of maternal deaths globally [25, 26].These causes include haemorrhage, sepsis, hypertension, abortion, and embolism [25]. Emergency obstetric care (EmOC) is a maternal health strategy that comprises of a set of interventions proven to be effective in combating these direct causes of maternal deaths and therefore necessary to save women's lives [27-31]. The majority of maternal deaths occur during labour, delivery and the early postpartum period [25, 26]. EmOC is concerned with providing appropriate obstetric care when a woman presents with complications in pregnancy, labour, or postpartum period [32]. Global recommendations to improve maternal outcomes focus significantly on improving EmOC [28, 33, 34]. EmOC needs to be available and accessible to women when required. Monitoring whether EmOC is adequately implemented nationally or at sub-national level to assure its effectiveness has been evaluated by a set of indicators developed by the United Nations (UN) [35] and used extensively around the world (Table 1).

Table 1: Indicators for monitoring EmOC

#	Indicator	Definition	Numerator	Denominator	Benchmark/ minimum acceptable level
1	Number and density of facilities providing EmOC services;	Number of health facilities that perform complete set of signal functions in relation to the size of population	Basic EmOC: Number of facilities that perform 7 basic UN EmOC signal functions Comprehensive EmOC: Number of facilities that perform all 9 UN EmOC signal functions	Denominator: Number of people in the geographical area	Basic EmOC: 4 per 500 000 people Comprehensive EmOC: 1 per 500 000 people
2	Geographical distribution of EmOC facilities	Same as first but considers geographical distribution and physical access to EmOC facilities by women	Basic EmOC :Number of facilities that perform 7 basic UN EmOC signal functions in a geographical location Comprehensive EmOC: Number of facilities that perform all 9 UN EmOC signal functions in a geographical location	Denominator: Number of people in the geographical area	Basic EmOC: 4 per 500 000 people Comprehensive EmOC facility: 1 per 500 000 people
3	Proportion of all births in EmOC facilities;	Proportion of all births in a geographical area that occur in EmOC health facilities	All births that occurred in EmOC facilities	All births that occurred in the area regardless of place of birth (in or out of health facilities)	100%
4	Met need for EmOC;	Estimate of the proportion of women with major direct obstetric complications who get treated in an EmOC facility (basic or comprehensive)	Number of women with direct obstetric complications	Expected number of women who would develop direct obstetric complications (15%)	100%
5	Caesarean section rate;	The proportion of all births by caesarean section in a geographical area	Women who have had a caesarean section regardless of indication	All live births in an area (including out of health facilities)	Unknown 5-15% suggested by the UN EmOC handbook
6	Direct obstetric case fatality rate	Proportion of women with major direct obstetric complications who develop this complications after admission and die before discharge	Women who die of direct obstetric complications in a health facility	Number of women with direct obstetric complications in a health facility	<1%

Adapted from UN EmOC Monitoring Handbook[34]

The UN Handbook comprises of a specific set of life saving obstetric procedures termed 'signal functions' [35]. These are classified as either basic or comprehensive obstetric emergency care signal functions [35]. Basic EmOC signal functions;

- are administration of parenteral antibiotics;
- administration of uterotonic drugs;
- administration of parenteral the anti-convalescent magnesium sulphate;

- manual removal of the placenta; removal of retained products of conception;
- performance of assisted deliveries;
- performance of basic neonatal resuscitation [35].

Comprehensive EmOC, includes all the basic signal functions and adds;

- the administration of blood;
- the performance of Caesarean sections [35].

Maternal health in South Africa

South Africa has performed confidential enquiries into maternal death audits since 1998. According to the National Committee on Confidential Enquiries into Maternal Deaths (NCCEMD), institutional maternal mortality rose from 151.8 per 100 000 live births in 2007 to 176.2 per 100 000 in 2010 despite several developments in maternal health in the country [36, 37]. Estimates of the overall population MMR have also increased from about 150 per 100 000 in 1990 to 300 per 100 000 live births in 2010 [36, 38]. While PMTCT has duly reduced HIV related deaths, to bring down the MMR to 146.7 per 100 000 live births [39], more needs to be done to reduce it further.

The NCCEMD) showed that 29.6% of deaths were due to non-pregnancy related maternal sepsis [40]. The first NCCEMD report, had 5 main causes of maternal mortality, namely hypertension (19.0%), obstetric haemorrhage (15.4%), pregnancy related sepsis (13.9%), pre-existing maternal disease (7.9%), and non-pregnancy related sepsis mostly from AIDS (29.6%) [40]. It was concerning that most maternal deaths were AIDS related, and sparked increased national efforts to reduce disease progression from HIV to AIDS in pregnant mothers, while limiting transmission of HIV from mothers to babies [41]. Increased access to anti-retrovirals (ARVs) for HIV-positive mothers has led to a significant reduction in indirect causes in South Africa [16, 18, 41].

Meanwhile, direct causes (mostly obstetric haemorrhage and hypertension) have remained high [16, 39, 42]. EmOC is an important intervention in South Africa to reduce these direct causes [35, 43]. The seventh NCCEMD report shows increase in deaths from hypertension in pregnancy in particular [16].

Persistent direct maternal deaths are associated with deficiencies in the availability and quality of EmOC services by the NCCEMD in South Africa. For example, quality of care issues were observed and potentially avoidable in at least 60% of deaths [16, 17]. Poor quality of care is in fact a recurrent theme in two thirds of maternal deaths in all 7 saving mother's reports of the NCCEMD [16-18, 39, 40, 44, 45].

To address the 5 high priority areas for reducing maternal mortality highlighted by the NCCEMD [36], national government and researchers have responded. South African maternal health guidelines [46, 47] have been developed to address hypertension in pregnancy and obstetric haemorrhage. Obstetric clinical protocols have been developed by the national department of health (NDoH) for the management of haemorrhage and hypertension [47]. An in-service training program for EmOC providers (doctors and midwives) called Essential Steps in the Management of Obstetric Emergencies (ESMOE) has been the subject of evaluation and other scientific enquiry to determine its effect in SA [48]. ESMOE addresses health worker training in EmOC. Life-long ART has been rolled out country-wide to all pregnant women that test HIV positive without out of pocket payment by mothers. All these are clear strategies of what needs to be done to decrease avoidable mortality for at least four (hypertension, haemorrhage, health worker training, HIV) NCCEMD identified priorities. However, what needs strengthening in the health system or what to prioritise first to reduce the MMR seem less clear.

Health systems strengthening for maternal health

There has been a need to define what the health system is, to bring some uniformity of understanding as stakeholders and health authorities discuss strategies for health system strengthening for maternal health. The World Health Organisation (WHO) [49] defined the health system as all the activities whose primary purpose is to promote, restore, and maintain health. Hsaio [30] defined the health system as a set of relationships in which the structural components and their interactions are connected to the goals the system desires to achieve (ends). Increasingly, global health actors, such as Global Fund, recognise that priority health programmes and interventions have to be delivered

through national health systems which are responsible for good population health outcomes, equity in health services provision and access, efficiency in the dispensation of care, as well as responsiveness of health interventions to the needs of the target populations [49-53].

Health systems frameworks have been developed by several scholars to bring clarity to what is entailed by a health system, and how health components fit together in the system. Approaches to structured thinking about the health systems were pioneered by economists who battled with ways to generate and sustain funds to support healthcare since the wellbeing of the population was found to be closely linked with economic productivity [54, 55]. An economic model by Evans [56] conceptualised health systems as the pattern of relationships between key actors: the population requiring care, health care providers, third party payers, as well as government which regulates the system. Similarly, Hurst [55] described health systems in terms of payment methods and flows of funds between providers, consumers of health care, and institutions. Cassels [57] characterised health systems in relation to supply and demand where supply represents the human and material resources of the health service delivery system and demand represents patient and population factors related to the utilisation of the available services. All these frameworks remain useful, but focus primarily on financing arrangements.

More recent frameworks emphasise other aspects of the health system. In 2000, WHO developed a health systems performance framework which defined critical functions for improving population health outcomes [49, 58, 59]. These were resource generation, financing, service provision, and stewardship [49].This framework is useful in the evaluation of a health system, to help decide if it is reaching expected outcomes or performing as expected. In 2007 WHO expanded this model and proposed a health systems framework with six concrete building blocks [60, 61]. This building blocks framework has become widely used in the health systems field [62]. They are: governance and leadership; health finance; human resources; medicines, vaccines and technologies; health information; as well as services delivery [63]. These building blocks are specific, concrete and

measurable [64] providing a pragmatic way to scientifically study the health system, and understand the linkage with programmatic interventions such as the maternal health programme.

Meanwhile, other scholars have caution that conceptualisation of the health system should not be limited to the WHO building blocks [54, 65]. For example, Smith and Hanson [65] define the health system as concerned with all elements that directly or indirectly influence population health. This would include the wider context such as the local political context, local socio-economic surroundings, other sectors such as the agricultural and educational sector, as well as the wider global health policy context. Other scholars warn that the building blocks framework mainly focuses on the 'supply side' of the health systems and ignore the demand side such as the community [66]. Others add that health systems are 'open' not 'closed' systems that interact with their external environment by exchanging materials, energies, or information, and are influenced by and can affect the external environment [67, 68].

As open systems, health systems are subject to their local, national, national and global influences. van Olmen [69] adds that health systems are social institutions whose frameworks are developed from a particular political context specific to its developers at the time. A useful approach by Chee *et al* [70] expanded the building blocks into a 'cube' to reflect the vertical disease-specific programs (e.g. maternal health), and to show performance drivers of the system (e.g. policies).

Weak health systems perform poorly and contribute to poor maternal outcomes [18, 33, 64, 71]. Given the complexity of health systems and their intersection of health programs (e.g. maternal health), measurement methods to interrogate the link should be developed. In the current literature, there are few studies that have directly evaluated the size of these effects, making it difficult to weigh the relative importance of different health system factors to prioritise in health system strengthening [62, 64, 72]. Health systems factors are often regarded as 'soft' with their impact on maternal outcomes hard to measure, and are therefore commonly described, without detail exploration of the nature of their relationship [20, 73-76].

Health system building blocks and health systems strengthening

Health systems strengthening (HSS) has a wide ranging definition with different approaches in the literature [70, 77]. There is a debate over the kind of activities that constitute health systems strengthening and those that do not [70, 78]. Marchal [68] argued that the meaning of health systems strengthening is largely ill-defined by global health actors who have since labelled any form of capacity strengthening in the health sector as HSS. He urges that this renderers the term HSS meaningless, creates confusion, and deviates attention from the critical need to strengthen health systems for improved health outcomes in target populations. Actors often perform various kinds of activities in efforts to strengthen the health system, targeting different things in the process. Strengthening of the health system is said to be different from supporting the health system [70].

To measure the impact of health systems initiatives therefore, there needs to be a consensus on what is meant by the term 'health systems strengthening' [78, 79]. According to Chee *et al* [70] health systems strengthening is more about intensive efforts to improve the function of the health system rather than just performing small acts to fill up gaps in the system such as supplying needed EmOC drugs. It entails activities that provide a more holistic approach changes to improve multiple health services rather than one specific service such as changes in policies, organisational structures, relationships, and governance approaches [70]. Authors caution that unless health system strengthening activities are properly differentiated from other activities, evaluations may wrongly conclude that health systems strengthening fails to improve health system performance after measuring possibly mis-labelled activities.

According to the WHO definition, health systems strengthening is improving the building blocks and their relationships with one another [62]. de Savigny [77] argues that the relationships between the building blocks and their interactions with one another is what transforms them from mere blocks or inputs into a system. van Olmen [80] also stated that the nature of the relationship between the building blocks and the population is what determines the health system. Other schools of thought seek to determine more general drivers of performance rather than more narrow activities that do

not actually improve the overall functioning of the system [81-84]. In Rwanda for example, Sayinzoga and Biljmakers [81] observed that strengthening the health system required a holistic approach containing multiple concurrent interventions with complex relationships. This is different from the provision of a singular activity or narrow of interventions targeting an individual health program [70]. In agreement, Marchal and colleagues [79] add that strategies needed to target the broader health system rather than select disease specific initiatives if HSS is to be a reality.

HSS requires that the strengths and weaknesses to the health system be identified in order to work out what needs strengthening and how [70, 80]. The WHO health systems building block is useful for conceptualising the various essential elements of the supply side of the health system that need be functional for it to yield favourable maternal health outcomes [61]. Scholars and policy makers find this framework useful because it spells out resource inputs required to build a health system in concrete terms that are easy to understand. While the framework is useful for thinking about health system inputs abstractly, users have found the boundaries of each block difficult to delineate in practice because of their perceived interrelated nature. There are also questions around the nature of the relationships between building blocks [77, 85]. Some have suggested that they may be a hierarchy between the building blocks, where the governance building block possibly overarches the other building blocks [1]. There are also questions about which building block have most value for money in improving outputs. In the planning of health system strengthening, policy makers often have to make decisions about the prioritisation and sequencing of interventions in the face of limited resources, particularly in LMICs. These questions have not yet been adequately resolved, and require further empirical work.

According to Zakus *et al* [65] there is a tension between approaches that invest in general health activities supporting a comprehensive package of care (horizontal approach), versus strategies that focus on a narrower range of health services targeting specific diseases (vertical approach) [67]. Debates on vertical versus horizontal interventions have become less polarised as scholars agree that

both approaches are necessary to yield desired improved health outcomes [68, 86, 87]. According to Atun *et al* [68, 87], for example, the dichotomy between vertical and horizontal health interventions is not rigid in practice but exists in a continuum such that the extent of verticality or integration varies between programmes.

Integration of EmOC and health services delivery

The UN recommends that EmOC services should be organised in such a way that they are integrated into national health services [88]. Comprehensive primary health care packages advocate for the performance of basic EmOC signal functions in clinics, while comprehensive EmOC is to be offered in district hospitals and other higher levels of care [35]. For universal health care to be a reality, health services need to be easily accessible to the populations they are intended to serve [89]. Studies consistently find physical access to maternal health care facilities to be a determinant of their use by women [90-92]. Integration of maternal health services into other health services (e.g. primary health care) promotes access to women as they are able to use all the health services they require at the lowest level. Integration of maternal health services is also associated with good quality of care [93, 94]. For example, de Jongh *et al* [95] showed that integrated maternal health services have better outcomes for both mothers and babies better than when the same services are offered separately. Also, the integration of postnatal services into antenatal care in Burkina Faso led to improved screening and management of postpartum problems such as sepsis, post-partum haemorrhage, and neonatal diseases [96]. In a Zimbabwean study assessing integration of prevention of mother to child transmission (PMTCT) into maternal health services, Wiegert *et al* [97] cautioned that insufficient integration of anti-retroviral programmes into maternal health undermines the effectiveness of those programmes and their subsequent outcomes.

In view of the evidence, the World Health Organisation has proposed a strategy to bring together all known effective interventions to promote maternal health and reduce morbidity and deaths into a continuous model spanning from the community to health facilities [98]. Integration of the different

aspects of maternal health services including EmOC provides an opportunity for the delivery of various health services, such as the prevention of mother-to-child (PMTCT) [95].

Insights from near miss studies on maternal outcomes in South Africa

A maternal near miss is a woman who almost dies during pregnancy, childbirth, or after giving birth [73]. Near miss studies have been found useful additions to maternal death audits as near misses occur more commonly than deaths, providing more frequent data from which to draw lessons [99, 100]. This is pertinent as mortality progressively becomes less common due to global advances in health care [101]. Mortality trends from high income countries already show very low incidence of maternal deaths [101-104]. Although not numerous, near miss studies done by South African scholars have described the causes of severe maternal outcomes (SMOs), their distribution in referral hospitals, and quality of care issues that surround these adverse outcomes [100, 105-107]. This information has been useful in identifying important gaps and focus areas to improve care and maternal outcomes.

In a study to confirm if near miss audits could be used as reliable surrogate studies for the confidential enquiries into maternal death audits from Pretoria and the Free-State, Pattinson *et al* [100] observed that the most common causes for maternal near misses were hypertension and obstetric haemorrhage. Soma-Pillay's [108] assessment of the spectrum of morbidity from life threatening disease and death in a Pretoria Academic Hospital also found hypertension and haemorrhage to be the leading culprits in maternal near misses. In Cape Town, Iwuh *et al* [105] conducted a study to measure the occurrence of near misses in a Metro West Maternity Hospital. Similarly, findings depicted haemorrhage, hypertension, and maternal sepsis as the most common causes of severe morbidity [105]. Maswime and Buchmann's near miss study [107] in the Wits cluster of hospitals in Gauteng targeted near misses from obstetric haemorrhage to investigate important contributory factors. They found that having previous Caesarean section, anaemia, and pregnancy induced hypertension were risk factors for near misses from obstetric haemorrhage [107].

While the information generated from these studies is useful, the analysis remains descriptive and is therefore limited in exploring the nature of relationships between underlying causes or risk factors and severe maternal outcomes (SMOs). Such an analysis requires a comparator or comparison group in the study design. Unfortunately, none of these South African studies included a control group for comparative analysis. Since these studies have presented the basic pertinent information on risks and causes of SMOs, the next step is for researchers to conduct studies that quantify more clearly the nature of relationships between risk factors or underlying causes and SMOs. Study designs that allow for such comparative analysis include case-control and cohort observational studies

South African near miss studies have measured the overall near miss mortality index, a rate of fatalities from those women that had serious obstetric complications [99, 100, 105, 109]. This has been suggested as a potentially useful measure in showing the ability of the health system to effectively administer EmOC and prevent mortality [99, 100]. A higher index would mean the health system is not coping as well as expected with severe acute obstetric complications or struggling to provide adequate EmOC.

South African near miss studies have also contributed to the adaptation of the framework used to analyse avoidable factors in maternal death audits for use in near miss studies. Mantel and colleagues [75] found preventable problems in near misses and maternal deaths, dubbing them missed opportunities for care in a Pretoria tertiary hospital. They observed substandard care from health providers such as doctors refusing to see maternal patients when called, and nurse-midwives sleeping on duty. Patient-related problems, such as lack of information, and administrative breakdowns, such as unavailable ambulances, were also identified [75]. A follow-up study by the same authors expanded the inquiry to Soweto, Pretoria, and the Free State, covering both urban and rural settings [100]. Findings showed clinical deficiencies in care by health providers and some factors well beyond the control of providers that contributed to SMOs. These included lack of facilities like intensive care units (ICU), lack of ambulances, and those related to the women such as presenting late in the disease

process [100]. In both studies, scholars observed that administrative deficiencies were more common in maternal deaths than for near misses [75, 100]. Maswime and Buchmann [74, 110] recently profiled health systems problems identified in maternal near misses and maternal deaths from haemorrhage following Caesarean section. Findings showed that administrative problems included referral transport delays, and prolonged time from when doctors made the decision to perform an emergency Caesar to actual incision in theatre [107]. Their work also showed inequities in resources required for EmOC between hospitals in the same province (Gauteng)and this contributed to SMOs [111]. Diagnostic issues in recognising hypovolaemic shock and monitoring issues by health providers were some of the quality of care issues they identified [74]. Currently, the three studies above are the only ones done in South Africa so far that consider health systems issues in near miss audits. Other South African scholars have mainly focused on describing the underlying obstetric and medical conditions that trigger events that culminate in SMOs [105, 109]. Health systems factors that may contribute to SMOs have been less well studied. Therefore, more near miss studies are required to unpack preventable health systems factors and their role in the occurrence of SMOs in South Africa.

Near miss studies from other Africa countries

Because of the persistence of high levels of preventable maternal mortality in sub-Saharan Africa, investigation of the degree of implementation of known effective interventions and potential bottlenecks that may obstruct effectiveness of these interventions is necessary. There has been a proliferation of near miss audits in sub-Saharan Africa in recent years [99, 100, 112]. Generally, the incidence of severe maternal morbidity appears to be higher in the rest of sub-Saharan Africa compared to that of South Africa· This could be because of improved EmOC services in South Africa compared to the rest of Africa according to Iwuh *et al* [105]. An Ethiopian study by Kasahun and Wako [113] identified dystocia and obstetric haemorrhage as the most common triggering conditions for near misses in that setting. Similar to South Africa scholars, Liyew *et al* [114] identified hypertension and obstetric haemorrhage as the leading underlying causes for near misses in 5 hospitals of Addis Ababa in Ethiopia, while anaemia was contributory. Tanzanian scholars also found obstetric

haemorrhage to be the most common underlying cause for near miss morbidity [115]. Studies from Malawi identified anaemia as the biggest contributing factor to near misses or deaths, while hypertension, obstetric haemorrhage, and sepsis were the leading causes [116]. In agreement with most sub-Saharan scholars, Oppong and colleagues [117] found hypertension to be the most important underlying cause for maternal near misses followed by haemorrhage and sepsis. In Rwanda, Sayinzoga *et al* [118] recorded haemorrhage as the leading underlying cause as well.

Very few African near miss studies in the literature consider avoidable quality of care issues in the administration of EmOC to prevent near misses or deaths in health facilities [74, 75, 99, 100, 111, 119]. Malawian scholars utilised the 3-delay framework by Thaddeus and Maine [90] to unpack health system issues that underlay maternal deaths, and found the third delay (relating to health facility problems in giving EmOC) as the most significant contributor to near misses and deaths [117]. Sayinzoga *et al* [118] observed administrative discrepancies that obstructed timeous provision of EmOC to women such as the lack of a blood bank on the hospital premises to facilitate timeous availability of blood for transfusions when required. Only a few studies include patient related problems that underscore SMOs. These include presenting very late in the disease process for care, lack of or inadequate information about maternal disease, and transport problems to access health facilities for care [113, 117]. More work is required to understand barriers to the implementation of EmOC in sub-Saharan Africa, in order to inform strategies to improve the quality of care and subsequent maternal outcomes.

Monitoring of EmOC

The health system has to make EmOC services sufficiently available for women when required. Availability of EmOC entails access to services, sufficient and equitable distribution across the population (coverage), and full utilisation by the targeted population. Shortages in physical facilities of EmOC corresponds to a lack of access to EmOC for women, particularly in sub-Saharan Africa [120].The United Nations (UN) agencies have developed indicators to monitor EmOC in order to help

policy-makers with information that determines whether the EmOC intervention is sufficiently available [35]. These are shown in Table 2.

To effectively promote and improve health, the selection of health services needs to be carefully done [89]. Availability of EmOC is the first indicator and is assessed by measuring the density of EmOC facilities in a population [33]. The UN standard is five EmOC facilities per 500 000 population where at least one is a comprehensive EmOC facility reflecting density of health facilities per unit population [35]. To be classified as basic EmOC giving facilities, health facilities have to perform all 7 designated life-saving procedures, called signal functions according to the UN EmOC handbook [35] (Table 2). LMICs consistently record a shortage of basic EmOC facilities [121-124]. Commonly, LMIC health facilities give some of the basic signal functions, thereby missing the opportunity to be classified as EmOC facilities [125, 126].

Table 2: UN EmOC signal functions

Classification		Signal functions
	Basic	1. Administer parenteral antibiotics
		2. Administer uterotonic drugs (e.g. parenteral oxytocin)
		3. Administer parenteral anticonvulsants for pre-eclampsia and eclampsia (e.g. Mg_2SO_4)
		4. Manually remove the placenta
Comprehensive		5. Remove retained products of conception (e.g. manual vacuum extraction, dilatation and curettage
		6. Perform assisted delivery (e.g. vacuum extraction and forceps delivery
		7. Perform basic neonatal resuscitation (e.g. with bag and mask)
		8. Perform surgery
		9. Perform blood transfusion

Some studies have observed that the overall density of EmOC facilities may meet requirements, but there are often differences in EmOC availability when geographic distribution of the facilities is considered [123, 124, 127]. To assure equity in access to EmOC, geographic biases in the distribution of services need to be avoided in the health system. This in turn maximises coverage of EmOC in the health system. In a geocoded inventory of the location of health facilities in sub-Saharan Africa, Ouma *et al* [120] found that EmOC hospitals were not in sufficient numbers to cater for populations adequately with variability within and across countries. This makes universal access of sub-Saharan women to EmOC a challenge that could undermine the region's ambitions to meet Sustainable

Development Goals (SDGs) by the year 2030. For example, a Zambian study observed low rural coverage of EmOC which was insufficient to make it readily available for population needs compared to access in urban areas [127]. This study highlights the rural-urban geographical imbalance. Likewise, a Tanzanian study showed an uneven distribution of EmOC facilities as well as low presence compared to need, particularly basic EmOC facilities [123]. Nigerian studies in West Africa also show low availability of EmOC compared to requirements by women [128, 129].

Prior to this work, South Africa had only one study that had investigated the availability of EmOC in selected districts using the UN process indicators [130]. It also showed a shortage of EmOC facilities that undermined access of women to EmOC. A spatial analysis of the availability of EmOC by geographical distribution is yet to be conducted in South Africa. Our study focuses on the first two UN EmOC indicators shown in the EmOC handbook [34] (Table 1).

Problem statement

Ekurhuleni district has an unacceptably high MMR at 169 per 100 000 live births that is persistently greater that the Gauteng Province average of 129 per 100 000 live births [16, 131]. This has prompted the province to identify the district as high priority in its efforts to reduce the MMR and end preventable maternal mortality. The national confidential enquiries into maternal deaths committee (NCCEMD) has observed that haemorrhage, hypertension in pregnancy, and HIV account for 66.7% of all potentially preventable maternal deaths in South Africa [36]. The NCCEMD states that these conditions are largely avoidable and are closely associated with the knowledge and skills of health personnel, as well as broader health system challenges. The majority of these priority areas relate to direct pregnancy related causes of maternal deaths. EmOC is the known effective strategy against direct causes and is provided in the district. In South Africa, EmOC (or at least aspects of it) has been in existence nearly as long as modern medicine to look after women in labour. However the persistently high MMR suggests suboptimal effectiveness of the strategy, requiring further investigation. Furthermore, strategies to combat haemorrhage, hypertension, and HIV and health

worker training are well defined in the NCCEMD report and by other studies, but it is less clear which aspect of the health system requires strengthening. Understanding the health systems factors that influence EmOC will help identify the specific elements of the health system that require strengthening to improve maternal health outcomes. A health system analysis is therefore needed to unpack elements of the health system that are weak in the district, how they influence the delivery of EmOC, and their relationship to severe maternal outcomes (SMOs). This will generate pertinent information that can be used by policy makers in the Gauteng province and Ekurhuleni district to develop and implement targeted health system strengthening strategies to improve maternal outcomes.

Justification for the PhD

Policy makers needed information on what exactly was weak about the health system in Ekurhuleni, and how this affected maternal health. Such information was needed to plan health system strengthening interventions to improve maternal health outcomes. The Gauteng Province had an unacceptably high MMR at 169 per 100 000 live births [16]. Ekurhuleni District had the highest MMR at 129 per 100 000 live births [132], and this was greater than the provincial average. Health systems was one of the key problems identifies by NCCEMD in previous reports [36, 45, 133] . The province partnered with the University of the Witwatersrand to investigate these health system factors, in order to inform future health system strengthening interventions to improve maternal health outcomes. In the literature, studies on health system influences on maternal health outcomes were few [73, 74, 134] and often gave contextual descriptions of health systems without measuring the sizes of their effect. An empirical study to make this measurement was required therefore. Moreover, findings from this study contributed to a larger comparative study on mainstreaming a health system approach to the delivery of maternal health services in South Africa and Rwanda (MHSAR).

PhD contribution

This PhD unpacks the intersection of the health system and emergency obstetric care. It quantitatively measures, for the first time, the impact of the health system on maternal health outcomes in South

Africa. While the health system has been extensively identified as contributory to maternal outcomes in the literature, to the best of our knowledge, the weight of this contribution has not been measured previously. The PhD demonstrates the value of adding a comparator to traditional maternal near miss studies and the consideration of health system factors. There is a dearth of near miss studies with a case control design particularly in LIMICs. Even fewer studies measure health system factors in the literature, limiting evidence on the burden of health system factors on SMOs. Inadequate evidence limits the ability of the information to be used meaningfully in planning by policy makers. This PhD has shown that health systems factors do contribute to severe maternal outcomes in a powerful way. Efforts to improve SMOs should therefore first measure health systems factors, to find the most problematic ones to inform priorities in interventions.

Study objectives

Aim

The overall aim of the study was to examine the health system factors that influence the delivery of emergency obstetric care (EmOC) in the Ekurhuleni district.

Specific objectives

The specific study objectives were:

1. To assess the availability of EmOC services in Ekurhuleni using the UN EmOC process indicators.
2. To perform a rapid measurement of the health systems building blocks.
3. To identify the health system factors that influence the occurrence of near miss in EmOC services at two hospitals in Ekurhuleni district.
4. To explore and describe EmOC managers' experiences of the health system.

Chapter 2: Research Methods

This chapter describes the methods used in this study to fulfil respective objectives. It presents each of the objectives and details each corresponding method·

Summary of methods

A mixed method approach was employed to investigate the health systems factors that influence the delivery of emergency obstetric care. Quantitative methods were used to establish the extent to which emergency obstetric care was available in the district, identify health system factors that impact on maternal outcomes, and explore the nature of these relationships. Qualitative methods were employed to explore the experiences of district managers of the health system and its influence on the delivery of EmOC. Figure 1 and Table 3 show a summary of the methods used.

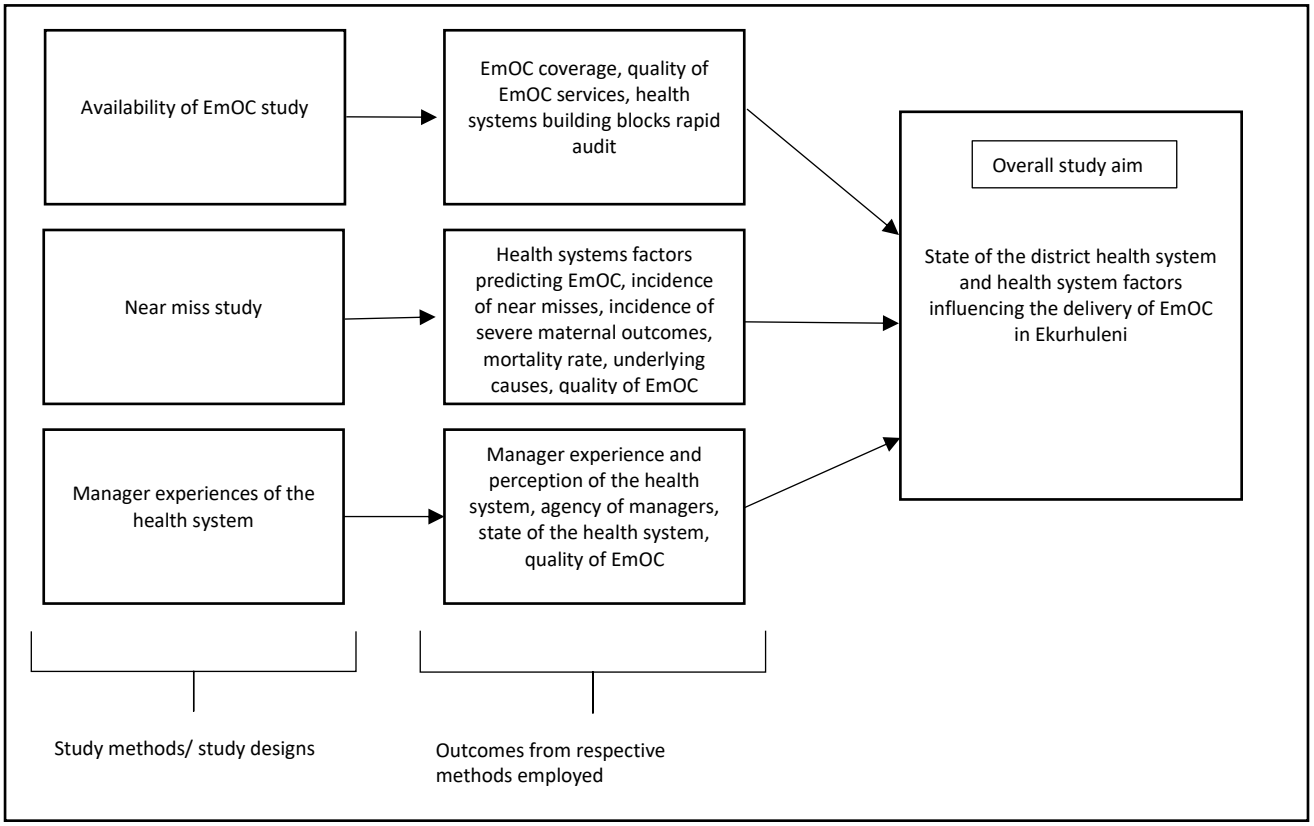


Figure 1: Summary of methods used

Table 3 Summary of methods and research outputs

Objective	Study design	Data sources	Data collection tools	Analysis	Output
To assess the availability of EmOC services in Ekurhuleni using the UN EmOC Process indicators	UN EmOC monitoring Handbook	• Maternity registers • Labour ward operational managers or their equivalent	Adapted averting maternal deaths and morbidity (AMDD) tools	UN EmOC indicators and benchmarks	
To perform a rapid measurement of the health systems building blocks	Health facility checklists	• Maternal registers • Doctors schedule • Nurses schedules • Maternity managers • Heads of department (obstetrics and gynaecology) managers • Hospital chief executive officers	Checklists	Descriptive statistics- proportions and means	Published article titled; Measuring the preparedness of health facilities to deliver emergency obstetric care in a South African district
To identify the health system factors that influence the occurrence of near miss in EmOC services at two hospitals in Ekurhuleni	Prospective case control audit of maternal near-miss	• Patient files • Labour ward operational managers or their equivalent	Adapted maternal confidential inquiry into maternal deaths forms	• Chi-squares • Conditional logistic regressions • Penalised logistic regressions	Two manuscripts drafted to be submitted for publication; • Clinical factors of severe maternal outcomes in two South African hospitals: a case-control study • Health systems factors predicting severe maternal outcomes in two South African hospitals: a case-control study
To explore and describe the experiences of the health system of EmOC managers	Key informant interviews	• Senior district management (directorate) • Chief executive officers • CHC operational managers	Unstructured interview guide	• Inductive content analysis • Deductive content analysis	Published article titled; 'It needs a complete overhaul…' district manager perspectives on the capacity of the health system to support the delivery of emergency obstetric care in an urban South African district.

Study conceptual framework

WHO [63] stated that the health system is made up of six building blocks namely: human resources; essential medicine and supplies; finance; governance and leadership; information systems; and health services delivery. However, more detail is required on which building blocks are important for improving maternal health outcomes. The question of how interventions in different building blocks influence one another, and which building block hold the best value for money is yet to be answered.The WHO building blocks framework is descriptive in nature and provides a practical lens with which to describe the health system and its components at national and sub-national level.

The conceptual framework used for this study (Figure 2) highlights the link between maternal health interventions and the health systems factors that influence implementation. Health system factors were interrogated through the six WHO building blocks to explore relationships between the health system factors and maternal health outcomes. In this study, EmOC was used as a tracer to investigate health systems issues that require strengthening in order to achieve the ultimate goal of reduced maternal mortality in the district. Assessment of a health system using the tracer approach is about tracking carefully selected health problems in order to identify strengths and weaknesses of the health system [135, 136].

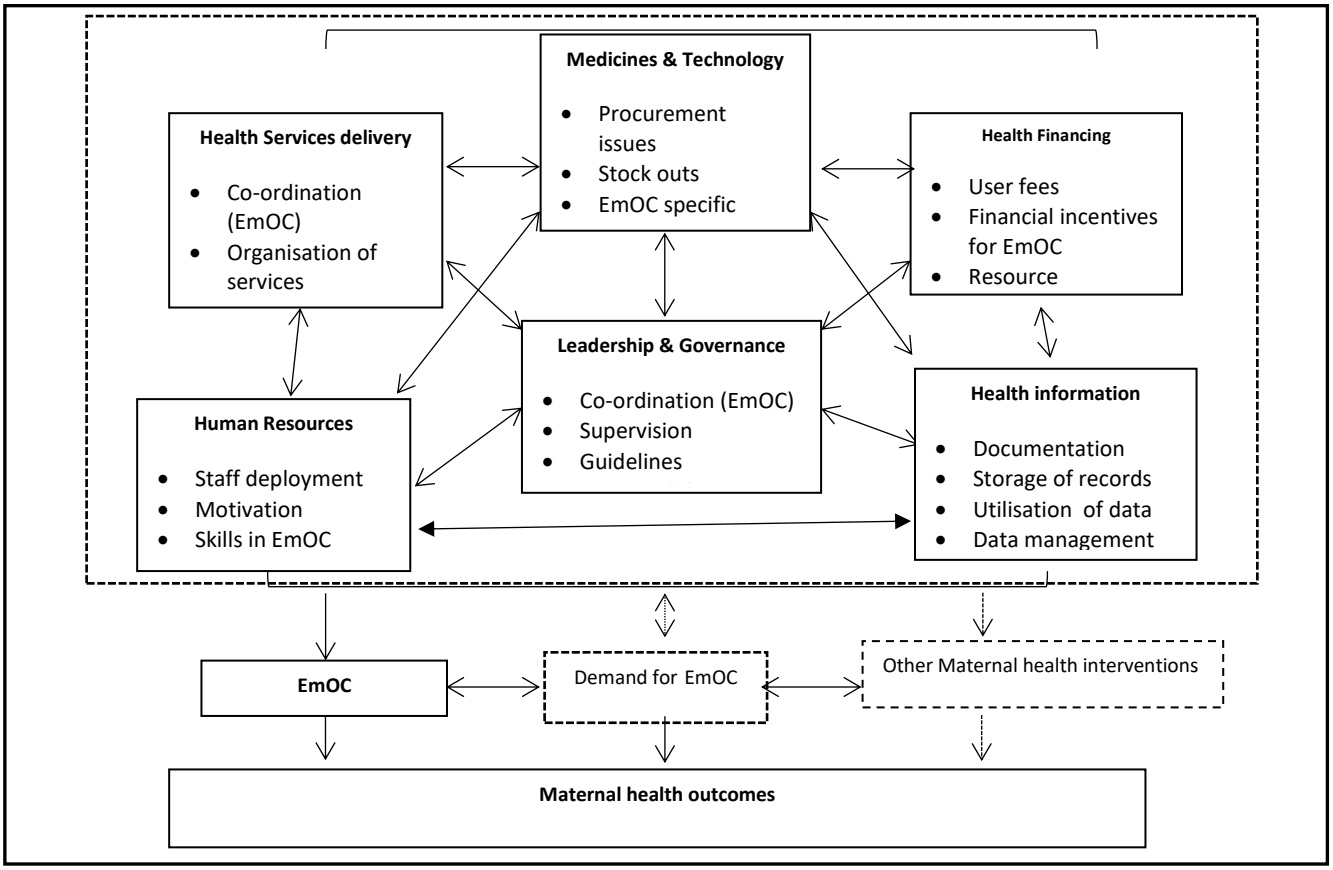


Figure 2: Study conceptual framework

Setting of the study

The study took place in the Ekurhuleni metropolitan district of the Gauteng Province of South Africa. According to the Ekurhuleni municipality (2013) [137], the district is regarded as the industrial centre of Gauteng, as it houses over 41 000 enterprises and accounts for a quarter of Gauteng's total economic output. Historically, the largest production of gold occurred in Ekurhuleni. The vibrant industrial activity has attracted migrants who move from rural parts of South Africa, and other parts of Africa, seeking jobs. The district is thus densely populated, with 2.9 million people living in approximately 1 924 square kilometres. Informal settlements and poverty are common, challenging the public health care system. There is also an increased need for maternity care services, including emergency obstetric care and this affects the health system's ability to deliver care [137].

The institutional MMR In Ekurhuleni District is estimated at 169 per 100 000 live births while the average MMR for the Gauteng province is 129 per 100 000 live births [16, 138]. Therefore, Ekurhuleni is a priority district in efforts to reduce maternal mortality in Gauteng. Ekurhuleni has seven public hospitals in total providing EmOC, one level I (district) hospital, 5 level II (regional) hospitals, and one level III (tertiary) hospital. Other public health facilities offering EmOC in the district include eight midwife obstetric units (MOU's). This makes a total of 15 facilities providing EmOC. The district refers more complicated and high risk maternal cases to referral hospitals outside the district. These are Charlotte-Maxeke Johannesburg Academic Hospital, Chris Hani Baragwaneth Hospital in Soweto, and Steve Biko Hospital in Pretoria. The objective of this analysis is to identify priorities for health systems strengthening to improve maternal health services in Ekurhuleni as promoted in the 2010 NCCEMD report [36].

Objectives 1& 2-To assess the availability of EmOC services in Ekurhuleni using the UN Process indicators; and to perform a rapid audit of the EmOC services in Ekurhuleni using the health system building blocks

Study design

A rapid audit of the availability of EmOC to non-medically insured population was conducted using the United Nations (UN) handbook for monitoring emergency obstetric care [31]. Indicators defined in this UN handbook to track EmOC availability are as follows [31]:

1. Geographical distribution of EmOC facilities;
2. Number and density of facilities providing EmOC services;
3. Met need for EmOC;
4. Proportion of all births in EmOC facilities;
5. Caesarean section rate;
6. Direct obstetric case fatality rate.

In this study, a focus on three of these indicators was given, namely; number and density of facilities providing EmOC services; proportion of all births in EmOC facilities; as well as the geographical distribution of EmOC facilities. All these indicators were measured in the study. However, only three of the indicators are reported on in detail for the purposes of the PhD work. Indicators reported on are meant to complement the other methods interrogating the health systems factors that influence EmOC delivery in the district.

Study sites

The study took place in 15 provincial public health facilities of Ekurhuleni district, in the Gauteng Province. These were 8midwife-obstetric units (MOUs), and 7 hospitals in the district.

Sampling frame: inclusion and exclusion criteria

All public provincial health facilities that provided emergency obstetric care (EmOC) in the district were included. Only facilities that were designated basic and comprehensive health facilities were included. Local government (municipality) clinics were excluded because they predominantly provided

primary health care (screening and maternity services for normal pregnancy) and therefore did not offer basic or comprehensive EmOC. All EmOC (basic or comprehensive) cases were referred to health facilities of higher levels of care. Private facilities were excluded because the focus of this study was on health systems factors influencing the delivery of maternal health in the public health care system, which is also where the Saving Mothers reports identify most weaknesses [18, 36].

Data collection tools

Validated Averting Maternal Death and Disability (AMDD) tools were adapted and used to collect data. These tools were turned into multiple data collection checklists that were used to collect data, designed according to the different sources of data. Tools were designed in such a way that data collection is according to source to improve efficiency in data collection. Information for collecting data 1 and 2 is integrated across the tools listed in Table 4. For example, if data for both objectives 1 and 2 was found in one maternity register, then the tool would have different questions within the same tool that capture data for the two. The following table shows a list of data collection tools used and their respective sources:

Pre-testing of tools

Tools were pretested in the Johannesburg district at Edenvale hospital. Edenvale hospital is a public provincial level II (regional) hospital that has similar characteristics to the hospitals under study in Ekurhuleni district. Both Ekurhuleni and Johannesburg are metropolitan districts found in the Gauteng Province of South Africa. Tools were edited following pre-tests, and adjusted to where data would be sourced in the health facility. Questions that collected data from the same source were grouped together into the same tool. Other adaptations/ adjustments included re-wording questions where unclear as necessary.

Table 4: Data collection tools for objectives 1 and 2

Tool	Function/ purpose of data collection	Source of data
Form A1	Records numbers of doctors in CHCs, and their professional designation	• PHC doctors in CHCs
Form A2	Records doctors working in hospitals and their professional designation	• Heads of department Obs & Gyn
Form B1	Records numbers of nurses formally trained in midwifery and advanced midwifery in CHCs	• Operational managers of MOUs
Form B2	Records numbers of nurses formally trained in midwifery and advanced midwifery in hospitals	• Maternity area managers of hospitals • Labour ward operational managers
Form F	Performance of signal functions in the previous 3 months of data collection day	• maternity registers • maternity area managers or their equivalent (e.g. labour ward operational managers)
Form G	Resuscitation equipment checklist, fluids, drugs, equipment, EmOC protocols	• Direct observation of labour ward walls, nurses station, etc., • Inventory of resuscitation trolleys • Direct observation of wards

Fieldworkers

Three fieldworkers were recruited to collect data throughout the life of the study. One fieldworker was a retired advanced midwife, another was a research nurse-midwife, while the last was a physiotherapist. Fieldworkers were trained to use data collection tools and on how to collect data. As principal researcher I formed part of the data collection team to collect data, as well as to supervise fieldworkers during the data collection process.

Data collection

Fieldworkers reviewed maternity registers and admission registers of labour ward and postnatal wards to collect data. Data collection took place from the 20th of August 2014, to the 7TH OF January 2015. The data collection team spent approximately 1 week in each hospital, and about 3 days in each MOU, on average for data collection.

Data collection on the density of EmOC facilities

Fieldworkers physically reviewed labour ward and postnatal ward maternity registers to identify signal functions that had been performed within the last 3 months from the day of data collection. Maternity registers were viewed for evidence of the signal functions performed. Where signal functions were not identified from the registers, operational managers or their equivalent to confirm if they had been performed, as well as any reasons why they had not been performed in the 3 months preceding data collection. Geographic Information System (GIS) receivers were used to measure geographic positioning. Table 4 shows a list of the tools used. As researchers travelled to facilities, they also noted the geographic terrain and recorded facility catchment areas.

Table 5: Signal function Scores

EmOC level	Signal functions
Basic EmOC	1. Administer parenteral antibiotics 2. Administer uterotonic drugs (e.g. parenteral oxytocin) 3. Administer parenteral anticonvulsants for pre-eclampsia and eclampsia (e.g. Mg_2SO_4) 4. Manually remove the placenta 5. Remove retained products of conception (e.g. manual vacuum extraction, dilatation and curettage 6. Perform assisted delivery (e.g. vacuum extraction and forceps delivery 7. Perform basic neonatal resuscitation (e.g. with bag and mask) **Total score= 7**
Comprehensive EmOC	8. Perform surgery 9. Perform blood transfusion **Total score=9**

Data collection using other facility checklists

Multiple checklists were used to measure other essential elements of EmOC care. Availability of skilled EmOC providers was measured by considering health professionals that had formal training in maternity care (obstetrics and midwifery). Only skilled providers working in maternity were counted. The number, category, and level of training of providers were obtained from the heads of obstetric departments and maternity nursing managers. The number of health providers that had undergone

the in-service training of providers using the South African Essential steps in the management of obstetric emergencies (ESMOE) program in maternity wards was also recorded. Data on the availability of selected EmOC protocols to support standardised quality care was collected by checking the availability and access to these protocols when required by a heath provider during an emergency in the labour ward. Fieldworkers viewed labour ward walls, files and drawers to observe these protocols, and recorded their observations in a checklist.

Maternal and neonatal resuscitation trolleys were checked by fieldworkers for the availability of resuscitation equipment, intravenous fluids, and drugs as provided for in the checklists. Expiration dates were also noted and recorded. Operational ward managers (nurse-midwives) or their equivalents were asked about the frequency of resuscitation drills in the past year (2013). The date of the last drill was recorded. Availability of selected EmOC drugs and fluids was assessed on the day of data collection. A score of 2 was given for each drug or fluid if physically present, 1 if present but expired, and 0 if not physically present in the labour ward. The physical presence of useable whole blood was also assessed in all hospitals. Availability of adult and neonate resuscitation equipment was audited by determining if items were present and functional in the respective resuscitation trolleys. Resuscitation equipment items were scored 1 if available and functional, and 0 otherwise. We also evaluated if 10 selected EmOC protocols were present and readily accessible for use in the labour ward, displayed on the wall for example, on the day of data collection. The protocols were scored 1 if readily available and 0 otherwise. We also enquired from the labour ward manager about the frequency and dates of both adult and neonatal resuscitation drills in 2013.

Routine maternal health data was extracted from the district health information system (DHIS). This included number of births, outcome of births (maternal deaths, number of live births, fresh still births, macerated still births, birthweight);mode of delivery (normal vaginal delivery (NDV), assisted vaginal deliveries, caesarean section deliveries). The indication for caesarean section deliveries by month from maternity registers for the year 2013 was also recorded from maternity registers.

Table 6: Summary of tools and indicators for facility audits

General measures	Blood, drugs, fluids and equipment availability measures				Quality control measures	
	Drugs	Blood and Fluids	Adult resuscitation equipment	Neonate resuscitation equipment	Availability of protocols	Performance of resuscitation drills
1. Facility opening hours 2. Availability of electricity 3. Tap water for washing	1. Oxytocin 2. Syntometrine 3. Ergometrine 4. Magnesium sulphate 5. Rivotril / diazepam / equivalent 6. Misoprostol 7. Insulin 8. 50% Glucose 9. Parenteral antibiotics	**Blood** 1. Whole blood **Fluids** 1. Normal saline 2. Ringers lactate 3. 5% Dextrose	1. Suction machine 2. Adult suction catheter 3. Laryngoscope set 4. Endo-tracheal tube 5. Oxygen 6. Magill's forceps 7. Airway 8. Adult sized ambubag 9. Intravenous cannula 10. Fluid administration set 11. Blood administration set 12. Stethoscope 13. Sphygmomanometer 14. Glucostix 15. Glucometer	1. Suction machine 2. Neonate suction catheters 3. Laryngoscope set 4. Endo-tracheal tube 5. Oxygen 6. Incubator 7. Radiant infant warmer 8. Neonate sized ambubag 9. Airway 10. Stethoscope	1. Eclampsia 2. Postpartum haemorrhage 3. Active management of the 3rd stage of labour 4. Shoulder dystocia 5. Cord prolapse 6. Obstructed labour 7. Puerperal sepsis 8. Antepartum haemorrhage 9. Retained placenta 10. Acute collapse/Adult CPR/ unconscious patient	1. Adult resuscitation drills 2. Neonate resuscitation drills 3. Maternal morbidity and mortality meetings
3 Items	**9 Items, Score=18**	**3 Items, Score=6**	**15 Items, Score=15**	**9 Items, Score=10**	**10 Items, Score=10**	**3 Items**

Finally, the presence of electricity and running water in each health facility was observed and recorded by fieldworkers. Opening hours of the labour ward, adult intensive care unit (ICU), operating theatres, adult high-care, neonatal intensive care units (NICU), and neonatal high care units were also observed and recorded.

Data handling and processing

Completed checklists were checked on site for completeness and accuracy by the principal researcher. Tools were give unique health facility codes, and a control sheet of all tools to be collected per facility checked. Completed tools were then kept under lock and key in the principal researcher's office. Double data entry was made on excel spreadsheets by trained research assistants and checked by the principal researcher and one of the researcher's supervisors for accuracy and completeness. Discrepancies were corrected from actual tools.

Data analysis

Data was imported from excel spreadsheets onto Stata 14 for processing, cleaning, and analysis.

Health facilities were classified as BEmOC and CEmOC facilities if they had provided all 7 BEmOC or 9 CEmOC signal functions respectively (Table 5). The required number of EmOC facilities in the district was calculated against the UN benchmarks of at least 4 BEmOC facilities and 1 CEmOC facility per 500 000 population as follows [35]:

$$Required\ BEmOC\ facilities = \frac{Public\ sector\ population}{500\ 000} x4$$

$$Required\ CEmOC\ facilities = \frac{Public\ sector\ population}{500\ 000} x1$$

The required density of EmOC facilities was also calculated per 20 000 births for comparison. The district had a total population of 3 284 630 in 2014, of which 2 446 204 were without private health insurance and assumed to make use of the public sector facilities [138-140]. Descriptive statistics were used to analyse the data and proportions were calculated from checklist scores. Indicator values were then compared against recommended UN indicator benchmarks where applicable.

Objective 3: To identify the health system factors that influence the occurrence of near miss in EmOC services at two hospitals in Ekurhuleni district

Study design

A prospective matched case control study design was used. The study was conducted in two regional hospitals (Tambo Memorial and Natalspruit) of Ekurhuleni district, from the 1st of June 2015 to the 31st of June 2016. Near-misses and maternal deaths that occurred during the 12 month study period were identified as cases. Each case, was matched to two different controls.

Analytical framework

Figure 3 shows the analytical concept that guided bivariate and multiple regression analysis. Maternal outcomes are influenced by a number of known factors. Administrative (e.g. operating theatre functional when a woman needs a Caesarean section) and health provider (e.g. wrong diagnosis) related factors contribute to maternal outcomes [16, 43]. Patient factors such as delaying coming to hospital till late in the disease process also influences outcomes. Clinical factors such as parity and the presence of disease (e.g. hypertension) are also known to lead to poor outcomes [141]. In addition, demographic factors (e.g. marital status) are also known to be correlated to maternal outcomes [142]· Matching of controls to cases was used to control for the different types of influences to outcomes (confounders) so that health system weights could be explored·

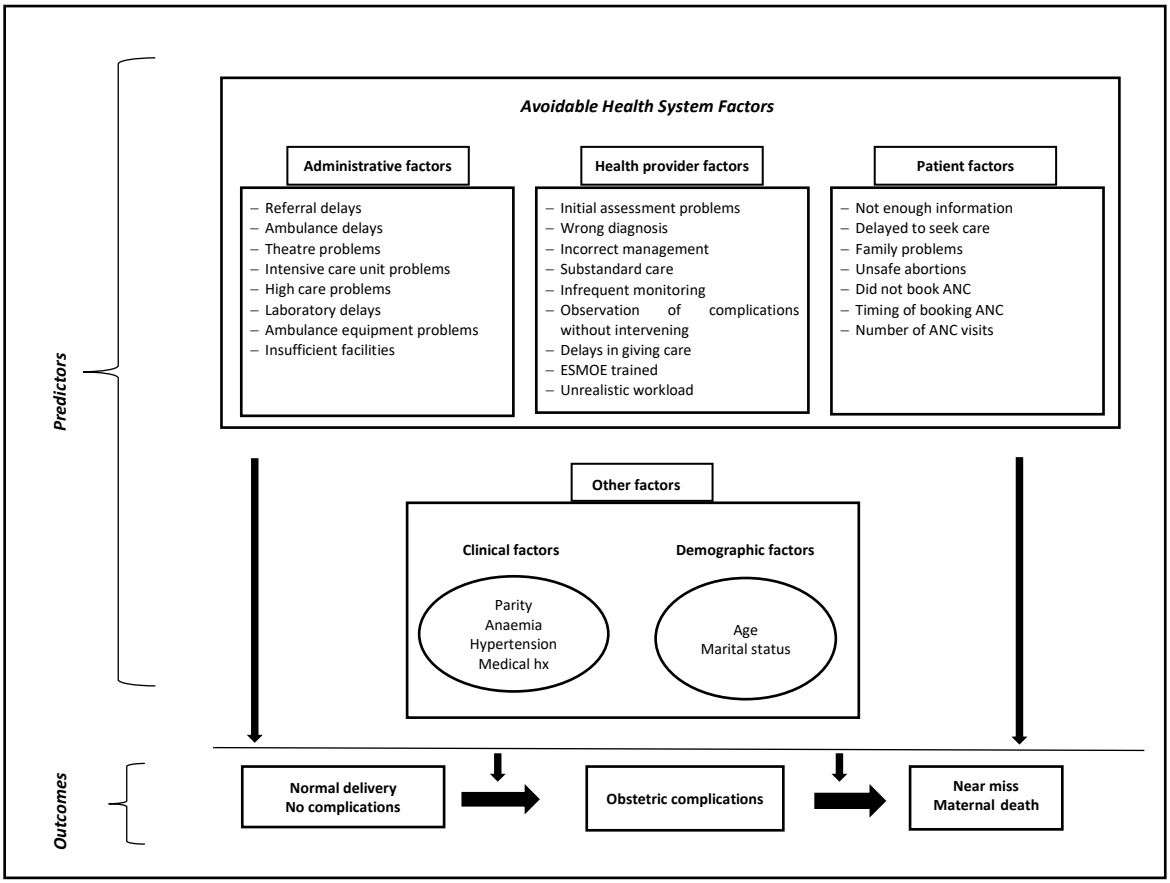


Figure 3: Analytical framework

Study sites

Two level II hospitals were purposively selected in the Ekurhuleni district based on outcome maternal indicators such the numbers of maternal deaths, perinatal deaths, and births for the year 2012; willingness of the hospitals to participate in the audit; and consultations with provincial and district health authorities. A poorer performing public regional hospital was selected, and compared to a better performing public regional hospital.

The better performing hospital is the oldest hospital regional hospital in Ekurhuleni district, and one of the oldest hospitals in the Gauteng Province. It has a catchment area of about 1.2 million people [140, 143], and has approximately 540 hospital beds. It is situated in the industrial town of Boksburg, and services high proportions of economically disadvantaged women from townships surrounding Boksburg. The poorer performing hospital is also a regional hospital, and has been recently

constructed in Vosloorus Township and has 821 beds. It services Vosloorus, Katlehong, and Thokoza Townships. Both hospitals have high volumes of women requiring childbirth services including EmOC.

Selection of cases

Maternal near misses and deaths were identified as cases and selected prospectively. Organ failure was used as the definition for near-misses. Women with organ dysfunction or organ failure during pregnancy, labour and the first 42 days of the puerperium period were identified as near misses [144-146]. The WHO criteria for identifying obstetric near-misses was adapted as recommended for the LMIC setting [147].

Table 7: **Criteria for near-miss identification**

WHO criteria	Haydom Criteria
Clinical picture criteria	
Acute cyanosis	Acute cyanosis
Gasping	Gasping
Respiratory rate >40 or <6 per minute	Respiratory rate >40 or <6 per minute
Shock	Shock
Oliguria non-responsive to fluids or diuretics	Oliguria non-responsive to fluids or diuretics
Failure to form clots	Failure to form clots
Loss of consciousness>12 hours	Loss of consciousness>12 hours
Cardiac arrest	Cardiac arrest
Stroke	Stroke
Uncontrollable fit/ total paralysis	Uncontrollable fit/ total paralysis
Jaundice in the presence of pre-eclampsia	Jaundice in the presence of pre-eclampsia
Laboratory based criteria	
Oxygen saturation <90% for >=60 minutes	Oxygen saturation <90% for >=60
PaO2/FiO2 <200mmHg	
Creatinine >=300umols/l or = 3.5 mg/dl	
Bilirubin >100umols/l or >6.0mg/dl	
pH < 7.1	
Lactate > 5 mEq/ml	
Acute thrombocytopenia (<50,000 platelets/ ml)	Acute thrombocytopenia(<50,000 platelets/ml)
Loss of consciousness and ketoacids in urine	
Severe maternal complications/ Disease based	
	Eclampsia
	Uterine rupture
Management based criteria	
Blood transfusion >=5litres	Blood transfusion>=1 litres
Hysterectomy	Hysterectomy
Dialysis	Dialysis
	Admission into ICU

WHO criteria uses a combination of a laboratory, clinical, and management based criteria to spot organ failure as the basis for a near death experience among obstetric patients [148]. Adaptation of the WHO criteria saw inclusion of other categories to help pick up cases. These were disease based severe maternal complications such as eclampsia; and management criteria such as admission into an intensive care unit (ICU). The threshold of some of the indicators for diagnosing a near-miss was adjusted· For example, women that had at least one unit of blood transfused were included rather than 5 units and more, to accommodate scarcity of blood common in LMICs [118, 149]. These modifications was based on those done in a near-miss study by Nelissen *et al* in Haydom [147], where there was limited availability of the laboratory to diagnose organ failure. Table 7 above summarises the criteria used in this study and shows the comparison of the two methods (Haydom and UN near-miss method).

Inclusion and exclusion criteria of cases

All patient files of women that attended at Tambo Memorial or Natalspruit hospitals that were pregnant, in labour, or within 42 days post termination of the pregnancy were prospectively included. This included patient files of women with;

- Abortion or were post abortion;
- Ectopic pregnancies;
- Maternal deaths (during pregnancy or within 42 days post termination of pregnancy). Women that died from direct or indirect pregnancy related causes during pregnancy or within 42 days of termination of pregnancy;
- Diseased women and women with pregnancy related complications (e.g. pregnancy induced hypertension) during pregnancy or post pregnancy;
- Women with normal pregnancies and births

Patient files of women that had pregnancy related complications beyond 42 days of termination of the pregnancy, or childbearing women that were not admitted in the two hospitals (Tambo Memorial and Natalspruit Hospitals) were excluded. Cases were also dropped if they met the following criteria;

- Women whose patient file could not be found;
- Women whose obstetric file notes were missing;
- Cases (maternal death/ near misses) of women for whom suitable controls could not be traced/ allocated.

Selection of controls

Cases (near misses and maternal deaths) were matched to two different control groups. The first control consisted of women without pregnancy and birth related conditions or illnesses. They had normal vaginal deliveries, and were matched by parity and age to the case. The second control consisted of women with a similar condition to that of a case, but had not complicated to the level of a near miss or a maternal death (e.g. and anaemic woman (anaemia defined as Hb <10g/dl). These were matched by age, parity and mode of delivery to the case. Age groups categorised into women less than 18 years, women between 18 and 34 years, as well as and women 35 years and older. Parity was categorised into 3 which is primigravidas (para 0), parity < 5, and parity =>5. Table 8 shows a summary of matching parameters.

Table 8: Matching criteria

Case	Uncomplicated Control	Complicated Control
Maternal death or near-miss as defined by the set criteria	No complications	Disease/ condition similar to that of the case (near-miss/ death)
	Age category; <18 years >=18 years <=34 years >=35 years	Age category; <18 years >=18 years <=34 years >=35 years
	Parity; Parity 0 Parity >0<=4 Parity >=5	Parity; Parity 0 Parity >0<=4 Parity >=5
	Mode of delivery: Normal vaginal delivery	Mode of delivery: Similar to that of case (near miss or death)

Sample size

The required sample size for the matched case-control study was calculated as 165 cases matched to two controls, assuming an odds ratio (OR) of 1.8, power of 80%, probability of exposure in cases of 0.5, and alpha of 0.05. Ultimately, a total of 175 cases were included in the study and successfully matched to controls without complications. However only 140 cases were matched to women with pregnancy and birth related complications, because of the difficulty in finding controls for certain SMO cases with rare complications such as cardiac disease or epilepsy.

The research team

Fieldworkers consisted of the principal, a research assistant, and a file clerk· the principal researcher, a nurse-midwifery specialist, with clinical experience in emergency obstetric care. The research assistant was a physiotherapist, who was also clinically experienced was trained to collect obstetric type information from patient files. Two senior researchers who were medical doctors and specialists in health systems and policy research supervised the principal researcher throughout the study, while general consortium members of the research team who were implementing a similar study in Rwanda provided broader consultative support. Doctors in obstetrics and gynaecology, midwives, and nurses in the two hospitals also participated in the study and offered invaluable insight throughout the data collection process, from identification of prospective cases discussion of cases (maternal deaths and near-misses); gave health system information (e.g. circumstances surrounding events) whenever required; as well as provided continuous engagement throughout the study. A research clerk, with previous experience in clerical work involving patient files in a maternity setting was enlisted to assist for tracking and retrieval of patient files. A senior obstetrics and gynaecology specialist provided consultative support on validity of data collected as well as provided an expert opinion on difficult cases.

Research instruments and tools

Three study registers (Table 9) were used to track the data collection process. The first register was a census of all near misses and maternal deaths identified during the study period. Corresponding

controls for each case were also recorded in this register. This register recorded names of subjects, their hospital numbers, whether they were alive or dead, date, whether it was a case or control (and type if control), as well as parameters used for matching (age, parity, mode of delivery, condition/ disease). This register was used to track enrolled cases and controls. The second register was a simpler version of the first and used by the research clerk to locate and retrieve patient files that had been selected for enrolment in the study. This register showed patient names, hospital numbers, date, age, and parity to help the clerk identify the correct patient file. The third register recorded the number births in each hospital by month throughout the data collection period.

For each subject (case or control), 3 tools were completed. These were adapted from the maternal death audit forms used in South Africa [150]. The tools were:

- Form C: recorded biographic, clinical, and obstetric information of the subject;
- Form D: recorded health system information of the hospital during the time of the obstetric event; and
- Form E: recorded conclusions of researchers on administrative, health provider, and patient problems/ factors that contributed to the outcome or occurrence of the near miss/ complication/ death.

Table 9 below provides a summary of tools used and their function in this study.

Table 9: Research tools

Tool	Information gathered	Source
Form B	Register tracking cases and controls selected	Maternity record book
Form B1	Clerk register for tracking identified cases and controls	Maternity record book
Form N	Number of births per month	Maternity record book
Form C	Demographic, clinical, obstetric information	Patient file
Form D	Health system information, e.g. skilled birth attendant, availability of equipment, etc.	Labour ward operational manager or equivalent
Form E	Health provider, administrative, and patient factors	Patient file, form d, form c

Table 10: Summary of near-miss tools

Tool	Purpose	Source of data	Who completed it
Register B	• Tracked recruited cases and corresponding controls • Kept a census of all maternal deaths and near misses	• Doctors rounds • Mortality and morbidity meetings • Doctors • Nurses • Registers from ICU, gynaecology ward, ANC ward, labour ward, and postnatal wards	• Principal researcher • Research assistant
Register B1	• Used to locate retrieve patient files of subjects enrolled (cases and controls	• Register B	• Research clerk
Register N	• Recorded the number of births by month throughout the study period	• Ward statistics book	• Principal researcher • Research assistant
Form C	• Recorded demographic, clinical, and obstetric information of subjects	• Patient files	• Principal researcher • Research assistant
Form D	• Recorded health system related information around the occurrence of event	• Doctors and nurses schedule • High care and ICU admission registers • Doctors present in ward • Nurses/midwives present in the ward	• Principal researcher • Research assistant
Form E	• Recorded decisions on what administrative, health provider, and patient problems contributed to the complication, near miss or death	• Form C • Form D • Patient files	• Principal researcher • Senior obstetrics consultant

Piloting the study and pre-testing tools

The study was piloted between 1st of April 2015 and 31st May 2015. The principal researcher piloted the study tools in both hospitals, going through the entire research process to test the feasibility of the planned methods and logistics. One maternal death and 4 near misses were identified during this time with data extraction into the relevant tools. Other near-misses were identified but files could not be readily accessed or traced within hospitals. From the pilot experience, difficulties to do with tracking of patient files within hospitals, and retrieval of these files from the archives after patient discharge were observed. Adjustment to data collection were made by dropping discharge variables, and deciding to collect data from the patient file as soon as a case was identified, at the bedside if possible to minimise losing cases due to misplace patient file. Patients identified at or after discharge (such as after weekends) were still included once files were located however.

Data collection tools were also modified by dropping variables that were not easy to collect reliably from patient files such as citizenship, occupation, income status, tuberculosis (TB) status, date of discharge, condition at discharge.

Data collection

Obstetric near-misses and maternal deaths were identified prospectively, and data collected over a period of 12 months from 1st June 2015 to 31 June 2016. A pilot had been done for 1 month from the 1st to the 31st of May 2015. Lessons from the pilot study were used to pre-test tools, modify logistics of data collection processes, and confirm analysis plans. Daily, the principal researcher and as a research assistant identify new near miss or maternal death cases by going through high care wards, labour wards, and intensive care unit (ICU) registers; patient files and maternity registers in postnatal care wards; patient files and ward registers in gynaecology and antenatal (ANC) wards. The two hospitals were visited on alternate days by the research team to perform surveillance and extract data. Hospital heads of department in obstetrics and gynaecology, operational nurse managers, and the nursing maternity area managers also actively helped in identifying and alerted the research team whenever they notes potential cases for inclusion in the study. Hospitals were not visited on weekends

but researchers combed through weekend patient files and registers every Monday morning. The principal researcher also attended maternal mortality and morbidity meetings weekly where adverse events, severe morbidity and mortality of women and new-borns were discussed. A census of all near misses and maternal deaths that occurred during the study was also recorded.

Corresponding controls (uncomplicated controls and complicated controls) for every case were enrolled prospectively. Controls were selected 48 hours after the case had occurred to avoid overmatching for health systems problems over time. Controls were systematically selected by identifying the first patient without complications and first patient with similar complications as the case. Maternity registers in labour, ANC, postnatal, and gynaecology wards were used to identify names, hospital numbers, and dates for potential controls. Cases that could not be matched to either control were dropped from the study.

Researchers located patient file of cases and controls from the patient bedside (if still admitted) or in the patient file archives if the patient had been discharged or transferred. Because of difficulties in finding patient files, a dedicated clerical research assistant (research clerk) was recruited to find patient files (cases and controls) that had been selected.

Each subject (case or control) had 3 forms (Form C, Form D, and Form E). For every subject, demographic, obstetric data, and clinical data was extracted from patient files and entered onto Form C by the principal researcher and research assistants. General health system data such as whether operating theatre, or intensive care was available when required by the patient; the number of doctors and nurses/ midwives on duty during the near miss or maternal death, or normal childbirth; etc., were entered into Form D by researchers after consultation with health providers in the ward (e.g. nurse or doctor) to solicit health system information that was not in the patient files. Form E was completed last, and included assessor conclusions on administrative, health provider, or patient problems that contributed to the outcome of the woman and her baby. This tool had sections with checklists of either

administrative, health provider, or patient factors drawn from the literature [73, 96, 151]. The tool is appended to this report·

Internal validity of data extraction

The senior obstetric consultant reviewed patient files of 28 (16% of total cases) randomly selected cases (near misses and maternal deaths), and independently completed Form E in which he made decisions about administrative, provider, and patient problems that contributed to the outcomes of the women. The consultant was given completed forms C and D, along with the patient file notes, whereupon he completed the assessment of contributing health systems factors on Form E from these two forms. The consultant's data entry for form E was then compared to that completed by the principal researcher to determine differences or disagreements in conclusions. Overall, the consultant and principal researcher conclusions regarding cases were consistent. Discrepancies arose for two cases, where the consultant ruled that a maternal death patient had more likely suffered an amniotic embolism rather than a pulmonary embolism as doctors had ruled. In the other case, the consultant ruled that maternal death had more likely died from complications of sepsis postpartum, rather than just lower respiratory tract infection as doctors had concluded. The consultant's opinion was deemed correct and adopted in these cases. Otherwise, administrative, provider, and patient problems picked by the consultant were similar those concluded by the principal researcher.

Data analysis

Data was imported from Microsoft Excel onto Stata 14 for analysis. During data cleaning, duplicates were removed as sampling had been by replacement. All cases were matched to a control without complications· However, not all cases could be matched to a complicated control because of time limitations that made it impossible to match cases with rare diseases (e.g. trophoblastic disease).

Initial analysis worked out some EmOC indicators to get a sense of the performance of the hospitals in maternal health (Table 11). These were the near miss incidence ratio, SMO incidence rate, fatality rates, and the institutional maternal mortality ratio (iMMR).

Table 11: Indicators

Indicator	Description	Numerator	Denominator	Formula
Severe maternal outcome incidence ratio (SMO)	Severe pregnancy related outcomes (near-misses and maternal deaths)occurs per 1000 live births	Near-misses + maternal deaths	Number of live births	NM+MD X 1000 Live births
Maternal near-miss incidence ratio	The ratio at which near-misses occurred per 1000 live births	Near-misses	Number of live births	NM X 1000 Live births
Over all Case fatality rate (CFR)	Number maternal deaths from all conditions that occur per near misses (regardless of condition/ disease)	Total maternal deaths	Total near-misses	MD X100 NM
Number of near-misses for every death	Number of near-misses for every death	Near-misses	Maternal deaths	NM MD
Hospital MMR (iMMR)	Maternal mortality ratio per hospital per 100 000 live births	Number of deaths per hospital	Number of live births per hospital	Deaths in hospital X 100 000 Number of live births in hospital

The main analysis was to identify demographic, clinical, obstetric, and health systems factors (administrative, health provider, patient) that were predictive of SMOs. The analytical framework (Figure 3) shows some of the independent variables (predictors) considered. Table 12 has the list of variables considered in the analysis.

The unit of analysis was a study group (a case and its corresponding controls). Statistical methods for matched case-control studies were used throughout [152]. Initially we looked for associations between independent factors and SMOs using chi-squares. Conditional logistic regressions of the paired data were then used to obtain odds ratios, 95% confidence intervals and p values for the bivariate relationships between predictor variables and SMOs (near-miss or maternal death) as the outcome variable. Final multiple regression models were developed for each analysis. A 20% significance level in bivariate analysis was used as the criteria for initial inclusion in the development of the multiple regression models.

Table 12: Variables

Source	Category	Form c
Form c	Demographic variables	Age
		Marital status
	Clinical variables	HIV status
		Parity
		ANC Booking
		Number of ANC visits
		Mode of delivery
		Maternal outcome (NM, dead, complicated, normal)/ category of patient
		NM underlying causes
		Anaemia
		Hypertension
		Obstetric haemorrhage
		Prolonged labour
		Abortion
		Ectopic pregnancy
		Sepsis
		HIV
		Pulmonary oedema
		Cardiac
		Epilepsy
		Causes of maternal death
		Abortion
		Trophoblastic disease
		Pulmonary oedema
		Hypertension
		Sepsis
		HIV
		Obstetric haemorrhage
		Prolonged labour
		Syphilis test
		Anaemia
		Previous Caesarean section
		Multiple pregnancy
		Hypertension
		Postpartum haemorrhage
		Preeclampsia
Form e	Patient problems	Delay in seeking medical care
		Did not book ANC or had fewer than 4 visits
		Did not have enough information
		Family problems
		Refused treatment/ did not heed medical advice
		Illegal abortion
		Overall patient problems
Form e	Administrative problems (form e)	Facilities not enough/ struggling to meet need/ overburdened
Form e		Referral delays overall
Form d		Laboratory delays
Form d		Problems with blood bank, blood and blood products
Form e		Overall administrative problems
Form e	Health provider problems	Partogram use to manage labour
		Magnesium sulphate use for pre-eclampsia
		Workload (patient demand for care affecting health systems ability to deliver EmOC) disproportionate to health providers available
		Delayed to provide care/ late provision of care
		Did not refer
		Communication problems
		Poor teamwork
		Supervision problems
		Overall health provider problems
Form e	NCCEMD variables	Presence of avoidable factors
		Initial assessment problems
		Incorrect diagnosis
		Referral delays
		Substandard care
		Incorrect management
		Monitoring problems overall (composite variable infrequent monitoring or prolonged observation of complications without intervention)

A number of the identified predictor variables showed separation or sparse data characteristics which complicated the analysis [153]. This was caused by the low occurrence of certain predictors, particularly for the uncomplicated controls. For example, none of the uncomplicated controls experienced prolonged labour compared to 3.2% of cases. Such comparisons are either not solvable or produce extremely large or even infinite odds ratios using traditional analytical methods. Firth's penalised logistic regression has become the most widely recommended method for dealing with this problem [154-156]. We used Firth penalised logistic regression for all analyses, using the Firth logit ado program for Stata [157], and the FL and CFL SAS macros by Heinze [157, 158].

Data management and handling

The three completed tools (Forms C, D and E) were assembled for each subject. Completed tools of the corresponding controls (Control A and Control B) were then attached to the tools for each case as soon as they were completed. In the end, tools were stored in groups of 9 consisting of 3 tools for a case, 3 tools for a corresponding control A, as well as 3 tools for a corresponding control B. All subjects were given individual study numbers as unique identifiers. Every case and its corresponding controls was given a common group number to link them. Enrolled cases and controls from each hospital were entered onto an excel spreadsheet to keep track of the group, as well as numbers enrolled. All data were doubly entered into Microsoft Excel.

Objective 4- To explore and describe EmOC managers' experiences of the health system

Study design

A qualitative approach was used to explore and describe the experiences and perceptions of the health system by district managers overseeing the delivery of EmOC services.

Sampling techniques: Inclusion and exclusion criteria

A purposive sampling technique to recruit 19 senior managers at province, district, and health facility level that were responsible for public provincial EmOC services in Ekurhuleni district. This included the provincial district directorate, heads of department of obstetrics and gynaecology in hospitals, and operational managers in midwife obstetric units (MOUs).

Figure 4 below shows the provincial directorate organogram from which participants were drawn. In addition, senior hospital managers who were the chief executive officers of the 7 hospitals, heads of Obstetrics and Gynaecology departments, maternity area managers, and CHC operational managers were included in the sampling frame. A key informant approach was adopted where participants with the most information/ detail or their equivalent were approached for inclusion. Managers or directors whose jurisdiction did not include emergency obstetric care (EmOC) services were excluded from the study. Managers from the local (municipal) government facilities, or private facilities were also excluded. Participation was voluntary.

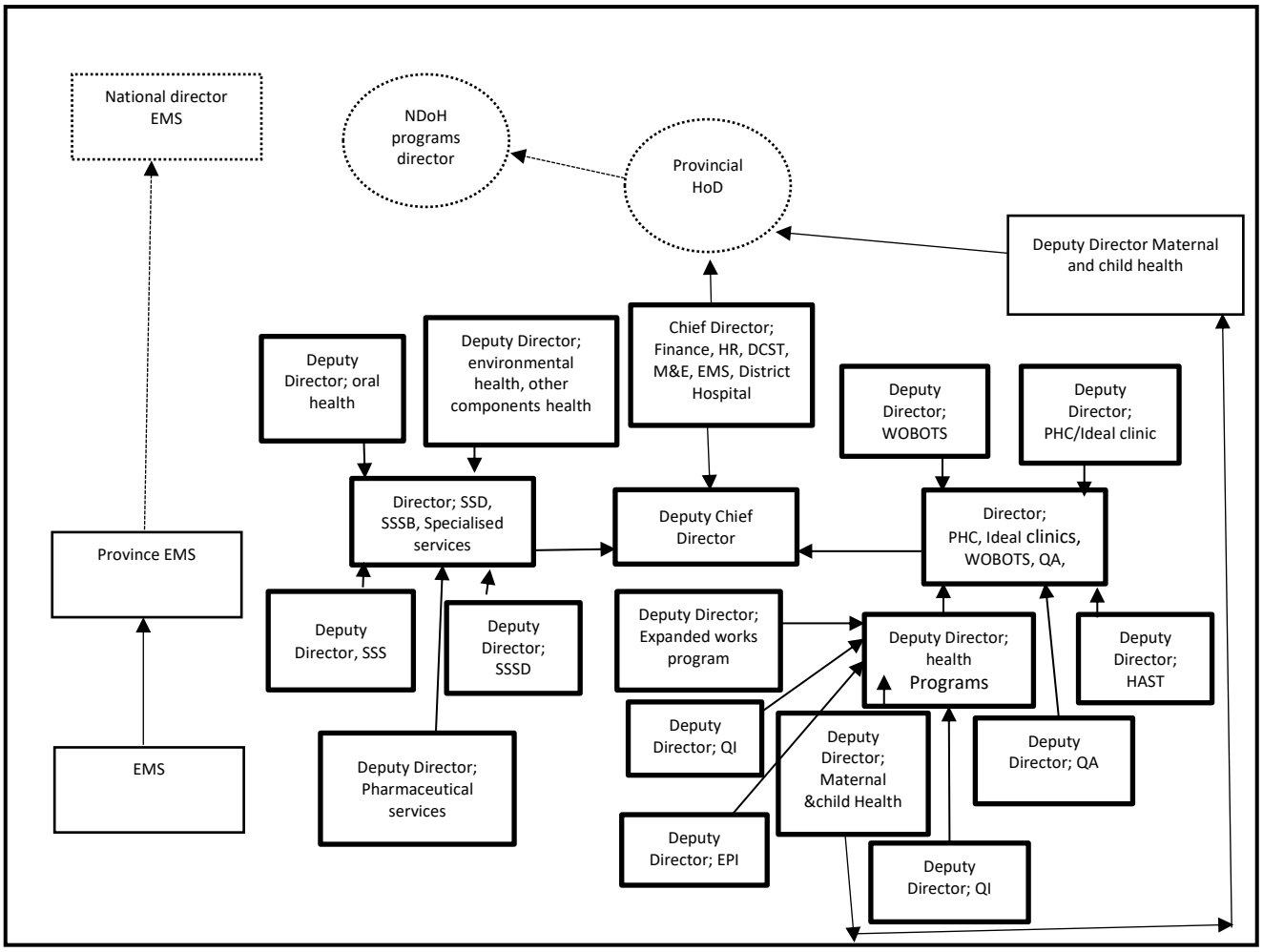


Figure 4: Provincial Directorate Organogram

Key to figure:

- HR- Human resources
- DCST- District clinical specialist team
- M & E- monitoring and evaluation
- WBOTs- ward based outreach teams in the community
- PHC- primary health care
- SSD- sterile services department
- QA- Quality assurance
- HAST- HIV/AIDS, sexually transmitted infections and tuberculosis control programme
- QI-Quality Improvement
- EPI-Expanded immunisation program
- EMS-emergency services
- NDoH-National department of health

Research instrument and tools

An interview guide with one open ended question was administered by the researcher. The researcher asked participants to each share their daily experiences, struggles/ challenges, and successes as experienced by them. Participants were first asked to relate their experiences of the health system as managers, including perceived failures and successes. The following open-ended question was asked to open the discussion;

> *"Please tell me about your experiences as a manager that oversees EmOC in the district. What are some of the challenges you experience?"*

The health system building block framework was used to structure probing questions to capture how managers related to the health system building blocks. Probes were customized according to the type of manager (responsible portfolio).

Piloting the study

A district manager was recruited from Johannesburg district to pilot the study. Johannesburg is a metro district in the same province as the study district. The researcher audio-recorded the interview and analysed it to test validity of the questionnaire and data collection method. The questionnaire and method was found to be appropriate and did not require adjustment.

Data collection

Face-to-face key informant interviews (KIs) were conducted with each participant in the privacy of participant offices at times of their choosing. Interviews were audio-recorded, with consent, and took approximately an hour each, depending on participant dynamics (e.g. friendly and willing to chat). All interviews were conducted in English by the principal investigator/ researcher.

Data analysis

All audio-interviews were transcribed onto a Microsoft Word document. Thematic analysis was used for both inductive and deductive coding [159, 160]. Transcribed manuscripts were read line by line by the principal researcher to inductively identify themes that emerge from the content. Initial codes

were then grouped together into similar sub-categories to bring meaning. Sub-categories were further collapsed into broader categories. The WHO health systems framework [62] was then deductively applied onto emerged themes to classify them into each of the building blocks as appropriate. Thematic content analysis was used to first inductively identify themes and the deductively categorise them into the broader themes of the health system building block framework.

Research rigour/ trustworthiness

Reliability/ dependability

The principal researcher piloted the study to replicate the research process to measure the extent to which it would yield the desired data when applied in the actual study. That all interviews were conducted by one person, the principal researcher, assuring consistency in measurement.

Credibility/ internal validity

Transcribed manuscripts were reviewed by the research supervisors to verify that codes and themes reflected manuscripts and collected data measured what was intended to be measured. Findings were also confirmed by participants during feedback meetings in the district. This also confirmed objectivity of the researcher in collecting and interpreting results.

Confirmability/ objectivity

The researcher was external and an outsider to participants in the district and did not have pre-conceived notions of health system experiences by them prior to data collection. Not being part of the district health system allowed objectivity and reduced otherwise possible biases.

Generalisability/ transferability (External validity)

Due to the qualitative nature of this study, findings may not be transferrable to other settings. Verbatim quotes of the results have been provided and the context has been described in detail to guide users on the extent to which findings can be applied to districts of similar contexts.

Chapter 3: Results and Papers

Doctoral thesis outputs

This study was performed in fulfilment of PhD studies by publication. Four papers have been prepared from the study. These papers form the basis of the integrated discussion, in order to fulfil the study aim. The papers and their status are as follows:

	Paper	Status
1.	Measuring the preparedness of health facilities to deliver emergency obstetric care in a South African district	Published in PLOS One (2018)
2.	"It needs a complete overhaul…" District manager perspectives on the capacity of the health system to support the delivery of emergency obstetric care in a South African district	Published in Global Health Action (2019)
3.	Predictors of poor maternal outcomes in two South African hospitals: a case-control study	Draft manuscript to be submitted
4.	Health system s factors predicting severe maternal outcomes in two South African hospitals: a case-control study	Draft manuscript to be submitted

Paper 1: Measuring the preparedness of health facilities to deliver emergency obstetric care in a South African district

PLOS ONE

RESEARCH ARTICLE

Measuring the preparedness of health facilities to deliver emergency obstetric care in a South African district

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Abstract

Background

Improving the delivery of emergency obstetric care (EmNOC) remains critical in addressing direct causes of maternal mortality. United Nations (UN) agencies have promoted standard methods for evaluating the availability of EmNOC facilities although modifications have been proposed by others. This study presents an assessment of the preparedness of public health facilities to provide EmNOC using these methods in one South African district with a persistently high maternal mortality ratio.

Methods

Data collection took place in the final quarter of 2014. Cross-sectional surveys were conducted to classify the 7 hospitals and 8 community health centres (CHCs) in the district as either basic EmNOC (BEmNOC) or comprehensive EmNOC (CEmNOC) facilities using UN EmNOC signal functions. The required density of EmNOC facilities was calculated using UN norms. We also assessed the availability of EmNOC personnel, resuscitation equipment, drugs, fluids, and protocols at each facility. The workload of skilled EmNOC providers at hospitals and CHCs was compared.

Results

All 7 hospitals in the district were classified as CEmNOC facilities, but none of the 8 CHCs performed all required signal functions to be classified as BEmNOC facilities. UN norms indicated that 25 EmNOC facilities were required for the district population, 5 of which should be CEmNOCs. None of the facilities had 100% of items on the EmNOC checklists. Hospital midwives delivered an average of 36.4±14.3 deliveries each per month compared to only 7.9±3.2 for CHC midwives ($p<0.001$).

Conclusions

The analysis indicated a shortfall of EmNOC facilities in the district. Full EmNOC services were centralised to hospitals to assure patient safety even though national policy guidelines

authors declare no competing interests to this work. NWO-WOTRO URL: https://www.nwo.nl/en; ADDRF URL: http://aphrc.org/our-work/research-strengthening/partnership-with-universities/african-doctoral-dissertation-research-fellowship-ADDRF. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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sanction more decentralisation to CHCs. Studies measuring EmNOC availability need to consider facility opening hours, capacity and staffing in addition to the demonstrated performance of signal functions.

Introduction

Significant progress has been made to combat maternal mortality. From 1990 to 2015, the maternal mortality ratio (MMR) reduced by 45% globally, and by 49% in sub-Saharan Africa [1]. While this improvement is commendable, evaluation of the millennium development goals (MDGs) achievement by region has shown that the MMR remains very high in sub-Saharan Africa [2]. For the new sustainable development goals (SDGs), the world has resolved to end all preventable maternal mortality, and committed to the ambitious goal of reducing the global MMR to 70 per 100 000 live births or less, while making sure that no country has an MMR above 140, by the year 2030 [3]. Realisation of these targets requires immediate and concerted efforts [4].

Emergency obstetric and neonatal care (EmNOC) services are effective in dealing with direct causes of maternal mortality and therefore necessary to achieve these global goals [5–8]. Measurement of the availability of EmNOC identifies the number of health facilities that are able to provide basic or comprehensive EmNOC services, and is one of eight key process indicators (Table 1) developed by the World Health Organization (WHO) and other United Nations (UN) agencies to monitor EmNOC services provision [9]. Measurement of this indicator requires that facilities demonstrate recent performance of seven so-called EmNOC 'signal functions' to be recognised as a basic EmNOC (BEmNOC) facility, or nine specified 'signal functions' to be considered a comprehensive EmNOC (CEmNOC) facility. The UN handbook originally proposed that four BEmNOC and one EmNOC facilities are required per 500 000 population [9]. This standardised approach to measuring the availability of EmNOC uses basic, easily collected information, and has been applied in many countries, making it possible to compare them [10–13].

However, a number of scholars and practitioners have argued that the UN EmNOC approach to measuring the availability of EmNOC facilities, the first EmNOC process indicator, requires modification and expansion [14–16]. The UN EmNOC Handbook does not discriminate between the size and therefore demand on facilities and this is a gap as smaller facilities (e.g. health centres) are counted the same as larger facilities (e.g. referral hospitals). Measuring skilled provider distribution across facilities and geographical access along EmNOC availability could potentially redress this gap [15]. Another criticism of the 'signal functions' is that they do not consider that identified EmNOC facilities may not be open 24

Table 1. UN indicators for monitoring EmNOC [9].

Indicator 1	Availability of EmNOC
Indicator 2	Geographical distribution of EmNOC facilities
Indicator 3	Proportion of all births in EmNOC facilities
Indicator 4	Met need for EmNOC
Indicator 5	Caesarean sections as a proportion of all births
Indicator 6	Direct obstetric case fatality rate
Indicator 7	Intrapartum and very early neonatal death rate
Indicator 8	Proportion of deaths due to indirect causes in EmNOC facilities

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hours, always have skilled staff on duty, or have sufficient capacity to deal with EmNOC cases [15, 17, 18]. Gabrysch et al (2012) proposed additional signal functions, such as the availability of fluids to control hypovolemic shock, inorder to improve the measurement of EmNOC service availability [16]. Consensus on these modifications is emerging as several studies have measured the availability of EmNOC in facilities using both the UN EmNOC signal functions and these additional signal functions reflecting other aspects of availability [19–21]. Furthermore, the UN EmNOC handbook changed the density of facilities indicator norm to at least 5 EmNOC facilities per 500 000 population from facilities per births previously used in the world health report of 2005 [9, 22]. Others argued that the norm should be calculated per 20 000 live births because different populations have different fertility and different corresponding needs [10, 15].

In South Africa, an unacceptably high MMR persists at 133 per 100 000 live births[23]. Therefore, the country has not achieve the MDG goal of reducing maternal deaths by 75% between 1990 and 2015 [1, 24–27]. Some progress has been made recently in decreasing HIV-related maternal mortality, but more needs to be done to improve EmNOC services and address the direct causes of maternal mortality to achieve any further meaningful reduction of the MMR [24, 27]. Surprisingly, there have been very few studies using the UN process indicators to evaluate EmNOC services in South Africa[28]. A recent paper evaluated the availability of EmNOC services in 12 districts in South Africa and found that important aspects of both basic and comprehensive EmNOC are not readily available in many public health facilities [21].

Given the persistently high MMR of 113 per 100 000 live births in the Gauteng Province of South Africa, the provincial government requested the assessment of the availability EmNOC in one priority district with a MMR of 169 per 100 000 live births, significantly higher than the provincial average [26]. This study aimed to measure the availability of EmNOC services in the district using the UN EmNOC signal function method adapted to suit the district EmNOC needs. We also sought to critically appraise the UN method of measurement of EmNOC availability in the district.

Materials and methods

All 15 designated public health facilities in the district were included in the study: 8 community health centres (CHCs), 4 regional hospitals, 2 district hospitals, and 1 tertiary hospital. The district also has 87 smaller clinics and 42 ward based primary health care outreach teams offering mobile services to 30 wards which were not included in this evaluation [29]. The department of health (DoH) does not promote deliveries at these lower clinics or consider them as EmNOC facilities. They do not have labour wards or midwife obstetric units (MOUs) and mainly provide outpatient services. All private health facilities were also excluded. The district had a total population of 3 284 630 in 2014, of which 2 446 204 (about 74%) were without private health insurance and assumed to make use of the public sector facilities [26, 30].

Data collection took place in the last quarter of 2014. Health facilities were surveyed for performance of the UN BEmNOC and CEmNOC signal functions (Table 2) in the 3 months preceding data collection, using tools adapted from the Averting Maternal Disability and Death (AMDD) manual [9, 31]. Maternity registers were viewed for evidence of the signal functions performed. Where signal functions were not identified from the registers, labour ward nurse managers were asked to confirm that these signal functions had not been performed, and asked why they had not been performed. Dates of EmNOC drills in the previous year were recorded to establish the frequency of performance of resuscitation drills to safeguard quality of care. The number of births for 12 months were also recorded from all facilities.

Table 2. UN EmNOC signal functions.

EmNOC level	Signal functions	
Basic EmNOC	1. Administer parenteral antibiotics 2. Administer uterotonic drugs (e.g. parenteral oxytocin) 3. Administer parenteral anticonvulsants for pre-eclampsia and eclampsia (e.g. Mg_2SO_4) 4. Manually remove the placenta 5. Remove retained products of conception (e.g. manual vacuum extraction, dilatation and curettage 6. Perform assisted delivery (e.g. vacuum extraction and forceps delivery 7. Perform basic neonatal resuscitation (e.g. with bag and mask)	**Total score = 7**
Comprehensive EmNOC	8. Perform surgery 9. Perform blood transfusion	**Total score = 9**

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Facilities were classified as BEmNOC and CEmNOC facilities if they had provided all 7 BeMNOC or 9 CEmNOC signal functions respectively (Table 1). The required number of EmNOC facilities in the district was calculated against the UN benchmarks of 5 EmNOC required, of which at least 1 ought to be a CEmNOC facility of per 500 000 population as follows [9];

$$Overall\ required\ EmNOC\ facilities = \frac{Public\ sector\ population}{500\ 000} x5$$

The required density of EmNOC was also calculated per 20 000 births for comparison;

$$Overall\ required\ EmNOC\ facilities = \frac{Number\ of\ public\ sector\ births}{20\ 000} x\ 5$$

Other indicators to measure EmNOC included are based on the current literature on measuring EmNOC availability, e.g. availability of skilled staff, opening hours of facilities, and the presence of electricity in facilities [16].

To benchmark skilled staff availability, a critical mass of 5 advanced midwives and 5 midwives in CHCs at any given time to achieve safe dispensation of maternity care including BEmNOC services as proposed by a south African maternal health expert was used [32]. This benchmark was used in the absence of staffing norms developed by the South African government that could have been used to benchmark staffing levels for the safe delivery of basic EmNOC in CHCs.

Multiple checklists were used to measure the availability of essential elements of EmNOC care (Table 3). For EmNOC human resources, health professionals that had formal training in maternity care (obstetrics and midwifery) were regarded as skilled providers. Only skilled providers working in maternity were counted. The number, category, and level of training of providers were obtained from the heads of obstetric departments and maternity nursing managers. Availability of selected EmNOC drugs and fluids was assessed on the day of data collection. A score of 1 was given for each drug or fluid if physically present, and 0 if not physically present in the labour ward, or present but expired. The physical presence of useable whole blood was also assessed in all hospitals. Availability of adult and neonate resuscitation equipment was audited by determining if items were present and functional in the respective resuscitation trolleys. Resuscitation equipment items were scored 1 if available and functional, and 0 otherwise. We also evaluated if 10 selected EmNOC protocols were present and readily accessible for use in the labour ward, displayed on the wall for example, on the day of data collection. The protocols were scored 1 if readily available and 0 otherwise. We also enquired

Table 3. Summary of tools and indicators.

General measures	Blood, drugs, fluids and equipment availability measures				Quality control measures	
	Drugs	Blood and Fluids	Adult resuscitation equipment	Neonate resuscitation equipment	Availability of protocols	Performance of resuscitation drills
1. Facility opening hours 2. Availability of electricity 3. Tap water for washing	1. Oxytocin 2. Syntomentrine 3. Ergometrine 4. Magnesium sulphate 5. Rivotril / diazepam / equivalent 6. Misoprostol 7. Insulin 8. 50% Glucose 9. Parenteral antibiotics	**Blood** 1. Whole blood **Fluids** 1. Normal saline 2. Ringers lactate 3. 5% Dextrose	1. Suction machine 2. Adult suction catheter 3. Laryngoscope set 4. Endo-tracheal tube 5. Oxygen 6. Magill's forceps 7. Airway 8. Adult ambubag 9. Intravenous cannula 10. Fluid administration set 11. Blood administration set 12. Stethoscope 13. Sphygmomanometer 14. Glucostix 15. Glucometer	1. Suction machine 2. Neonate suction catheters 3. Laryngoscope set 4. Endo-tracheal tube 5. Oxygen 6. Incubator 7. Radiant infant warmer 8. Neonatal ambubag 9. Airway 10. Stethescope	1. Eclampsia 2. Postpartum haemorrhage 3. Active management of the 3rd stage of labour 4. Shoulder dystocia 5. Cord prolapse 6. Obstructed labour 7. Puerperal sepsis 8. Antepartum haemorrhage 9. Retained placenta 10. Acute collapse/Adult CPR/ unconscious patient	1. Adult resuscitation drills 2. Neonate resuscitation drills 3. Maternal morbidity and mortality meetings
3 Items	**9 Items, Score = 9**	**3 fluid Items, Score = 3**	**15 Items, Score = 15**	**10 Items, Score = 10**	**10 Items, Score = 10**	**3 Items**

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from the labour ward manager about the frequency and dates of both adult and neonatal resuscitation drills in 2013 to assess maintenance of the quality of EmNOC skills by providers.

Data from the checklists were entered and analysed using Stata v13 (StataCorp). Scores were converted to percentages of the total maximum checklist score for easier comparison. Means and standard deviations were calculated for CHCs and hospitals in the district respectively. Score means from the various checklists were compared using Krusskal-Wallis and Mann-Whitney tests.

Ethical clearance to conduct the study was obtained from the Human Research Ethics Committee of the University of the Witwatersrand. Approval to conduct the study was also obtained from the district research committee of the department of health, and each health facility gave permission for data collection. Labour ward nurse managers signed informed consent before giving any information to researchers. All participants were assured of their right to withdraw participation at any stage without prejudice.

Results

Classification of EmNOC facilities

Based on their performance of the UN signal functions, only 7 (46.7%) of the facilities in the district would be classified as EmNOC facilities. All 7 of the hospitals in the district fulfilled the requirements to be classified as CEmNOC facilities, and the same 7 provided BEmNOC services. The 8 CHCs performed some of the BEmNOC signal functions, but none of them performed all 7 to earn classification as a UN EmNOC facility (Table 4). All CHCs offered parenteral anti-convulsants, uterotonic drugs, and performed neonatal resuscitation. Five CHCs (62.5%) had given parenteral antibiotics, while only two (25.0%) performed manual removal of the placenta or remove retained products of conception in the previous 3 months. None of the CHCs performed assisted vaginal deliveries (Table 4). The primary reason given by all CHCs for not performing some of the basic signal functions was district policy which stated that CHCs should not perform assisted deliveries, manual removal of placenta, or

Table 4. Percentage of facilities performing signal functions and availability of general measures.

Category	Indicator	% of CHCs (n = 8)	% of Hospitals (n = 7)	% of Total (n = 15)
BEmNOC signal functions	Administer uterotonic drugs	100.0%	100.0%	100.0%
	Administer parenteral anticonvulsants	100.0%	100.0%	100.0%
	Perform basic neonatal resuscitation	100.0%	100.0%	100.0%
	Administer parenteral antibiotics	62.5%	100.0%	80.0%
	Manual removal of placenta	25.0%	100.0%	60.0%
	Remove retained products	25.0%	100.0%	60.0%
	Perform assisted delivery	0.0%	100.0%	46.7%
CEmNOC signal functions	Perform caesarean section	0.0%	100.0%	100.0%
	Perform blood transfusion	0.0%	100.0%	100.0%
General measures	Open 24 hours, 7 days a week	100.0%	100.0%	100.0%
	Electricity	100.0%	100.0%	100.0%
	Tap water for washing	87.5%	100.0%	93.3%

https://doi.org/10.1371/journal.pone.0194576.t004

removal of retained products because of inadequate resources in the CHCs to safely support these activities. This was despite national policy guidelines that sanctioned the performance of these signal functions at the CHC level [33]. Nurses in facilities (CHCs) that did not administer parenteral antibiotics recorded that it was out of their scope of practice to prescribe them to patients even when indicated. They therefore referred such patients to higher levels of care. Other less common reasons provided were: lack of equipment and supplies; training deficiencies among staff; management problems; as well as no indication/ requirement for the signal function from service users.

All 15 health facilities in the district were open 24 hours a day, 7 days a week. Electricity was also available in all facilities. Only one CHC did not have running water (Table 4).

Density of EmNOC facilities

According to the UN EmNOC guidelines there should be at least 5 EmNOC facilities per 500 000 people of which a minimum of 1 must be a CEmNOC facility [9]. A total of about 25 EmNOC facilities are required for the public sector population in the district, indicating a shortfall of at least 18 EmNOC facilities (Table 5). If we use the UN EmNOC Handbook configuration of 4 BEmNOC facilities and 1 CEmNOC facility per 500 000 people, 25 EmNOC facilities in total are required of which at least 5 are supposed to provide CEmNOC and 20 provide BEmNOC. Table 5 compares the current number of EmNOC facilities to the number that should be available using this norm. There was therefore an adequate number of CEmNOC facilities in the district (7), but a significant undersupply of BEmNOC facilities. Even if all 8 of the available CHCs were upgraded to function as BEmNOC facilities, there would still be a

Table 5. Required density of EmNOC facilities.

Category	Current facilities	Analysis per 500 000 population‡		Analysis per 20 000 births‡	
		Target	Surplus/deficit	Target	Surplus/deficit
BEmNOC	7	19.6	-12.6	12.9	-5.9
CEmNOC	7	4.9	+2.1	3.2	+3.8
Total	7	24.5	-17.5	16.1	-9.1

‡ For 2 446 204 uninsured population in the district with 64 544 births [26]

https://doi.org/10.1371/journal.pone.0194576.t005

shortfall of at least 10 BEmNOC facilities in the district for the current population according to this analysis.

There were 64544 births recorded from all 15 facilities in the district. When the norms per 20 000 births rather than 500 000 population are used, the shortfall in EmNOC facilities is less marked at 9 facilities Table 5. There is a deficit of at least 6 BEmNOC facilities.

Availability of skilled EmNOC providers

Skilled EmNOC providers included general professional nurses whose formal training included midwifery, specialised professional nurses with advanced midwifery training, and doctors. However, only advanced midwives and doctors have the requisite formal training to perform all 7 UN BEmNOC signal functions.

Advanced midwives were available in all 15 facilities, but not 24 hours per day or 7 times per week. Only 12.5% of CHCs and 42.9% of hospitals were able to provide such cover Table 6. According to duty rosters, the number of advanced midwives in CHCs ranged from 1 to 4 during the day, and from 0 to 2 at night. The corresponding figures for hospitals were 1 to 3 during the day, and 0 to 1 at night. Absence of an advanced midwife on duty meant that the facility had an impaired ability to perform all BEmNOC signal functions, unless a doctor was present. More midwives and advanced midwifes were employed in CHCs yet there were markedly more deliveries in hospitals. This made the workload of hospital midwives significantly higher than those at CHCs (Table 6). CHCs had a doctor available some days of the week, mostly during the daytime. All hospitals had doctors available 24 hours for all days of the week, and only two hospitals did not also have a specialist working in maternity. The presence of doctors was particularly thin afterhours on weekdays and on weekends, risking potentially compromise of the performance of EmNOC signal functions to all women needing the service in hospitals. Hospital midwives delivered an average of 36.4±14.3 deliveries each per month compared to only 7.9±3.2 for CHC midwives ($p<0.001$, Mann-Whitney).

Since South Africa has not yet developed staffing norms for the safe delivery of basic EmNOC in CHCs, although it has been suggested that a minimal staff of 5 advanced midwives

Table 6. EmNOC human resources and workload.

Category	Indicator	CHCs (n = 8)	Hospitals (n = 7)	Total (N = 15)
Midwives	Total number of midwives	140	128	268
	% Facilities with midwife available 24/7 on site	100.0%	100.0%	100.0%
Advanced Midwives	Total number of advanced midwives	56	34	90
	Number of advanced midwives per day shift (range)	1–4	1–3	1–4
	Number of advanced midwives per night shift (range)	0–2	0–1	0–2
	% Facilities with advanced midwife available 24/7 on site	12.5%	42.9%	26.7%
Doctors	Total number of doctors working fulltime	0	89	89
	Number of doctors per day shift (range)	0–3	5–18	0–18
	Number of doctors per night shift/ weekend	0	1–3	0–3
	Total number of obstetric consultants	0	9	9
	% Facilities with obstetric consultant	0.0%	71.4%	33.3%
	% Facilities with doctor available 24/7 on site	0.0%	100.0%	46.7%
	% Facilities with obstetrician available 24/7 on site	0.0%	0.0%	0.0%
Workload	Number of deliveries in month of data collection	1090	4786	5876
	Deliveries per midwife (mean ± sd)	7.9 ± 3.2	36.4 ± 14.3	21.2 ± 17.6

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and 5 midwives are required in CHCs at any given time to dispense safe maternity care [34]. None of the CHCs in the district achieved this critical mass.

Availability of EmNOC drugs and equipment

All hospitals had whole blood available for transfusion on the day of data collection (Table 7). We did not, however, ascertain the availability of different blood groups. None of the facilities in the district scored 100.0% for availability of either EmNOC drugs or fluids. The average drug availability score in the district was 56.7% ± 13.3%, ranging from a minimum of 33.3% to a maximum of 88.9%, with higher scores in hospitals than CHCs. The mean score for fluids was 80.0% ± 27.7% with a range of 33.3% to 100.0%. Fig 1 shows the details of the drugs and fluids available in CHCs and hospitals. Parenteral antibiotics, syntometrine, diazepam and insulin were not available in many CHCs, but the figures for hospitals were also surprisingly low. Ergometrine was not available in any of the facilities.

The mean score for the availability of adult resuscitation equipment was 78.7% ± 11.3% (Table 7). Individual facility scores ranged from 60.0% - 100.0%. The average score for neonatal resuscitation equipment was 85.0% ± 13.0% with a range of 60.0% - 100.0%. Surprisingly, the least available adult resuscitation tool was a functional stethoscope as only 5 facilities (33.3%) had one readily available for use in the resuscitation trolley on data collection day. Doctors generally had their own stethoscopes with them at all times but midwives and nurses did not, which was problematic when confronted with an emergency. When probed nurse-managers reported that stethoscopes often got lost. They were therefore no longer kept in the trolleys, but locked up in the nursing sister's office, although this was contrary to standard operating procedures.

Availability of EmNOC protocols and resuscitation drills

Maternal Health Guidelines prescribe the presence of EmNOC protocols across all facilities, and these have been developed at both the national and provincial levels [33]. Overall, health facilities performed poorly on the availability of these protocols as the mean score for the district was 41.0% ± 18.0%, with a range of 0.0% - 70.0%. The most readily available protocols in facilities were those of eclampsia (93.3%) and postpartum haemorrhage (86.7%). Only one facility had protocols on the management of retained placenta and shoulder dystocia (Fig 1). CHCs performed slightly better than hospitals, although some hospitals argued that the absence of protocols was not critical as they had obstetricians to provide guidance when needed. 73.3% of facilities had performed at least one neonatal resuscitation drill in the previous year, but only 6.7% had undertaken an adult resuscitation drill. Most facilities (93.3%) held regular obstetric and perinatal mortality and morbidity meetings.

Discussion

All facilities in the study district performed some EmNOC life-saving functions. However, only hospitals performed all the required signal functions to be classified as CEmNOC

Table 7. EmNOC equipment and supplies.

Category	CHCs (n = 8)	Hospitals (n = 7)	Total (n = 15)
% Facilities with whole blood	0.0%	100.0%	100.0%
Drug score, as % out of 9 (mean ± sd)	59.4 ± 14.4	65.6 ± 12.2	56.7 ± 13.3
Fluid score, as % out of 3(mean ± sd)	80.0 ± 27.7	81.7 ± 30.7	80.0 ±27.7
Adult resuscitation equipment score, as % out of 15 (mean ± sd)	78.7±9.3	79.3± 14.7	78.7±11.3
Neonate resuscitation equipment score, as % out of 13 (mean ± sd)	90.0±11.0)	79.0±13.0	85.0±13.0

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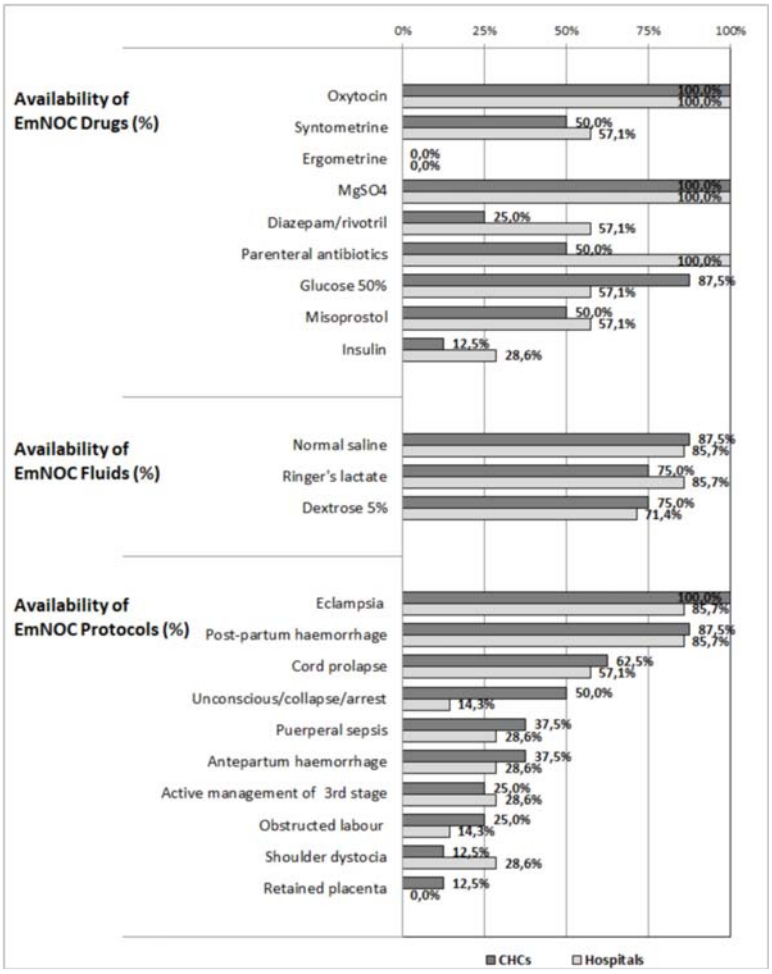


Fig 1. Availability of individual drugs, fluids, and protocols across facilities.

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facilities. The same hospitals provided all basic EmNOC services as well. None of the CHCs performed all required EmNOC signal functions to earn classification as basic EmNOC facilities. The overall target number of EmNOC facilities was 25, yet only 7 were present giving a shortfall of at least 18 facilities for the current district population. When births were used in the denominator rather than the general population, 16 facilities were required and the deficit was 9. The shortfall was more pronounced for basic EmNOC services. In addition, all facilities did not achieve optimal scores on nearly all checklists. Neonate resuscitation drills were performed by most facilities (73.3%) while only one facility performed adult resuscitation drills indicating absence of an important safeguard to quality of EmNOC care. While midwives were available in all facilities, advanced midwives were not always available 24 hours a day, 7 days a week. Doctors were available in CHCs only some days of the week. The mean workload for midwives (deliveries per midwife) in hospitals (36.4 ± 14.3) was disproportionately higher than that of CHCs (7.9 ± 3.2) and this difference was significant ($p<0.01$).

A limitation of this study was that only public health facilities were included. These results therefore show availability of EmNOC for public patients in the district. Adjustment of the population for those without medical insurance to estimate the population that relies on public facilities for care is common practice for planning purposes in South Africa [35, 36]. Although

uninsured woman may fund private medical services out of pocket at times, this is less likely for expensive delivery services particularly when they are exempt from user fees in public facilities [37]. This study focused only on the first UN process indicator (Table 1). Evaluation of all process indicators would provide a more comprehensive assessment of EmNOC services in the district. However, inconsistent recording of obstetric emergencies in facility maternity registers at present prohibit the valid estimation of the important 'met need' or direct obstetric case fatality rates indicators for the district [38]. This prospective data collection in all facilities which was beyond the scope of this evaluation. Nevertheless, measuring the number of EmNOC facilities available remains important information for planning by policy makers and is part of EmNOC monitoring [10, 11, 19–21]. The Caesarean section rate is a routine district indicator [35] and there are national systems for the identification of maternal and neonatal mortality[24, 39].

As confirmed in this study, different denominators proposed to estimate the required density of EmNOC can produce significantly different results. The UN agencies have been criticised for inconsistently using both population and birth denominators interchangeably [10, 11, 40]. Populations with high fertility logically require more EmNOC facilities than similar sized populations with low fertility, rendering the births denominator more accurate for calculating the number of facilities required [10, 12, 41, 42]. In this study as the population denominator showed a much higher shortfall in EmNOC facilities than the births denominator for the same district. The births denominator seems more relevant for South Africa, as the country has one of the lowest fertility rates in sub-Sahara Africa at 2.41 births per woman [43, 44].

The availability of EmNOC in the literature is currently only measured by the number of EmNOC facilities [10, 15, 19, 38, 45, 46]. The capacity of these facilities in terms of size or numbers of delivery beds or numbers of women for whom EmNOC care can be provided are important considerations. But valid metrics for evaluating this capacity remain largely unexplored in the literature which is a critical gap.

Consensus on the package of life-saving functions that constitute basic and comprehensive EmNOC is important for planning purposes and as a basis for comparison [21, 41, 47–50]. While useful, the organisation of EmNOC services implied by the UN classification may not match low and middle income country (LMIC) settings. Studies show that many lower level facilities in LMICs are unable to provide all the signal functions required for basic EmNOC [17, 51]. Scholars have observed that signal functions that require more resource intensive (e.g. skilled providers, specialised equipment, infrastructure e.g. operating theatre) are performed less in many LMICs [51, 52]. The BEmNOC signal functions may be allocated in different configurations across existing facilities depending on the distribution of required resources [17, 21, 40, 51].

In this study, district management policy did not support three of the BEmNOC functions to be provided at the CHC level, and prescribed referral to hospitals where required resources (specialised skills and equipment) were available, thereby centralising EmNOC. Performance of EmNOC services such as assisted vaginal delivery at the primary level without an operating theatre and neonatal resuscitation facilities was considered unsafe. This was despite national policy guidelines stipulating that all the BEmNOC signal functions should be available in CHCs [33]. The disparity between the policy prescriptions of central policymakers in national maternal health guidelines and the services local providers believe are feasible, has been observed in other studies [32, 53]. To avoid such discrepancies, it has been recommended that policymakers should pilot policies before their adoption and scale-up [54]. It is also important to plan for the resources required to implement the policy [55].

On the other hand, centralising the provision of certain BEmNOC signal functions to secondary and tertiary levels of care may compromise coverage and access to essential EmNOC

services [56, 57]. The centralisation-decentralisation tension typically ensues as it is often not feasible to decentralise all services to lower levels of care, particularly where resource scarcity prevails [58]. Furthermore, centralisation of all EmNOC to comprehensive facilities (hospitals) may not be the most efficient use of resources as more women would have to make use of relatively expensive hospital care for basic health needs that could have been provided more cheaply at lower levels of care. Moreover, for EmNOC services to be truly available to women when needed, coverage, and access of good quality EmNOC that is safe cannot be ignored [11, 19, 20, 32, 59]. It is necessary, therefore, to strike a balance between restricting performance of some signal functions to facility levels that guarantee patient safety and quality of care without compromising service coverage and access.

Additional signal functions (e.g. intravenous fluid administration for treating hypovolemic shock) have been proposed particularly for LMIC settings to provide more comprehensive measurement of the functionality of EmNOC facilities, [11, 16]. In this study these additional indicators proved important as some facilities did not attain full scores even for basic fluids that should have been readily available in any general health facility. General measures of facility functioning (e.g. opening hours, electricity, skilled providers) also gave important information on the ability of facilities to perform EmNOC and should be part of availability of EmNOC availability assessments as suggested by others [11, 16]. The UN EmNOC guidelines do not provide staffing norms for the distribution of skilled providers required to achieve availability of the signal functions in facilities across populations [10, 38, 60]. This study, for example, showed inequity in skilled staff distribution in relation to the workload across the district. Pattinson found similar discrepancies in the distribution of midwives in districts due to overstaffing in some facilities and understaffing in others [32].

In addition, there are no clear recommendations for how the quality of EmNOC services could be incorporated into the measurement of EmNOC availability. We included the availability of EmNOC protocols and the performance of EmNOC resuscitation drills in our facility evaluations. These could constitute more quality-orientated EmNOC signal functions as they have been shown to be useful in addressing avoidable maternal mortality [20, 24].

Conclusions

The UN EmNOC signal functions were found to be useful for measuring the availability of EmNOC in the district to inform planning by provincial and district policymakers. The analysis revealed a deficit of EmNOC facilities, particularly basic EmNOC facilities. CHCs did perform some basic signal functions, but not all required to earn EmNOC facility classification. District policy restricted some signal functions to higher level facilities, and this led to centralisation of EmNOC. To improve the sensitivity of the availability of EmNOC indicator, studies measuring EmNOC availability need to consider facility opening hours, capacity and skilled staffing in addition to the demonstrated performance of signal functions. Furthermore, the use of births rather than population as the denominator in estimating the required density of EmOC facilities seems more applicable, particularly in countries with low fertility such as South Africa. We also advocate for the development and inclusion of indicators that better reflect the actual quality of available EmNOC care, as well as the capacity of EmNOC facilities in future EmNOC availability assessments.

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Paper 2: 'It needs a complete overhaul…' district manager perspectives on the capacity of the health system to support the delivery of emergency obstetric care in an urban South African district

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'It needs a complete overhaul…' district manager perspectives on the capacity of the health system to support the delivery of emergency obstetric care in an urban South African district

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ABSTRACT

Background: A high maternal mortality ratio persists in South Africa despite developments in emergency obstetric care (EmOC), a known effective intervention against direct causes of maternal deaths. Strengthening the health systems is one of the focus areas identified by the National Committee for Confidential Enquiries into Maternal Deaths in South Africa. District managers as immediate overseers of the frontline health system are uniquely positioned to provide insight into the overall health system processes that influence the delivery of EmOC.

Objective: We sought to identify health system enablers and barriers to the delivery EmOC from the perspective of district managers. This would potentially unearth aspects of the health system that require strengthening to better support EmOC and improve maternal outcomes.

Methods: Face-to-face audio-recorded key informant interviews were conducted with 19 district managers in charge of the delivery of EmOC in one urban district. Interviews were transcribed and coded. Related codes were inductively grouped into emerging themes. Deductive thematic analysis was then applied to categorise emergent themes into the WHO health system building blocks.

Results: Themes included a weaknesses in the organisation of health services; a high vacancy and turnover of senior management; poor clinical accountability from EmOC providers; inadequate resources (including infrastructure, staffing, and funding); and the need to improve district health information system indicators.

Conclusion: The functioning of the district health system was weak, affecting the delivery of EmOC. Unless staffing is effectively addressed, the health system is unlikely to reduce maternal mortality to the desired level. Coordination of EmOC services by managers needs to be strengthened to limit fragmentation of care and improve the continuity EmOC. Furthermore, a high turnover of senior leadership affects implementation priorities and continuity in the overall strategic direction of EmOC.

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Background

A strong health system is necessary to support the delivery of health services and the implementation of interventions to improve the maternal mortality ratio [1]. Emergency obstetric care (EmOC) is an important maternal health intervention effective in reducing the direct causes of maternal deaths [2–4]. However, a high maternal mortality ratio (MMR) from direct pregnancy causes persists in the sub-Saharan Africa region despite EmOC [5]. Weak health systems common in low- and middle-income countries (LMICs) have been implicated [6,7]. Health system strengthening has therefore been declared a priority by many scholars to reduce maternal mortality [8–12]. The World Health Organization (WHO) structures the health system into six concrete building blocks. These are: leadership and governance; health services delivery; health information; medical products, vaccines, and technologies; financing; and health workforce [1]. The framework has been widely used and provides a unifying language to understand and conceptualise health systems [13,14].

The leadership and governance building block is concerned with effective oversight and stewardship, making it an important building block for health policy governing service delivery [5]. It is the overarching building block that coordinates the others [7,12]. Good governance is critical for health system performance including the reduction of maternal and child mortality [7,12,15]. For example, Rwanda, a country that met its millennium developmental goal of MMR reduction, attributes its success largely to a strong commitment to improving leadership and governance [9,16–19]. While provision of the strategic direction and vision is usually situated at the senior levels within ministries of health and departments, decentralisation of roles and power to sub-national levels where policy implementation actually occurs is important to drive health system performance [20–22]. Positioning the role of leadership and governance at the point of health

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service delivery means district health managers are important stewards. They provide oversight to ensure that the elements of the district health system work together to achieve common goals [1,23]. District managers are thus uniquely positioned to understand the overall processes of health system functioning at subnational level. Management perspectives of the strengths and weaknesses of the health system in implementing maternal health policies can provide useful insights into the state of the district health system and its capacity to support the delivery of EmOC.

In South Africa, the MMR remains high at 138 per 100 000 live births, despite EmOC and other interventions aimed to reduce it [24]. The National Confidential Enquiry into Maternal Deaths (NCCEMD) has identified five priority areas requiring attention inorder to reduce the MMR in South Africa. These are haemorrhage, hypertension, HIV, health worker training, and health systems strengthening. While it is clear what needs to be done for the first four priority areas [25–27], strategies to address health systems strengthening to improve maternal outcomes are less clear. Scholars have identified inequity in resource allocation in health facilities [28]; shortage of health providers [29,30]; shortage of basic EmOC services [31]; and substandard leadership [30,32] as some of the broad health systems problems that influence poor health outcomes in South Africa. We sought to explore and describe health systems weaknesses that specifically affect the delivery of EmOC from the perspective of district managers. This will potentially unearth health systems issues that limit improvements in the MMR of the district and help identify local solutions to strengthen the health system. This study was part of a larger body of work that investigated the link between the health system and maternal health outcomes in South Africa and Rwanda (MHSAR) [9,33–36].

Methods

Setting

Data collection took place in one urban district of the Gauteng Province. The province has five districts. The district under study is the economic hub of the province with vibrant industrial activity that attracts migrants looking for labour, including low-skilled jobs. It is therefore densely populated, with about 3.2 million people living in approximately 1 975.31 km^2 [37]. Informal settlements and poverty are common, challenging the public healthcare system with an increased demand for childbearing services, including EmOC. The MMR of the study district is estimated at 202 per 100 000 live births while the provincial MMR for the province is 148 per 100 000 live births [11], making it a priority district in efforts to reduce the MMR for Gauteng. About 26% of the district population access private health care mostly through private health insurance [38]. This leaves 74% of the population dependent upon public healthcare services funded by the government [38]. Public health care is administered at the district level jointly by the provincial government and the municipality (local government).

Research design

A qualitative research design was used to explore and describe experiences and perceptions of district managers as they oversee the delivery of EmOC services in the district health system.

Participants

A total of 19 senior managers were purposively selected from the study district. Inclusion criteria were people in leadership positions that and could make decisions that governed EmOC services. These were senior managers in the district directorate, health facilities (community health centres (CHCs) and hospitals), members of the district clinical specialist team (DCST), as well as the provincial managers that directly governed maternal health services in the district. Seven (36.8%) of the participants were male and 12 (63.2%) were female aged between 45 and 62 years. They were either medical doctors or nurse professionals.

Procedure

Face-to-face key informant interviews were conducted in English with individual participants in the privacy of their offices at times designated by them. Interviews took about an hour on average, depending on interpersonal participant dynamics. Participants were initially asked to relate their experiences of the health system as managers, including perceived failures and successes. The following open-ended question was asked to open the discussion;

> *"Please tell me about your experiences as a manager that also oversees EmOC in the district. What are some of the challenges you experience?"*

The health system building blocks framework was used to guide probing questions and tease out discussions. The researcher used active listening to encourage participant discussions during interviews. All interviews were conducted in English and recorded. Field notes were also taken by the researcher to document participant non-verbal cues such as body language during interviews. Findings were validated in a feed-back workshop at the district.

Analysis

Thematic content analysis was used to first inductively identify themes and then deductively categorise them into the broader themes of the health system building block framework [1]. Thematic analysis allows flexibility enabling both inductive and deductive coding. The process starts by identifying variables as they emerge from the data [39]. It then progresses to creating broader categorisations and ultimately theory application [39,40]. Audio-tapes were transcribed and typed in MSWord. Phrases and words were coded from the transcripts that gave participant impressions, perceptions, and experiences of the health system. This first step of analysis was done inductively, without reference to researcher preconceived ideas or classifications [41]. From the transcripts, we looked for clues regarding the overall state of the district health system as perceived by managers. We also looked for barriers or bottlenecks encountered during EmOC governance and services delivery, problem-solving or troubleshooting strategies, innovations employed by managers, and identified successes or failures. We grouped related words into emerging themes. Emerged themes were then deductively categorised using the six building blocks of the WHO health systems framework [1]. To assure reliability, an experienced health systems researcher reviewed transcripts and the coded themes to confirm inter-coder agreement [41]. Field notes were also scrutinised thematically and added to themes identified from verbal transcriptions.

Results

Table 1 shows themes identified and classified into the health systems building blocks framework.

Health services delivery and organisation of health services

Dual organisation of EmOC

EmOC was delivered through two separate and parallel arms of government, namely the provincial government and local (municipal) government. These two arms of government were commissioned and funded by national government to deliver health care to the district population without health insurance. Local government clinics referred women to provincial CHCs and hospitals for EmOC, yet there was no opportunity for dialogue or collaboration between these two arms of government. The result was frustration of provincial managers who felt that bottlenecks in the delivery of EmOC could be solved if operations were planned and implemented collectively rather than separately (in silos) or if collaboration to troubleshoot problems was made possible.

> "… There should not be a local government and a provincial government, only health services in one District. Because local government has its own systems and its own mandate, you [provincial government] come with yours and you clash in the system that's what's happening." D7

> "We need a serious overhaul of how maternal health services are organised in XYZ [province name]. You know when you do an engine overhaul … " D9

More health facilities required for EmOC delivery

Managers claimed that the district did not have enough health facilities in which to deliver basic EmOC. The northern and far-eastern areas of the district were particularly underserved. In the northern area, one tertiary hospital served over 2.5 million people and had at least 16,000 births per year without a district or regional hospital to relieve it. In the far-eastern area, one district hospital was upgraded to a regional hospital without increasing its capacity. It served a dense population, including informal settlements of over a million people, and did not have a district hospital or CHC to relieve it. These facilities were particularly overwhelmed and overcrowding in labour wards was common.

Leadership and management

Management issues: poor communication, duplication of management roles, and poor coordination by managers

All managers in the district were aware of the national goal to eliminate preventable maternal deaths. This provided uniformity of purpose as everyone strived to

Table 1. Analytical themes related to the health system building blocks.

Health system building blocks framework	Emerged themes
1. Organisation of EmOC services	Dual organisation of EmOC
	More health facilities for EmOC required
2. Leadership and governance	Clear vision guiding all managers
	Poor coordination of EmOC and fragmented care
	Duplication of management efforts
	High vacancy and turnover of senior management overseeing EmOC
3. EmOC staffing challenges	Acute shortage of skilled EmOC providers
4. Finance	Budgetary constraints failing implementation of new management plans
	Lack of funding a barrier to recruitment of senior managers
5. Drugs, equipment, and supplies	Procurement challenges frustrating managers
6. Health information	Need for improvement of health systems indicators
	Data clerks needed to administrate patient files in health facilities

align their activities to achieve the goal. However, these efforts were undermined by poor coordination of health care, duplication of management roles, and a high turnover in senior management positions, at the province. Since EmOC services were delivered under different health programmes and managed by different directors in the district, strong coordination by managers was required to assure continuity of care. However, interviewees indicated that there were at least three coordinators in the district, who directed different aspects of EmOC and were in charge of the health system and the implementation processes within it. National government coordinated the DCST activities, the provincial EMS director coordinated all EMS services, while the head of department (HoD) coordinated all other district health programmes and primary health care where basic EmOC was housed. These three coordinators did not have formal platforms of communication to help them link up all the programmes under their care. Routine district management team (DMT) meetings did not include all health programme managers, limiting communication and collaboration. Thus, the three aspects of EmOC were not coordinated.

> "*So we have no forum to communicate with them at any point as management in the District … we have the DMT [District Management Team], which is where most of the managers from deputy director upwards meet … But they [hospitals] don't come … So that will not work because they [hospitals] don't report to us [district].*" D9

Fragmented EmOC services

Different aspects of EmOC services were packaged in different health programmes and managed by different directors within provincial government in the district. For example, basic EmOC services were performed by CHCs and these were the responsibility of the primary health care (PHC) programme, while hospitals that offered comprehensive EmOC services were under the directorship of the province. The district clinical specialist team (DCST) in charge of clinical governance was under the directorship of national government. Obstetric ambulances were managed by a separate directorship (emergency services (EMS)) in the province. The result was a lack of understanding of some elements of EmOC in the different programmes. EMS, for example, was poorly understood by managers in health facilities and the district, affecting necessary collaboration between programmes in order to deliver EmOC efficiently. The managers or staff in these four aspects of EmOC did not engage or communicate directly in any way, and this negatively affected services delivery.

> "… because it's [EMS] poorly understood in the department of health, it's not well accommodated …" D12

Confusion and duplication of management efforts

In addition, lack of clarity over management roles and inadequate communication between national and provincial management led to duplication of efforts. For example, the province developed EmOC protocols only to find that facilities were already implementing protocols developed by national government.

> "… Now it goes back to what the question, what is our responsibility? … And so we [province] ended up developing a lot of protocols for them [health facilities], which was not necessary. Because protocols were already there [from national government], documents were already there, you know … That's why the system is confusing in this country." D9

High vacancy and turnover of senior management posts

Vacancy of senior management posts at the province and district was also a barrier to implementation of maternal health policy according to district managers. A provincial human resources (HR) department was responsible for hiring of senior provincial and district management including chief executive officers (CEOs) of hospitals. The province had not had a permanent head of department (HoD) responsible for all health programmes in the province for more than 5 years. Between 2013 and 2017, the province has had at least three different HoDs, and this affected EmOC delivery as strategies priorities changed with each HoD. Furthermore, only two out of seven hospitals (28.6%) in the district had appointed CEOs while the rest were acting (71.4%). In one hospital, for example, we (researchers) engaged with six different acting chief executive officers in a space of 3 months.

> "… So that's where the problem is, is that you don't have a permanent head of department (HoD) … Everyone who comes, comes in with their vision …." D9

Human resources for EmOC

Too few EmOC providers to meet demand

The district had skilled EmOC providers (doctors, obstetricians, and midwives). However, they were insufficient in number to meet population demand across all facilities, and some health facilities worse off than others. Unfilled vacant posts were common in all facilities. Because of the high workload, some facilities had applied for posts in order to hire more doctors and midwives. Unfortunately, they were struggling with long and slow bureaucratic processes in the province since approval of new posts rested with the finance department, and not the department of health.

> "… they [hospitals] are short-staffed [doctors]. So if one doctor reports sick then a gap opens … Just like last Monday, the gynae doctor had to do rounds until 8 o' clock in the evening." D8

Shortage of staff affected the quality of EmOC delivered. Problems included: newly-trained staff with limited experience left to deliver EmOC services without adequate supervision; women sometimes left unattended during care; delays in administering EmOC by providers (doctors and midwives) because they were busy with other patients; queueing of obstetric emergencies (e.g. for an intensive care unit (ICU) bed or caesarean section); and unsatisfactory monitoring of patients during care. Poor monitoring also drove up the demand for EmOC as small complications were likely develop into emergencies if not addressed early on. The following manager narrates;

> "… In your station [e.g. labour ward], if the patient is booked for theatre, then the sister [midwife] has to leave her workstation unattended and go and catch that baby in theatre, even in high care, we do leave patients unattended if we are short staffed. There's nothing we can do." D11

Poor clinical accountability

EmOC providers (doctors and midwives) often displayed poor clinical accountability that negatively affected EmOC delivery according to managers. Unexplained late coming to work, absenteeism, and general poor quality care were common among staff. As a result, the district reportedly experienced frequent legal suits from patients with poor maternal and neonatal outcomes in a bid to enforce accountability. Managers resolved to introduce tougher measures to enforce accountability. These included issuing warning letters to doctors or making midwives defend their care in legal proceedings themselves. In the past, it had been customary for managers to represent midwives in hearings and law suits. However, managers stated that these efforts were often undermined by unions who made representations for EmOC providers in such a way that the disciplinary process was frustrated and became unduly tedious for managers. This difficulty discouraged managers from enforcing accountability to avoid the long processes involving unions.

> "The union is very powerful in this hospital. It makes it very difficult to discipline doctors. We have the union represents the doctor under disciplinary action … then you have to attend endless meetings as management … you end up feeling like just letting it be. It's too stressful." D13

Finance

Scarcity of funding for EmOC

Inadequate funding for health programmes hampered implementation of national health policies and the delivery of EmOC services in the district. For example, responding to overall EMS challenges and resource challenges (too few and very old ambulances, acute shortage of emergency staff, etc.) a turnaround strategy was developed for EMS, without a corresponding budget to operationalise it. This lead to implementation failure.

> "In fact, it [turnaround strategy for EMS] came from the premier's office, but it collapsed in the province when it got to the money issue. There was no funding allocated to the project, and the project we were told to reprioritise within the current under- funded budget and it hasn't worked." D12

> "… approximately 50% of our vehicles technically need to be replaced for the whole province, you're looking at 50% plus that needs to go, either for complete replacement or major refurbishment … if you also look at the norms and standard by government that states how many ambulances should be on the road, we are completely under-resourced." D6

Budgeting processes were said to be one of the biggest obstacles to the delivery of EmOC services. District managers unanimously expressed frustration at the general budget structure, which did not disaggregate to a maternal health budget line item or specific expenditure at the district level. As a result, managers felt disempowered to plan and execute various aspects of the maternal health programme. They felt unable to manoeuvre budget line items. Neither did they have the room to suggest changes nor cuts without a specific maternal health budget line which could have been the basis for argument. Budgetary constraints also interfered with recruitment of staff for both replacements of retired or resigned staff and staff for newly created posts.

Insufficient resources

Inadequate resources, including infrastructure and staff, were also a barrier to full implementation of national policies such as maternal health guidelines. For example, magnesium sulphate to manage patients with severe hypertension in pregnancy was sometimes not used because of inadequate nursing staff to monitor patients on the drug in facilities as it was considered labour intensive. Moreover, CHCs did not offer some of the prescribed basic EmOC services (e.g. manual removal of placenta) because of a lack of reliable transport to refer women safely if complications developed.

> "We do not routinely use magnesium sulphate for severe pre-eclampsia as the national guidelines advise because we have an acute shortage of sisters [nurse-midwives]. It would require frequent monitoring for magnesium toxicity, but we can't do that because of staffing …." D17

Insufficient funding a barrier to management recruitment

According to the government's occupation-specific dispensation (OSD) policy, some senior management positions (e.g. chief executive officers of hospitals) were to be staffed by highly trained professionals, such as doctors. However, budgetary constraints made recruitment difficult, with district directors appointing managers in acting positions because it was much cheaper than proper appointment. As a result, most (71.6%) hospitals had acting senior managers rather than properly appointed managers. It was also difficult to appoint managers who were medically trained in the district according to policy and budgetary constraints, limiting implementation of the policy.

> "… Because if you act in a post, it means … you come in and work but don't necessarily paid by for the post as a manage … which saves money for the district." D7

Drugs, equipment, and supplies

Respondents indicated that health facilities were mostly able to access essential equipment, blood, and other supplies for EmOC. This is a positive aspect of the delivery of EmOC services. Whole blood and blood products were often readily available in all hospitals as expected. However, frustration with procurement procedures was common and managers felt that accountability of the procurement department was unsatisfactory and at times led to unexplained stock-outs of lifesaving drugs and supplies. Equipment such as the balloon tamponade and syntometrine (uterotonic drug) used for managing obstetric haemorrhage were an example of frequent stock-outs due or delays by the procurement department.

> "The problem is the procurement process in the hospital … They send me from pillar to post … And I was thinking as a doctor all I need to say, 'I need this equipment', and somebody's job is to go and source it. But I have to go and get a quotation, when you get the quotation, you wait for finance …." D7

Health information

The district health information system (DHIS) was viewed as a valuable tool for gathering useful information to inform planning of EmOC services. District managers suggested that the quality of data collected could be improved by hiring data clerks in all health facilities, rather than relying on non-governmental organisation (NGO)-supported clerks. These clerks had very high attrition and turnover rates as the NGO frequently ran out of funding. They gave clerks very short contracts of less than a year. This could partly curb the problems such as of lost patient files, as trained clerks are proficient in schematically filing, archiving, and retrieving information. Also, indicators collected by the DHIs could also be improved. Emergency services (EMS), for example, wanted indicators that could directly monitor the responsiveness of EMS. The existing DHIS indicator showed significant increases on the number of ambulance calls for EmOC patients to be transported from CHCs to hospitals but it was not clear if this development was positive or negative, or what the implication for the health system overall was;

> "… if inter-facility demand for ambulances increases, does it mean EMS is doing well or not? … What does it mean for you as a hospital? Or what does it mean for me as EMS? If last month I moved a thousand patients from your facility to another facility and next month I move two thousand, is the service improving or deteriorating? … And for me it's to say if I start moving every second patient, then maybe you are not providing appropriate level of care. But they [health facilities] don't want to accept that …." D12

Discussion

Health services delivered in dual parallel arms of government (provincial and municipal) that did not communicate or collaborate effectively undermined the delivery of quality EmOC services. Bottle-necks in the delivery processes of EmOC across these parallel arms of government were difficult to resolve because of the lack of communication platforms and links. This affected the quality of care offered. Within provincial government, different aspects of EmOC services were packaged between different poorly coordinated health programmes resulting in the fragmentation of care. In addition, a high turnover and vacancy of senior management brought instability in the health system leadership. This disrupted management implementation plans as priorities changed with each new manager. There was also a lack of clarity of management roles between national and provincial managers, leading to duplication of efforts. Furthermore, inadequate resources were a barrier to implementation of maternal health (EmOC) policies and compromised the quality of care for EmOC.

High vacancy and turnover of senior management posts in the district are worrisome as it introduces instability in the strategic direction and implementation priorities of the health system as pointed out by managers. Duffield and colleagues [42] identify numerous health system problems associated with a high turnover of senior management. These include instability of organisations from loss of human capital, unwarranted high economic costs, compromised quality of care, and general reduction in staff morale [42]. This demonstrates the importance of leadership in driving EmOC implementation policies and strategies in the district.

Poor quality of care in health systems is associated with high maternal mortality [43,44]. Health services therefore need to be organised in such a way that delivery of care is continuous and not fragmented to uphold the quality of health systems. Strong coordination of health services by managers and integration of health services is mandatory to assure continuity of care [45]. In this study, the organisation of health services was considered complex and poorly coordinated, and this compromised the quality of the health system and corresponding quality of EmOC delivered to women. To improve integration, managers proposed positioning EMS governance within the district rather than at the national level. It then becomes fully integrated with other district health programmes for planning and reporting. This change could potentially give EMS space to discuss operational challenges, make recommendations, enable other managers to understand EMS, and streamline operations for more efficient and effective service delivery.

Donabedian proposed that quality of care is attributable to the structure (e.g. infrastructure, resources where EmOC is given); the process (e.g. assessment and treatment modalities for EmOC); and the outcomes (e.g. maternal mortality) [46]. It is therefore important to safeguard the quality of care by improving the process (e.g. coordination and integration services to assure continuity of care) in the delivery of EmOC.

Inadequate resources limit implementation of health policies aimed at improving maternal outcomes [47]. In this study, for example, the policy-prescribed drug of choice to manage severe hypertension in pregnancy was not always used when indicated because of staff shortage. Hypertension in pregnancy is one of the leading causes of maternal mortality [8]. We also observed that CHCs in the district struggled to safely give all prescribed basic EmOC life-saving procedures prescribed in the maternal health guidelines [27] as previously reported [36]. This decision although reasonable in the short term promoted centralisation of EmOC to higher levels of care [36]. Thus, primary health care (PHC) implementation in which basic EmOC services are located is also undermined. PHC is one of the key strategies endorsed to turn around the persistent MMR [48,49]. Other LMIC studies have also shown fewer basic EmOC facilities than the recommended benchmarks [31,50,51]. To ease the EmOC burden on EMS and hospitals in the short term, all CHCs need to be provided with requisite resources to be fully functional basic EmOC facilities [27,52]. This could potentially relieve hospitals by decentralising the currently centralised basic EmOC services [36]. In the long term, policymakers may need to consider adding health facilities, to relieve hospitals overwhelmed by a high demand for EmOC [52,53].

Finally, acute shortages of EmOC providers (doctors and midwives) persist and continue to undermine the district health system's ability to provide EmOC timeously and on demand [36]. To put it into perspective, a recent study on EmOC preparedness in the same district showed that only 12.5% CHCs and 42.9% hospitals were able to provide skilled providers for EmOC 24 h a day, 7 days a week [36]. Similarly, scholars identify a shortage of health providers as one of the major health system weaknesses in LMICs [31,54,55]. The South African government has introduced policies such as the occupation-specific dispensation policy (OSD) aimed at improving retention of skilled health providers in districts through financial incentives [56,57]. Unfortunately, health system challenges like insufficient funding for remuneration of highly skilled health providers and senior managers, limits the implementation of OSD making it difficult to resolve the staffing problem. More needs to be done to aggressively increase staffing numbers to meet the demand for EmOC as part of health strengthening initiatives.

Conclusion

Overall, managers perceived the district health system as weak and this undermined the quality of EmOC delivered to women. To improve the quality of care delivered by the district health system, the way in which health services are currently organised will have to be reviewed. Coordination of health programmes needs to be improved to enable continuity of EmOC. Lack of stability in the district leadership responsible for the strategic direction as well as directing implementation of EmOC policies is a critical gap that needs a prompt address. Furthermore, the persistence of acute staff shortage considerably compromises the quality of EmOC delivered.

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Author contributions

Thwala conceptualised and conducted the study, prepared all drafts of the paper, as well as edited them. Blaauw contributed in conceptualising the study, reviewed manuscripts and edited them. Ssengooba also reviewed the manuscript, gave inputs and edits.

Disclosure statement

No potential conflict of interest was reported by the authors.

Ethics and consent

Ethics clearance to perform this study was obtained from the Human Research Ethics Committee- Medical of the University of the Witwatersrand (ethical clearance certificate no: M13096), and the district Research Ethics Committee (research project no: 24/02/2015-1). Permission to conduct the study was sought from each health facility (hospital or CHC). Written informed consent for participation in the study and for recording of interviews was obtained from all participants. Confidentiality of participant identities was also assured in the communication of findings from the study.

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Paper context

Health systems strengthening is one of the five high-priority areas requiring focus to reduce the MMR in South Africa [8]. However, it is unclear what about the health systems needs strengthening or how. This study investigates health system weaknesses that have a bearing on the delivery of EmOC from the perspectives of district managers as immediate overseers of implementation at sub-national level. Findings thereof will inform a tailor-made health system strengthening initiative for the district.

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Paper 3: Predictors of poor maternal outcomes in two South African hospitals: a case-control study

Predictors of severe maternal outcomes in two South African hospitals: a case-control study

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Shortened running title:

Clinical predictors of severe maternal outcomes

Abstract

Objectives
To determine the incidence and identify clinical predictors of severe maternal outcomes (SMOs), in two South African hospitals.

Design
Prospective matched case-control study of SMOs

Setting
Two urban public regional hospitals.

Sample

175 SMO cases matched to two different controls: 175 controls without obstetric complications; and 140 controls with the similar obstetric complications as the SMOs.

Methods
All near misses and maternal deaths occurring during the study period were identified. Data on individual and clinical characteristics of cases and controls was extracted from clinical case files. Firth penalised conditional logistic regression was used to evaluate the impact of these factors on the likelihood of being a SMO case.

Main outcome measures

Near misses and maternal deaths.

Results
The overall SMO incidence ratio and maternal mortality ratio (MMR) were 34.7 per 1000 live births and 130.8 per 100 000 live births respectively. Haemorrhage (35.4%) and hypertension (32.5%) were the most common underlying causes of SMOs. Anaemia (OR=3.04), hypertension (OR=70.97), not booking antenatal care (ANC) (OR=9.61), and having less than 4 ANC visits (OR=2.00) were predictive of being a SMO compared to controls without complications. In comparison with women with complications, not booking (OR= 11.00) and having less than 4 ANC visits (OR=2.21) significantly increased the risk of being a SMO.

Conclusions
SMO incidence and maternal mortality was high in both hospitals. Obstetric haemorrhage and hypertension caused most SMOs. Booking for ANC and frequent ANC attendance were protective against developing a SMO compared to controls without or with complications.

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Keywords
Near miss, severe maternal outcomes, maternal death, emergency obstetric care

Tweetable abstract

South Africa has high rates of maternal deaths and near-misses. Antenatal care protects against these outcomes.

Introduction

Emergency obstetric care (EmOC) is a set of interventions known to be effective in addressing the direct causes of maternal deaths[1,2]. Nevertheless, unacceptably high maternal mortality persists in many countries[2]. Maternal near misses, (women with complications during the childbearing period with complications who nearly die but ultimately survive[3]), occur more frequently than maternal deaths. Near miss audits have proven useful for identifying factors that contribute to severe maternal outcomes (SMOs)[4,5], and their routine use has been associated with reductions in maternal and neonatal deaths[6]. However, only a few published near miss studies have included control groups in their design[7-11]. The absence of a comparison group provides much weaker evidence that identified risk factors are actually responsible for near misses, and means that it is not possible to quantify the relative size of effects. Previous South African near miss studies[4,12-14] are also mostly descriptive studies without controls.

It is encouraging that the maternal mortality ratio (MMR) in South Africa has been declining in recent years, from a peak of 188 per 100 000 in 2009 to 134 per 100 000 in 2016[15]. However, the rate remains very high in comparison to other middle-income countries. The recent report of the National Committee for Confidential Enquiry into Maternal Deaths (NCCEMD) shows that mortality from human immunodeficiency virus (HIV) and obstetric haemorrhage is declining, while deaths from hypertension remain on the rise[15]. A number of clinical factors have been attributed to preventable maternal mortality in hospitals. These include antenatal care attendance, parity, presence of disease (e.g. hypertension)[15]. Although these clinical factors are well documented, more data on the relative sizes of their effects would aid prioritisation of action, especially in settings with limited resources. We sought to measure the impact of obstetric predictors of SMOs in two South African regional hospitals in the Gauteng Province. Findings were intended to inform the design of clinical strategies to improve maternal outcomes in public hospitals.

Methods

A prospective matched case control study was conducted from the 1st of June 2015 to 31st July 2016 in two public regional hospitals in an urban district of the Gauteng Province. The district had an MMR of 169 per 100 000 live births at the time of the study, and this was higher than the provincial average of 113 per 100 000 live births[16]. The two hospitals deliver over 20 000 live births annually. They act as referral hospitals for

district hospitals and community health centres (CHCs), and therefore have medical specialists including obstetricians, intensive care units (ICU), laboratories and blood banks.

Cases and controls

SMOs (near-misses and maternal deaths) in the hospitals were defined as cases. An obstetric near-miss was defined as a woman with acute organ dysfunction or failure during pregnancy, labour, or up to 48 days postpartum in keeping with World Health Organisation (WHO) criteria[17], summarised in Table 1 . WHO uses a combination of laboratory, clinical, and management criteria as the basis for identification of a near miss[17]. The WHO criteria were adjusted to include eclampsia and uterine rupture as recommended for low-and middle-income country (LMIC) settings[18]. We also used blood transfusion of at least 1 unit of blood rather than 5 units, because of the scarcity of blood in LMICs[7,19].

Table 1: Near miss criteria

WHO criteria[17]	Adapted criteria used in the study
Clinical criteria	
Acute cyanosis	Acute cyanosis
Gasping	Gasping
Respiratory rate >40 or <6 per minute	Respiratory rate >40 or <6 per minute
Shock	Shock
Oliguria non-responsive to fluids or diuretics	Oliguria non-responsive to fluids or diuretics
Failure to form clots	Failure to form clots
Loss of consciousness>12 hours	Loss of consciousness>12 hours
Cardiac arrest	Cardiac arrest
Stroke	Stroke
Uncontrollable fit / total paralysis	Uncontrollable fit / total paralysis
Jaundice in the presence of pre-eclampsia	Jaundice in the presence of pre-eclampsia
Laboratory based criteria	
Oxygen saturation <90% for >=60 minutes	Oxygen saturation <90% for >=60
PaO2/FiO2 <200mmHg	
Creatinine ≥300µmols/l or ≥3.5 mg/dl	
Bilirubin >100µmols/l or >6.0mg/dl	
pH < 7.1	
Lactate > 5 mEq/ml	
Acute thrombocytopenia (<50,000 platelets/ml)	Acute thrombocytopenia (<50,000 platelets/ml)
Loss of consciousness and ketoacids in urine	
Complication based criteria	
	Eclampsia
	Uterine rupture
Management based criteria	
Blood transfusion ≥5litres	Blood transfusion≥1 litres
Hysterectomy	Hysterectomy
Dialysis	Dialysis
	Admission into ICU

Table 2: Frequencies of near misses sampled according to study criteria

Criteria for near-miss classification	Frequency of near-misses n=161 (%)
Shock	11 (6.83%)
Continuous use of vasoactive drugs	6 (3.73%)
Cardiac arrest	3 (1.86%)
Cardio pulmonary resuscitation	6 (3.73%)
Hypo-perfusion	3 (1.86%)
Pulmonary oedema	4 (2.48%)
Intubation	8 (4.97%)
Acute cyanosis	7 (4.35%)
Gasping	2 (1.24%)
Severe tachypnoea	2 (1.24%)
Severe bradypnoea	1 (0.62%)
Severe hypoxaemia	8 (4.97%)
Oliguria non-responsive to diuretics or fluids	5 (3.11%)
Urine output <400mls in 24hrs	3 (1.86%)
Dialysis for acute renal failure	5 (3.11%)
Jaundice in severe pre-eclampsia	1 (0.62%)
Severe acute hyperbilirubinemia	2 (1.24%)
Acute thrombocytopenia	7 (4.35%)
Stroke	1 (0.62%)
Status epilepticus	1 (0.62%)
Paralysis	1 (0.62%)
Eclampsia	33 (20.5%)
Severe acidosis	3 (1.86%)
Uterine rupture	5 (3.11%)
ICU admission	34 (21.11%)
Hysterectomy	11 (6.83%)

Two different controls were matched to every case from the same hospital. The first control was a woman without complications who progressed to a normal vaginal delivery, matched by age group and parity. The second control was a woman with similar obstetric complications to the case, but who did not progress to the level of a near miss or a maternal death. Complications were defined as any difficulty in the pregnancy and or delivery. These included bleeding of at least 500mls or 1000mls for normal vaginal deliveries and

Caesarean section deliveries respectively; any hypertension during the current pregnancy, delivery or postpartum; antenatal or postpartum clinical infection that triggered a systemic inflammatory response (septicaemia); and abortions (before 20 weeks gestation). The second controls were also matched by age, parity, and mode of delivery (e.g. assisted vaginal delivery). Age categories for matching were < 18 years, 18-34 years, and >=35 years; parity categories were Para 0, 1-4, and >=5.

Sampling strategy

The required sample size for the matched case-control study was calculated as 165 cases matched to two controls, assuming an odds ratio (OR) of 1.8, power of 80%, probability of exposure in cases of 0.5, and alpha of 0.05. It was estimated that it would take approximately one year to accumulate sufficient cases. By the end of the study period, a total of 175 cases were included and successfully matched to women with uncomplicated deliveries.

However, only 140 cases could be matched to women with similar complications because of the low frequency for particular maternal conditions (e.g. epilepsy in pregnancy). The estimable odds ratio for this comparison is 1.9 rather than 1.8. Cases were included in the sample until the size was completed. Thereafter, cases were recorded without data extraction from files to workout the number of SMOs during the study period.

Data collection

On alternate days in each hospital, study researchers went through patient registers and files in all labour, antenatal, postnatal and gynaecology wards, as well as intensive care units (ICUs), to identify cases of maternal deaths and near misses. We also used maternity clinical heads, nurse managers and doctors in the study hospitals to help identify potential cases. In addition, researchers attended the weekly maternal mortality and morbidity meetings which discussed adverse events and all cases of severe morbidity or mortality of women and new-borns.

Controls (women without complications and women with complications) for each enrolled case were prospectively and systematically selected at least 48 hours after the case had been identified. Controls were

chosen by selecting the first woman presenting without a complication that matched the case (control 1), and the first presenting eligible woman with a similar obstetric complication that matched the case (control 2). The researchers located the clinical files of cases and controls from the patient bedside if still admitted or from the patient file archives if the patients had already been discharged or transferred. The delay of 48 hours was to avoid matching for specific hospital circumstances that may have contributed at the time of the SMO.

The data collection tool was modified from that used for the South African confidential enquiries into maternal deaths[20], and used to extract data from patient files. The data collection tool captured study category (case, control1, control2), near-miss criteria, demographic characteristics, obstetric history, antenatal history, medical history, HIV status, obstetric and/or medical complications, key interventions (e.g. blood transfusion, ICU admission), delivery details, and pregnancy outcomes. Data was collected by the primary researcher (a research midwife) supported by two trained fieldworkers. The primary researcher also checked all questionnaires for completeness, created and maintained a database to keep track of groups (cases and corresponding controls), and processed questionnaires for data entry.

To assist in the completion of the data collection forms, we also reviewed each case with hospital teams during mortality and morbidity meetings to determine causes of death or near-miss, as well as discuss the circumstances around each case and their impact on outcomes

Data analysis

Data were captured using Microsoft Excel and imported into Stata14 for further processing and analysis. Statistical differences between cases and corresponding controls were compared using matched case-control analysis. Conditional logistic regression was used to evaluate the impact of predictors on the likelihood of being a case rather a control, with separate analyses for the two different controls. Potential effects of age, parity and hospital are not estimable in this analysis because cases and controls were matched on those variables. Because a number of variables showed significant separation, with low occurrence particularly in the uncomplicated controls, Firth penalised logistic regressions were used as recommended for such data[21-23]. A 20% significance level in bivariate analysis was used as the criteria for initial inclusion in the development

of the multiple regression models. We also analysed whether routine and emergency obstetric care was given to women as per the South African Maternal Health Guidelines[24] .

Ethics

Ethical clearance to conduct this study was obtained from the University of the Witwatersrand Human Scientific Research Ethics Committee-Medical (Clearance certificate No: M130967) on the 5th October 2013 and the Ekurhuleni Health District Research Committee (Project certificate no: 24/02/2015-1) on the 25th February 2015. The Gauteng Province also authorised the study and the two hospitals independently granted permission for the study.

Funding

The study was funded by the Netherlands Scientific Research Organisation *(NWO)*, grant number: W07.45.202.00. The funder had no part in the conceptualisation, implementation, analysis, interpretation, or write-up of this work. All authors were involved from conceptualisation of the study to the writing of the report and had access to the data from the study. The African Doctoral Dissertation Fellowship (ADDRF) supplemented funding for the PhD student on this study.

Results

Maternal outcome indicators

A total of 739 near-misses and 31 maternal deaths were identified during the 14 month study period (Table 3). There were 22174 live births during this time. Therefore, the overall SMO ratio (maternal deaths plus near-misses) was 34.7 per 1000 live births (Table 3). The near-miss incidence ratio was 33.3 per 1000 live births. The combined hospital/ institutional maternal mortality ratio (iMMR) for the two hospitals was high at 139.8 per 100 000 live births. Hospital1 contributed the most to mortality in this study with an iMMR of 229.8 per 100 000 live births as compared to 46.0 per 100 000 live births in Hospital2 (Table 3).

Table 3: Maternal outcomes in study hospitals during study period

Indicator	Total	Hospital 1	Hospital 2
Total live births	22174 (100.0%)	11315 (51.0%)	10859 (49.0%)
Total near-misses	739 (100.0%)	416 (56.3%)	323 (43.7%)
Total maternal deaths	31 (100.0%)	26 (83.9%)	5 (16.1%)
Near miss incidence ratio	33.3 per 1000 live births	36.8 per 1000	29.7 per 1000
Severe maternal outcome (SMO) ratio:	34.7 per 1000 live births	39.0 per 1000	30.2 per 1000
Mortality index	3.2 per 100	3.8 per 100	0.9 per 100
Hospital Maternal mortality ratio (iMMR)	139.8 per 100 000 live births	229.8 per 100 000	46.0 per 100 000

Underlying causes of SMOs

Table 4 shows that the leading underlying causes for SMOs (n=175) were obstetric haemorrhage (35.4%), and hypertension (32.5%). Anaemia was a noteworthy contributing factor (13.9%). Some women experienced near miss events due to prolonged labour (3.0%), abortion (3.4%), and sepsis (3.4%). Indirect underlying causes for near misses included HIV (2.5%), cardiac problems (0.8%), and epilepsy (0.4%). SMOs from trophoblastic disease (0.4%) and embolism (0·8%) were less common.

Table 4: Underlying causes for SMOs

Underlying causes	Frequency (%) N=175
Obstetric haemorrhage	84(35.4%)
Hypertension	77(32.5%)
Anaemia (contributory)	33(13.9%)
Abortion	8(3.4%)
Sepsis	8(3.4%)
Prolonged labour	7(3·0%)
HIV	6(2.5%)
Pulmonary oedema	6(2.5%)
Ectopic	2(0.8%)
Embolism	2(0.8%)
Cardiac problems	2(0.8%)
Epilepsy	1(0.4%)
Trophoblastic disease	1(0.4%)

Neonatal outcomes

Table 5 shows that SMO cases had significantly worse neonatal outcomes than controls. Having a SMO was associated with significantly lower Apgar scores and a higher risk of low birth weight, in comparison with both uncomplicated and complicated controls.

Demographic and clinical predictors- bivariate analysis

The bivariate analysis of socio-demographic and clinical predictors of being an SMO case, compared to controls without or with obstetric complications, is shown in Table 5. The table presents the breakdown of each predictor for cases and controls, as well as the odds ratio and p values from the Firth conditional logit analysis. Some complications were uncommon in the controls producing large odds ratios and confidence intervals despite the Firth correction.

In comparison to the uncomplicated controls, having 4 or more ANC visits and a marital partner decreased the likelihood of being an SMO case (Table 5). Not attending any ANC (un-booked), less than 4 visits, a previous Caesarean section, prolonged labour, multiple pregnancy, anaemia, hypertension and pre-eclampsia all significantly increased the likelihood of being an SMO. However, in comparison to women with obstetric complications only not booking for ANC, having less than 4 ANC visits, and pre-eclampsia increased the odds of being an SMO.

Table 5: Neonatal outcomes, demographic factors, and obstetric factors of SMO cases and controls

			SMOs compared to Uncomplicated controls (n=175)				SMOs compared to Complicated controls (n=140)			
			Controls	Cases	OR (95% CI)	p-value	Controls	Cases	OR (95% CI)	p-value
Neonatal Outcomes	**Apgar 1 minute**	7-10	164 (95.9%)	99 (66.9%)	–	–	114 (85.7%)	81 (66.9%)	–	–
		4-6	5 (2.9%)	26 (17.6%)	**7.97 (3.30 – 22.93)**	**<0.001**	14 (10.5%)	21 (17.4%)	**3.15 (1.38 – 8.27)**	**0.006**
		0-3	2 (1.2%)	23 (15.5%)	**8.26 (1.77 – 79.20)**	**0.027**	5 (3.8%)	19 (15.7%)	**7.25 (1.26 – 79.15)**	**0.025**
	Apgar 5 minutes	7-10	169 (98.8%)	120 (81.1%)	–	–	123 (94.6%)	97 (80.2%)	–	–
		4-6	1 (0.6%)	7 (4.7%)	**7.03 (1.51 – 67.30)**	**0.041**	3 (2.3%)	7 (5.8%)	**4.82 (1.08 – 44.46)**	**0.038**
		0-3	1 (0.6%)	21 (14.2%)	**15.5 (1.73 – 2 038.4)**	**<0.001**	4 (3.1%)	17 (14.1%)	**15.73 (1.12 – 2 570.7)**	**0.039**
	Low birth weight (<2500g)	No	141 (89.8%)	74 (64.4%)	**5.6 (2.61 – 14.24)**	**<0.001**	94 (79.0%)	58 (63.0%)	2.07 (0.89 – 5.24)	0.092
		Yes	16 (10.2%)	41 (35.7%)			25 (21.0%)	34 (37.0%)		
Demographic factors	**Marital status**	Not single	82 (50.0%)	104(62.7%)	**0.58 (0.36 – 0.92)**	**0.020**	69 (53.5%)	80 (60.6%)	0.66 (0.39 – 1.11)	0.117
		Single	82 (50.0%)	62(37.3)			60 (46.5%)	52 (39.4%)		
Obstetric factors	**ANC attended** (booking status)	Booked	170 (97.1%)	154 (88.0%)	**5.57 (2.01 – 21.03)**	**<0.001**	138 (98.6%)	121 (86.4%)	**35.0 (4.78 – 4459.9)**	**<0.001**
		Un-booked	5 (2.9%)	21 (12.0%)			2 (1.4%)	19 (13.6%)		
	Timing of booking	<20 weeks	65 (40.4%)	47 (36.2%)	1.42 (0.90 – 2.26)	0.139	54 (41.5 %)	41 (37.6%)	1.46 (0.88 – 2.44)	0.142
		>=20 weeks	96 (59.6%)	128 (63.9%)			76 (58.5%)	68 (62.4%)		
	Number of ANC visits	<4 visits	51 (21.9%)	69 (39.4%)	**2.2 (1.4 - 3.4)**	**<0.001**	42 (30.0%)	55 (39.3%)	**2.5 (1.5 - 4.0)**	**<0.001**
		>=4 visits	124 (70.9%)	106 (60.6%)			98 (70.0%)	85 (60.7%)		
	Risks during ANC	No	102 (58.3%)	67 (38.3%)	**2.43 (1.54 – 3.96)**	**<0.001**	51 (36.4%)	55 (39.3%)	0.87 (0.51 – 1.46)	0.596
		Yes	73 (41.7%)	108 (61.7%)			89 (63.6%)	85 (60.7%)		
	Referred into the hospital	No	142 (81.1%)	128 (73.1%)	1.6 (0.96 – 2.7)	0.072	90 (64.3%)	96 (68.6%)	0.82 (0.49 – 1.36)	0.442
		Yes	33 (18.9%)	47 (26.9%)			50 (35.7%)	44 (31.4%)		
	Previous C/S	No	168 (96.0%)	147 (84.0%)	**4.23 (1.91 – 10.90**	**0.001**	109 (77.9%)	115 (82.1%)	0.66 (0.30 – 1.37)	0.263
		Yes	7 (4.0%)	28 (16.0%)			31 (22.1%)	25 (17.9%)		
	HIV positive	Negative	129 (73.7%)	123 (70.3%)	1.19 (0.74 – 1.92)	0.470	93 (66.4%)	100 (71.4%)	0.77 (0.45 – 1.32)	0.340
		Positive	46 (26.3%)	52 (29.7%)			47 (33.6%)	40 (28.6%)		
	Adverse medical history	No	175 (98.9%)	171 (97.7%)	1.80 (0.40 – 10.32)	0.447	136 (97.1%)	136 (97.1%)	1.00 (0.26 – 3.87)	1.000
		Yes	2 (1.1%)	4 (2.3%)			4 (2.9%)	4 (2.9%)		
	Prolonged labour	No	175 (100.0%)	169 (96.6%)	**13.0 (1.54 – 1695.8)**	**0.014**	136 (97.1%)	134 (95.7%)	1.44 (0.44 – 5.22)	0.545
		Yes	0 (0.0%)	6 (3.4%)			4 (2.9%)	6 (4.3%)		
	Multiple pregnancy	No	175 (100.0%)	169 (96.6%)	**13.0 (1.54 – 1695.8)**	**0.014**	135 (96.4%)	134 (95.7%)	1.18 (0.38 – 3.87)	0.773
		Yes	0 (0.0%)	6 (3.4%)			5 (3.6%)	6 (4.3%)		
	Anaemia	No	163 (93.1%)	145 (82.9%)	**2.9 (1.44 – 6.39)**	**0.003**	123 (87.9%)	117 (83.6%)	1.39 (0.73 – 2.71)	0.320
		Yes	12 (6.9%)	30 (17.1%)			17 (12.1%)	23 (16.4%)		
	Syphilis	Negative	174 (99.4%)	171 (97.7%)	7.00 (0.68 – 941.2)	0.112	137 (97.9%)	138 (98.6%)	0.71 (0.12 – 3.67)	0.680
		Positive	1 (0.6%)	4 (2.3%)			3 (2.1%)	2 (1.4%)		
	Proteinuria	No	175 (100.0%)	171 (97.7%)	9.0 (0.96 – 1192.6)	0.055	138 (98.6%)	136 (97.1%)	1.80 (0.40 – 10.32)	0.447
		Yes	0 (0.0%)	4 (2.3%)			2 (1.4%)	4 (2.9%)		
	Hypertension	No	175 (100.0%)	148 (84.6%)	**55.0 (7.73 – 6973.0)**	**<0.001**	105 (75.0%)	115 (82.1%)	0.57 (0.29 – 1.11)	0.098
		Yes	0 (0.0%)	27 (15.4%)			35 (25.0%)	25 (17.9%)		
	Pre-eclampsia	No	175 (100.00%)	119 (68.00%)	**165.9 (23.5 – 21 016.8)**	**<0.001**	109 (77.9%)	89 (63.6%)	**4.08 (1.84 – 10.5)**	**<0.001**
		Yes	0 (0.0%)	56 (32.00%)			31 (22.1%)	51 (36.4%)		

OR,CI and p value from Firth conditional logistic regression, p value ≤0.05 in bold

Demographic and clinical predictors- multiple regression

Multiple regression analysis started with significant predictors from the bivariate analysis. There was overlap between some of the predictors so the final multiple regression models were much more parsimonious, as shown in Table 6. A single composite ANC attendance variable was constructed for the multiple regression to deal with the intersections between ANC booking, timing of first booking, and total number of visits.

Table 6: **Multiple regression: Predictors of SMO**

	SMO compared to Uncomplicated controls			SMO compared to Complicated controls		
	OR	**CI**	**p-value**	**OR**	**CI**	**p-value**
Multiple pregnancy	20.57	(1.14 - 372.60)	0.041 *	2.20	(0.62 - 7.78)	0.222
ANC attendance						
< 20 weeks, ≥ 4 visits	-			-	-	
≥ 20 weeks, ≥ 4 visits	1.18	(0.60 - 2.32)	0.635	1.09	(0.55 - 2.17)	0.807
< 4 visits	2.00	(1.06 - 3.79)	0.032 *	2.21	(1.15 - 4.24)	0.017 *
Un-booked	9.61	(3.25 - 28.39)	<0.001 ***	11.00	(2.63 - 46.01)	<0.001 **
Anaemia	3.04	(1.39 - 6.64)	0.005 **	1.60	(0.77 - 3.31)	0.206
Hypertension	70.97	(4.21 - 1,196.16)	0.003 **	0.75	(0.40 - 1.40)	0.360
Prolonged labour	16.39	(0.75 - 358.42)	0.076	1.73	(0.41 - 7.20)	0.454
HIV positive	1.31	(0.73 - 2.33)	0.366	0.85	(0.48 - 1.49)	0.568

Firth conditional logistic regression
**** p<0.001, ** p<0.01, * p<0.05*

Multiple pregnancy, anaemia, and hypertension remained significantly more likely in SMO cases than uncomplicated controls. Not attending ANC at all (not booking) increased the odds of being an SMO case by nearly 10 times, while having fewer than 4 visits doubled the risk, compared to women with good ANC attendance (booked before 20 weeks and with 4 or more visits). Booking after 20 weeks did not increase the odds of being an SMO if more than 4 ANC visits were still completed, and HIV status was also not a significant contributory factor in this analysis.

Obstetric complications such as anaemia or hypertension did not increase the likelihood of being an SMO case in comparison to complicated controls, mainly because the pairs are matched on these or related variables. However, no ANC attendance or having less than 4 ANC visits remained significant predictors of being a SMO even in comparison to controls with obstetric complications, and with similar odds ratios to the comparisons with uncomplicated controls (Table 6).

Process indicators

Table 7 shows oxytocin as the drug most commonly used routinely (98.6%) to prevent postpartum haemorrhage as per national guidelines.[25] All (100.0%) women that delivered by caesarean section correctly received prophylactic antibiotics. However, just two thirds (66.7%) of women with preeclampsia were given magnesium sulphate, when all should have received it according to national management guidelines[25] prescriptions. Furthermore, the partogram was used to monitor labour in only 61.0% of women in labour.

Table 7: Adherence to routine and emergency obstetric care guidelines

Category	Indicator	Level Achieved
Routine Care (n=490)	Uterotonic given in 3rd stage of labour	485 (99·9%)
	Tested for syphilis	490 (100.0%)
	HIV status known	490 (100.0%)
In labour (n=356)	Partogram used	217 (61.0%)
C/S (n-203)	Prophylactic antibiotics	203(100.0%)
HIV +ve (n=145)	PMTCT given	139 (95.9%)
PIH (n=87)	Mg_2SO_4 given	50 (66.7%)

Discussion

Main findings

This study found persistently high rates for maternal deaths and near miss in two urban public hospitals in South Africa, despite concerted national investment in strategies to decrease maternal morality over the last two decades[15,26-28]. Overall, the maternal mortality index was 3.2 per 100. The overall hospital iMMR was high at 131 per 100 000, and this was consistent with the district MMR [26,29]. Haemorrhage (36.8%) and hypertension (35·4%) were the leading underlying causes of near miss. Not attending ANC at all or having fewer than 4 ANC visits were significantly more common in cases than in normal uncomplicated controls, or controls with obstetric complications that did not progress to a SMO. Multiple pregnancy, anaemia, and hypertension were significantly associated with SMO cases compared to uncomplicated controls, but not in comparison to complicated controls. Compliance with national guidelines was good for certain indicators, such as HIV testing and the use of oxytocics to prevent haemorrhage, but problematic for others, such as the use of partograms to monitor labour or giving magnesium sulphate to manage preeclampsia.

Study strengths and limitations

This study adds to the current literature on the use of near miss audits in LMICs. An important strength of this analysis is the inclusion of controls to increase the validity of identified predictors of near miss and maternal deaths. Only a few studies in the current near-miss literature have included a comparison group[7-11]. Some studies[30-32] have used a mix of complicated and uncomplicated controls, while the remaining few compare near misses to women with normal deliveries[33-35]. In a couple of studies, types of controls used were not clearly defined[9,30]. All of the existing controlled audits have compared near misses to normal deliveries. This study used two different controls to provide complementary comparisons.

There are also certain limitations to the study. Data was extracted from patient files which may be incomplete or not accurately reflect what actually happened. All cases were matched to normal uncomplicated controls, but only 80% (n=140) of cases could be matched to complicated controls because of the low frequency of some obstetric complications (congestive cardiac failure, for example). This decreased slightly the measurable effect size in that comparison. Patient files as sources of data sometimes had gaps of missing information and this limited analysis of some variables (e.g. source of income). Lastly, we were unable to include all maternal deaths in the case-control analysis because of restricted access to some patient files when legal investigations were underway.

Interpretation

The results reported here are similar to those reported from other near-miss studies,[3,30,36-39] and from the South African NCCEMD reports[15,26]. South African maternal near miss studies similarly find haemorrhage and hypertension as common underlying causes on near misses [3,40,41]. The NCCEMD notes a high proportion of maternal deaths from haemorrhage after a caesarean section delivery.[15] Strengthenning of medical training and in-service training on caesarean sections is one of the recommendations by the committee to reduce SMOs.[15]This study confirmed that ANC attendance and having more than 4 ANC visits significantly decreased the likelihood of an SMO. It is well described that ANC attendance during pregnancy is important to allow for the screening of medical and obstetric risks[42-44], and that a number of visits are required to achieve this[45-47]. The latest WHO recommendations are for at least 8 ANC visits during pregnancy[42]. Although health system

interventions, such as the abolition of user fees for women[48], have improved the effective coverage of ANC services, deficiencies in utilisation persist. Overall in our study, only 5.7% of women had not attended ANC at all, but 35.1% had less than 4 visits, and 63.0% booked after 20 weeks. The figures for SMOs were considerably worse (Table 4), 12% had not attended any ANC, for example. A systematic review of the determinants of ANC utilisation in sub-Saharan Africa found that affordability, geographical access, literacy, marital status, maternal knowledge, and access to health information promote ANC attendance[49]. On the other hand, transport costs, poor attitudes of health workers, and the lack of privacy in public clinics have been identified as deterrents of ANC attendance for South African women[50]. Wabiri *et* al[51] observed that poverty and inequity was a barrier to early ANC booking by South African women. Early booking (<20 weeks) for ANC is associated with good perinatal outcomes. To improve ANC utilisation to 100% therefore, a multipronged approach is needed to address issues like social barriers (e.g. inequity and poverty), improve experiences of women of ANC facilities (privacy and health worker attitudes), and address any low literacy of women. Our study did not find an independent effect of booking early, suggesting that the main impact of early booking is to allow a sufficient number of ANC visits.

Anaemia and hypertension were associated with SMO cases compared to normal deliveries but not to women with complications, which suggests that they mainly impact on SMOs through the development of obstetric complications. In their systematic review, Daru et al[52] confirmed that severe anaemia remains an important indirect cause of maternal mortality throughout the world, mainly by increasing the likelihood of postpartum haemorrhage[53-55]. Similarly, in South Africa, Maswime and Buchmann[56] found that anaemia was an associated risk factor for haemorrhage in at least 55% of maternal near misses. Preventing and treating anaemia in pregnant women remains a maternal health priority worldwide[42,52], and in South Africa[25,57]. However, 12.0% of women in this study were identified as anaemic, and this increased the risk of SMO. Although 94.3% of cases and controls had attended ANC at least once this may not be sufficient, as discussed above. In addition, more attention needs to be focused on the content and quality of ANC visits, to fully realise the value of ANC attendance, and improve maternal outcomes[58-61].

The dangers of hypertension in pregnancy to mothers and their babies are also well described [62,63]. Good quality ANC care should be able to screen, identify and manage women with hypertension in pregnancy, thereby minimising its impact on SMO[25,42]. However, the NCCEMD in South Africa has also noted that hypertension-associated maternal mortality remains high, even though deaths from other leading causes (haemorrhage and HIV) are slowly declining[15,28]. Pre-eclampsia is the serious complication of poorly managed pregnancy-induced hypertension, and the immediate precursor of SMOs[64-66]. Magnesium sulphate is an effective treatment for pre-eclampsia, and the recommended first line drug of choice [67-69]. Therefore, it is concerning that we found that one third of women with pre-eclampsia did not receive magnesium sulphate, despite clear national maternal guidelines recommending its use[24].

Conclusion

The MMR may be decreasing in South Africa but remains unacceptably high compared to similar middle-income countries. The focus has to shift to direct obstetric causes, mainly haemorrhage and hypertension, now that HIV-associated mortality is more under control. Near miss audits are important in identifying and prioritising risk factors of SMOs, but would be strengthened by the wider use of controls for comparison. This study confirms the importance of frequent ANC attendance in preventing SMO. Good quality ANC care would also address a significant proportion of SMO associated with anaemia and hypertension. Deficiencies in compliance with national treatment guidelines, for both routine and emergency obstetric care, require urgent attention.

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Paper 4: Health systems factors predicting severe maternal outcomes in two South African hospitals: a case-control study

Health systems factors predicting severe maternal outcomes in two South African hospitals: a case-control study

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Abstract

Background

Health system strengthening is one of the priorities identified by the National Confidential Enquiries into Maternal Deaths Committee (NCCEMD) to reduce maternal mortality in South Africa. However, which health systems weaknesses are important and how to tackle them is less clear. We sought to measure the impact of health system factors on maternal outcomes to help define priorities for health systems strengthening.

Method

A prospective matched case-control study was used to identify administrative, health provider, and patient related avoidable factors that contributed to severe maternal outcomes (SMOs) in two public regional hospitals. Two different types of controls were matched by parity and age to 175 SMO cases. The first control was a woman who had a normal vaginal delivery. The second control was a woman with similar obstetric complication as the case. Clinical case files were used to identify avoidable factors for both cases and controls. Firth penalised conditional logistic regression were used to evaluate the impact of the avoidable factors on SMOs.

Findings

The presence of avoidable health system factors increased the likelihood of being an SMO case. Health system factors remain highly significant even when weighed alongside clinical obstetric predictors. Administrative and health provider factors accounted for most of the risk of SMOs in the hospitals, compared to both groups of controls. Avoidable patient factors also contribute to SMOs, but have a lesser impact when measured alongside administrative and health provider problems. Significant administrative predictors included lack of EmOC facilities, OT and ICU access problems, ambulance problems, and the availability of blood. Important health provider problems included substandard care, delays in providing care, and not using partograms to manage women in labour. Advanced training in EmOC management significantly decreased the risk of SMOs.

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Keywords:

Health system, avoidable factors, severe maternal outcomes, maternal mortality, near miss

Introduction

The frequency of severe maternal outcomes (SMOs), maternal deaths and near-misses, remain unacceptably high in many countries.[1] Near-miss audits have been used to investigate the underlying causes of SMOs and related quality of care issues. [2,3] Predictors of SMOs may be unavoidable (e.g. age) or avoidable (e.g. delays in giving care). [3,4] The majority of SMOs are considered avoidable, particularly in low- and middle-income countries (LMICs). [5,6] The identification, control and elimination of avoidable factors is essential to improve maternal outcomes. [3,4,7] Avoidable predictors have commonly been categorised as administrative, patient and provider related factors. [3]

Recent commentators have called for greater attention to health system strengthening in global maternal health initiatives. [8,9] It is argued that weak health systems in LMICs contribute to poor maternal outcomes. [10-13] Mainly because there are insufficient system resources, such as skilled birth attendants, medicines, and operating theatres, to provide the essential emergency obstetric care (EmOC) needed to prevent SMOs. [1,14,15] However, there is limited rigorous evidence on the impact of these health system factors on SMOs, making it difficult to quantify their relative importance to maternal health programmes. [9,11,16]

One limitation is that few near miss audits have included a comparison control group to provide more valid assessments of the impact of identified risk factors on SMOs. [5-7,17,18] A second problem is that most existing studies have focused on socio-demographic and clinical obstetric factors rather than avoidable health system deficiencies, probably because these are more difficult to measure. [4,19-22] One exception is the study by Ozimek *et al* [23] which investigated the system, provider and patient factors associated with severe maternal morbidity among woman delivering in a large hospital in the United States.

In South Africa, health system strengthening has been identified as a key priority by the National Committee on Confidential Enquiries into Maternal Deaths (NCCEMD) to reduce maternal mortality. [12] However, which aspects of the health system need strengthening is less clear. This study used a controlled near-miss study in one priority health district in South Africa to identify and quantify the importance of health system factors that contribute to SMOs, in order to inform health system priorities to reduce maternal mortality.

Methods

The study methods have been reported in detail previously. [24]

Setting and design

A prospective matched case-control study was conducted from the 1st of June 2015 to the 31st of July 2016 in two public regional hospitals in one urban district of Gauteng Province. Both were teaching hospitals, with obstetrics and gynaecology specialists. The two hospitals had a similar number of births per annum but had differing performance as measured by maternal and neonatal outcomes.

Cases

All maternal near misses and maternal deaths were classified as cases. A maternal near miss was defined as a woman with organ dysfunction in pregnancy, birth, and up to 28 days post birth using the criteria of the World Health Organization (WHO) [25]. The WHO definition employs laboratory results, clinical management, and the patient clinical picture (Table 1). The WHO definition was adapted for this study by adding three disease-based criteria (eclampsia, uterine rupture and severe systemic infections), and lowering the blood transfusion thresholds from 5 units to 1 unit of blood, as recommended previously for low resource settings [17,26].

Daily, researchers surveyed the two hospitals to find cases. Maternity doctors and midwives in the two hospitals also alerted researchers to potential cases for inclusion in the study. The research team also attended morbidity and mortality perinatal meetings in the hospitals in which maternal near misses and deaths were discussed in detail.

Controls

Two different controls were matched to each case. The first control was a woman with a normal vaginal birth and no pregnancy complications, of the same age group and parity. The second control was a woman with similar morbidity (obstetric complications) as the case but who did not become a SMO, and of the same age group, parity, and mode of delivery. All controls were selected at least 48 hours after the case was selected to avoid over-matching for health system problems in the same time period.

Sample size

The required sample size for the matched case-control study was calculated as 165 cases matched to two controls, assuming an odds ratio (OR) of 1.8, power of 80%, probability of exposure in cases of 0.5, and alpha of 0.05. Ultimately, a total of 175 cases were included in the study and successfully matched to controls without complications. However only 140 cases were matched to women with pregnancy and birth related complications,

because of the difficulty in finding controls for certain SMO cases with rare complications such as cardiac disease or epilepsy.

Table 1: Near-miss criteria

WHO criteria[27]	Adapted criteria used in the study
Clinical criteria	
Acute cyanosis	Acute cyanosis
Gasping	Gasping
Respiratory rate >40 or <6 per minute	Respiratory rate >40 or <6 per minute
Shock	Shock
Oliguria non-responsive to fluids or diuretics	Oliguria non-responsive to fluids or diuretics
Failure to form clots	Failure to form clots
Loss of consciousness>12 hours	Loss of consciousness>12 hours
Cardiac arrest	Cardiac arrest
Stroke	Stroke
Uncontrollable fit / total paralysis	Uncontrollable fit / total paralysis
Jaundice in the presence of pre-eclampsia	Jaundice in the presence of pre-eclampsia
Laboratory based criteria	
Oxygen saturation <90% for ≥60 minutes	Oxygen saturation <90% for ≥60 minutes
PaO2/FiO2 <200mmHg	
Creatinine ≥300µmols/l or ≥3.5 mg/dl	
Bilirubin >100µmols/l or >6.0mg/dl	
pH < 7.1	
Lactate > 5 mEq/ml	
Acute thrombocytopenia (<50,000 platelets/ml)	Acute thrombocytopenia (<50,000 platelets/ml)
Loss of consciousness and ketoacids in urine	
Complication based criteria	
	Eclampsia
	Uterine rupture
Management based criteria	
Blood transfusion ≥5litres	Blood transfusion≥1 litres
Hysterectomy	Hysterectomy
Dialysis	Dialysis
	Admission into ICU

Data collection

Data was collected by two trained researchers (a midwife and a physiotherapist). A data collection clerk was responsible for finding identified patient files. Three tools were completed for all cases and controls. The first tool extracted socio-demographic, clinical, and delivery information from patient files. The second tool recorded prevailing health system circumstances in each facility at the time of delivery from facility checklists and interviews with health managers and providers. The third tool was adapted from the maternal mortality audit tool used by the NCCEMD [28], and used to identify and classify health system avoidable factors from the clinical case

notes of cases and controls. To confirm reliability, an independent specialist obstetrician consultant completed forms for 28 (16%) cases in duplicated. Their data was compared to that completed by the primary researcher to identify any disagreements in identified avoidable factors and conclusions. Minor disagreements, occurred in only two cases, in which case the specialist's judgement was accepted.

Data analysis

Data were captured (double entry) using Microsoft Excel software and imported into Stata14 for processing and analysis. Conditional logistic regression was used to evaluate the impact of predictors on the likelihood of being a case rather a control. Because a number variables showed separation, with low occurrence particularly in the uncomplicated controls, Firth penalised logistic regressions were used, as recommended for such data. [29-31] A 20% significance level in bivariate analysis was used as the criteria for initial inclusion in the development of the multiple regression models. Two different multiple regression models were built. The first performed comparisons between cases and uncomplicated controls, the second model compared cases to women with complications.

Figure 1 shows the analytical framework that guided the bivariate and multiple regression analysis. Ideally, all pregnant women should experience normal uncomplicated pregnancies that deliver a healthy baby. We are interested in the factors that influence two clinical transitions: firstly, in factors that promote the development of obstetric complications; and secondly, once complications occur, the factors that influence the progression to near miss and to maternal deaths. The comparison of SMOs with uncomplicated controls provides some insight into the first transition, whereas the comparison with complicated controls evaluates the second. Avoidable factors from the clinical case notes are classified as administrative/system, provider or patient related, as shown in the Figure. In addition, socio-demographic and clinical obstetric factors are also potential predictors.

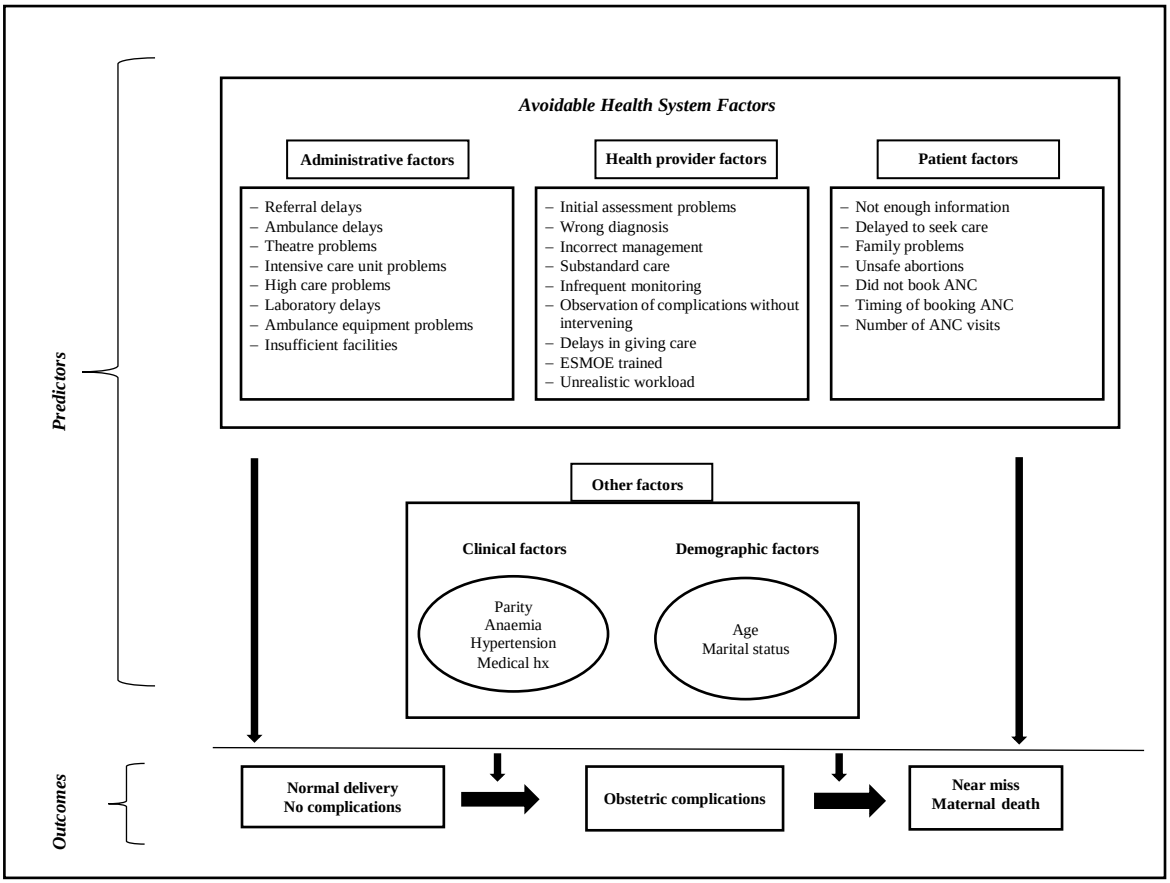


Figure 1: Analytical framework

Ethics

The Human Scientific Research Ethics Committee of the University of the Witwatersrand approved the study (Clearance certificate No: M130967). Permission to conduct the study was granted by the Gauteng Province, the local district research committee, and the hospital authorities. Informed consent was given by health providers for all interviews.

Results

Influence of administrative, health provider, and patient health system factors

Table 2 shows the bivariate analysis of the impact of administrative, patient, and health provider related avoidable factors on the odds of being an SMO case from Firth conditional logistic regression analysis. Having any avoidable factors increased the odds of being an SMO 9.3 times compared to uncomplicated controls, and 3.4 times compared to complicated controls. Significant bivariate predictors are shown in bold and were in the subsequent multiple regression analysis.

Table 2: Health system avoidable factors in SMO cases and controls

			SMOs compared to Uncomplicated controls (n=175)				SMOs compared to Complicated controls (n=140)			
			Controls	Cases	OR (95% CI)	p–value	Controls	Cases	OR (95% CI)	p-value
	Presence of avoidable factors	No	121 (69·1%)	34 (19·4%)	**9·3 (5·2 0 – 18·7)**	**<0·001**	47 (33·6%)	24 (17·1%)	**3·4 (1·7 – 7·5)**	**<0.001**
		Yes	54 (30·9%)	141 (80·6%)			93 (66·4%)	116 (82·9%)		
Administrative factors	Referral delays	No	174 (99·4%)	152 (86·9%)	**15·7 (4·1 – 140·5)**	**<0·001**	133 (95·0%)	118 (84·3%)	**3·7 (1·6 – 10·6)**	**0.002**
		Yes	1 (0·57%)	23 (13·1%)			7 (5·0%)	22 (15·7%)		
	Ambulance problems	No	172 (98·3%)	129 (73·1%)	1·9 (0·5 – 7·8)	0·339	115 (82·1%)	100 (71·4%)	0·56 (0·12 – 1·6)	0.299
		Yes	3 (1·7%)	46 (26·3%)			25 (17·9 %)	40 (28·6%)		
	Theatre problems	No	172 (98·29 %)	150 (85·7%)	**9·8 (3·2 – 48·4)**	**<0·001**	172 (98·29 %)	150 (85·7%)	0·50 (0·30 – 1·0)	0·059
		Yes	3 (1·7%)	25 (14·3%)			3 (1·7%)	25 (14·3%)		
	Intensive care problems	No	175 (100·0%)	162 (92·6%)	**29·2 (1·7 – 494·5)**	**0·020**	140 (0·0%)	131 (93·6%)	**57·0 (8·0 – 7224·3)**	**<0.001**
		Yes	0 (0·0%)	13 (7·4%)			0 (0·0%)	9 (6·4%)		
	High care problems	No	175 (100·0%)	171 (97·7%)	9·21 (0·49 – 172·4)	0·137	138 (98·6%)	137 (97·9%)	**2·7 (1·6 – 4·8)**	**<0.001**
		Yes	0 (0·0%)	4 (2·3%)			2 (1·4%)	3 (2·1%)		
	Laboratory delays	No	175 (100·0%)	160 (91·4%)	**31·0 (4·2 – 3957·3)**	**<0·001**	128 (91·4%)	128 (91·4%)	1·0 (0·4 – 2·4)	1·000
		Yes	0 (0·0%)	15 (8·6%)			12 (8·6%)	12 (8·6%)		
	Ambulance equipment problems	No	174 (99·4%)	165(94·3%)	**19·0 (2·4 – 2449·4)**	**0·002**	140 (100·0%)	133 (95·0%)	**15·0 (1·8 – 1946·7)**	**0·007**
		Yes	1 (0·6%)	10 (5·71%)			0 (0·0%)	7 (5·0%)		
	Insufficient facilities	No	175 (100·0%)	138 (78·9%)	**93·2 (5·7 – 1531·7)**	**0·002**	136 (97·1%)	109 (77·9%)	**8·4 (3·1 – 31·2)**	**<0.001**
		Yes	0 (0·0%)	37 (21·1%)			4 (2·9%)	31 (22·1%)		
Health provider factors	Initial assessment problems	No	173 (98·9%)	161 (92·0%)	**5·8 (1·8 – 29·4)**	**0·002**	134 (95·7%)	127 (90·7%)	2·3 (0·87 – 6·8)	0·095
		Yes	2 (1·1%)	14 (8·0%)			6 (4·3%)	13 (9·3%)		
	Wrong diagnosis	No	173 (98·9%)	148 (84·6%)	**11·0 (3·6 – 54·1)**	**<0·001**	133 (95·0%)	117 (83·6%)	**4·6 (1·8 – 14·5)**	**0.001**
		Yes	2 (1·1%)	27 (15·4%)			7 (5·0%)	23 (16·4%)		
	Incorrect management	No	172 (98·3%)	162 (92·6%)	**3·9 (1·3 – 14·9)**	**0·012**	137 (97·9%)	129 (92·1%)	**3·3 (1·1 – 12·9)**	**0·034**
		Yes	3 (1·7%)	13 (7·4%)			3 (2·1%)	11 (7·9%)		
	Substandard care	No	172 (98·3%)	129 (73·1%)	**18·2 (6·2 – 88·3)**	**<0·001**	115 (82·1%)	100 (71·4%)	**1·9 (1·1 – 3·4)**	**0.033**
		Yes	3 (1·7)	46 (26·3%)			25 (17·9 %)	40 (28·6%)		
	Infrequent monitoring	No	162 (92·6%)	164 (93·7%)	0·9 (0·4 – 1·9)	0·689	134 (95·7%)	129 (92·1%)	1·9 (0·7 – 5·8)	0·207
		Yes	13 (7·4%)	11 (6·3%)			6 (4·3%)	11 (7·9%)		
	Prolonged observation without intervening	No	173 (98·9%)	141 (80·6%)	**22·3 (5·9 – 98·6)**	**<0·001**	119 (85·0%)	109 (77·9%)	1·8 (0·9 – 3·7)	0.089
		Yes	2 (1·1%)	34 (19·4%)			21 (15·0%)	31 (22·14%)		
	Delays in giving care	No	173 (98·9%)	138 (78·9%)	**24·3 (6·5 – 16·1)**	**<0·001**	111 (79·3%)	106 (75·7%)	1·2 (0·7 – 2·1)	0·488
		Yes	2 (1·1%)	37 (21·1%)			29 (20·7%)	34 (24·3%)		
	ESMOE trained	No	157 (89·7%)	149 (85·1%)	1·6 (0·8 – 3·1)	0·187	132 (94·3%)	117 (83·6%)	**3·3 (1·5 – 8·7)**	**0.004**
		Yes	18 (10·3%)	26 (14·9%)			8 (5·7%)	23(16·4%)		
	Unrealistic workload	No	121 (69·14%)	65 (37·14%)	**4·4 (2·6 – 7·8)**	**<0·001**	69 (49·3%)	55 (39·3%)	**1·6 (0·9 – 2·71)**	**0·072**
		Yes	54 (30·86%)	110 (62·86%)			71 (50·7%)	85 (60·7%)		
Patient factors	Insufficient information	No	166 (94·9%)	154 (88·0%)	**2·3 (1·1 – 5·1)**	**0·029**	134 (95·7%)	122 (87·1%)	**3·2 (1·3 – 9·2)**	**0·010**
		Yes	9 (5·1%)	21 (12·0%)			6 (4·3%)	18 (12·9%)		
	Woman delayed in seeking care	No	153 (87·4%)	129 (73·7%)	**2·2 (1·3 – 3·7)**	**0·003**	126 (90·0%)	104 (74·3%)	**3·3 (1·7 – 7·2)**	**<0.001**
		Yes	22 (12·6%)	46 (26·3%)			14 (10·0%)	36 (25·7%)		
	Family problems	No	175 (100·0%)	167 (95·4%)	**17·0 (2·1 – 198·1)**	**0·003**	140 (100·0%)	133 (95·00%)	**15·0 (1·9 – 1946·7)**	**0·007**
		Yes	0 (0·0%)	8 (4·6%)			0 (0·0%)	7 (5·00%)		
	Unsafe abortion	No	175 (100·0%)	171 (97·7%)	9·0 (0·9 – 1192·6)	0·055	139 (99·3%)	136 (97·1%)	7·0 (0·7 – 941·2)	0·112
		Yes	0 (0·0%)	4 (3·3%)			1 (0·7%)	4 (2·8%)		
Obstetric factors	ANC attended (booking status)	Un-booked	5 (2·9%)	21 (12·0%)	**5·6 (2·0 – 21·0)**	**<0·001**	2 (1·4%)	19 (13·6%)	**35·0 (4·8 – 4459·9)**	**<0.001**
		Booked	170 (97·1%)	154 (88·0%)			138 (98·6%)	121 (86·4%)		
	Timing of booking	<20 wks	65 (40·37%)	47 (36·15%)	1·4 (0·895 – 2·26)	0·139	54 (41·5 %)	41 (37·6%)	1·5 (0·88 – 2·44)	0·142
		>=20 wks	96 (59·63%)	128 (63·85%)			76 (58·5%)	68 (62·4%)		
	Number of ANC visits	<4 visits	51 (21·9%)	69 (39·4%)	**0·5 (0·29 – 0·69)**	**<0·001**	42 (30·0%)	55 (39·3%)	**0· 4 (0·25 – 0·67)**	**<0.001**
		>=4 visits	124 (70·9%)	106 (60·6%)			98 (70·0%)	85 (60·7%)		

Multiple regression of administrative, health provider, and patient health system factors

The final multiple regression models are presented in Table 3. Separate models were constructed for the comparisons with uncomplicated and complicated controls respectively. In addition, two models are shown for each: the first includes only the avoidable factors; whereas the second model adds significant socio-demographic and clinical factors, analysed previously[24]**.** None of the patient-related factors remained significant in any of these models. In general the results for the health system factors are similar in the two models, so we focus mainly on the Model 2 results. Not booking or having fewer than 4 ANC visits were the most important obstetric factors in the complete models (Table 3).

Impact of health system factors: comparison of cases to women without complications

Queueing emergencies for operational theatre (OT), ambulance problems, laboratory inefficiencies, and inadequate staff to meet demand were significant administrative factors in comparing SMO cases and uncomplicated controls (Table 3). Women were nearly 18 times (AOR=17.4) more likely to be an SMO from lack of access to OT when required in an emergency, while ambulance problems (delays or unavailability) raised the risk 4 times (95%CI=0·73-22·31). Significant health provider factors included substandard care (AOR=10·0), problems with initial assessment of women (AOR=19·4) and delays in giving care (AOR=15·2). Not using a partogram was 3.2 times more common among SMOs.

Impact of health system factors: comparison of cases to women with complications

Fewer factors were predictive of being an SMO compared to complicated controls. If red packed cells were unavailable this increased the likelihood of being an SMO nearly 25-fold. Not being able to access an ICU when needed was also problematic and increased the odds of being an SMO 70.6 times. In relation to health provider factors, not referring a women when they should have increased the odds of being an SMO nearly 4 times, insufficient midwives increased it 3 times, and being attended by health providers who had not been trained on EmOC increased the risk 2.3 times.

Impact of aggregate/ composite avoidable health system factors:

To evaluate the relative important of the main groups of factors, Table 4 presents a simplified multiple regression comparing the impact of any administrative, provider or patient problem on the likelihood of being an SMO. Administrative and provider problems were highly significant predictors of an SMO in both comparisons, while patient-related factors were not statistically significant in either. In the comparison to women without complications, administrative factors had a higher odds ratio than provider problems, whereas the relationship was reversed when SMOs were compared with complicated controls.

Table 3: Multiple regression of health system factors predicting SMOs

Cases (near misses + maternal deaths) compared to women without complications						
	Model 1: Health system factors			Model 2: Health system factors + Obstetric factors		
Factors	**AOR (CI: 95%)**	**P-value**	**sig**	**AOR (CI: 95%)**	**P-value**	**sig**
Theatre queues and delays	17·6 (5·31 - 58·10)	<0·001	***	17·4 (4·28 - 70·56)	<0·001	***
Laboratory problems	15·7 (0·79 - 312·95)	0·07	*	18·5 (0·77 - 445·44)	0·07	*
Ambulance problems	4·0 (0·98 - 16·31)	0·05	*	4·0 (0·73 - 22·11)	0·11	
Initial assessment problems	10·7 (2·31 - 49·07)	<0·001	***	19·4 (3·61 - 104·09)	<0·001	***
No partogram used	5·1 (2·69 - 9·66)	<0·001	***	3·2 (1·53 - 6·68)	<0·001	***
Delays in administering care	13·7 (5·15 - 36·33)	<0·001	***	15·2 (4·87 - 47·72)	<0·001	***
Suboptimal care	12·9 (2·01 - 82·31)	0·01	***	10·0 (1·24 - 80·48)	0·03	**
Insufficient staff	3·0 (1·61 - 5·70)	<0·001	***	3·1 (·51 - 6·33)	<0·001	***
Health provider communication problems	33·1 (1·33 - 823·09)	0·03	**	43·3 (1·15 - 1628·12)	0·04	**
ANC attendance: ≥ 20 weeks, ≥ 4 visits				1·5 (0·53 - 4·12)	0·45	
ANC attendance: < 4 visits				3·2 (1·25 - 8·23)	0·02	**
ANC attendance: Unbooked				8·9 (1·75 - 45·22)	0·09	***
Anaemia				3·4 (1·16 - 10·16)	0·03	**
Hypertension				27·7 (1·45 - 530·26)	0·03	**
Prolonged labour				5·1 (0·18 - 142·42)	0·34	
Cases (near misses + maternal deaths) compared to women with complications						
	Model 1: Health system factors			**Model 2: Health system factors + Obstetric factors**		
Factors	**AOR CI**	**p value**	**sig**	**AOR CI**	**p value**	**sig**
Did not refer woman	3·6 (1·14 - 11·68)	0·03	**	3·9 (1·21 - 12·58)	0·02	**
Red packed cells unavailable	27·9 (1·58 - 489·30)	0·02	**	24·0 (1·35 - 424·77)	0·03	**
ICU inaccessible	77·6 (4·96 - 1213·21)	<0·001	***	70·6 (4·39 - 1135·35)	<0·001	***
Insufficient midwives in high care	3·0 (1·66 - 5·48)	<0·001	***	3·0 (1·63 - 5·50)	<0·001	***
No ESMOE training	2·6 (1·04 - 6·45)	0·04	**	2·3 (0·88 - 5·77)	0·09	*
ANC attendance: Unbooked				5·8 (1·32 - 24·99)	0·02	**

*** p<0.01, ** p<0.05, * p<0.1

Table 4: Multiple regression of composite health system factors

Cases (near misses + maternal deaths) compared to women without complications			
Factors	**AORs**	**P-value**	**Sig**
Any administrative problem	11·4 (4·45 - 29·26)	<0·0001	***
Any health provider problem	7·3 (3·42 - 15·78)	<0·0001	***
Any patient related problem	1·8 (0·94 - 3·51)	0·075	*
Cases (near misses + maternal deaths) compared to women with complications			
Factors	**AORs**	**P-value**	**Sig**
Any administrative problem	1·8 (1·0 - 3·14)	0·051	*
Any health provider problem	2·2 (1·18 - 4·25)	0·014	**
Any patient related problem	1·5 (0·89 - 2·64)	0·122	

*** p<0·01, ** p<0·05, * p<0·1

Discussion

Main Findings

Health system factors do predict the occurrence of SMOs. Health system factors remain highly significant even when weighed alongside clinical obstetric predictors. Administrative and health provider factors accounted for most of the risk of SMOs in the hospitals, compared to both groups of controls. Avoidable patient factors also contribute to SMOs, but have a lesser impact when measured alongside administrative and health provider problems.

Significant administrative predictors included lack of EmOC facilities, OT and ICU access problems, ambulance problems, and the availability of blood. Important health provider problems included substandard care, delays in providing care, and not using partograms to manage women in labour. Advanced training in EmOC management significantly decreased the risk of SMOs.

Limitations

Rarity of some maternal complications and time constraints for the duration of the study made it impossible to match all cases to complicated controls. However, all cases were successfully matched with uncomplicated controls and statistical power remained sufficient for conclusive analysis from the study. In addition, restricted access to patient files of maternal deaths limited comparison of maternal deaths to near misses in the analysis. Missing information from patient files prevented analysis of some of the patient socio-demographic variables (e.g. educational level).

Interpretation of results

The South African NCCEMD reports the numbers of maternal deaths that had avoidable health system failures[32]. These are classified into administrative, health provider, and patient related avoidable factors. This study shows similar results, and expands the analysis to SMO. It illustrates that health system avoidable factors are important alongside obstetric factors (e.g. hypertension) in contributing to SMOs.

Administrative factors were strong predictors of being a SMO case. Lack of readily available EmOC facilities like OT, ICU, high care, or inadequate red packed cells mean lower capacity for EmOC delivery than required. This suggests an overly burdened health system, whose capacity cannot cope with the demand for EmOC, a phenomenon that was also observed in Gauteng health facilities by health activist organisation Section 27. [33] Other South African studies have noted lower capacity of health facilities compared to the demand. [14,34,35] To strengthen the health system therefore, the capacity of facilities to deliver EmOC will have to be considered. This goes beyond the ability to perform EmOC signal functions, but includes the matching of resources to population

demand. [34] Each woman should get the blood she needs in an obstetric emergency for example to avoid the problem of giving 'too little too late' as noted by Miller *et al.* [36,37] Furthermore, administrative inefficiencies potentially contribute to an unfavourable environment in which to deliver EmOC. Inadequate medical supplies for providing care is one of the 'stressors' reported by nursing managers in South African clinics according to Munyewende and Rispel. [38]

Given the centralised nature of EmOC services in the district, reliable and efficient ambulances are crucial to effectively administer EmOC as basic EmOC (e.g. manual removal of placenta) is available only in hospitals in the district. [14,34] Delays in transporting women from lower levels of care to higher levels of care limit the swift delivery of EmOC, increasing the risk of SMOs. [39,40] This study highlights that ambulance problems significantly affect outcomes and suggests that preventable SMOs will be difficult to eliminate without improving obstetric ambulance services in the South African context. Ambulance problems have also frequently been reported in the South African Saving Mothers Report. [32]

Overall, few studies have evaluated health provider related factors in near miss studies. [4,21,40,41] These studies commonly report on proportions of near misses in which health provider problems were observed. Maswime and Buchmann [42] found that health provider delays in recognising and managing haemorrhagic shock were common among SMOs. Pattinson *et al* [41] also found problem recognition by health providers common in maternal deaths. Iwuh, Fawcus, and Schoeman [43] observed health provider related factors in over 38% of near misses in regional hospitals. In Rwanda, health provider related factors were recorded as the most common preventable factors surrounding SMOs. [44] The more rigorous controlled comparison undertaken in this study also finds health provider factors significantly predictive of SMOs.

Substandard care is one of the most commonly reported and avoidable health provider related predictor of SMOs. Substandard care is also recorded as common in all Saving Mothers reports on maternal deaths in South Africa. [32,45-48] A maternal death audit in the Netherlands found substandard care present in 96% of maternal deaths from hypertensive disorders, for example. [49] Similarly, a Jordanian study found substandard care in 52·6% of all maternal deaths. Substandard care includes not adhering to clinical guidelines, or not providing expected treatment when indicated. In this study, health provider delays in giving care (sometimes because they were busy caring for other patients) compounded the third delay in the 3-delay framework, aggravating complications for women. [50,51] A Brazilian study also confirmed that delays in receiving obstetric care while in hospital were associated with poor maternal outcomes.[52]

Patient related factors also contribute to SMOs from NCCEMD reports. [28,45] When women present for EmOC late in the disease process, or when they do not heed medical advice, SMOs are found to occur. Mantel and colleagues [4] described women's lack of information and family community problems as some of the patient related factors present in near misses. A Rwandan near miss study observed that when women delayed in coming for care, death became unavoidable. [17] Similarly, we found significant odds for SMOs when women did not have information on danger signs of pregnancy, or when women delayed coming to hospital for care, or when there were family issues present such as poor support of the woman. These patient related factors are among known delays of access to maternal health care recorded in the literature. [50,53] Although patient related factors independently influenced the occurrence of SMOs, their effect was not as strong when considered alongside administrative and health provider factors. This implies that through EmOC interventions, the supply side of the health system could prevent most maternal deaths that present in health facilities in South Africa.

Implications of the study

Presently, only a handful of near-miss studies include a comparison arm in their study design to enable measurement of the association between avoidable factors and SMOs. [19,54-59] Such information is important to inform planning for priorities to improve maternal outcomes. Even fewer near-miss studies have examined avoidable health system factors. [19,21,23,60] Of these, health system avoidable factors were mostly described as proportions. None measured associations between health system factors and SMOs, or explored the nature of the relationship.

One of the important considerations in designing near-miss case-control studies is the definition of appropriate controls. [61] While the discussion of the definition of a near-miss has matured, and consensus reached on near miss markers, there has been very little debate on which controls would be the most useful to compare to a near-miss. [19] To date, the selection of controls has varied across the few existing case-control near-miss studies. [7,17,56] Some have used women without complications during delivery as the control,[7,56] while others do not differentiate women with complications from those without in the analysis. [7,17] The reality is that the comparison of cases (women with SMOs) to different types of controls gives us different types of information, potentially leading to different insights and conclusions. In this study, two different kinds of controls were used. Comparing women with SMOs to women with pregnancy and birth related complications showed that the health system was generally weak, and struggled to cope when tested. Comparisons of SMOs to women without complications showed the magnitude of the risk of avoidable factors in producing SMOs.

Conclusion

The inclusion of a control arm proved helpful in this evaluation of the impact of health system factors on SMOs. Avoidable health system weaknesses were strongly predictive of SMOs. Administrative and health provider problems were the most significant predictors of SMOs. Essential EmOC facilities like OT and ICU were not readily available when women needed them predisposing them to progressing to SMOs. Women were also likely to have SMOs because of ambulance problems or inadequate blood supplies. When health providers gave substandard care, made errors in assessment, or delayed attending to women, SMOs were significantly more likely. Although patient related problems also contributed to SMOs, administrative and health provider problems were quantitatively more important predictors of EmOC deficiencies in hospitals.

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Chapter4: Discussion and Implications

This chapter summarises the main finding of the study, presents a discussion of the results organised around four cross-cutting themes.

Summary of main findings

Availability of EmOC

The first two objectives were about establishing the availability of EmOC in the district. We found that EmOC was not optimally available in the district. There were fewer EmOC health facilities than the populations' need affecting the health system's ability to deliver EmOC. While comprehensive EmOC was adequate, basic EmOC was in short supply and centralised to hospitals only. The result was an EmOC need that overwhelmed hospital infrastructure and resources, as well as emergency services (EMS) responsible for ambulances. In the end, even the few hospitals that could offer basic EmOC struggled to deliver it due to the unmanageable need that made it difficult to access EmOC for women even when they were in hospitals, resulting in delayed care. In all health facilities, none scored maximum scores for the availability of EmOC equipment, drugs, and supplies. Skilled health providers for EmOC were in short supply, and not always available in health facilities to give care to women when required.

Health systems factors and severe maternal outcomes

The third objective investigated health system factors that influenced the occurrence of severe maternal outcomes. We observed that administrative, health provider, and patient related factors were found significantly predictive women becoming near misses or maternal deaths. Health provider and administrative related factors were the most influential in the occurrence of severe maternal outcomes in the district. There were deficits in the process and structure of the quality of EmOC given, and this promoted the occurrence of SMOs. The overall impact was felt by women at the point of care as there were excessively long delays taken by ambulances to collect them from CHCs when confronted with obstetric emergencies. When they eventually did get to the hospital with the right

level of care to access EmOC, they were confronted with the limited capacity of EmOC facilities (e.g. OT, High care) forcing them to join queues of emergencies within the hospital. Access to ICU was difficult, and red packed cells were often less than the prescribed requirement for women during obstetric emergencies. The end result was a cascade of complications for women as their conditions advanced to major complications that threatened their lives even further. Doctors and midwives also struggled to deliver care as they could hardly cope with the need in facilities, as they were fewer than women needing EmOC and therefore sometimes left women unattended while attending to other patients. Health providers also acted in ways that promoted SMOs. They sometimes made errors in initial assessment of women perinatally, gave substandard care, delayed to see women needing care, and monitored them for prolonged periods with complications without intervention. All these actions strongly predicted women becoming near misses or maternal deaths. Patient related factors determined include women delaying coming to hospital for care late in the disease process. Women that lacked knowledge on the danger signs of pregnancy were also significantly likely to become near misses or maternal deaths. ANC attendance was protective of SMOs and a strength of the health system.

Manager perspectives of the health system

EmOC managers in the district felt that EmOC services could be better organised to deliver EmOC easier. Poor coordination of the different health services in the district meant fragmentation of EmOC and this ultimately translated to fragmentation of care given to women. There was also a high turnover in senior management in the district, and vacancy in management posts common. Temporary senior managers often acted in posts, and this rapid instability impacted the strategic implementation direction of EmOC. Skilled health providers for EmOC were also in short supply, making it challenging for managers assure adequate cover in EmOC giving departments. It was therefore not uncommon for midwives or doctors to sometimes leave women in need of care unattended while they were busy with other patients in health facilities. The workload of skilled providers was considered substantially

higher than they could cope. Furthermore, under resourcing (e.g. funding and ambulances) compared to the need was an important barrier to optimal implementation of EmOC in the district.

Cross-cutting themes

The overall aim of the PhD was to investigate the health system factors that influence the delivery emergency obstetric care (EmOC) in Ekurhuleni district. The health system building blocks framework was applied to assess areas of weakness of the health system that needed strengthening to potentially inform planning by policy makers and subsequently improve maternal outcomes. Across the four papers from this work, four cross-cutting themes were identified in relation to the building blocks framework, and form the basis of this discussion. These are outlined as follows:

1. State of EmOC services: This theme shows that the health system in the district did not perform as expected. It shows that the quality of EmOC delivered to women in the study district was sub-optimal, and was associated with severe maternal outcomes.
2. Health systems factors influencing EmOC: This constitutes the bulk of the discussion given that it was the focus of the PhD. The influence of each health system building block on EmOC and maternal outcomes is discussed in turn. Assessment of the preparedness of the health system to deliver EmOC is also discussed.
3. WHO health systems building blocks framework: This theme discusses the nature of relationships between the building blocks using data from this study. This is used to reflect on the usefulness of this framework for interrogating health system deficiencies, particularly in relation to maternal health.
4. Lessons on the measurement and evaluation of maternal health services: This theme details methodological issues in existing approaches to the evaluation of maternal health care. Useful solutions are suggested from experiences of this study.

Table 13: Cross-cutting themes and sources

Thesis theme #	Key findings/ arguments	Source/ paper
1. State of maternal health in the district		
1a. Poor state of EmOC	– Outcome indicators: MMR, mortality index, SMO ratio, NM ratio	Paper 3
	– Maternal disease profile/ underlying causes	Paper 3
	– Availability of EmOC	Papers 1, 2, 4
1b. Structural quality of EmOC	–	
	– Availability of BEmOC services, readiness to offer EMOC	Papers 1, 2, 4
	– Infrastructure issues (e.g. not enough OTs, ICU, etc.)	Paper 4
	– Equipment, blood and drugs for EmOC issues	Paper 4, paper 1
	– Skilled providers; not enough to provide EmOC 24 hours a day/ 7 days a week, poor quality of care given (substandard care, diagnostic errors, etc.)	Papers 1, 2, 4
	– Ambulance issues; not enough, ambulance related delays, ambulances unreliable	Papers 1, 2
	– Patients presenting late for EmOC, refusing treatment, not booking for ANC and its impact on outcomes	Paper 4
2.Building blocks analysis of health system factors supporting EmOC		
2a. Organisation of health services	– Organisation of health services & mix of health services (coverage versus quality)	Papers1, 2
	– Integration problems	Paper 2
	– Too few health facilities for to deliver EmOC adequately, classification of facilities	Paper 1
	– Poor EmOC services delivered (e.g. monitoring issues)	Papers 1, 2, 4
	– Centralisation-decentralisation tension	Paper 1
	– Inadequate resources to deliver EmOC	Papers1, 2, 4
	– Obstetric ambulances	Papers 2, 4
2b. Health workforce Skilled providers for EmOC/ human resources for EmOC	– Skilled providers available in district but not in sufficient numbers to meet demand	Papers 1,2, 4
	– Women sometimes unattended while in hospital because providers	Papers 2,4
	– Workload issues	Papers 2, 4
	– Increased referrals from CHCs partly because of lack of staff	Paper 2
	– Poor quality of care given (errors in diagnosis and management)	Paper 4
	– Redistribution of staff by management to cope with shortage and the use of low-experienced staff sometimes unsupervised	Papers 2, 4
	– Work environment issues: (high workload, not enough EmOC facilities, reliability issues of the ambulance	Papers 1, 2, 3, 4
	– Health worker performance	
2c. Leadership and governance	– Poor coordination of EmOC	Paper 2
	– Vacant senior management posts	Paper 2
	– Accountability, oversight , stewardship	Paper 2
2d. Funding for EmOC	– Difficulty in recruiting qualified managers (per policy) because of remuneration costs	Paper 2
	– Implementation of some EmOC stalled because of funding shortages	Paper 2
2e. EmOC related medicines, equipment, and drugs	– EmOC medicines availability	Papers 1, 4
	– Procurement of supplies issues	
2f. Health information for EmOC	– Unreliable personnel (temporary clerks with high attrition rates) to collect and store DHIS data in hospitals	Papers 1, 2
	– Near miss data not routinely collected	Paper 1
	– Indicators on EmOC need refinement	Paper2
3.Usefulness of the building blocks framework		
Understanding the links between the building blocks and its impact on maternal health outcomes	– Complex health systems	Papers 1, 3, 4
	– Centralisation of EmOC and its effect on other building blocks	
	– EmOC serviced demands on the finance building block	Paper 2
	– Impact of EmOC demand on health facilities	Paper 4
4. Maternal health services evaluation methods		
Lessons on measurement for EmOC	– Critique of EmOC indicators	Paper 1
	– Near miss methodology lessons :Need for controls, different types of controls	Papers 3, 4

Theme 1: State of EmOC services in the study district

Maternal outcomes from this study suggest sub-optimal performance of maternal health care services in the study district. The near miss incidence ratio high at 33.3 per 1000 live births. There was also a high MMR of 139.8 per 100 000 live births and a mortality index of 3.2 per 100 from the two study hospitals as reported in paper 3.This MMR was less than the district MMR of 169 per 100 000, but still higher than the provincial average of 113 per 100 000 live births recorded in the 2014-2015 triennium of the NCCEMD [39]at the time of the study. As discussed in paper 1, the availability of basic EmOC facilities was insufficient to meet the need for women. In paper 2, EmOC managers outlined several deficiencies of the health system undermining maternal services, and complained that inadequate resources affected nearly all aspects of EmOC services delivery. In addition, the poor maternal outcomes from this study reflect suboptimal performance of the health system in the district. One of the key reasons for poor maternal outcomes is a weak health system as stated by the NCCEMD [16, 151]. In agreement, a systematic enquiry on 137 LMIC countries found that health systems that give low quality care also produced poor maternal outcomes [161]. According to Kruk and Freedman, health system performance indicators can be classified into effectiveness, equity, and efficiency [162]. The indicators reported in this study reflect the effectiveness aspect of the health system performance in the district and therefore underscore Saving Mothers Report calls [163] to strengthen the health system in South Africa.

From this work (paper 3), we observe that the most common direct causes of SMOs are hypertension (32.5%) and obstetric haemorrhage (35.4%). Anaemia was an important contributory factor to a large proportion (20.6%) of SMOs. Maternal near-miss studies from South Africa and elsewhere have also found hypertension and haemorrhage to be the most common underlying causes for SMO [105, 109, 113, 114, 117, 118]. For example, Iwuh*et al's* [105] near miss study in the metro of Cape Town found hypertension and haemorrhage to be the most common causes of near misses at 44.6% and 33.9% respectively. Similar to our findings, they observed that not booking ANC and ambulance-related delays for EmOC were important avoidable factors for SMOs. Soma-Pillay and Pattinson [109]

investigated barriers to care among near-misses in a Pretoria academic hospital using the 3-delay framework of Thaddeus and Maine [90]. Soma-Pillay and Pattinson found that patient delays in seeking health care (1st delay) and health facility delays when the patient presented for care (3rd delay) were the most common barriers [109]. Similarly, we observed that administrative (OR=11.4; p<0·0001=) and health provider (OR=7.3; p<0.0001) related problems related to the 3rd delay, significantly accounted for near misses (paper 4), and were more influential than patient factors (OR=1.8; p=0·08) associated with delays in seeking care (1st delay).

On the other hand, ANC attendance was found to be significantly protective of SMOs (papers 3, 4). This was a strength of the health system in the district. Evidence from other settings [164, 165] confirm the effectiveness of ANC in preventing SMOs. WHO [166], a global health authority, also promotes ANC utilisation to protect women from SMOs.

Theme 2: Building blocks analysis of health system factors supporting EmOC

The deficiencies in EmOC in the district were related to a number of different health system weaknesses. This section reviews the problems related to each health system building block across the four papers.

Health services organisation:

Integration and coordination

This study demonstrates that the way in which health services are organised has a bearing on EmOC delivery within the health system and this influences subsequent maternal outcomes. As discussed in Paper 2, there was segmentation of the district health system into two parallel (municipal and provincial) governing structures. These structures were completely separate with no communication avenues or other formal mechanisms to link them even though they serviced the same population (paper 2). The status quo introduced complexity in overseeing EmOC services, and undermined accountability of the two governing bodies. Within the provincial government, health services were further segmented into different health programmes addressing different components of EmOC. Integration problems for maternal health care have been reported in other settings. Montenegro *et*

al [167] argued that the markers of a poorly integrated health system on maternal health include duplication of efforts, underutilisation of services by targeted users, and a poor location of hospitals away from the intended pregnant women.

Similarly, Aiga and colleagues [168] observed confusion among women and health providers because of the multiple separate home based health records for maternal and child health implemented in Vietnam. Vural *et al* [169] found that integrating postnatal care services into antenatal and peri-partum care improved utilisation of postnatal care from 34% to 99%, an important step towards improved outcomes. Postnatal care contributes significantly to preventing neonatal and postpartum maternal deaths from avoidable complications like infections and bleeding [170].

Lessons from a Jhaipego study monitoring EmOC in different countries also showed that integration and coordination of EmOC services is essential [171]. Additionally, scholars confirm that integration of EmOC into national health systems in essential to make EmOC available and accessible to women in need of it [88, 172]. This means that the governance and management of EmOC services should be done alongside other maternal health services to help managers pick up gaps and improve implementation. It also means that women are able to access EmOC in the same space as other health services to limit fragmentation of care that come with silos in organisation of health services. There is therefore a need to create and improve communication linkages between health programmes responsible for the different aspects of EmOC within provincial government as well as between the two parallel governing structures (municipal and provincial government in the district. Examples of such linkages could be a policy instalment of mandatory sharing and feedback meetings between managers of the two governing structures. According to the WHO [173] communication is important to foster collaboration and continuity of care. Since health services delivery and its subsequent outcomes is dependent on the quality of leadership, it is unsurprising that maternal health outcomes remain suboptimal in the district [18, 131, 174].

Centralisation or decentralisation of EmOC service delivery

This study demonstrates the centralisation-decentralisation tension in health systems, and the need to strike a balance in planning delivery of EmOC services. Because EmOC is necessary to reduce deaths from direct pregnancy causes (e.g. haemorrhage) [28], timely access to essential care is important to prevent maternal mortality and adverse morbidity. Health facilities offering EmOC to women therefore should be within a reasonable distance from them for easy access, and this favours decentralisation of EmOC services to assure availability [90, 175]. On the other hand, specialised resources are limited and it may be difficult to maintain quality of care at lower level facilities which is an argument in favour of centralisation. This is similarly argued by Pattinson [176] who pointed out that spreading EmOC services out had the problem of compromising safety for women because resources were not enough to support numerous health facilities. Larson et al [177] also stressed the need to look beyond the access and utilisation of EmOC services, arguing that the effectiveness of services depends on the quality of care received. A Tanzanian study by Muganyizi [178] showed a positive correlation between the availability of EmOC facilities with improvements in health facility deliveries and access to caesarean sections but not overall maternal outcomes. This was attributed to the need for improvement in the quality of EmOC alongside simple access [178].

In the long term, building of more EmOC facilities will have to be considered, particularly in the northern part of the district to relieve the overwhelmed tertiary hospital and existing CHCs (papers 1, 2). Rapid population growth in the district, primarily due to economic in-migration, will increase the demand for EmOC further [179-182]. These findings and conclusions are supported by others. For example, a study to evaluate the availability of EmOC in 24 countries observed a consistent shortage of basic EmOC facilities, and recommended an upgrade of maternity centres and health centres to offer the full complement of basic EmOC services [121]. Other, studies on the availability of EmOC in other LMICs also commonly show an undersupply of BEmOC facilities in particular [127, 183-185].

Obstetric ambulances

In paper2, EmOC managers reveal that emergency services (EMS) are overwhelmed, and struggle to cope with the current exponential rising need for ambulances in general, and obstetric ambulance calls in particular. This causes EmOC not to be readily available when needed by women. The centralisation of EmOC services in the district, also tax emergency services (EMS) by overwhelming them with increased volumes of EmOC referral transport to hospitals, for patients which could potentially have been treated in CHCs (paper 1). Health providers and managers expressed great concern at the unreliability of obstetric ambulances, yet the health system was largely dependent on referral transport to ferry women from the lower levels of care to hospitals in order to access EmOC services safely. Paper 4 found a significant increase in the odds for poor outcomes from ambulance related problems. Similarly, a referral study district in India observed a strong link between the occurrence of maternal deaths and timeliness of emergency transport [186]. A South African study on the role of inter-facility transport in the Free State Province demonstrated that obstetric dedicated ambulances were effective in reducing the maternal mortality ratio in the province [187].

Leadership and governance deficiencies

Management turnover

We identified high vacancy rates, acting appointments and turnover of senior management in the district. There were at least 3 different heads of department (HoD) at provincial level within a period of 5 years (paper 2). The HoD is the senior most leader governing nearly all health programmes in all the districts of the province. The overall strategic direction for the implementation of EmOC suffered in the face of instability in leadership as each new manager identified their own priorities. Senior managers need time to adjust and familiarise themselves with the context of each new position. They also need time to plan, direct, and evaluate their implementation strategies. Permanent appointment or a clear fixed-term contract affords managers the opportunity to plan knowing the time they have to effect implementation [188]. During data collection, we encountered six acting chief executive officers over a space of 3 months in one hospital, showing a lack of continuity or stability in leadership.

The result was frustration on junior EmOC managers who felt that changes occurred too often, and denied them space to implement and evaluate their effect on EmOC delivery.

Health services delivery deficiencies identified in paper 4 were also a reflection of sub-par governance. Laboratory inefficiencies (OR=15.7; 95%CI=0.79-312.95) and undue delays in restocking hospitals with supplies for EmOC such as red packed cells (OR=27.9; 95%CI=1·58-489·30) from the blood bank (paper 4). Managers are expected to direct implementation process and this includes assessing and dealing with administrative issues that may obstruct implementation. District management safeguard the quality of EmOC by applying national and provincial regulations (guidelines and polies). They also have the agency to adapt these regulations within their context [189].

Human resources / skilled providers for EmOC

Strong associations were noted between SMOs and the care provided by health providers (paper 4). Individual level factors of health providers were not measured however, and this is a limitation.

Shortage of EmOC workforce

Skilled providers (midwives and doctors) for EmOC are present in the district, but not in sufficient numbers to provide EmOC at all times (24 hours/ day) (papers 1, 2, 4). All facilities had insufficient staffing for EmOC, and hospitals were worse off compared to CHCs (paper 1). Women in need of care sometimes lay unattended in hospitals because doctors and midwives/ nurses were busy with other patients (paper 1, 2) In some instances, women in labour were unsupervised because midwives and doctors were in operating theatre (OT) attending to obstetric emergencies (paper 2). Managers admitted that this should not happen, but felt helpless given the staff shortage situation (paper 2). Under these conditions, errors in management occurred, including incorrect initial assessment of women, substandard care, and poor monitoring of EmOC patients (paper 4). Inadequate skilled staff was also partly responsible for the decision to centralise EmOC from CHCs to hospitals (paper 1, 2).

Management strategies to deal with staffing shortages in the district included the use of less experienced staff (newly qualified doctors and midwives) without supervision or assistance by more

experienced staff (paper 2). Another coping strategy was to employ temporary nursing staff through agencies, dubbed 'agency staff' against best practice policies of the district. Even though quality of care problems associated with the use of agency staff in public facilities were understood by managers, they felt forced into hiring temporary agency staff to mitigate the staffing crisis (paper 2). Rispel and Blaauw [190] observed serious adverse health system consequences when temporary nurses from agencies were used in South African facilities. Agency nurses typically moonlight staff from other facilities, with inadequate rest between work shifts resulting in exhaustion and poor quality of care [190]. Inconsistent quality of care and the lack of continuity of patient care are some of the adverse consequences of the use of temporary staff to address nursing shortages observed by scholars in other settings [191-193]. The Gauteng Province has ruled against the use of agency staff in light of these health system problems [194]. Thus, the long term under-staffing of EmOC facilities sometimes led to health facilities adopting coping strategies that were not in accordance with national or provincial policies.

This study strengthens the argument that unless the scarcity of skilled EmOC providers is addressed, efforts to end avoidable maternal mortality will remain unattainable [176, 195, 196]. Staffing problems for maternal health care have to be dealt with decisively by policy makers [197, 198]. The challenge of increasing staffing is that it unfortunately increases the government wage bill, a problem in the current economic climate. However, it is noteworthy that investment in human resources may in the long term bring returns that improve population health, offsetting the initial costs. Investing in maternal health does reap sizeable economic benefits in the long run as proven by Onarheim, Iverson, and Bloom [199].

The work environment and health provider performance

This study suggests that the health system provided a suboptimal work environment in which to deliver EmOC thereby affecting the ability of health providers to perform. Work environment issues included overwhelmed health facilities whose infrastructure (e.g. ICU, OT in this study) could not keep up with EmOC needs by women. This was difficult for health providers when they were unable to

prevent complicated cases progressing to SMOs. The lack of reliable ambulances made the work environment stressful for health providers, particularly in CHCs (papers 1, 2, 4). Furthermore, inadequate staffing and high care demands meant that health providers had unreasonable workloads (paper 4) which frustrated them (paper 2) and threatened their ability to deliver quality EmOC services. These work environment issues and their consequences manifest in all 4 papers. Environmental factors may have contributed to poor staff performance. Such an environment could potentially de-motivated EmOC staff. Demotivated health providers tend to perform poorly, affecting the quality of care [200-204]. According to Wyss [205], the workplace environment has substantial influence on the performance of health workers. Dieleman and Harnmeijer [201] add that poor health systems with insufficient equipment, supplies, and poor management structures result in low productivity of staff and poor responsiveness.

The result is a vicious cycle for the health system where the quality of EmOC deteriorates progressively and patient safety in hospitals cannot be guaranteed. Measurement of job satisfaction and motivation was beyond the scope of this study unfortunately. Further empirical work to study the relationship between the health system work environment and motivation or job satisfaction is therefore recommended in this district. Moreover, unresolved work environment issues often result in negative coping strategies by the actors in the health system as observed by several scholars [203, 206, 207]. In Uganda, for example, scholars found that unhappy underpaid doctors took up private jobs elsewhere during working hours [203]. In South Africa, Munyewende and Rispel [208] recorded absenteeism of nurses because of dissatisfaction with their work environment. Other studies observed high attrition of skilled health provider as they left to join the private sector because of unfavourable work environments, and this exacerbated the shortage of skilled health provider in public health facilities [209].

Inadequate EmOC funding

Funding of health system inputs for EmOC

The 2010 World Health Report states that financing of health services is one of the core functions of a health system and important to facilitate care delivery [210]. In this study, inadequate funding of health services in the district weakened the health system ability implement EmOC. Emergency services (EMS) managers could not implement planned dedicated obstetric ambulances because of lack of funds to procure enough ambulances or hire staff to man them (paper 2). This meant sharing available ambulances across all patients making them unreliable for EmOC as reported in paper 1. A turnaround strategy to improve the availability and reliability of obstetric ambulances was developed and adopted by the Gauteng provincial government, but could not be implemented due to the lack of financial resources (paper2). The much needed strategy for EMS was therefore abandoned. In paper 4, the shortages of ambulance was shown to significantly increase the risk of SMOs (OR=4.0; 95%CI=0·98-16·31).

Furthermore, inadequate funding interfered with leadership staffing in the district. High vacancy of senior leadership posts in the district was partly because the budget allocation was insufficient to recruit suitably qualified candidates (paper2) as prescribed by the country's human resource policy called the Occupation Specific Dispensation Policy [211]. While this saved the district on salary expenditure, the longer term effect was a lack of stability in the strategic direction of EmOC implementation (paper 2). Underfunding is common in health systems in low and middle income countries, and is one of the reasons for their weakness [212]. Kruk *et al* observed that increased funding of health care by governments increased access to essential maternal health services and utilisation by women [213]. This underscores the need for increased funding as one of the strengthening measures of the health system in the district.

Health information for EmOC delivery

The study district had a health information system (DHIS) in place that routinely collects maternal health data. This was considered useful by EmOC managers, as it generated information for planning

and evaluation (paper2). Although useful, there was a concern that indicators on EmOC or the health system were inadequate and needed refinement. For example, the DHIS had indicators on the rate of utilisation of ambulances. However, this indicator did not differentiate problems of availability of ambulances for EmOC from other needs making it difficult to interpret. The rate of utilisation also did not have a benchmark to help managers decide if high utilisation meant the health system was performing well or poorly (paper2). The World Health Organisation argues decision makers need clear indicators on which to base decisions [214].

While the DHIS routinely collected data on maternal deaths for maternal death audits by the NCCEMD, no data was systematically recorded for near misses. This was a missed opportunity because health facilities did discuss some of the near misses during routine weekly maternal morbidity and mortality meetings as seen in paper 1. Integrating near miss data collection into the DHIS could give facilities and EmOC managers quicker feedback than the NCCEMD triennial report, thus creating more frequent opportunities for self-evaluation to re-strategize EmOC service delivery. Pattinson and Hall confirm the usefulness of near miss studies as a supplement for maternal death audits [145].

Theme 3: Usefulness of the building blocks framework

From this study, we learn that the health system building blocks are all interconnected, and a problem in one building block can affect others. For example, this district had a problem of insufficient numbers of obstetric ambulances (medical products, medicines and technology building block) which were needed to transport women from CHCs to hospitals (paper 2). This prompted district managers (leadership and governance building block) to discourage performance of some of the basic EmOC signal functions (e.g. manual removal of the placenta) in CHCs because prompt ambulances would be required to ferry EmOC patient to higher levels of care should a complication arise (papers 1 and 2). This decision was considered responsible and in the interest of patient safety. However, the unintended effect was a general centralisation of EmOC to fewer health facilities, overwhelming them (paper 4). This arrangement also became predictive of SMOs as observed in paper 3 (health serviced delivery building block).

This shows how an event in one building block causes a chain reaction in mother building blocks, and in a sometimes unpredictable manner. Topp [215] similarly observed that introducing HIV services in the Zambian health system resulted in unintended perverse outcomes that undermined the same intervention efforts. Our initial framework (Figure 2) perhaps implies that the impact of the different health system building blocks can be isolated. However, the evidence from this work suggests that is quite difficult to do in practice. This contributes to the small but growing literature on the complexity of health systems, and the relationships between the building blocks and system actors. For example, a Rwandan study on health system drivers of performance maternal health [216] found that it was the combination of interventions within and across building blocks that collectively made a difference.

Ergo and *et al* [217] expressed the need for a framework that reflects both the elements (blocks) required to make a health system function and explains the nature of relationships between these elements Lipsitz [218] also argued that the health system is complex and that interventions may bring about both intended and unintended outcomes across multiple building blocks. Part of what makes the relationships dynamic and unpredictable is the social nature, or the 'software', of health systems [218-222]. This study has provided practical implementation examples of how the health system building blocks interact, and the impact of these interaction on maternal health. Health system strengthening frameworks should therefore reflect on this interconnectedness of the building blocks to reflect the complex integrating relationships.

Theme 4: Lessons on the measurement of maternal health services

Measurement of EmOC availability

In paper 1, this study confirmed that UN indicators [35] for measuring the availability of EmOC are inadequate alone to provide a comprehensive picture of the state of EmOC in an area. Additional, signal functions included in this study (e.g. fluids, drugs, equipment, opening hours of EmOC facilities) uncovered that EmOC was not always available to women when needed in all facilities because of insufficient resource inputs. We observed that neither equipment nor skilled health providers were always available to provide EmOC (papers 1 and 2). Meanwhile the infrastructure (high care, ICU, OT)

did not have enough space to accommodate all women requiring EmOC (paper 4) and this contributed significantly to SMOs (papers 2, 3, and 4). The need to expand the UN process indicators to measure EmOC is supported by Gabrysch [125] and other scholars [126, 223, 224].

We also observed that using the births metric (EmOC facilities per 20 000 births) as a denominator to measure the density of health facilities was more useful than using the population metric (EmOC facilities per general 500 000 population) (paper1). The required number of facilities for EmOC can be misleading for low fertility countries, like South Africa [225] if the general population is used in the denominator rather than births. In this study for example, we found that using the general population denominator yielded more health facilities required (25 facilities) than when the births denominator (16 facilities) was used (paper 1). In a study in Ghana on the spatial distribution of EmOC, Bosomprah et al [226] made similarly concluded that the births metric was more useful than the general population metric in the denominator.

Near-miss methodology lessons in measuring health system factors and SMOs

This study showed the value of incorporating a comparator in near-miss methodology, in order to measure strengths of association (papers 3 and 4). Our study is the first in the South African literature to use a case control design. Recent South African near miss studies tend to document incidences and causes of SMOs as well as detail quality of care issues surrounding SMOs [74, 105, 108, 227, 228]. Earlier near miss studies were instrumental in refining the near miss definition, and were among the earliest near miss studies to report on administrative, health provider, and patient health system factors [73, 75]. However, none of these near miss studies included a comparison arm in the design. While these studies were useful in profiling risks observed around these SMOs, none could measure the size of the effect. The classical maternal death audits provided by the NCCEMD [16, 45, 151, 163] also do not include a comparison arm in the study design, limiting measurement of strengths of association between outcomes and independent factors. The case-control design adds the ability to confirm and quantify the impact of avoidable factors on maternal outcomes, beyond mere identification.

In the overall near-miss literature, we have found only a few studies [21, 113, 117, 118, 229-233] that employed a case-control design or included a comparator in their design. However, none of these studies attempted to evaluate broader health systems factors and their relationship to SMOs. They limited their reports to incidences of SMOs and associated causes. A London study by Waterstone *et al* [233] found severe haemorrhage, severe preeclampsia, eclampsia, HELLP syndrome, and severe sepsis to be the predictors of mortality. It also ethnicity, maternal age above 34 years, past and current history, medical history, clinical depression as well as social exclusion to be predictors of SMOs. However, this study did not report on multiple regression analysis to evaluate the independent effects of these variables. A New York study by Goffman and others [229], performed a similar analysis to the London study with similar results. In Burkina Faso, Storeng *et al* [232] conducted a near miss study, but only performed bivariate analysis to assess compare demographic characteristics and mortality between controls and women with SMOs.

Ozimek *et al* [21] confirmed the most common causes for near misses as haemorrhage and preeclampsia, as well as the association of certain administrative factors to SMOs. Although health provider and patient factors were not considered, the investigation of some administrative factors was a positive step towards a more comprehensive health system measurement. More recently, studies by Kasahun *et al* [113] and Oppong *et al* [117] have also investigated incidences and clinical causes for near misses or deaths but have not reported on associated health systems factors. Our study attempts to fill this gap and provides a basis from which further empirical work on the nature of the relationship between health system factors and severe maternal outcomes.

Different types of controls for comparison to the near-miss are presented in this work (papers 3 and 4). Different types of comparison groups are used in the near miss literature, and the question of the significance of these different comparisons is yet to be sufficiently examined. Using different types of control, such as normal deliveries or women who already have complications, could lead to different conclusions. Waterstone and colleagues [233] used 4 controls who were women without near miss

complications in pregnancy for each near miss case identified. It is not clear from the paper however if any of the controls had minor, or moderate, or no disease. The reason for multiple controls was; the predictive power of the study improves if more than one comparison group is used. Adeoye [230] also used 4 controls who were women without complications for each near miss case identified. There was no matching of the characteristics of the cases to controls in this study. Goffman and colleagues [229] opted for 3 unmatched control. From the publication, it is unclear whether controls had any morbidity or not. Storeng [232] used a large cohort of pregnant women, and identified those that ended up with near misses while those without complications in their pregnancies became the controls. Sayinzoga *et al* [118] combined women with mild to moderate morbidity with women without complications in pregnancy as controls for identified cases of near miss or maternal death. The ratio of cases to controls was 1:2. Other researchers [21, 113, 117, 234] matched women without complications to cases identified at a ratio of 1:2.

This study shows the value of using two different comparisons for a severe maternal outcome (near-miss or death). In paper 4, the size of the effect between cases and women with complications was smaller than in the comparison between cases and women without complications paper 4.

Near miss methodology and maternal death audits

NCCEMD reports are extremely valuable for yielding descriptive information on health system circumstances around maternal deaths and the clinical profiles of women who die. However these reports are wide apart (once in 3 years) because they are only based on deaths, which are relatively rare events. On the other hand, near misses occur more frequently, thereby allowing a more rapid analysis. This presents opportunities to design and implement corrective measures against severe maternal outcomes (SMOs) quicker. This near miss study has been useful therefore as it has provided a detailed useful supplement to the existing NCCEMD reports. It has also added new information to that generated by traditional confidential enquiry audits by introducing a comparative element on the analysis to measure effect or impact of health system factors on maternal outcomes. Where NCCEMD reports merely indicated that avoidable factors were present in maternal deaths, this study has

measured the size of risk of SMOs if avoidable factors are present. We found that women without complications were 9 times more likely (OR=9.3) to develop SMOS when avoidable factors were present, while women with minor to moderate complications were at least 3 times more likely (OR=3.4).

Limitations of the study

This study used a case study design, focusing on EmOC services in a single district. The near miss study was done in only two hospitals in the district. This may limit the generalisability of the findings. Nevertheless, the study results resonate with other similar studies from South Africa [105, 108, 111, 227], and the maternal death audits of the NCCEMD [16, 151]. The detailed case study approach, utilising multiple and mixed methods, provided a deeper understanding of the complex relationship between the health system and maternal health care services in the district. The study also produced useful insights into methods and tools for the evaluation of EmOC services that could be utilised in broader national studies.

The study focused only on EmOC services in the public sector. This is the more important priority given that only 18% of the population with private health insurance in South Africa access care in the private sector [132]. Where necessary, for example in calculating population ratios, adjustments were made to include only public sector users, as is standard practice for such analyses in South Africa [139, 235]. Nevertheless, it would be important to undertake similar maternity care evaluations among private providers to get a more comprehensive national assessment of EmOC services. Very little is known of the quality of EmOC in the private sector, beyond the very high Caesarean section rates which have attracted some attention [236]. More research and comparative studies are needed, particularly as national universal health coverage policy reforms [237] include proposals for the contracting of priority services from private providers.

Although providing very rich data, the near miss study was a relatively small study, within the scope of the human and financial resources of a PhD project. Nevertheless, it took the principal researcher supported by two fieldworkers over a year to accumulate the required number of SMO cases. Although all 175 cases were matched to uncomplicated controls, it was only possible to find complicated controls for 140 (80%) of them in the time period available for data collection, mainly because of the low frequency of certain obstetric complications. This reduced the sample size for

analysis for this comparison, reducing the estimable effect size slightly. In addition, the use of patient files limited data collection of some demographic variables (e.g. Marital status) because of incomplete patient files. Conversion of hard copy files into electronic files in hospitals often led to scrambling of the file and loss of pages at times in stored digital copies (errors by clerks in the digitisation process). This further reduced the number of variables that could be consistently recorded for analysis.

Although interviews with various EmOC managers and providers formed a significant part of the study, certain components relied mainly on existing clinical records which were sometimes missing or incomplete or could not provide data that would have been useful in analysis (patient socio-economic status, for example). We did not undertake any formal observations to evaluate the practice and quality of EmOC services in the study facilities. Neither were interviews conducted with service users or near miss cases, which would have provided useful insights into their experiences of health services. Quality of care has both technical (correct medical management) and social (as perceived by users) dimensions [219]. Although this study interrogated the structural, process and outcome aspects of technical quality of care, it did not explore the perspectives of women as users of EmOC services. Including interviews with women would be an important addition to future near miss studies [166, 238, 239].

Because maternal health as a program is vast with multiple sub-programs and interventions, this study used EmOC as a tracer to identify health system weaknesses. Findings therefore relate more specifically EmOC, but can be translated to the whole maternal health program of the district.

Recommendations

Policy recommendations of priorities for health system strengthening to improve maternal health outcomes:

1. The provincial government should continue to pursue ways to increase the numbers of skilled providers (doctors and nurses) for EmOC to support the health system in the district. Although difficult to do in the face of current budgetary constraints, it is necessary to invest in building the workforce if the delivery of EmOC and subsequent health outcomes are to improve.
2. CHCs should be properly equipped to perform all basic signal functions as per country maternal health guidelines. This will go a long way to improve availability of EmOC services. It will also potentially relieve overwhelmed hospitals and obstetric ambulances of high patient loads. In the long term however, more hospitals and CHCs need to be built in the district to adequately supply EmOC, particularly to keep up with projected population growth.
3. Coordination links between provincial and municipal health services need to be created and or strengthened to facilitate governance of EmOC services, improve accountability among managers, as well as improve collaboration, communication, and joint planning. Multiple coordinators will probably need to be maintained, but with clear links between them to encourage integration and aid problem-solving in the implementation of EmOC.
4. At the policy level, instruments should be put in place to integrate EMS better into the district health system. EmOC cannot be implemented fully without alignment of EMS in the district. It is imperative for EmOC managers including EMS management to have formal and regular mechanisms for dialogue. Re-organisation of district health programmes should be considered to place EMS and the district clinical specialist team strategically within the district. This may go a long way to improve coordination of EmOC and limit fragmentation of care.
5. The appointment of senior management in the district should be prioritised to improve stability in governance, and assure continuity in implementation strategies that govern EmOC initiatives. Senior managers need the assurance of a specified term of office to allow them to

plan, direct, and evaluate management functions. The MEC for health in the province, should appoint a permanent head of department.

Policy recommendations for maternal health / EmOC evaluation:

1. Near miss studies offer an opportunity for generation of a wealth of useful information about quality of care, clinical causes of maternal disease or death, and the performance of the health system in promoting maternal health. We recommend the inclusion of control groups more commonly in future studies to enable comparative analysis and quantify the relative importance of contributory factors. Most existing near miss studies have focused on traditional socio-demographic, clinical and obstetric influences. This study has attempted to expand this analysis to health system determinants of SMOs which should be extended in future near miss studies.
2. UN EmOC indicators should be refined to include benchmarks on the size of EmOC facilities to reflect capacity to guide policy planners. The use of births in the denominator for measuring density of health facilities should become the standard for planning. Other key EmOC availability factors should be incorporated in facility audits, including opening hours, availability of electricity, running portable water, and the availability of skilled EmOC providers at all times.
3. ANC is effective in protecting women from SMOs. Ways to roll it out to 100% coverage and utilisation by women needs to be pursued. Known barriers from the literature to access and utilisation by women should be addressed

Conclusions

This study investigated health systems factors that influenced the delivery of EmOC in a one urban district of South Africa. Findings show that the availability of EmOC is not sufficient in the district and this is a factor that limits the delivery of EmOC. Other key health system factors that limit the delivery of EmOC are administrative, health provider, and patient related. These health system factors influence how well EmOC is delivered, and predict the occurrence of near misses and maternal deaths for women. Furthermore, the way in which health services are organised makes it difficult for managers to oversee EmOC in the district and has a bearing on its delivery.

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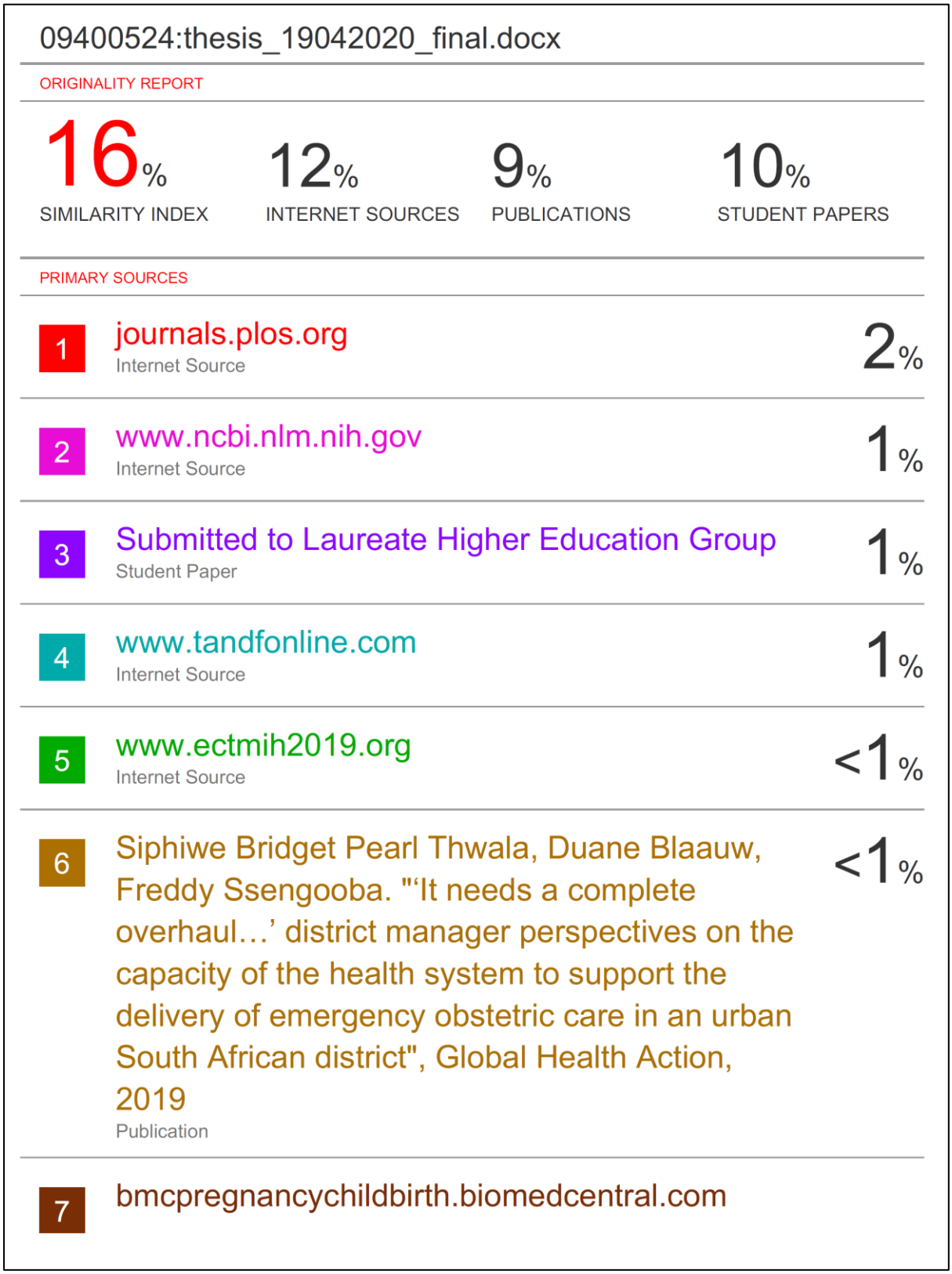
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Appendices

Plagiarism certificate



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Ethics clearance certificate

R14/49 Siphiwe Bridget Pearl Thwala and Dr Freddie P Ssengooba

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M130967

NAME: (Principal Investigator)	Siphiwe Bridget Pearl Thwala and Dr Freddie P Ssengooba
DEPARTMENT:	Public Health Centre for Health Policy Ekurhuleni Distric Hospitals, Gauteng Province
PROJECT TITLE:	Health Systems Factors Influencing the Delivery of Emergency Obstetric Care in a South African District
DATE CONSIDERED:	27/09/2013
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr Duane Blaauw
APPROVED BY:	Professor PE Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	25/10/2013

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 Secretary in Room 10004, 10th floor, Senate House, University.
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 resubmit the application to the Committee. **I agree to submit a yearly progress report**.

Principal Investigator Signature _____ Date _____

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Ekurhuleni District Research Approval

Ekurhuleni
METROPOLITAN MUNICIPALITY

RESEARCH CLEARANCE CERTIFICATE

Research Project Title: Health Systems Factors Influencing the Delivery of Emergency Obstetric Care in a South African District

Research Project Number: 24/02/2015-1

Name of Researcher(s): Siphiwe Bridget B.P. Twala

Division/Institution/Company: PhD student at the University of Witwatersrand and a researcher at the School of Public Health

DECISION TAKEN BY THE EKURHULENI HEALTH DISTRICT RESEARCH COMMITTEE (EHDRC)

- ***THIS DOCUMENT CERTIFIES THAT THE ABOVE RESEARCH PROJECT HAS BEEN APPROVED BY THE EHDRC. THE RESEARCHER(S) MAY THEREFORE COMMENCE WITH ALL OBJECTIVES OF THE RESEARCH.***
- *NOTE THAT THE RESEARCHER WILL BE EXPECTED TO PRESENT THE RESEARCH FINDINGS OF THE PROPOSED RESEARCH PROJECT AT THE ANNUAL EKURHULENI RESEARCH CONFERENCE.*
- *THE ETHICS PANEL WISHES THE RESEARCHER(S) THE BEST OF SUCCESS.*

DR. J. SEPUYA

DEPUTY CHAIRPERSON: EKURHULENI METROPOLITAN MUNICIPALITY
Dated: 25/02/2015

DR. R. Kellerman

CHAIRPERSON: GAUTENG DEPARTMENT OF HEALTH (EKURHULENI REGION)
Dated: 25/02/2015

Signal Functions Tool

EmOC Signal Functions

Health Facility Name	
Facility Code	
Health facility type	

Name of data collector: _____
Date of data collection: _____

Nearest EmOC providing health facility public/ private (circle the correct answer, and write the name of health facility):

EmOC Signal functions tools

Instructions: *To collect data for the signal functions, registers (maternity register, birth register, OT register) must be used as the source of choice. Where data is unclear in the registers or missing, ask health providers resident in the maternity units (nurses and midwives).*

Signal Function 1: Parenteral Antibiotics

No.	Item	Responses		Skip to	source of data
1	Have antibiotics been administered parenterally in the last 3 months?	Yes _____1 No _____0		If "Yes," skip to Item 4	register __1 health worker _0
2	If parenteral antibiotics were NOT administered in the last 3 months, why? *(circle 1 for all spontaneous answers; otherwise circle 0)*	Spontaneously mentioned	Not mentioned		
	a. availability of human resources	1	0		
	b. training issues	1	0		
	c. supplies/equipment/drugs	1	0		
	d. management issues	1	0		
	e. policy issues	1	0		
	f. no indication	1	0		
	g. insufficient funds	1	0		
	h. other *(specify)* _____				

Signal Function 2: Administer Uterotonic Drugs

No.	Item	Responses		Skip to	source of data
4	Have oxytocics been administered parenterally in the last 3 months?	Yes _____1 No _____0		If "No," skip to Item 6	register _____1 health provider _0
5	If parenteral oxytocics were NOT administered in the last 3 months, why? *(circle 1 for all spontaneous answer; otherwise circle 0)*	Spontaneously Mentioned	Not mentioned		
	a. availability of human resources	1	0		
	b. training issues	1	0		
	c. supplies/equipment/drugs	1	0		
	d. management issues	1	0		
	e. policy issues	1	0		
	f. no indication	1	0		
	g. other *(specify)* _____	1	0		
9	Is misoprostol used in this facility for obstetric indications?	Yes_____1 No_____0			

Signal Function 3: Parenteral Anticonvulsants

No.	Item	Responses		Skip to	Source of data
10	Have anticonvulsants been administered parenterally in the last 3 months?	Yes _____1 No _____0		If "No," skip to Item 12	register _____1 health provider __0
11	If parenteral anticonvulsants were administered in the last 3 months, which type of anticonvulsant was used? *(circle one)*	Magnesium sulfate _____1 Diazepam _____2 Other *(specify)* _____3 _____		All responses to this item skip to Item 15	register ____1 health provider ___0
12	If parenteral anticonvulsants were NOT administered in the last 3 months, why? *(circle 1 for all spontaneous answers; otherwise circle 0)* a. availability of human resources b. training issues c. supplies/equipment/drugs d. management issues e. policy issues f. no indication g. other *(specify)* _____	Spontaneously Mentioned 1 1 1 1 1 1 1	Not mentioned 0 0 0 0 0 0 0		

Signal Function 4: Manual Removal of Placenta

No.	Item	Responses		Skip to	source of data
15	Has manual removal of placenta been performed in the last 3 months?	Yes _____1 No _____0		If "Yes," skip to Item 18	register _____1 health provider __0
16	If manual removal of placenta was NOT performed in the last 3 months, why? *(circle 1 for all spontaneous answers; otherwise circle 0)* a. availability of human resources b. training issues c. supplies/equipment/drugs d. management issues e. policy issues f. no indication g. other (specify) _____	Spontaneously Mentioned 1 1 1 1 1 1 1	Not mentioned 0 0 0 0 0 0 0		

Signal Function 5: Removal of Retained Products

No.	Item	Responses		Skip to	Source of data
18	Has removal of retained products been performed in the last 3 months?	Yes ____1 No _____0		If "No," skip to Item 20	register _____1 health worker __0
19	If removal of retained products was performed in last 3 months, which method was used? *(read options)*	Yes	No	All answers to this item skip to Item 23	
	a. Vacuum aspiration	1	0		
	b. Dilatation and curettage (D&C)	1	0		
	c. Dilatation and evacuation (D&E)	1	0		
	d. Misoprostol	1	0		
20	If removal of retained products was NOT performed in the last 3 months, why? *(circle 1 for all spontaneous answers; otherwise circle 0)*	Spontaneously Mentioned	Not mentioned		
	a. availability of human resources	1	0		
	b. training issues	1	0		
	c. supplies/equipment/drugs	1	0		
	d. management issues	1	0		
	e. policy issues	1	0		
	f. no indication	1	0		
	g. other (specify)	1	0		
	_____	1	0		

Signal Function 6: Assisted Vaginal Delivery

No.	Item	Responses	Skip to	Source of data
23	Has assisted vaginal delivery (vacuum or forceps) been performed in the last 3 months?	Yes _____1 No _____0	If "No," skip to Item 25	register _____1 health worker __0
24	If assisted vaginal delivery was performed in last 3 months, what instrument was used? *(circle one)*	Yes _____1 No _____2	All responses to this item skip to Item 28	

No.	Item	Responses		Skip to	Source of data
25	If assisted vaginal delivery (vacuum or forceps) was NOT performed in the last 3 months, why? *(circle 1 for all spontaneous answers; otherwise circle 0)* a. availability of human resources b. training issues c. supplies/equipment/drugs d. management issues e. policy issues f. no indication g. other *(specify)* _____	Spontaneously Mentioned 1 1 1 1 1 1 1	Not mentioned 0 0 0 0 0 0 0		register _____1 health worker ___0

Signal Function 7: Newborn Resuscitation

No.	Item	Responses		Skip to	source of data
28	Has newborn resuscitation with bag and mask been performed in the last 3 months?	Yes _____1 No _____0		If "Yes," skip to Item 31	register __1 health worker ___0
29	If newborn resuscitation with bag and mask was NOT performed in the last 3 months, why? *(circle 1 for all spontaneous answers; otherwise circle 0)* a. availability of human resources b. training issues c. supplies/equipment/drugs d. management issues e. policy issues f. no indication g. *other (specify* _____	Spontaneously Mentioned 1 1 1 1 1 1 1	Not mentioned 0 0 0 0 0 0 0		

Signal Function 8: Obstetric Surgery (Cesarean Delivery)

No.	Item	Responses	Skip to	Source of data
31	Has a cesarean been performed in the last 3 months?	Yes _____1 No _____0	If "Yes," skip to Item 34	register _____1 health worker __0
32	If a cesarean was NOT performed in the last 3 months, why? *(circle 1 for all spontaneous answers; otherwise circle 0)*	Spontaneously Mentioned	Not mentioned	register _____1 health worker __0
	a. availability of human resources	1	0	
	b. training issues	1	0	
	c. supplies/equipment/drugs	1	0	
	d. management issues	1	0	
	e. policy issues	1	0	
	f. no indication	1	0	
	g. other *(specify)*	1	0	
	_____			

Signal Function 9: Blood Transfusion

No.	Responses		Skip to	Source of data
35	Yes .....1 No 0		If "No," skip to Item 37	register _____1 health worker _____0
36	Blood comes from central blood bank .....1 Blood comes from a facility blood bank .....2 Blood is collected from family or friends as needed (i.e., direct transfusion) .....3 Other *(specify)* .....4 _____		All responses to this item skip to Item 40	
37	Spontaneously Mentioned	Not mentioned		
	1	0		
	1	0		
	1	0		
	1	0		
	1	0		
	1	0		
	1	0		
	1	0		
38	Yes .....1 No 0		If "No," skip to Item 36	

Form A1- Hospital Doctors Tool

Availability of Doctors

1. Name of health Facility:	
2. Health facility Code:	
3. Name of data Collector:	
4. Date of data Collection:	

1.

From the medical officer in charge of maternity, ask for information on all the doctors that currently work in the labour ward in this hospital; their employment status; hours that they work per week; as well as whether they have been trained in ESMOE or not.

#	Doctor's code name	Category of doctor					Employment status *(tick)*		Hours worked per week in labour ward		Is the doctor ESMOE trained? *(tick)*	
		Obs./ gynae	Registrar	MO	CMO	Intern	FT	PT	reg. time	over time	Yes	No
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

2.

How has this changed over the last three months? How many doctors were working in the labour ward in mid-April, May, and June? Do not include doctors who were absent in those months for whatever reason.

#	Category of doctors working in labour ward	April		May		June	
		Full Time	Part Time	Full Time	Part Time	Full Time	Part Time
1	Obs./ gynae						
2	Registrar						
3	MO						
4	CMO						

5	Intern						
6	Total						

3.

In the following table, indicate the number of doctors that are generally allocated to each shift in labour ward according to the rotation roster. Ask the doctor in charge of maternity to assist you.

#	Category	Week Days				Week Ends			
		Day Duty		Night Duty		Day Duty		Night Duty	
		On site	On call	On site	On call	On site	On call	On site	On call
1	Obs./ gynae								
2	Registrar								
3	MO								
4	CMO								
5	Intern								
6	Total								

*4. For each day in the last week of June, indicate how many doctors from these shifts **were not at work** for whatever reason?*

Category	Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Obs./ gynae														
Registrar														
MO														
CMO														
Intern														
Total														

3. Ambulances

Please provide us with your honest opinion of what you think of the EMS ambulance services currently in use in your CHC.

No.	Item	Response
1	Obstetric referrals often delay due to ambulance related reasons	☐ Strongly agree ☐ Moderately Agree ☐ Not sure ☐ slightly disagree

		☐ Strongly disagree
2	Obstetric referral delay by 1 hour or more is common	☐ Strongly agree ☐ Moderately Agree ☐ Not sure ☐ slightly disagree ☐ Strongly disagree
3	The current transport system is useful but not reliable when confronted with an obstetric emergency	☐ Strongly agree ☐ Moderately Agree ☐ Not sure ☐ slightly disagree ☐ Strongly disagree

Are there any comments or issues you'd like to bring forward related to the ambulance service? Please write them below

Form A2-PHC Doctors

Availability of Doctors-CHC	
Name of health Facility:	
Health facility Code:	
Name of data Collector:	
Date of data Collection:	

1.

Find out from the doctor if he/ she has been available mid-month in the following months of the year 2014. Note any number days in each month where the doctor was away from the clinic for whatever reason. This includes meetings away from the clinic, trainings, leave, etc.

No.	Item	April	May	June
2	Total number of days that doctor was away *for whatever reason*	☐☐	☐☐	☐☐
3	During this time of absence, was another doctor brought to the CHC to cover whilst the main doctor was away?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
4	If yes, how many days was the temporary doctor able to come?	☐☐	☐☐	☐☐

2.

In the following table indicate the category of doctor in the CHC, hours spent in labour ward (MOU) per week, whether the doctor has been trained in ESMOE or not, as well as the employment status of the doctor in the CHC.

No.	**Item**	**Response**
1	Category of doctor	☐ Intern ☐ CMO ☐ MO ☐ PHC doctor ☐ Obs./gyna ☐ Family doctor ☐ Other (specify)
2	Employment status	☐ Full time ☐ Part time
3	How many hours a week in general do you spend in the labour ward	☐☐
4	Have you been trained in ESMOE	☐ Yes ☐ No

3.

*For each day in the last week of June, indicate if you were at work or on call for each of the following shifts. Please **do not** include times in which you **were not** at work for whatever reason?*

Doctor	Monday			Tuesday			Wednesday			Thursday			Friday			Saturday			Sunday		
	Day	Night	On call	Day	Night	On call	Day	Night	On call	Day	Night	On call	Day	Night	On call	Day	Night	On call	Day	Night	On call
On site *Put Y for yes and N for no*																					
Offsite *Put Y for yes and N for no*																					

4. Ambulances

Please provide us with your honest opinion of what you think of the EMS ambulance services currently in use in your CHC.

No.	**Item**	**Response**
1	Obstetric referrals often delay due to ambulance related reasons	☐ Strongly agree ☐ Moderately Agree

		☐ Not sure ☐ slightly disagree ☐ Strongly disagree
2	Obstetric referral delay by 1 hour or more is common	☐ Strongly agree ☐ Moderately Agree ☐ Not sure ☐ slightly disagree ☐ Strongly disagree
3	The current transport system is useful but not reliable when confronted with an obstetric emergency	☐ Strongly agree ☐ Moderately Agree ☐ Not sure ☐ slightly disagree ☐ Strongly disagree

Are there any comments or issues you'd like to bring forward related to the ambulance service? Please write them below

Form B1-Hospital Nurse Manager Tool

Nurse Manager Tool - Hospital

Name of health Facility:		
Health facility Code:		
Health facility Type:	**Community Health Centre**	
	Hospital	
Name of data collector:		
Date of data collection:		

Professional nurses and midwives

Ask the nurse manager to assist you to complete the following tables.

1.

How many professional nurses and advance midwives are currently employed in the labour ward?

#	Category of nurses working in labour ward	Number of nurses by Employment status			How many of these nurses have been trained in ESMOE?		
		Full Time	Part Time	Agency	Full time	Part time	Agency
1	Number of Professional nurses working in labour ward (excluding advanced midwives)						
2	Number of advanced midwives work in the labour ward						
3	Total						

2.

How has this changed over the last three months? How many professional nurses and advanced midwives were working in the labour ward in mid-April, May, and June 2014.Do not include nurses who were absent for at least a week in those months (such on leave, training, etc.), even if they appear on the roster.

#	Category of nurses working in labour ward	April			May			June		
		FT	PT	Agency	FT	PT	Agency	FT	PT	Agency
1	Number of Professional nurses working in labour ward (excluding advanced midwives)									
2	Number of advanced midwives work in the labour ward									
3	Total									

3.

In the following table, indicate the number of professional nurses and advanced midwives that are generally allocated to each shift in labour ward, by teams for day duty and night duty for

#	Item	Day Duty		Night Duty	
		Team 1	Team 2	Team 1	Team 2
1	Number of professional nurses (excluding advanced midwives)				
2	Number of Advanced midwives				
3	Total				

4.

*For each day in the last week of June, indicate how many professional nurses and advanced midwives from these teams **were not at** work for whatever reason?*

Category	Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night

Professional nurse														
Advanced midwife														
Total														

5.

Health Information

To complete the following table, ask for information from the maternity area nursing manager or equivalent

No.	Item	Response
1	How often are registers checked for completeness by the nursing manager?	☐ Daily ☐ weekly ☐ monthly ☐ less frequently ☐ Never _____ ☐ Other (details) _____
2	How often did you have morbidity and mortality meetings on maternal health between January and December 2013? *(ask to see the meeting minutes to confirm frequency)*	☐ monthly ☐ quarterly ☐ bi-annually ☐ annually ☐ Never ☐ other (details) _____
3	How many complaints from patients of maternity care did this hospital have in the year 2014?	
4	What was the score/ rating for maternity care on patient satisfaction surveys in the year 2013?	☐ Good/ exceptional ☐ fair/ moderate ☐ poor ☐ no specific evaluation measure for maternal health services ☐ surveys were not done in 2013 ☐ other (details) _____

6.

Management of maternity/ EmOC services:

Ask the maternity area manager or equivalent for information in order to complete the following table

No.	Item	Response
1	Does the hospital/ health facility have a permanently appointed labour ward manager?	☐ Permanatly appointed ☐ Acting ☐ No labour ward manager
2	Does the hospital/ health facility have a permanently appointed maternity area manager?	☐ Permanatly appointed Acting

		☐ No maternity area manager
3	Are there EmOC guidelines/ standard operating procedures (SOP's) in the lour ward? *(specify if they are national guidelines or not)*	☐ Yes ☐ No *(if no, skip to question 5)*
4	If yes, state if they are national guidelines (DoH) or not.	☐ National guidelines ☐ Provincial guidelines ☐ Facility created guidelines
5	Where are the management guidelines/ protocols located in the labour ward?	☐ Displayed on the walls of the ward ☐ Located in a file in the labour ward shelves ☐ Located in a drawer in labour ward ☐ Located in the nurse manager's office ☐ Not available ☐ Other *(specify)* _____
6	Is there a written ESMOE training plan in this facility? *(ask to see copy)*	☐ Yes ☐ No ☐ Other (specify) _____
7	Are there EmOC referral guidelines in place in this health facility? *(ask to see it and note their location)*	☐ Yes ☐ No ☐ Existent but copy unavailable
8	Is there a written down EmOC referral criteria in this health facility?	☐ Yes ☐ No
9	Are EmOC referral routes displayed in the maternity section of this health facility?	☐ Yes ☐ No ☐ They are well known, therefore no need to display them
10	Is there an EmOC referral logbook in this health facility *(make sure you see it if yes)*	☐ Yes ☐ No
11	Do the referral guidelines specify that the host health facility should be alerted that an EmOC referral is enroute?	☐ Yes ☐ No
12	Do the referral guidelines indicate whether the EmOC patient should be referred with her file or a referral card with details on condition and history?	☐ Yes ☐ No

7.

In the following table, tick the most appropriate response

No.	Item	Always	Most of the time	Sometimes	Rarely	Never
1	Do incoming referrals come with a referral note from referring facility?					
2	Do outgoing EmOC referrals carry a referral note or patient file when being referred to another health facility					

8.

Partograph:

Instructions: *From the maternity area manager or equivalent person in charge of maternity, ask the questions in the table below. Review the partograph with reference to the patient notes afterwards*

No.	Item	Responses		Skip to
1	Do you use a partograph in this facility?	Yes..... 1 No..... 0		If "Yes," skip to Item 3
2	Why do you not use the partograph in this facility?	Mentioned spontaneously	Not mentioned	
	a. Staff are not trained	1	0	
	b. No supplies (no blank partographs)	1	0	
	c. Staff do not have time	1	0	
	d. Use of the partograph is not mandatory/not policy	1	0	
	e. Other *(specify)* _____	1	0	
3	Are you using the department of Health partograph in this facility? _____	Yes 1	No 0	If yes skip to question 5
4	Specify the type of partograph you're using if it's not the one given by the department of health	_____ _____		
5	Is there a labor management protocol for a woman using a partograph? *(ask and then confirm by observation of poster/chart on the wall)*	Yes..... 1 No..... 0		

Form-B2 CHC Nurse Manager Tool

Nurse Manager Tool - CHC

Name of health Facility:

Health facility Code:

Name of data collector:

Date of data collection:

Professional nurses and midwives

Ask the nurse manager to assist you to complete the following tables.

2.

How many professional nurses and advance midwives are currently employed in the labour ward?

#	Category of nurses working in labour ward	Number of nurses by Employment status			How many of these nurses have been trained in ESMOE?		
		Full Time	Part Time	Agency	Full time	Part time	Agency
1	Number of Professional nurses working in labour ward (excluding advanced midwives)						
2	Number of advanced midwives work in the labour ward						
3	Total						

2.

How has this changed over the last three months? How many professional nurses and advanced midwives were working in the labour ward in mid-April, May, and June 2014.Do not include nurses who were absent for at least a week in those months (such on leave, training, etc.), even if they appear on the roster.

#	Category of nurses working in labour ward	April			May			June		
		FT	PT	Agency	FT	PT	Agency	FT	PT	Agency
1	Number of Professional nurses working in labour ward (excluding advanced midwives)									
2	Number of advanced midwives work in the labour ward									
3	Total									

3.

In the following table, indicate the number of professional nurses and advanced midwives that are generally allocated to each shift in labour ward, by teams for day duty and night duty for

#	Item	Day Duty		Night Duty	
		Team 1	Team 2	Team 1	Team 2
1	Number of professional nurses (excluding advanced midwives)				
2	Number of Advanced midwives				
3	Total				

4.

For each day in the last week of June, indicate how many professional nurses and advanced midwives from these teams ***were not at*** *work for whatever reason?*

Category	Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Professional nurse														

Advanced midwife														
Total														

5.

Health Information

To complete the following table, ask for information from the maternity area nursing manager or equivalent

No.	Item	Response
1	How often are registers checked for completeness by the nursing manager?	☐ Daily ☐ weekly ☐ monthly ☐ less frequently ☐ Never _____ ☐ Other (details) _____
2	How often did you have morbidity and mortality meetings on maternal health between January and December 2013? *(ask to see the meeting minutes to confirm frequency)*	☐ monthly ☐ quarterly ☐ bi-annually ☐ annually ☐ Never ☐ other (details) _____
3	How many complaints from patients of maternity care did this hospital have in the year 2013?	
4	What was the score/ rating for maternity care on patient satisfaction surveys in the year 2013?	☐ Good/ exceptional ☐ Fair/ moderate ☐ Poor ☐ No specific evaluation measure for maternal health services ☐ Surveys were not done in 2013 ☐ Other (details) _____

6.

Management of maternity/ EmOC services:

Ask the maternity area manager or equivalent for information in order to complete the following table

No.	Item	Response
1	Does the MOU have a permanently appointed operational manager?	☐ Permanatly appointed ☐ Acting ☐ No labour operational manager
2	Does the MOU have a permanently appointed maternity area manager?	☐ Permanatly appointed Acting ☐ No maternity area manager

3	Are there EmOC guidelines/ standard operating procedures (SOP's) in the lour ward? *(specify if they are national guidelines or not)*	☐ Yes ☐ No *(if no, skip to question 5)*
4	If yes, state if they are national guidelines (DoH) or not.	☐ National guidelines ☐ Provincial guidelines ☐ Facility created guidelines
5	Where are the management guidelines/ protocols located in the labour ward?	☐ Displayed on the walls of the ward ☐ Located in a file in the labour ward shelves ☐ Located in a drawer in labour ward ☐ Located in the nurse manager's office ☐ Not available ☐ Other *(specify)* _____
6	Is there a written ESMOE training plan in this facility? *(ask to see copy)*	☐ Yes ☐ No ☐ Other (specify) _____
7	Are there EmOC referral guidelines in place in this health facility? *(ask to see it and note their location)*	☐ Yes ☐ No ☐ Existent but copy unavailable
8	Is there a written down EmOC referral criteria in this health facility?	☐ Yes ☐ No
9	Are EmOC referral routes displayed in the maternity section of this health facility?	☐ Yes ☐ No ☐ They are well known, therefore no need to display them
10	Is there an EmOC referral logbook in this health facility *(make sure you see it if yes)*	☐ Yes ☐ No
11	Do the referral guidelines specify that the host health facility should be alerted that an EmOC referral in enroute?	☐ Yes ☐ No
12	Do the referral guidelines indicate whether the EmOC patient should be referred with her file or a referral card with details on condition and history?	☐ Yes ☐ No

7.

In the following table, tick the most appropriate response

No.	Item	Always	Most of the time	Sometimes	Rarely	Never
1	Do incoming referrals come with a referral note from referring facility?					
2	Do outgoing EmOC referrals carry a referral note or patient					

	file when being referred to another health facility					

8.

Partograph:

Instructions: *From the maternity area manager or equivalent person in charge of maternity, ask the questions in the table below. Review the partograph with reference to the patient notes afterwards*

No.	Item	Responses		Skip to
1	Do you use a partograph in this facility?	Yes..... 1 No..... 0		If "Yes," skip to Item 3
2	Why do you not use the partograph in this facility?	Mentioned spontaneously	Not mentioned	
	f. Staff are not trained	1	0	
	g. No supplies (no blank partographs)	1	0	
	h. Staff do not have time	1	0	
	i. Use of the partograph is not mandatory/not policy	1	0	
	j. Other *(specify)* _____	1	0	
3	Are you using the department of Health partograph in this facility? _____	Yes 1	No 0	If yes skip to question 5
4	Specify the type of partograph you're using if it's not the one given by the department of health	_____ _____		
5	Is there a labor management protocol for a woman using a partograph? *(ask and then confirm by observation of poster/chart on the wall)*	Yes..... 1 No..... 0		

Form G

Drugs, fluids, Resuscitation equipment

Name of health Facility:

Health facility Code:

Name of data collector:

Date of data collection:

Drugs checklist

In this section, go to the drug storage section of maternity.

#	Drug	Is the drug available on the day of data collection?
1	Magnesium sulphate	Yes ☐ No ☐ Expired ☐
2	Rivotril or equivalent (e.g. diazepam)	Yes ☐ No ☐ Expired ☐
3	Oxytocin	Yes ☐ No ☐ Expired ☐
4	Syntometrine	Yes ☐ No ☐ Expired ☐
5	Ergometrine	Yes ☐ No ☐ Expired ☐
6	Misoprostol	Yes ☐ No ☐ Expired ☐
7	Injectable Insulin	Yes ☐ No ☐ Expired ☐
8	Glucose 50%	Yes ☐ No ☐ Expired ☐
9	Essential parenteral antibiotics	Yes ☐ No ☐ Expired ☐

B1 -Near miss registers

Maternal health and the health System in South Africa and Rwanda (MHSAR)- Form B1

1. **Name of health**

2. **Facility Code:**

3. **Health facility Type *(tick)*:**

Level II	
Level III	

4. **Contact Person**
   In the health Facility

Tel:	**Contact person:**

#	Patient name	Reference/ hospital Number	Date of admission	Parity	Age (yrs)	Del. mode	Outcome of the woman	Notes on location status *(write the date as well)*	Maternal Health study group		Study group #
									Category	Mat. study #	
			___/___/____			☐ NVD ☐ Ass. del ☐ c/secn ☐ N/A	☐ Alive ☐ Dead	_____ _____	☐ Case ☐ Control A ☐ Control B		
			___/___/____			☐ NVD ☐ Ass. del ☐ c/secn ☐ N/A	☐ Alive ☐ Dead	_____ _____	☐ Case ☐ Control A ☐ Control B		
			___/___/____			☐ NVD ☐ Assisted del ☐ c/secn ☐ N/A	☐ Alive ☐ Dead	_____ _____	☐ Case ☐ Control A ☐ Control B		
			___/___/____			☐ NVD ☐ Assisted del ☐ c/secn ☐ N/A	☐ Alive ☐ Dead	_____ _____	☐ Case ☐ Control A ☐ Control B		
			___/___/____			☐ NVD ☐ Assisted del ☐ c/secn ☐ N/A	☐ Alive ☐ Dead	_____ _____	☐ Case ☐ Control A ☐ Control B		
			___/___/____			☐ NVD ☐ Assisted del ☐ c/secn ☐ N/A	☐ Alive ☐ Dead	_____ _____	☐ Case ☐ Control A ☐ Control B		
			___/___/____			☐ NVD ☐ Assisted del ☐ c/secn ☐ N/A	☐ Alive ☐ Dead	_____ _____	☐ Case ☐ Control A ☐ Control B		

Form B2-Data clerk register

Maternal health and the health System in South Africa and Rwanda (MHSAR)

1. **Name of health**

2. **Facility Code:**

3. **Health facility Type** ***(tick)*****:**

Community Health Centre	
Hospital	

4. **Contact Person In the health Facility**

Tel:	**Fax:**	**Contact person:**

#	Patient name	Reference/ hospital Number	Date of admission	Outcome of the woman	Location status (state date and area of location)	Date *(if referred or discharged)*	Mat study #
			___/___/____	☐ Alive ☐ Dead	_____ _____ _____	___/___/____	
			___/___/____	☐ Alive ☐ Dead	_____ _____ _____	___/___/____	
			___/___/____	☐ Alive ☐ Dead	_____ _____ _____	___/___/____	
			___/___/____	☐ Alive ☐ Dead	_____ _____ _____	___/___/____	

Form C-Patient file form (Near miss study)

Obstetric History Tool

Name of health facility:

Facility Code:

Use the ANC section of the patient notes to complete the tables on questions 1 and 2;

I.

Patient Name:	**Registration/Hosp. number:**

II. ANC

☐ Un-booked ☐ No ANC record ☐ Booked	**If you tick anyone these please skip to question II below**

If woman booked and ANC card available, complete the table below;

Locality of ANC booking	☐ Clinic ☐ CHC ☐ Dist. Hosp. ☐ Reg. Hosp. ☐ Tert. Hosp. ☐ Private ☐ Other ☐ no information
Name of ANC health facility	☐ No info
Gestational age at 1st booking	☐ < 20 weeks ☐ >= 20 weeks ☐☐ weeks ☐ No info/unknown
Total number of ANC visits	☐☐ ☐ No information/ unknown
ANC risk factors	☐ None known ☐ HTN ☐ Proteinuria ☐ Glycosuria ☐ Anaemia Hb<10gms/dl ☐ Abnormal lie ☐ Prev.c/s ☐ mult. Preg. ☐ Past Med. Hx. ☐ Other *(specify)* _____
Prev. c/s	☐ Yes ☐ No ☐ If yes state, # times; e.g. x2
Prolonged/ obstructed Labour	☐ Yes ☐ No ☐ Unknown
Syphilis (RPR)	☐ Pos. ☐ Neg. ☐ Unknown/ no info

HIV status

HIV infection	☐ Unknown ☐ Test declined ☐ Negative ☐ Positive

*If HIV status unknown or negative, skip to **question III;***

PMTCT	☐ Yes ☐ No ☐ Unknown/ unclear
CD4 count	☐ No info ☐ CD4 count

ARV regimen

ARV regimen (answer only if known)	☐ No info ☐ None ☐ FDC ☐ Dual therapy ☐ Other HAART *(specify)* 1st drug;_____ 2nd drug; _____ 3rd drug; _____ ☐ no info

III. Demographic Characteristics

#	Item	Response *(Tick appropriate response)*
1	Date (day/month/year) and time of admission (24hr)	Date: ____/____/_____ ☐☐☐☐ Time (24hrs) ☐ no info
2	On admission?	☐ Aborting ☐ Ectopic ☐ ANC ☐ In labour ☐ Postpartum
3	Reason for admission	_____
4	Condition on admission	☐ Stable ☐ Critically ill ☐ Other *(specify)* _____
5	Age	☐☐ ☐ No information
6	Marital Status	☐ Single ☐ Married ☐ Divorced ☐ Widowed ☐ No info ☐ Stable relationship

IV. Referral details

#	Item	Response
	Referred from another health facility	☐ Yes If yes, write name of facility referred from _____ ☐ No Reason for referral: _____
1	Referred to another health facility	☐ Yes If yes, write name of facility referred to _____ ☐ No Reason for referral: _____

I. Current pregnancy:

Abortion; If not an abortion skip to Ib;

Ia. Abortion

If abortions, state whether; *(tick)*	☐ Spontaneous ☐ Induced ☐ Septic ☐ No information/ unknown
Gestational age (weeks): ☐☐	LMNP: ____/_____/_____ Parity ☐☐ Gravida ☐☐
Date of uterine evacuation	Date: ____/_____/_____ ☐☐☐☐ Time
Uterotonic used to prevent PPH	☐ Oxytocin ☐ Syntometrine ☐ Other uterotonic *(specify)* _____
Antibiotics	Prophylactic antibiotics during c/s: ☐ Yes ☐ No ☐ N/A

If not an ectopic pregnancy skip to Ic

Ib. Ectopic pregnancy

Was this an ectopic pregnancy?	☐ Yes ☐ No
Gestational age (weeks): ☐☐	LMNP: ____/_____/_____ Parity ☐☐ Gravida ☐☐
Date (day/month/year) and time of termination	Date: ____/_____/_____ ☐☐☐☐ Time

Ic. Term and premature delivery

#	Item	Response	
1	Pregnancy summary	☐☐ Gravida ☐ No info. ☐☐ Parity ☐ No info. LMNP: _____/_____/_____ ☐ No info EDD: _____/_____/_____ ☐ No info	
2	Is the woman still pregnant or has she delivered?	☐ Still pregnant ☐☐ If pregnanant Gestational age (weeks). If delivered gest age in weeks ☐ No info ☐ Delivered	*If still pregnant, **skip to section VII** below*
3	Did labour occur?	☐ Yes ☐ No ☐ Unclear ☐ Induced ☐ Spontaneous onset	
4	Mode of delivery/ termination of pregnancy	☐ NVD ☐ Vacuum/ forceps ☐ Caesarean section	
5	Indication for c/s or assisted birth	☐ N/A Specify: _____	
6	Date (day/month/year) and time of delivery/ uterine evacuation	Date: ____/_____/_____ ☐☐☐☐ Time ☐ No info	
7	Uterotonic used to prevent PPH	☐ Oxytocin ☐ Syntometrine ☐ Other uterotonic *(specify)* _____ ☐ No info	
8	Did the woman have a postpartum haemorrhage?	☐ Yes ☐ No ☐ No info	
10	Treatment of postpartum haemorrhage	☐ N/A ☐ Oxytocin ☐ Ergometrine ☐ Misoprostol ☐ Other uterotonics *(specify)* ____ _____ ☐ Tranexamic acid ☐ Removal of retained products ☐ Balloon or condom tamponade ☐ Artery ligation (uterine/epigastric ☐ Hysterectomy ☐ Abdominal packing) ☐ No info	
11	Did the woman have PIH	☐ Yes ☐ No ☐ No info	
12	Treatment of PIH (anticonvulsant)	☐ N/A ☐ None ☐ Magnesium sulphate ☐ Other anti-convalescent *(specify)* _____	
13	Antibiotics	Prophylactic antibiotics during c/s: ☐ Yes ☐ No ☐ No info	
14	Foetal lung maturation	☐ Yes ☐ No	

Partogram use

#	Item		Response	
1	Was the partogram started?		☐ Yes ☐ No	***If no, skip to question 12 below***
2	Where was the partogram started?	For dilatation <4cm at which the partogram was started, was the partogram started **on the y-axis**?	☐ Yes ☐ No	
		For dilatation >=4cm, at which the partogram was started, was the partogram started on the **alert line?**	☐ Yes ☐ No	
3	Cervical dilation recorded 2 hourly		☐ Yes ☐ Recorded but not 2 hourly ☐ No	
4	Membranes recorded 2 hourly?		☐ Yes ☐ Recorded but not 2 hourly ☐ No	
5	Uterine recorded contractions hourly?		☐ Yes ☐ Recorded but not hourly ☐ No	
6	Descent recorded hourly?		☐ Yes ☐ Recorded but not hourly ☐ No	
7	Blood pressure recorded hourly?		☐ Yes ☐ Recorded but not hourly ☐ No	
8	Pulse recorded hourly?		☐ Yes ☐ Recorded but not hourly ☐ No	
9	Foetal heart recorded half hourly?		☐ Yes ☐ Recorded but not 1/2 hourly ☐ No	
10	Temperature recorded 4 hourly?		☐ Yes ☐ Recorded but not 4 hourly ☐ No	
11	Partogram place of delivery in relation to alert and action lines?		☐ Before or on alert line/between alert and action lines/on action line ☐ After alert line	
12	Outcome of the new-born?		☐ Live normal new-born (good Apgar >7) ☐ Live baby but with distress (Apgar<=7) ☐ Still birth (Apgar 0)	

VIII. Condition of the woman

Answer the following if the patient (mother Is alive. ***If dead, skip to VIIIb***

VIIIa.

What was the diagnosis of the near-miss or complication condition? (e.g. PPH,APH, etc.)	_____ ☐ Unknown/ unclear ☐ N/A
Underlying or precipitating condition (specify)	_____ ☐ Unknown/ unclear ☐ N/A

VIIIb.

Cause use of death (if cause of death known)	_____ ☐ **Unknown / unclear**
Underlying obstetric or medical condition	**Obstetric condition:**_____ ☐ **Unknown/unclear** ☐ **N/A** **Medical condition:** _____ ☐ **Unknown/unclear** ☐ **N/A**
Date and time of death	☐ N/A Date: ____/____/_____ ☐☐☐☐ Time (24hrs)
Diagnosis at moment of death (tick)	☐ N/A ☐ Abortion ☐ Ectopic pregnancy ☐ Not in labour ☐ In labour ☐ Postpartum

IX. Other critical interventions

Evacuation	☐ Y ☐ N
Laparotomy	☐ Y ☐ N
Symphysiotomy	☐ Y ☐ N
Manual removal of the placenta	☐ Y ☐ N
Anaesthesia	☐ GA ☐ Local ☐ No info ☐ No
ICU ventilation	☐ Y ☐ N
Cardiopulmonary resuscitation	☐ Y ☐ N
Blood transfusion	☐ Y ☐ N If yes, state # units: RPC ☐☐ Platelets ☐☐ FFP's ☐☐

X. Outcome of the pregnancy/ baby/infant

Status of infant at birth	☐ Alive ☐ FSB ☐ MSB
Apgar score	☐ No info ☐ N/A ☐ 1 minute ☐ 5 minutes
Did the baby require resuscitation?	☐ No info ☐ Yes ☐ No
Type of resuscitation	☐ N/A ☐ No info ☐ Tactile ☐ O2 ☐ Drugs ☐ Suction ☐ bag & mask
Birth weight	☐ Term baby ☐ Pre-term baby ☐☐☐☐ Grams ☐ No info

xi.

Near miss criteria:

To complete the following table, use the patient notes. Where unclear, seek clarity from the nursing manager in charge of labour ward or equivalent or medical officer.

#	Category	Organ dysfunction /life threatening condition that the patient has	Tick
1	**Cardiovascular dysfunction**	Hypovolemic Shock	☐ Y ☐ N
2			
3		Continuous use of vasoactive drugs	☐ Y ☐ N
4		Cardiac arrest	☐ Y ☐ N
5		Cardio-pulmonary resuscitation	☐ Y ☐ N
6		Severe hypo-perfusion (lactate >5mmol or >45mg/dl) or severe acidosis	☐ Y ☐ N
7		Pulmonary oedema	☐ Y ☐ N
8		Clinical diagnosis necessitating intravenous furosemide or intubation	☐ Y ☐ N
9	**Respiratory dysfunction**	Acute cyanosis	☐ Y ☐ N
10		Gasping	☐ Y ☐ N
11		Severe tachynpnoea (respiratory rate >40 bpm)	☐ Y ☐ N
12		Severe bradypnoea (respiratory rate <6 bpm)	☐ Y ☐ N
13		Severe hypoxemia (PAO2/FiO2 <200 saturation <90% for 60 mins) or intubation and ventilation not related to anaesthesia	☐ Y ☐ N
14	**Renal dysfunction**	Oliguria non-responsive to fluids or diuretics	☐ Y ☐ N
15		Oliguria (defined as <400 mU 24hrs, which does not respond to either careful adequate intravascular rehydration or attempts at inducing diuresis with furosemide or dopamine	☐ Y ☐ N
16		Dialysis for acute renal failure or severe or acute thrombocytopaenia (<50, 000 platelets/ml)	☐ Y ☐ N
17	**Liver/ hepatic dysfunction** (Pre-eclampsia defined as BP >=140/90 together with>1+ proteinuria	Jaundice in the presence of pre-eclampsia	☐ Y ☐ N
18		Severe acute hyperbilirubinemia (bilirubin >100umol/L or 6.0mg/dl	☐ Y ☐ N
19		Diabetic keto-acidosis. Thyroid crisis	☐ Y ☐ N
20		Acute thrombocytopenia requiring transfusion	☐ Y ☐ N
21	**Neurologic dysfunction** [subarachnoid or Intracerebral haemorrhage]	Prolonged unconsciousness/ coma (lasting 12 hours)	☐ Y ☐ N
22		Stroke	☐ Y ☐ N
23		Status epilepticus/ uncontrollable fits	☐ Y ☐ N

24		Total paralysis	☐ Y ☐ N
25	**Other Categories (management and disease)**	Eclampsia	☐ Y ☐ N
26		Severe sepsis	☐ Y ☐ N
27		Uterine rupture	☐ Y ☐ N
		Blood transfusion	☐ Y ☐ N
28		Maternal admission into ICU Indication for admission into critical care : _____	☐ Y ☐ N
29		Hysterectomy following infection/ haemorrhage	☐ Y ☐ N

xii. Is this a near-miss? ☐ **Yes** ☐ **No**

(NB: If you have answered yes to any of the questions in the tale above then this is a near-miss)

Complete the following table to classify this case patient and allocate a study number

Classification	**Tick If yes)**	**Near-miss #/ control #/ maternal health study #**	**Mat heath group #**
Near Miss		☐☐☐☐☐☐	☐☐☐☐☐☐
Control A		☐☐☐☐☐☐	☐☐☐☐☐☐
Control B		☐☐☐☐☐☐	☐☐☐☐☐☐
Maternal Death		☐☐☐☐☐☐	☐☐☐☐☐☐

State the events that occurred around the birth experience/ complication/ near-miss/ death experience

State the events that occurred around the complication/ near-miss/ death experience / birth experience **(continued)**

Form D-health system context

Health Systems Context Tool- Near miss study

Name of health facility	
Facility Code:	

Kindly answer the following questions as best you can regarding the health facility environment context in which the woman was cared for. Please note that this information is to help understand the context in which the woman are cared for.

I.

Patient Name:	Registration/Hosp. number:
Maternal health study #:	Group study #

II. Health systems context *(tick as many as apply):*

Ask this information from the nursing sister in charge of the relevant ward (labour or postnatal).

#	Question	Response	Comments
1	How many midwives/ nurse-midwives were on duty when the condition of the patient complicated or when the patient was admitted?	☐☐ ☐ Unknown/ no info	
2	How many doctors were on duty *(on site)* for obs. and gynae at the time that the event occurred? *(write the number)*	☐☐ ☐ Unknown/ no info	
3	No open/ available theatre when the patient / woman required one?	☐ Y ☐ N ☐ No info	
4	Not all required OT staff available to attend the patient when the need arose?	☐ Y ☐ N ☐ No info /unclear ☐ OT staff present but busy	
5	Laboratory not giving back results on time, blood specimens not found, reagents not available, etc.	☐ Y ☐ N ☐ No info /unclear	
6	No bed available immediately for the patient at the time that she needed it?	☐ Y ☐ N ☐ No info	

#	Question	Response	Comments
7	Required drugs NOT readily available at the time that they were needed? *If no, details*	☐ Y ☐ N ☐ No info	Name(s) of unavailable drug(s): _____
8	Required blood/ blood products not available at the time that they were needed?	☐ Y ☐ N ☐ No info	If yes, type of unavailable blood product; ☐ RPC/ whole blood ☐ FFP's Platelets
9	Required equipment not readily available at the time that it was needed	☐ Y ☐ N ☐ No info	Name of unavailable required equipment:_____
10	If patient was in a critical care unit (high care/ICU), what was the ratio of nurses/ midwives to patients? *(Write ratio of midwives to patients in the unit)*	High ca☐ ☐ Y N …….Midwives:…….Patients	
		ICU☐ Y ☐ N _____Nurses: _____Patients	
11	Ambulance did not come within a reasonable time frame to collect this patient if called	☐ Y ☐ N ☐ No info	
12	Ambulance not adequately equipped with functional equipment to transport the woman?	☐ Y ☐ N ☐ No info	

#	Question	Response	Comments
.	Health care provider context		
13	Birth attendant not ESMOE trained?	☐ Y ☐ N ☐ No info	
14	Is there anything you thought was important about the health provider who looked after this woman that you think may have helped the woman or made her condition worse? *Please state it*	☐ Y ☐ N	

Form E-Assessor Form

Health Systems Context Tool

Name of health facility:

Facility Code:

Kindly answer the following questions as best you can regarding the health facility environment context in which the woman was cared for. Please note that this information is to help understand the context in which the woman are cared for.

II.

Patient Name:	**Registration/Hosp. number:**
Maternal health study #:	**Group study #**

III. Health systems context *(tick as many as apply):*

Ask this information from the nursing sister in charge of the relevant ward (labour or postnatal).

#	Question	Response	Comments
1	How many midwives/ nurse-midwives were on duty when the condition of the patient complicated or when the patient was admitted?	☐☐ ☐ Unknown/ no info	
2	How many doctors were on duty *(on site)* for obs. and gynae at the time that the event occurred? *(write the number)*	☐☐ ☐ Unknown/ no info	
3	No open/ available theatre when the patient / woman required one?	☐ Y ☐ N ☐ No info	
4	Not all required OT staff available to attend the patient when the need arose?	☐ Y ☐ N ☐ No info /unclear ☐ OT staff present but busy	
5	Laboratory not giving back results on time, blood specimens not found, reagents not available, etc.	☐ Y ☐ N ☐ No info /unclear	
6	No bed available immediately for the patient at the time that she needed it?	☐ Y ☐ N	
		☐	

#	Question	Response	Comments
		☐ No info	
7	Required drugs NOT readily available at the time that they were needed? *If no, details*	☐ Y ☐ N ☐ No info	Name(s) of unavailable drug(s): _____
8	Required blood/ blood products not available at the time that they were needed?	☐ Y ☐ N ☐ No info	**If yes, type of unavailable blood product;** ☐ RPC/ whole blood ☐ FFP's ☐ Platelets
9	Required equipment not readily available at the time that it was needed	☐ Y ☐ N ☐ No info	Name of unavailable required equipment:_____
10	If patient was in a critical care unit (high care/ICU), what was the ratio of nurses/ midwives to patients? *(Write ratio of midwives to patients in the unit)*	High ca☐ ☐ Y N …….Midwives:…….Patients	
		ICU☐ Y ☐ N _____Nurses: _____Patients	
11	Ambulance did not come within a reasonable time frame to collect this patient if called	☐ Y ☐ N ☐ No info	
12	Ambulance not adequately equipped with functional	☐ Y ☐ N ☐	

#	Question	Response	Comments
	equipment to transport the woman?	No info	
.	**Health care provider context**		
13	Birth attendant not ESMOE trained?	☐ Y ☐ N ☐ No info	
14	Is there anything you thought was important about the health provider who looked after this woman that you think may have helped the woman or made her condition worse? *Please state it*	☐ Y ☐ N	

Form K-Number of births tool

Number of births

Health facility name:	**GPS coordinates:**

In the following table, write down the total number of births for the months of January to December for the years 2015 and 2016 respectively.

Month	**2015**	**2016**
Jan		
Feb		
Mar		
April		
May		
June		
July		
Aug		
Sep		
Oct		
Nov		
Dec		
Jan		
Feb		
Mar		
April		
May		
June		
July		
Aug		
Sep		
Oct		
Nov		
Dec		

Interview Guide

“Please tell me about your experiences as a manager that oversees EmOC in the district. What are some of the challenges you experience?”

Information Sheet for Consent

Information Sheet For health providers (doctors, nurses, midwives)

Dear Participant

Re: Invitation to participate in a research study

My name is Siphiwe Thwala. I am a PhD student at the University of Witwatersrand and am doing a study in fulfilment of my doctoral studies. I am also part of a team of researchers from the Centre for Health Policy (CHP) at the University of Witwatersrand in Johannesburg who are doing a study in partnership with the Gauteng Province.

I am inviting you to be part of this study to assess the health system in the delivery of emergency obstetric care in the Ekurhuleni district. You have been selected to participate because you are one of the health care providers that give emergency obstetric care and therefore have experience with the health system. The title of the study is;

Health Systems Factors Influencing the Delivery of Emergency Obstetric Care in a South African District

Your participation in this study is completely voluntary. There will be no negative consequences if you do not want to participate and you can withdraw your participation at any time. There will also be no direct benefit to you if you participate in this study however.

All the information collected from you will be anonymous and we will not be able to identify individuals by name. I will endeavour to keep all information confidential. Organisations such as the Research Ethics Committee may inspect our research records for quality assurance purposes.

Ethical approval for this study has been obtained from the University of the Witwatersrand Ethics Committee for Research on Human Subjects.

If you have any further questions, or any complaints about the way that the study is being implemented you can contact myself and my supervisor and principal investigator of the project. His details are listed below.

Dr Duane Blaauw (Principal investigator)	Ms Siphiwe Thwala (researcher)
Centre for Health Policy	Centre for Health Policy
School of Public Health	School of Public Health
University of the Witwatersrand	University of Witwatersrand
Tel: (011) 717-3422	Tel: (011) 717 2226

Email: duane.blaauw@wits.ac.za Email: Siphiwe.thwala2@wits.ac.za

You can also contact the Wits University Human Research Ethics Committee which is responsible for overseeing the ethical aspects of this study through Ms Anisa Keshav on (011) 717-1234.

Thank you for taking your time to read and consider this.

Yours sincerely

Siphiwe Thwala

Consent Form signature

STATEMENT OF CONSENT

I have been given an information sheet and I understand the objectives of the study. I further understand that my responses will be kept confidential and that it is up to me whether or not to complete this questionnaire. It has been explained to me that even if I choose not to complete this questionnaire, I should still return it to the researchers and indicate so in the space below. My refusal to participate will in no way prejudice me**.**

I agree voluntarily to complete the questionnaire **(please tick). Yes [ ] No [ ]**

Signature/Initial:..... Date:.....

Consent Form- Recording of interview

Consent form for recording during In-depth Interviews on Health system factors

I hereby declare that I have been given and read the information sheet on the study titled;

Health Systems Factors Influencing the Delivery of Emergency Obstetric Care in a South African District

I confirm that the researcher has explained to me in clear language and that I have read and understood the following from the information sheet;

- The study is about assessment of the health system in the delivery of emergency obstetric care in Ekurhuleni.
- I understand that the researcher will make every effort to ensure confidentiality, and that my name will not be used in the study, and that comments or views that I make will not be reported back to anybody at the hospital
- My participation will not affect my work or professional relationships in my workplace in any way and that I can withdraw my participation at any time or refuse to answer questions I am uncomfortable with, without incurring any negative consequences of any kind.
- Participation requires me to participate in an audio-recorded interview
- My participation in this study will not benefit to me personally

Please be aware that all recordings of this interview will be destroyed six years after publication of the results of the study. Where publication has not occurred, recordings will be destroyed 10 years after conclusion of the study.

I hereby agree to being recorded during this interview:

Participant's signature: _____ Date: _____ Place: _____

Researcher: _____ Date: _____ Place: _____