THE ACCURACY OF VISUAL ESTIMATION OF BLOOD LOSS ON SWABS BY OPERATING THEATRE STAFF AT TWO ACADEMIC HOSPITALS

Dr. Henko van den Bergh

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DECLARATION

I, Henko van den Bergh declare that this research is my own work. It is being submitted for the degree of Master of Medicine in the branch of Anaesthesiology in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

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ABSTRACT

Visual estimation of intra-operative blood loss is commonly used, however it is known to be inaccurate with both over and under estimation being reported. The aim of this study was therefore to assess accuracy of visual estimation of blood loss on commonly used swabs by operating theatre staff at two academic hospitals in Johannesburg.

A prospective, descriptive, single blinded, contextual research design with convenience sampling was used. Twelve swabs (4 vascular swabs, 4 small abdominal swabs and 4 large abdominal swabs) with known volumes of reconstituted red pack cells were displayed for estimations.

Hundred and forty six participants made 1739 of a possible 1752 estimations. Of these estimations 316 (18%) were accurate within 10% of the actual blood volume. There were significant differences between different size swabs with different volumes (p=0.0001), large swabs with similar volumes (p=0.0001) and two different size swabs and same volumes (p=0.0001). No significant difference was found between large swabs with same volumes. Significance between same size swabs with same volumes varied.

Anaesthetists and surgeons were significantly more accurate (p= 0.025) than nurses in estimating blood volumes. There was no significant difference (p=0.109) between years of experience of participants.

Visual estimation of blood on swabs is the subjective method used at the two academic hospitals to estimate intra-operative blood loss. Operating theatre staff at these hospitals were inaccurate in estimating blood volumes on swabs.

Inaccurate blood volume estimations may have clinical implications for patients, it is therefore recommended that various strategies should be used to educate operating theatre staff.

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DEDICATIONS

To my wife, Jonette, for endless and selfless support and love, and my boys Hugo and Daniel for keeping me alive and awake for unexpected challenges.

Mostly for my Saviour who leads my path to my future.

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ABBREVIATIONS

CMJAH – Charlotte Maxeke Johannesburg Academic Hospital

CHBAH – Chris Hani Baragwanath Academic Hospital

DIC – Disseminated intravascular coagulopathy

OSCE – Objective structured clinical examination

SANBS – South African National Blood Service

CHAPTER ONE: OVERVIEW OF THE STUDY

1.1 Introduction

This chapter is an overview of the research report. It includes the background, problem statement, aims and objectives, research assumptions, demarcation of the study field, ethical consideration, research methodology, and significance of the study, validity and reliability of the study and an outline of the research report.

1.2 Background

The measurement of blood loss intra-operatively is either objectively or subjectively assessed. Objective methods of blood loss estimation such as gravimetric, colorimetric, electrolyte conductivity and labelled red cell volume are rarely used in clinical practice, because they're complicated to do, expensive and time consuming (1-3). The subjective method includes visual estimation of blood loss on swabs, gowns, drapes and the floor, as well as in suction containers. Visual estimation is commonly used in the operating theatre (1-3).

Visual estimation of blood loss is a rapid, real time assessment and is inexpensive. Pavlin (4), in 1984, stated that the only dependable way to estimate blood loss is for both anaesthesiologist and surgeon to estimate the bleeding as it occurs.

It is known that visual estimation of blood loss is inaccurate, with both under- and overestimation being reported (5-10). Estimation of blood loss intra-operatively, along with haemodynamic parameters and patient variables, is a critical measurement in deciding whether a patient needs resuscitative intervention or not. A large volume of blood loss can result in consequences of haemorrhagic shock, such as disseminated intravascular coagulopathy (DIC) and organ failure (11). In this scenario underestimation of blood loss can result in death. During major surgery an overestimation of blood loss can result in unnecessary treatment, which is costly and exposes patients to the known risks of transfusion (12).

Pillitteri (13) was one of the first authors to acknowledge that it is tough to visually estimate blood loss after determining that nurses do not know how much blood it takes to saturate a perineal pad (13). Quantifying blood loss depends on accurate knowledge of swab capacities. Swabs capacities differ due to the brand, the ply and the thread.

Vital signs and clinical parameters influence visual estimation of blood loss. Frank et al (14), in 2010, studied how accurate 145 emergency physicians and paramedics were on visual estimation of blood loss when they were influenced by different vital signs. The vital parameters that suggested instability, led to overestimation of blood loss in both emergency physicians and paramedics.

Clinical experience does not appear to improve visual estimations of blood loss (7, 14, 15). Ashburn et al (15) studied the accuracy of blood loss estimation in 26 residents and 30 attending physicians in their emergency department. The range of their estimates were 0% to 1233% with a mean standard error of all estimates 116%. There was no significant difference in estimates between the residents and attending physicians.

The literature showed that accuracy of visual estimation of blood loss can be improved by clinical reconstructions, training and educational programmes (5, 6, 16). Sukprasert et al (16) and Dildy et al (6) used PowerPoint presentations as didactic tools to improve the accuracy of visual estimation of blood loss. Mathematical formulas to calculate the blood volume of objects were described; blood volumes on familiar objects were demonstrated to the participants and simple rules regarding visual estimation of blood loss were offered.

Ninety nurses were studied by Sukprasert et al (16), and Dildy et al (6) had 53 different health care providers (faculty, fellows, residents and medical students). The authors concluded that their educational process may improve and assist clinicians' accuracy in visual estimation of blood loss.

1.3 Problem statement

Blood loss intra-operatively is inevitable. Accurate estimation of blood loss is essential in order to treat patients appropriately. The literature showed that visual estimation of blood loss in general was inaccurate (5, 8-10). More objective measures of blood loss are available, but not commonly used (1).

In the operating theatres of Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) and Chris Hani Baragwanath Academic Hospital (CHBAH) blood loss is not objectively measured. It was not known how accurate the operating theatre staff at CMJAH and CHBAH was at visual estimation of blood loss, which may place patients at risk.

1.4 Aim and objectives

1.4.1 Aim

The aim of this study was to assess the accuracy of visual estimation of blood loss on commonly used swabs by operating theatre staff at CMJAH and CHBAH.

1.4.2 Objectives

The primary objective of this study was to describe the accuracy of visual estimation of blood loss on different swabs.

The secondary objectives of this study were to:

- describe and compare the accuracy of visual estimation of blood loss between different operating theatre staff disciplines
- describe and compare the accuracy of visual estimation with years of experience working in the operating theatres.

1.5 Research assumptions

The following definitions were used in this study.

Visual estimation of blood loss: is a cognitive process by which blood, of a specific amount, on a swab, is subjectively and visually assessed. The amount of blood in millilitres is subjectively estimated on a swab.

Accuracy: how closely the measured value approached the real value. For the purpose of the study it was within 10% of the actual blood volume. This value was obtained related to prior studies (5-7).

Study blood: packed red blood cells that have been collected, processed and stored in bags as blood product units. In this study products obtained from the SANBS was used.

Operating theatre staff: in this study included the theatre nurses, anaesthetists, and surgeons from the different surgical disciplines.

Theatre nurses: were registered and enrolled nurses that function as scrub nurses, floor nurses, anaesthetic nurses and recovery room nurses who were involved in estimation of blood loss.

Anaesthetists: will include a registered specialist, registrar and medical officer working in the Department of Anaesthesiology.

Surgeons: will include a registered specialist, registrar and medical officer working in the Department of Surgery.

OSCE – objective structured clinical examination is a modern type of examination used in health sciences. It is designed to evaluate clinical skill performance and competence in skills such as medical procedures, clinical examination, interpretation of results etcetera (17).

1.6 Demarcation of study field

The study will be conducted in the theatre complex of CMJAH and CHBAH that are affiliated to the Department of Anaesthesiology at the University of the Witwatersrand.

CMJAH is a 1200 bed central hospital. The hospital has 23 theatres and on average 23 000 cases are done annually.

CHBAH is a 2888 bed tertiary hospital. The hospital has 25 theatres and on average 65 000 cases are done annually.

1.7 Ethical considerations

Approval to conduct this study was obtained from the relevant authorities. An Information letter was given to all potential participants. Consent was implied by participation in the study. The study was conducted in accordance with the principles of the Declaration of Helsinki (18) and the South African Good Clinical Practice Guidelines (19).

1.8 Research methodology

1.8.1 Research design

A prospective, descriptive, single blinded and contextual research design was used in the study.

1.8.2 Study population

The study population was the operating theatre staff that worked in the CMJAH and CHBAH operating theatres during the study period.

1.8.3 Study sample

A minimum sample size of 72 participants was determined in consultation with a biostatistician and a convenience stratified sampling method was used. Inclusion and exclusion criteria for the study were defined.

1.8.4 Data collection

Study blood was obtained from the SANBS and warmed to reach 36.5°C before it was used. It was reconstituted with normal saline to achieve similar haematocrit levels as whole blood. Twelve stations containing different swabs with a known volume of blood, in random order, were set up exactly the same at both hospitals. Each participant was given a data collection sheet, participants filed past each station and completed the estimation of blood on each swab. The completed data collection sheet was placed in a sealed data collection box. Disposal of contaminated materials were performed in accordance with a standardized protocol, which is stipulated in Appendix 9.

1.8.5 Data analysis

Data were analysed by means of descriptive and inferential statistics using Statistica® version 10.

1.9 Significance of the study

Quality of health care has become an international priority and health care providers are increasingly interested in having objective information about their performance (20).

Espin et al (21) suggests that the "operating room theatre is an area where improved safety is an urgent and significant challenge and an important first step is to understand the factors that result in unsafe practise''.

The accuracy of visual estimation of blood loss on swabs by the operating theatre staff at CMJAH and CHBAH were not known. The estimations were found to be inaccurate and therefore may have resulted in patients receiving inappropriate treatment. An educational training programme regarding visual estimation of blood loss may contribute to the quality of care rendered in the operating theatres of CMJAH and CHBAH.

1.10 Validity and reliability of the study

Measures were put in place to ensure the validity and reliability of the study.

1.11 Study outline

The Chapters in this study includes:

Chapter 1: Overview of the study

Chapter 2: Literature review

Chapter 3: Research methodology

Chapter 4: Results and discussion

Chapter 5: Summary, limitations, recommendations and conclusion.

1.11 Summary

This chapter presented an overview of the research report, the next chapter contains a review of the literature.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Blood loss is an important obstacle in surgery. Accurate measurement of intraoperative blood loss is essential for good patient outcome. The physiology and pathophysiology, clinical importance and significance of blood loss are reviewed in this chapter. The different characteristics of swabs will be discussed. Subjective and objective methods for estimation of bleeding will be deliberated. The primary focus of this review is aimed at visual estimation of blood loss.

2.2 Background

The first milestone in managing bleeding was when Asian tribes used cauterisation, by lighting a mixture of saltpetre and sulphur on open wounds (22). Ligatures were invented, a piece of material used to tie the end of an open blood vessel, and believed to have originated from the 10^{th} century with Abulcasis (22, 23). It was improved by Ambroise Pare in the 16^{th} century and his invention withstands (22, 23).

The barrier of replacing the blood lost was only conquered in 1818, when the first successful transfusion of human blood was done for postpartum haemorrhage, by British Obstetrician Dr. James Blundell (12). In 1840 Dr. Blundell accomplished the first successful whole blood transfusion to treat haemophilia. (12)

2.3 Physiology and pathophysiology of blood loss

To maintain haemostasis in the body, circulating blood volume is needed (24). Blood transports carbon dioxide, oxygen, hormones, nutrients and waste; it regulates temperature, pH and influences water contents of cells; blood protects against blood loss via clotting mechanisms and against foreign microbes via white cells (24). Blood loss or an insufficient supply of blood will lead to poor tissue perfusion and ultimately organ dysfunction (25).

Severe blood loss at cellular level results in oxygen deprivation, which affects skeletal muscle and splanchnic organs due to lack of delivery of fuel substrates. Close to 95% of aerobic energy originates from oxygen and produces water and carbon dioxide. Transfer of electrons in the mitochondria is delayed with poor oxygen delivery and prevents pathways of acetyl-coenzyme A input into the tricarboxylic acid cycle. Thus little energy is harnessed which results in the formation of lactic acid. Lactic acidosis is an indicator of poor tissue perfusion. (25)

To preserve homeostasis with severe blood loss the body initiates compensatory mechanisms and stress responses that preserve flow to vital organs and signal cells to supplement internal energy stores. (25)

Severe blood loss activates baroreceptors and adrenergic reflexes; they have neural and circulating hormonal components, which give rise to the physiological effects of blood loss. Sympathetic fibres from the stellate ganglion stimulate the heart, and sympathetic fibres from regional ganglia cause peripheral arterial vasoconstriction. The hormones released lead to secretion of epinephrine and norepinephrine from the adrenal medulla and corticosteroids from the adrenal cortex, renin from the kidney and glucagon from the pancreas. These substances signal the liver to initiate glycogenolysis in order to release glucose into plasma, promote lipolysis, and stimulate the breakdown of tissue glycogen stores, thus providing necessary energy resources for the body to function optimally. (25)

The American College of Surgeons define the physiological responses of the body to increased blood loss in their Advanced Trauma Life Support student course manual. The physiological responses are classified and observed in a certain percentage of blood lost and are graded in different classes of haemorrhage (Table 2.1). (26)

Table 2.1 Estimated blood loss based on a 70 kg adult (26)

	Class I	Class II	Class III	Class IV
Blood loss (ml)	Up to 750	750-1500	1500-2000	>2000
Blood loss (% Blood volume)	Up to 15%	15%-30%	30%-40%	>40%
Pulse rate (beats/min)	<100	100-120	120-140	>140
Blood pressure	Normal	Normal	Decreased	Decreased
Pulse pressure	Normal or Increased	Decreased	Decreased	Decreased
Respiratory rate (breaths/min)	14-20	20-30	30-40	>35
Urine output (ml/hr)	>30	20-30	5-15	Negligible
Mental status	Slightly anxious	Mildly anxious	Anxious, confused	Confused, lethargic
Fluid replacement	Crystalloid	Crystalloid	Crystalloid and blood	Crystalloid and blood

The cardiovascular response to blood loss differ according to the underlying comorbidities, age, and cardiopulmonary reserve, the presence of hypo- or hyperthermia and the presence of possible ingested drugs. These classifications pertain only to adults and not young children and infants, who are more dependent on heart rate and stroke volume in response to blood loss. (26)

A parameter, not mentioned above, to recognise severe blood loss is the acidbase status. The base deficit and bicarbonate level in arterial and venous blood will decrease early in haemorrhage even if the blood pressure and pH are within the normal range. Much information can be obtained from acid-base analysis, depending on the type of machine used; the acid-base status, haemoglobin and haematocrit value, glucose concentration, and lactate level. Thus acid-base analysis provides early and useful information regarding acute blood loss. (27)

The importance of understanding the pathophysiological effects of blood loss is crucial to prevent life-threatening complications. The measurement of blood loss can either be objective or subjective and often depends on the availability of resources.

2.4 Objective measurements of blood loss

Objective methods of estimating blood loss are seldom used in clinical practice because they're complicated to do, expensive and time consuming. These include gravimetric, colorimetric, electrolyte conductivity, dyes, and radioisotopes or labelled red cells estimations. (1-3)

2.4.1 Gravimetric method

In the clinical setting a gravimetric method is applicable and accurate in blood loss estimation. It provides surgeons and anaesthesiologists with an objective tool to evaluate intra-operative blood loss (28). Two specific ways of estimating blood loss gravimetrically are by either patient or swab weighing (1).

With patient weighing, blood loss cannot be assessed during the course of the operation and allowance must be made for intra-operative maintenance or resuscitative fluid, drains, dressings, removal of tissues and insensible water loss. (1)

Caceres and Whittembury (29), in 1959, demonstrated that the amount of blood loss as determined by swab weighing, plus 25%, is equivalent to true operative blood loss.

Limitations of the methods are:

- When swabs are contaminated with blood, they should be weighed as soon as possible to exclude evaporative losses.
- Limitation of this method is inevitable loss on gowns, drapes and floors, which is not included on the final balance.
- Lack of international standardization of weight and size of gauze, sponges and pads as well as inaccuracies can arise at several steps in this method. (1)

These limitations result in inaccurate blood loss measurements.

2.4.2 Colorimetric (spectrophotometric) method

This method relies on the consistency of the blood haemoglobin concentration during the course of the surgery and estimation. Blood is extracted from swabs and the concentration of the resultant solution can be used to determine the actual blood loss. (30)

With the patients' haemoglobin concentration known, a value for the blood loss can be calculated in a colorimeter (31). Quantifying intra-operative blood loss using spectrophotometric haemoglobin analysis accurately assesses the amount of blood loss. However, this is time consuming and primarily used during research (28).

Thornton et al (1) studied 120 patients aged from 20 to 60 years (mean 42 years; SD ± 9.88) that underwent mitral valvotomy. The average blood loss was 316 ml (SD ± 144). They did a comparison of the measurement of blood loss by colorimetric and gravimetric methods between the subjects. The two methods compared well, confirming conclusions of Baranofsky, Treolar and Wangensteen (2) in 1946, who adopted the gravimetric method because of its simplicity.

2.4.3 Electrolyte conductivity method

This method was introduced by Leveen and Rubricius (32) in 1958, and is an automated blood loss meter based on electrolyte conductivity. Thornton (1) is of the opinion that this method has the advantage of giving a continuous reading, but is dependent on the consistency of the electrolyte content of the blood during the period of estimation.

2.4.4 Dyes, radioisotopes and labelled red cells estimation

Blood volume estimation using radioisotope or dye-dilution methods are time consuming, laborious, and requires special equipment. Red cell labelling was described by Mollison and Veall (33) in 1955 when they measured the red cell volume of patients pre-operatively using red cells labelled with Chrome.

A comparative study between colorimetric, gravimetric and red cell volume, done by Thornton et al, (1), suggested that the latter shows an even greater blood loss (mean difference between colorimetric and red cell volume was 145ml with a range of 115-193ml). Chaplin in 1954 (3) reported similar observations. The assumption therefore was that the actual blood loss during mitral valvotomy was actually more than measured by the colorimetric and gravimetric methods. (1)

With labelled red cells estimation, the measurement in the change of blood volume is dependent on the haematocrit and inaccuracies can arise when the circulation is disturbed in a condition like severe oligaemia. This method cannot be relied upon to give concurrent blood loss values during the surgery. It is relatively expensive and requires trained technical staff. (1)

2.5 Subjective measurements of blood loss

Subjective estimations are a standard measurement method in operating theatres and includes visual estimation of blood loss on swabs, floors, gowns, drapes and in suction containers (1). Pertaining to suction containers, the errors arising include failure to collect all the blood, and mixing of blood with contaminating fluid (lymph, amniotic fluid, urine, faeces, and pus) (34, 35).

The literature shows that visual estimation of blood loss, in general, is inaccurate (5, 8-10). The inaccuracy can be narrowed down to the following influencing factors:

- Swab demographics
- Educational/training programs
- Clinical parameters of patients
- Health care professionals (nurses, surgeons and anaesthetists) exposure, training and clinical experience

Lastly, a brief review in the latest estimation of blood loss via a mobile application will be discussed.

2.5.1 Swab demographics

Accurate knowledge of swab absorbing capacities is essential to accurately estimate blood loss. Pillitteri (13), in 1977, was one of the first people to acknowledge that estimating blood loss was difficult. She said this after finding out that nurses did not know how much blood it takes to saturate a perineal pad (13).

Swab absorption capacities will differ due to brand, ply and means of threading. Hughes et al (36) quantified the absorption capacities of gauze swabs. They used 2x2 (12 ply) and 4x4 inch gauze swabs (4 ply) and concluded that completely soaked 2x2 inch gauze swabs (12 ply) have an average carrying capacity of 3.25 ml ±1.25 ml, and that 4x4 inch gauze swabs (4 ply) has an average carrying capacity of 10ml ± 2ml.

In an article on observer accuracy of visual estimation of blood loss by Yoong et al (7), accuracy was shown to be blood volume dependent. With smaller volumes (with 25ml the mean estimated volume was 41.94ml), and with larger volumes (with 200ml the mean estimated volume was 222.07ml), there was a tendency to overestimate (7). This was in contrast with findings of previous authors, where the total amount of underestimation increased the larger the blood loss (5, 7, 9, 37, 38).

Accuracy is also dependent on swab size as determined by Bose et al (5): with large swabs, healthcare providers predominantly underestimate the volume and with small swabs they overestimate it. The maximum capacity of a saturated large 12 ply swab (450mm x 450mm) is 350ml, and all the participants underestimated the capacity (median percentage error was -57% for the obstetricians). Participants overestimated the blood loss on the sanitary towel, with a median percentage for the anaesthetist 50% and midwife 67%. (5)

Kodkany and Derman (30) commented on the failures of visual assessment of blood loss. The most common error reported by studies was underestimation of blood loss, when estimates at the time of a normal vaginal delivery were compared to more precise measurements, there was an average error of 46%. They mentioned that with large blood losses after a vaginal delivery, health care providers underestimated, and with losses less than average they tended to overestimate, by reviewing a study of Newton et al (39).

2.5.2 Educational/training programs

Sukprasert et al (16) used a fifteen minute PowerPoint presentation as a didactic tool to better the accuracy of visual estimation of blood loss at Ramathibodi Hospital, Mahidol University, Bangkok in 2006. Mathematical formulas to calculate the volume of surgical materials were described; blood volumes of known objects were presented to the participants and simple rules of thumb regarding visual estimation of blood volume was presented. Ninety nurses were studied. They were randomly divided into two groups, an experimental and control group. The experimental group, who received the PowerPoint presentation showed a significant improvement in accuracy in visually blood loss estimation in all seven stations. (16)

To improve the accuracy of estimated blood loss at obstetric haemorrhage, Bose et al (5) at Queen Charlotte's Hospital, London, in 2006, concluded that participation in an education program may establish early diagnosis and early management of postpartum haemorrhage. One hundred and three nurses, midwives, healthcare assistants, obstetricians and anaesthetists were studied and the results displayed significant underestimation at 5 of 12 stations: 500ml (50cm diameter) floor spill, 1000ml (75cm diameter) floor spill, 1500ml (100cm) floor spill, 350ml capacity of soaked 45cm x 45cm large swab and the 2 litres vaginal blood on the bed and floor. A pictorial guideline was then produced to facilitate future visual estimation. (5)

2.5.3 Clinical parameters of patients

In a study by Frank et al (14) with 145 participants, 51% underestimated and 39% overestimated with visual estimation of blood loss. They explored the influence of different vital signs on visual estimation of blood loss and discovered that estimations were influenced by the given parameters. Occupational status, gender and level of experience were the demographics that was explored.

Six realistic trauma scenarios were presented to participants in random order. In the unstable scenarios (300ml blood loss and a given high heart rate and low blood pressure) both emergency physicians and paramedics overestimated the blood volume compared to the stable scenarios (300ml blood loss and a normal heart rate and blood pressure). In the unstable and stable scenes with 800ml and 1500ml blood loss, the emergency physician and paramedics underestimated the volume. (14)

When unstable and stable patients were compared on the same scenarios with the same volumes, emergency physicians and paramedics estimated the volume of blood loss significantly higher in the unstable patients. Furthermore, they concluded that occupational status does not seem to influence the accuracy of blood loss estimations. (14)

2.5.4 Health care professionals (nurses, surgeons and anaesthetists) exposure, training and clinical experience

Gynaecological ward nurses, midwifes and theatre nurses in a study by Bose et al (5), where the accuracy of estimated blood loss at obstetric haemorrhage was evaluated, had a median percentage error of -13%, -14%, -13% respectively compared to the median percentage error of the obstetrician, -11%, and the anaesthetist, 4%.

An audit done at Aga Khan University in India on the estimation of blood loss during caesarean section in 2006, reviewing 126 patients, the mean blood loss was estimated to be more by the surgeons as compared to the anaesthetists. The average blood loss estimated by the surgeons was 592 ± 222ml and that by the anaesthetists was 498 ± 176ml. (40) No statistical difference was explored between the two different groups.

If surgeons and anaesthetists work together for some years however, the average blood loss estimate falls within a relatively narrow range (1). Bonica and Lyter (41), in 1951, determined the blood loss in 651 surgical procedures and together with the summarized work of 17 other investigators concluded that the surgeons usually underestimate.

Experience does not appear to be a confounding variable as concluded by Meiser et al (37) in 2001, Dildy et al (6) in 2004 and Bose et al (5) in 2006; senior obstetricians compared to students have equally inaccurate estimations.

Clinical experience does not appear to improve visual estimations of blood loss (7) as concluded by Ashburn et al (15), in a brief research report, and Frank et al (14). Ashburn studied the accuracy of blood loss estimation in 30 attending physicians and 26 residents in their emergency department. Their range was between 05 to 1233% with a mean standard error of 116% for all estimates. There was no significant difference between residents and attending physicians.

2.5.5 Estimation of blood loss with mobile applications

The latest literature research reveals a modern approach to visual estimation of blood loss. FDA approved Triton, an iPad blood loss App courtesy of Gauss Surgical is already in use at Cedars-Sinai Medical Centre, UC Irvine Healthcare, the Memorial Care Health System and other hospitals (2014). An iPad camera takes a picture of a blood canister or swabs and sponges. These images get analyzed via algorithms to assess haemoglobin content and blood loss.

2.6 Summary

Most literature articles and reviews conclude that visual estimation of blood loss is unreliable and inaccurate. Objective methods are more reliable but time consuming. Subjective visual estimations are still widely used as the most popular method in real time. Educating programmes and training do improve accuracy of visual estimation of blood loss and needs to be addressed more aggressively in preventing life-threatening complications.

2.7 Conclusion

This chapter contained the literature review. The following chapter will address the methodology of the study.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter contains the research methodology of the study. It includes the problem statement, the aims and objectives, ethical considerations, the research design, study population and sample, data collection and analysis, and the validity and reliability of the study.

3.2 Problem statement

Blood loss intra-operatively is inevitable. Accurate estimation of blood loss is essential in order to treat patients appropriately. The literature showed that visual estimation of blood loss in general was inaccurate (5, 8-10). More objective measures of blood loss are available, but not commonly used (1).

In the operating theatres of CMJAH and CHBAH blood loss is not objectively measured. It was not known how accurate the theatre staff at CMJAH and CHBAH was at visual estimation of blood loss, which may place patients at risk.

3.3 Aim and objectives

3.3.1 Aim

The aim of this study was to assess the accuracy of visual estimation of blood loss on commonly used swabs by operating theatre staff at CMJAH and CHBAH.

3.3.2 Objectives

The primary objective of this study was to describe the accuracy of visual estimation of blood loss on different swabs.

The secondary objectives of this study were to:

- describe and compare the accuracy of visual estimation of blood loss between different operating theatre staff disciplines
- describe and compare the accuracy of visual estimation with years of experience working in the operating theatres.

3.4 Ethical considerations

Approval to conduct this study was sought from the Post Graduate Committee (Appendix 1) and the Human Research Ethics Committee (Medical) of the University of the Witwatersrand. (Appendix 2)

The Chief Executive Officer of the CMJAH (Appendix 3) and the Medical Advisory Committee of CHBAH (Appendix 4) granted permission to conduct the research in the respective hospitals. The nursing managers of the operating theatre complexes were informed prior to the commencement of the study.

A letter was send to the SANBS to request blood products for use in the study (Appendix 5). Approval to conduct the study was obtained from the SANBS Human Research Ethics Committee (Appendix 6).

An information letter (Appendix 7) and data collection sheet (Appendix 8) was given to all potential participants. Consent was implied by participation in the study. Each completed data collection sheet was placed in a sealed data collection box. No identifying data was requested from the participants. Only the researcher and the supervisors did have access to the completed data collection sheets. Anonymity and confidentiality were thereby maintained. Collected data will be stored for six years.

The blood obtained from the SANBS was used for the reason specified and disposal of contaminated materials were performed in accordance with the SANBS and respective hospitals protocol (Appendix 9). Appropriate precautions were taken to avoid spillage and contamination.

The study was conducted in accordance with the principles of the Declaration of Helsinki (18) and the South African Good Clinical Practice Guidelines (19).

3.5 Research methodology

3.5.1 Research design

A prospective, descriptive, single blinded and contextual research design was used in the study.

Brink (42) defines a prospective study as when variables are measured while they occur during the course of the study. Data was collected during the participants' estimation of blood volume on different swabs.

Brink (42) states that a descriptive design is "research studies in which phenomena are described or the relationship between variables are examined; no attempt is made to determine cause-and-effect relationship". This study described the accuracy of visual estimation of blood on different swabs.

Blinding in a study design is defined as "Structure of a design where either the patient or those providing care to the patient are unaware of whether the patient is in the experimental or the control group." (43) The study was single blinded as the researcher was the only one who knew the amount of blood per swab that was used.

The study was conducted at CMJAH and CHBAH and therefore was a contextual research design. De Vos et al (44) refers to contextual research design as a "small scale world".

3.5.2 Study population

The study population was the operating theatre staff that worked in the CMJAH and CHBAH operating theatres during the study period.

3.5.3 Study sample

Sample size

The sample size was determined in consultation with a biostatistician using

Statistica® version 10. It was calculated that a minimum of 72 participants would give a power of more than 80%. Each group (nurses, surgeons and anaesthetists) should contain more than twenty participants to compare the accuracy of visual estimation of blood loss between the different groups. The blood loss estimation will be regarded as accurate if the estimation falls within 10% of the actual blood volume.

Sampling method

The sampling method is a process whereby a group of subjects from the study population are selected to participate in the study (43). It is important to have a sample that accurately represents the population from which it is chosen (45).

In the study a convenience sampling method was used whereby all readily available participants were invited to participate in the study until the sample size was realized (42, 43).

Stratified sampling was used to attempt to obtain representativeness from the different disciplines working in the operating theatres. It improved the representativeness of the sample by reducing sample error and produced a weighted mean that had less variability. (42)

3.5.4 Inclusion and exclusion criteria The

inclusion criteria of the study were:

- operating theatre staff who were involved with patients during surgery
- who had a minimum of 1 month experience working in the operating theatres.

The exclusion criteria were:

- operating theatre staff who did not consent to take part in the study
- or were on annual or sick leave.

3.5.5 Data collection

Written permission was obtained from the relevant authorities to conduct this research. The nursing manager of the operating theatre complex was informed prior to the commencement of the study. Blood was obtained from the SANBS where it was stored at 4ºC. On the morning of the study the blood was transported to the study area and allowed to reach 36.5 degrees Celsius in the theatre incubator (Getinge®) before use.

Red packed cells (haematocrit 60%) were used and reconstituted by dilution with normal saline to achieve similar haematocrit levels as whole blood (haematocrit 40%), thus the consistency of the blood on the swabs was as similar as possible to what would be seen in a real life scenario. The calculation of the amount of normal saline that was added for reconstitution was:

- Amount of normal saline added = (40 x amount of red pack cell volume) ÷ 60

The researcher invited participants to take part in the study. Those agreeing to participate were given a participant information letter (Appendix 7) explaining the aim of the study and elucidating their rights as participants in research projects. Participation in the study was taken as consent.

In the operating theatre 12 stations containing different swabs, in random order, were set up. The researcher dipped the swabs in known volumes of blood or applied a known volume. Twelve swabs were used, four vaginal/vascular 12 ply swabs (75 mm x 900 mm), four large abdominal 6 ply swabs (370 mm x 450 mm), and four small abdominal 4 ply swabs (170 mm x 200 mm).

A 50 ml syringe was used to ensure accuracy of the dipped or applied volume. Some swabs had blood applied directly to the dry swab, whereas others were dipped or soaked in the blood volume. These simulated real life scenarios. The swabs were labelled from A to L. Data were collected on two separate occasions in order to maximize the study sample.

Each participant was given a data collection sheet (Appendix 8) requesting the following demographic information:

- discipline
- years of experience working in the operating theatre

The data collection sheet had a table labelled from A to L with an adjacent space where the estimated blood volume on each swab was documented in millilitre (ml) (blood volume on swabs was in multiples of 10, e.g. 20 ml, 50 ml, 130 ml).

Each completed data collection sheet was placed in a sealed data collection box. No identifying data were requested from the participants. Only the researcher and the supervisors had access to the completed data collection sheets. Anonymity and confidentiality were thereby maintained.

Disposal of contaminated materials was performed in accordance with CMJAH and CHBAH protocol (Appendix 9). Appropriate precautions were taken to avoid spillage and contamination.

3.5.6 Data analysis

Descriptive statistics was used to summarize the demographic data. Data capturing was done using a spread sheet on Microsoft Excel® 2010.

The data was analysed as a non-normal distribution by the Shapiro-Wilk test and Skewness/Kurtosis test. The primary objective was determined and further analysed on the estimates of blood volume between:

- similar volumes on same size swabs
- same volumes on same size swabs
- same volumes on two different size swabs
- large volumes on abdominal swabs.

The vascular swabs with similar volumes and the two different swabs with the same volumes were analysed with a Kruskal-Wallis and Dunn's post hoc test. A Wilcoxon signed-rank test was used for the large and small abdominal swabs.

For the secondary objectives data were rearranged in a long format. Given that there were multiple observations per participants, mixed effects logistic regression was used to model the association between accuracy and separately with experience and discipline.

Descriptive statistics was also used for the secondary objectives.

Statistical analysis was performed using Statistica® version 10.

3.6 Validity and reliability of the study

Botma et al defines the validity of the study as “the degree to which a measurement represents a true value” and reliability of the study as “the consistency of the measure achieved.” (46) The study was valid and reliable as:

- each swab contained a predetermined volume of blood
- the swabs were laid out in a random order to discourage participants comparing volumes on swabs of the same size
- expired red pack cells reconstituted to a haematocrit of 40% instead off simulated blood or red fluid was used as would be seen in a real life scenario
- the same data collection sheet was used by all participants
- one participant at a time visually estimated the volume of blood on the swabs in order to prevent contamination of data by participants discussing the volumes with each other.

3.7 Summary

The research methodology of the study was presented in this chapter, in the next chapter the results of the study and the discussion thereof will be presented.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

The results of the study according to the objectives and the discussion are presented in this chapter. The objectives of the study are therefore repeated.

The primary objective of the study was to describe the accuracy of visual estimation of blood loss on different swabs.

The secondary objectives were to:

- describe and compare the accuracy of visual estimation of blood loss between different operating theatre staff disciplines
- describe and compare the accuracy of visual estimation with years of experience working in the operating theatres.

4.2 Sample realization

The data collection was done over two days, one day at CHBAH and one day at CMJAH during August, 2015. A total number of 180 data collection sheets were issued to participants of which 146 (81%) were returned.

4.3 Results

Accurate estimation was defined as within 10% of the actual blood volume on the swab. Percentages are rounded off to the nearest whole number.

4.3.1 Demographics

Demographics of participants

Of the 146 participants, 67 (46%) were theatre nurses, 47 (32%) anaesthetists and 32 (22%) surgeons.

Years of experience were reported by 141 participants with 76 (54%) having ≤5 years of experience and 65 (46%) having >5 years of experience. This is shown, by discipline, in Figure 4.1. The median years of experience (range) was 5 (0.1 to 36) years.

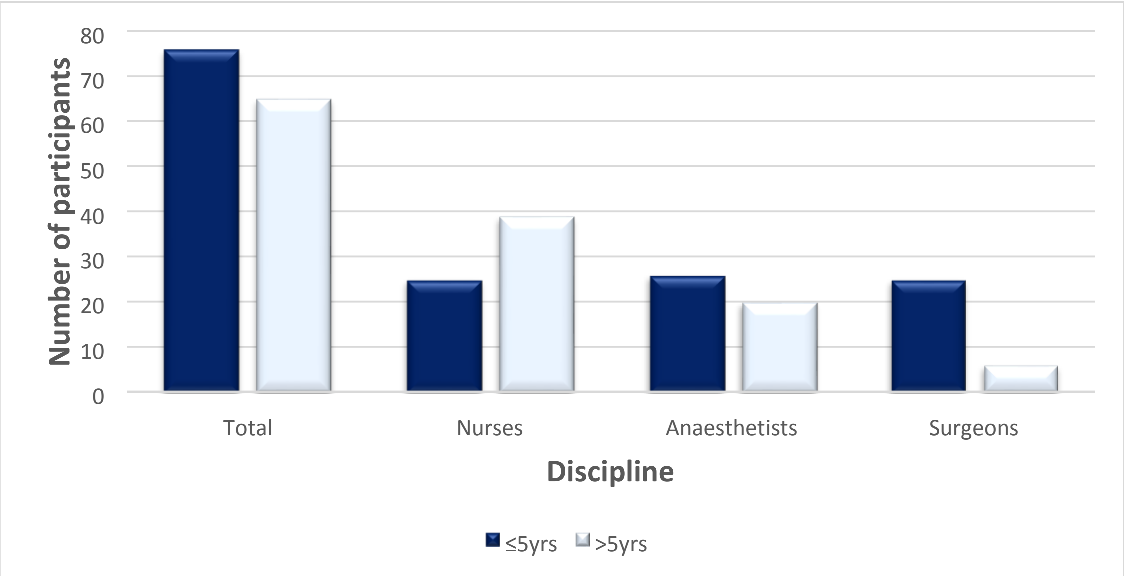


Figure 4.1 Participants years of experience by discipline

Demographics of swabs

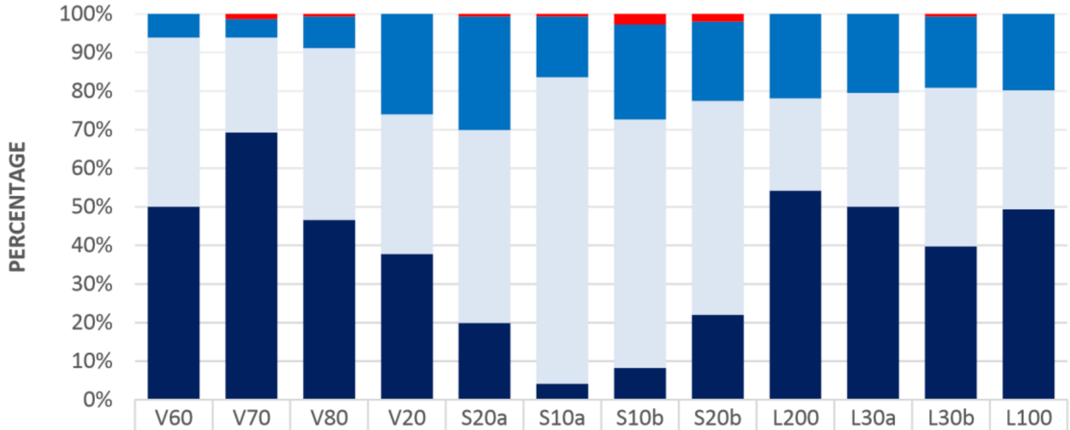
Twelve swabs were displayed at stations A to L. The station, type of swab, the volume of blood and how the swab will be referred to is shown in Table 4.1.

Table 4.1 Demographics of the swabs

Swab type and station	Blood volume (ml)	Refer to as
Vascular swabs		
Station A	60	V60
Station B	70	V70
Station C	80	V80
Station D	20	V20
Small abdominal swabs		
Station E	20	S20a
Station F	10	S10a
Station G	10	S10b
Station H	20	S20b
Large abdominal swabs		
Station I	200	L200
Station J	30	L30a
Station K	30	L30b
Station L	100	L100

4.3.2 Primary objective: to describe the accuracy of visual estimation of blood loss on swabs

A total of 1739 of a possible 1752 estimations were made. Only 316 (18%) of these estimations were accurate, 765 (44%) were overestimates and 658 (38%) were underestimates. Accurate, over and underestimates are shown in Figure 4.2. Appendix 10 shows 3 examples of the different size swabs with the respective estimations of participants on scatter plots.



	V60	V70	V80	V20	S20a	S10a	S10b	S20b	L200	L30a	L30b	L100
Missing	0	2	1	0	1	1	4	3	0	0	1	0
Accurate	9	7	12	38	43	23	36	30	32	30	27	29
Over	64	36	65	53	73	116	94	81	35	43	60	45
Under	73	101	68	55	29	6	12	32	79	73	58	72

SWABS

Figure 4.2 Accurate, over and under estimates per swab

Further analyses were done on the estimates of blood volume between:

- similar volumes on same size swabs
- same volumes on same size swabs   same volumes on two different size swabs
- large volumes on large abdominal swabs.

Estimates of blood volume between similar volumes on same size swabs

This analysis was done with vascular swabs with similar volumes of blood (V60, V70 and V80). The actual volumes applied to these swabs were within 25% of each other. As illustrated in Table 4.2 the estimates of volumes on the three swabs were significantly different (p=0.0001). The median of V70 (n=47.5) was expected to be higher than V60, but it was not. A Dunn's post hoc test showed a difference between all the swabs, with the most significant margin between V70 and V80.

Table 4.2 Blood volume between similar volumes on same size swabs

Swabs	Median	Range	IQR	Overall	Differences
V60	55	8-350	30-100	p=0.0001	V60 vs V70 p<0.05
V70	47.5	5-300	30-78		V70 vs V80 p<0.005
V80	80	10-350	50-120		V80 vs V60 p<0.01

Estimates of blood volume between same volumes on same size swabs

With analysis of the small abdominal swabs participants tend to overestimate more, for example 80% at S10a, as captured in Figure 4.2. There was a significant difference between estimates of blood volume on the two small abdominal swabs (S10a and S10b) that each had 10 ml of blood (p=0.0001). However, the two small abdominal swabs with 20 ml of blood (S20a and S20b) showed no significant difference in visual estimation (p=0.6209). Participants underestimated by 20% and overestimated by 50% on S20a. They underestimated by 22% and overestimated by 57% on S20b. With analysis of the two large abdominal swabs participants underestimated with 50% and overestimated with 29% on L30a. They underestimated with 40% and overestimated with 41% on L30b. There was no significant difference (p=0.1174). This is shown in Table 4.3.

Table 4.3 Blood volume between same volumes on same size swabs

Swabs	Median	Range	IQR	p value
S10a	25	5-200	15-50	0.0001
S10b	20	2-200	10-30	
S20a	25	3-200	20-50	0.6209
S20b	30	5-120	20-50	
L30a	27.5	2-150	20-50	0.1174
L30b	30	2-160	20-50	

Estimates of blood volume between same volumes on two different size swabs

Estimates of blood volume between same volumes on a vascular swab and two small abdominal swabs (V20, S20a and S20b) displayed significant differences (p=0.0001) and is shown in Table 4.4. A Dunn's post hoc test showed the most significant margin between V20 and S20a.

Table 4.4 Blood volume between same volumes on two different size swabs

Swabs	Median	Range	IQR	Overall	Differences
V20	20	3-250	10-30	p=0.0001	
S20a	25	3-200	20-50		V20 vs S20a p<0.0005
S20b	30	5-120	20-50		V20 vs S20b p<0.005

Estimates of blood volume between large volumes on large abdominal swabs

Table 4.5 illustrates the analysis of two large abdominal swabs (L200 and L100) with large volumes of blood and the difference was significant (p<0.0001).

As deducted from Figure 4.2 there were more underestimates (L200, 54% and L100, 49%) as opposed to overestimates (L200, 24% and L100, 31%). The medians show that participants tend to underestimate large blood volumes on large abdominal swabs (Table 4.5) more than smaller volumes on large abdominal swabs (Table 4.3).

Table 4.5 Large blood volume on large abdominal swabs

Swabs	Median	Range	IQR	Overall
L200	**150**	**10-500**	**100-200**	**p<0.0001**
L100	**90**	**9-300**	**50-130**	

4.3.3 Secondary objective: describe and compare the accuracy of visual estimation of blood loss between different operating theatre staff disciplines

Nursing participants made a total of 792 estimations, of which 125 (16%) were accurate. The surgical participants made a total of 384 estimations, of which 80 (21%) were accurate. Anaesthetic participants made a total of 563 estimations, of which 111 (20%) were accurate as illustrated in Table 4.6.

Table 4.6 Accuracy of visual estimations between disciplines

Disciplines	Correct estimations	Percentage
Nurses	**125 (of 792)**	**16%**
Anaesthetists	**111 (of 563)**	**20%**
Surgeons	**80 (of 384)**	**21%**

Given that there were multiple observations per participants, mixed effects logistic regression was used to model the association between accuracy and disciplines.

Anaesthetists and surgeons' accuracy were in close range and thus a difference between them and nurses were explored. Anaesthetists and surgeons were 26% less likely to be inaccurate compared to nurses (p=0.025). When broken down by specialty, anaesthetists and surgeons were 23% and 31% respectively less likely to be inaccurate than nurses. The association was significant for surgeons (p=0.03) but not significant for anaesthetists (p>0.09).

4.3.4 Secondary objective: describe the accuracy of visual estimation according to years of experience working in the operating theatres

Years of experience were reported by 141 of 146 participants with 76 (54%) having ≤5 years of experience and 65 (46%) having >5 years of experience. The participants with ≤5 years of experience made 189 correct estimations of 912 (21%). The participants with >5 years of experience made 117 correct estimations of 780 (15%). There was a 6% difference in accuracy between the two groups (Table 4.7).

Table 4.7 Estimations related to years of experience

Participants	Correct estimations	Percentage
≤5 Years of experience	189 (of 912)	21%
>5 Years of experience	117 (of 780)	15%

Given that there were multiple observations per participants, mixed effects logistic regression was used to model the association between accuracy and experience.

The interpretation concluded that participants with >5 years of experience were

24% more likely to be inaccurate than participants with ≤5 years of experience, but the association was not significant (p=0.109).

4.4 Discussion

The results of this study show both similar and different findings to other studies in the accuracy of visual estimation of blood loss.

Visual estimation of blood loss in any scenario is inaccurate (5-10, 15, 16). This statement is confirmed by operating theatre staff at CMJAH and CHBAH with only18% accuracy of visual estimation of blood loss on swabs. The inaccuracies are influenced by swab demographics, availability of/or exposure to educational programs, different disciplines training and clinical experiences, and clinical parameters of patients (5-8, 10). Accurate estimation was defined as within 10% of the actual blood volume on the swab. This was a very strict and possibly too narrow margin for error on especially small abdominal swabs.

Hughes et al (36) quantified the absorption capacities of gauze swabs. They concluded that awareness of individual absorption capacities provide a clinically practical and rapid method to estimate blood loss. It is important to know the maximum absorptive capacity of a swab, because different companies supply swabs of different sizes, thread and ply. Knowing the absorption capacity will guide and aid in estimating blood loss more accurately. The maximum capacities on the swabs supplied by BSN Medical (via personal communication) are illustrated in Table 4.8.

Table 4.8 Maximum absorption capacities of swabs

Swab	Maximum volume
Vascular swab (75 x 900 mm, 12 ply)	100 ml
Small abdominal swab (170 x 200 mm, 4 ply)	40 ml
Large abdominal swab (370 x 450 mm, 6 ply)	200 ml

Accuracy is also dependent on swab size as described by Bose et al (5). Their estimations were in keeping with my study's estimations that large swabs are predominantly underestimated and small swabs overestimated.

Underestimations were close to 50% with the vascular and large abdominal swabs which could have important clinical implications. With delayed or inadequate resuscitation, the clinical implication is hypovolaemic/haemorrhagic shock, which could result further in disseminated intravascular coagulation and multiple organ damage. (11, 24)

Overestimations were as high as 75% with small abdominal swabs which may have implications especially in the neonatal population, where over or unnecessary transfusion of crystalloids or blood components can have serious consequences. These include metabolic, haemorrhagic, vascular (glycocalyx), and cardiac complications; potential infectious agents being transmitted; donor erythrocyte injury and alloimmunisation (12). Economic implications are vast with expensive blood products. Blood is a precious, limited resource for the appropriate patients in need.

Yoong et al (7), have showed that accuracy was blood volume dependent. There were overestimations with small and large volumes (with 25 ml the mean estimated volume was 41.94 ml, and with 200 ml the mean estimated volume was 222.07 ml). These findings were in contrast with my study, and with previous authors (5, 7, 9, 37 and 39), where underestimations were higher with a larger blood volume. Overestimations were analyzed on the smaller volumes of the small abdominal swabs with Bose et al. (5)

The nurses had significantly less accurate estimations on the different swabs compared to surgeons and anaesthetists (p=0.025). The surgeons and anaesthetists were mostly similar in their estimations with no statistical differences. Bose et al (5) showed that nurses had a median percentage error of 13%, obstetricians 11% and anaesthetists 4% which is similar in my study. An audit done at Aga Khan University in India on the estimation of blood loss during caesarean section in 2006, showed the average blood loss estimated by the surgeons was 592 ± 222ml and that by the anaesthetists was 498 ± 176ml. Their estimations were in close proximity as in my study, but the anaesthetists' margins were less. Estimations in my study showed surgeons were slightly more accurate (21%) than anaesthetists (20%) in visual estimation. Thornton et al (1) established that if surgeons and anaesthetists work together for some years, the average blood loss estimate falls within a relatively narrow range. In our setting at CMJAH and CHBAH registrars from different disciplines tend to rotate at different times and to different hospitals which could influence the accuracy of estimations. It is important for the different disciplines to aid each other and communicate differences in theatre to the best interest of the patient.

In my study surgeons had the most accurate estimations as a group, however, a vascular theatre nurse, with >5 years of experience, was the most accurate individual with visual estimation of blood loss on swabs. She was 92% (11 out of 12 stations) accurate and with the station she incorrectly assessed, she was still within 20% of the actual blood volume. It was not known whether she has ever received any education regarding visual estimation of blood loss on swabs.

The distribution of blood on swabs or the appearance/display of swabs on the theatre rack potentially interferes with the accuracy of their estimation. When evaluating the estimation of blood on the same swab with the same volume, significant differences ($p=0.0001$) were captured on the small abdominal swabs with small volumes. However, the estimations with larger swabs and small volumes had no significant difference ($p=0.1174$).

It would be expected that more time spent on assessing blood loss, will assure increased accuracy. However, Ashburn et al (15) confirmed that attending physicians and residents did not perform significantly different on visual estimation of blood loss ($p>0.05$). Experience does not appear to be a confounding variable as concluded by Meiser et al (37) in 2001 and Dildy et al (6) in 2004. Medical students and experienced faculty showed equally inaccurate estimations. In my study the lesser experienced group, ≤5 years of experience was more accurate (21%) than the more experienced group, >5 years of experience (15%). It would be expected that participants with more experience (mainly consultants) be more accurate, however registrars (less experienced) are more involved in the clinical setting in theatre, which may possibly account for these results.

The sub analysis of estimations on swabs and the secondary objective results should be interpreted with caution as the sample size may not be adequate to power these.

4.5 Summary

The results and a discussion thereof were presented in this chapter. In the final chapter the limitations, recommendations and overall conclusion will be presented.

CHAPTER FIVE: SUMMARY, LIMITATIONS, RECOMMENDATIONS AND CONCLUSIONS

5.1 Introduction

In this chapter a summary, the limitations, recommendations and a conclusion are presented.

The primary objective of the study was to describe the accuracy of visual estimation of blood loss on different swabs.

The secondary objectives were to:

- describe and compare the accuracy of visual estimation of blood loss between different operating theatre staff disciplines
- describe and compare the accuracy of visual estimation with years of experience working in the operating theatres.

5.2 Summary of the study

5.2.1 Aim and objectives

The primary objective of the study was to describe the accuracy of visual estimation of blood loss on different swabs.

The secondary objectives were to:

- describe and compare the accuracy of visual estimation of blood loss between different operating theatre staff disciplines
- describe and compare the accuracy of visual estimation with years of experience working in the operating theatres.

5.2.2 Summary of methodology

A prospective, descriptive, single blinded and contextual research design was used in the study. A convenient sampling method was used.

Data was collected over two days. Twelve OSCE style stations of swabs were displayed for estimations. It included 4 vascular swabs, 4 small abdominal swabs and 4 large abdominal swabs with their respective actual blood volume. Reconstituted red pack cells were used (haematocrit of 40% and temperature of 36.5°C).

5.2.3 Summary of results

Visual estimation of blood loss on swabs in operating theatres by theatre operating staff was inaccurate at CMJAH and CHBAH. A total of 146 participants made 1739 of a possible 1752 estimations. A total of 316 (18%) estimations were accurate to within 10% of the actual blood volume. Accurate estimations between the different disciplines ranged from 16 to 21%.

The vascular swabs had significant differences in their estimations ($p=0.0001$).

There were statistical significant differences on the estimates of different swabs with the same volume ($p=0.0001$).

Participants tend to overestimate on small abdominal swabs, S10a (80%) and S10b (66%).

Small abdominal swabs with the same volume of blood (S10a and S10b) displayed significant differences (p=0.001) on their estimations. This however was in contrast with large abdominal swabs (L30a and L30b) with the same volume of blood which displayed no significant difference (p=0.1038).

On large abdominal swabs with large volumes of blood participants revealed significant differences (p<0.0001).

Anaesthetists and surgeons were 26% less likely to be inaccurate compared to nurses (p=0.025). When broken down by specialty, anaesthetists and surgeons were 23% and 31% respectively less likely to be inaccurate than nurses. The association was significant for surgeons (p=0.03) but not significant for anaesthetists (p>0.09).

As many prior studies proved, there were no statistical differences in estimations regarding years of experience (p=0.109).

5.3 Limitations of the study

The following limitations were identified in this study.

This study was done contextually at two academic hospitals affiliated to the University of the Witwatersrand and therefore the results may not be generalizable to other academic or private hospitals.

This study used clinical reconstruction and not real-time/real-life scenarios. The influential factor of clinical parameters was therefore not available to the participants. This may have influenced participant's estimations of blood loss.

Red pack cells were reconstituted with normal saline to achieve the same physiological haematocrit levels as in healthy individuals. This method has been used in many research studies. This reconstitution may have interfered with the viscosity, the absorptive capacity and the appearance of the blood and thus the accuracies of the estimations.

Different brands of swabs supplied to institutions have different specifications. Their blood absorption capacities differ according to these specifications. Different size, ply and means of threading of swabs could interfere with absorption and therefore make the accuracy of visual estimations more difficult.

Dry swabs were used at the twelve stations. In clinical practice both wet and dry swabs are used. Dry swabs have an increased absorptive capacity compared to wet swabs which could influence the accuracy of the estimations.

The sample size was not powered to find differences in the secondary objectives. The results of the secondary objectives should therefore be interpreted with caution.

5.4 Recommendations from the study

5.4.1 Recommendations for clinical practice

The following recommendations are made for clinical practice:

Due to different brand, ply and means of threading, swab absorption capacities of different swabs should be known. Different brands of swabs and their absorptive capacities could be displayed on posters in theatre.

Educational programs using pictures, algorithms and simulated scenarios could aid in the accuracy of visual estimation of blood loss on swabs.

5.4.2 Recommendations for further research

The following recommendations are made for further research.

The study could be repeated following an educational program.

A comparison between two groups could be done, one exposed to an educational program and the other not; or a before-after study design could be used to assess the impact of an educational program on the accuracy of visual estimation of blood loss.

Distribution of blood on swabs differ. A study could assess how this influence the accuracy of estimations.

Any further study should be adequately powered to determine if there are differences between disciplines and years of experience.

5.5 Conclusion

Only 18% of swab volumes were accurately estimated. This reiterates the difficulty in accurately estimating blood loss in operating theatres. However, visual estimation of blood loss is still widely used. Education programs and training do improve accuracy of visual estimation of blood loss and need to be addressed more aggressively in preventing life-threatening complications. Familiarizing the clinician with absorptive capacities of dry and wet swabs may aid in their accuracy. A pictorial guideline of the different swabs used is produced in Appendix 10.

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APPENDICES

Appendix 1– Post Graduate Committee of Wits

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

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

Reference: Ms Thokozile Nhlapo
E-mail: thokozile.nhlapo@wits.ac.za

08 July 2015
Person No: 702316
PAG

Dr H Van Den Bergh
PO Box 13464
Leraatsfontein
1034
South Africa

Dear Dr Van Den Bergh

Master of Medicine: Approval of Title

We have pleasure in advising that your proposal entitled *The accuracy of visual estimation of blood loss on swabs by operating theatre staff at two academic hospitals* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

Appendix 2 - Human Research Ethics Committee (Medical) of the University of the Witwatersrand

R14/49 Dr Henko van den Bergh

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M130101

NAME: (Principal Investigator)	Dr Henko van den Bergh
DEPARTMENT:	Department of Anaesthesiology Charlotte Maxeke Johannesburg Academic Hospital Chris Hani Baragwanath Academic Hospital
PROJECT TITLE:	The Accuracy of Visual Estimation of Blood Loss on Swabs by the Operating Theatre Staff at Two Academic Hospitals (Title changed 18 May 2015)
DATE CONSIDERED:	25/01/213
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Mrs Helen Perrie
APPROVED BY:	Professor P Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	18/05/2015

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

–

Appendix 3 Permission of Chief Executive Officer at CMJAH

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

CHARLOTTE MAXEKE JOHANNESBURG ACADEMIC HOSPITAL

Enquiries:
Mr. J. Maepa
Office of the Clinical Director
Tell: (011): 488-3365
Fax: (011): 488-3753
07 July 2015

CMJAH

Dear: Dr. Henko van den Bergh

STUDY TITLE: The Accuracy of Visual Estimation of Blood Loss on Swabs by the Operating Theatre Staff at Two Academic Hospitals

Permission is granted for you to conduct the above recruitment activities as described in your request provided:

1. Charlotte Maxeke Johannesburg Academic Hospital will not anyway incur or inherit costs as result of the said study.
2. Your study shall not disrupt services at the study sites.
3. Strict confidentiality shall be observed at all times.
4. Informed consent shall be solicited from patients participating in your study.

Please liaise with the HOD and Unit Manager or sister in charge to agree on the dates and time that would suit all parties.

Kindly forward this office with the results of your study on completion of the research.

Supported/~~not supported~~

Dr. M.I. Mofokeng
Clinical Director
DATE: 14/7/2015

Approved/not approved

Ms. G. Bogoshi
Chief Executive Officer
DATE: 16.07.2015

Appendix 4 – Permission of Medical Advisory Committee of CHBAH

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

MEDICAL ADVISORY COMMITTEE
CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

PERMISSION TO CONDUCT RESEARCH

Date: 10 March 2015

TITLE OF PROJECT: The accuracy of visual estimation of blood loss on swabs by the operating theatre staff at two academic hospitals

UNIVERSITY: Witwatersrand

Principal Investigator: H van den Bergh

Department: Anaesthesiology

Supervisor (If relevant): H Perrie

Permission Head Department (where research conducted): Yes

Date of start of proposed study: March 2015
Date of completion of data collection: December 2016

The Medical Advisory Committee recommends that the said research be conducted at Chris Hani Baragwanath Hospital. The CEO /management of Chris Hani Baragwanath Hospital is accordingly informed and the study is subject to:-

- Permission having been granted by the Committee for Research on Human Subjects of the University of the Witwatersrand.
- the Hospital will not incur extra costs as a result of the research being conducted on its patients within the hospital
- the MAC will be informed of any serious adverse events as soon as they occur
- permission is granted for the duration of the Ethics Committee approval.

....
Recommended
(On behalf of the MAC)
Date: 10 March 2015

....
Approved/Not Approved
Hospital Management
Date: 2015/03/16

–

Appendix 5 Letter to the SANBS

Dr. Henko van den Bergh

Anaesthetic Registrar

University of the Witwatersrand

Department of Anaesthesiology

(011) 488-4344 Dr. Charlotte Ingram (SANBS)

This letter is regarding the use of expired blood products for a study at CMJAH and CHBAH. I will do this study as part of my degree, Masters in Medicine (MMed) in the Department of Anaesthesiology, University of the Witwatersrand.

The study is to describe the accuracy of visual estimation of blood loss on theatre swabs. The material that I would like to use is 10 units of expired red packed cells. Blood volumes will be put on different swabs and a visual estimation by participants will be made. The handling of the materials will solely be done by the researcher. The disposal of the materials will be done according to the policy for disposal of theatre material at CMJAH and CHBAH.

Data will be collected on two occasions and blood will only be used for the purpose of this study.

Requirements to obtain the material as requested by SANBS:

- I, together with my supervisors in the Department of Anaesthesiology (CMJAH), will be the end user of the materials provided.

- We undertake to dispose of all the material once the study's data has been collected on the day of participation.
- We will not dispose of all or any part of the material to any third party except as products prepared by our department in terms of the permitted uses above.
- The material will not be used for anything other than the intended purpose.
- We understand that although you are providing us with HIV, HBV and HCV negative tested blood, there is a window period as well as other infections that you do not test for, and therefore we will treat blood as infectious and not hold SANBS liable for anything whatsoever in the event of injury.
- SANBS Research Ethics Committee Application Form

My protocol was reviewed by our ethics committee in January 2013. This study scheduled to be done in July or August 2015. Thus, the blood products will only be needed at that time.

I hereby request permission from SANBS to obtain expired blood to use in my study.

Kind regards,

Dr. Henko van den Bergh

My contact details:

Cell no. – 0824188719

E-mail - Henkovdb@gmail.com

–

Appendix 6 SANBS Human Research Ethics Committee approval

SOUTH AFRICAN NATIONAL BLOOD SERVICE NPC

Human Research Ethics Committee

SANBS
South African National Blood Service

OHRP Number	: IORG0006278
FWA Registration Number	: IRB00007553
SA NHREC Registration Number	: REC-270606-013

Secretariat: Tel: 011 761 9135 | Fax: 011 761 9137 | Cell: 082 523 8523 | thandiwe.matsoso@sanbs.org.za

To: Dr. Henko van den Bergh
E-mail:Henkovdb@gmail.com

Dear Dr van den Bergh

DATE OF COMMITTEE MEETING:	**24 August 2015**
PROJECT TITLE:	**The accuracy of visual estimation of blood loss on swabs by the operating theatre staff at two academic hospitals**
DECISION OF THE COMMITTEE:	**Approved**
CLEARANCE CERTIFICATE NO:	**2014/24**

- Execution of the study must be compliant with applicable guidelines and policies.
- Any amendment, extension or other modifications to the protocol must be submitted to this Ethics Committee for approval prior to implementation.
- The Committee must be informed of any serious adverse event, planned and unplanned termination of the study.
- A progress report should be submitted yearly for long-term studies and a final report at completion of both short term and long term studies.
- Kindly refer to the SANBS HREC clearance certificate number on all future correspondence on this study to the HREC secretariat.
- This approval is valid for 5 years from the date stated above.

COMMITTEE GUIDANCE DOCUMENTS:

- International Conference on Harmonization (ICH) Good Clinical Practices (GCP) Guideline (ICH, 1996), Ethics in Health Research: Principles, Structures and Procedures (SA Department of Health, 2004); Guidelines for Good Practice in the Conduct of Clinical Trials in Human Participants in South Africa (SA Department of Health, 2006); Ethical Principles for Medical Research Involving Human: Declaration of Helsinki (World Medical Association, 2013); Reviewing Clinical trials: A Guide For Ethics Committees (Karlberg and Speers, 2010)

CHAIRPERSON: Prof J.N. Mahlangu

24 August 2015
DATE

Appendix 7 – Participants information letter

Dear colleague,

Hello, my name is Henko van den Bergh and I am an anaesthesiology registrar at CMJAH, on the University of the Witwatersrand's anaesthesiology registrar circuit.

I would like to invite you to participate in a MMed research study entitled:

The accuracy of visual estimation of blood loss on swabs by the operating theatre staff at two academic hospitals.

This study forms part of the training program at Wits Anaesthesiology Department as fulfilment of my MMed degree.

The study has been approved by the Human Research Ethics Committee (HREC) (Medical) (*M130101)*, and the Post Graduate Committee of the University of the Witwatersrand. Permission was obtained from the Chief Medical Officer of CMJAH and CHBAH.

The study will not take more than 5 - 10 minutes of your time. A data collection sheet will be provided and all the necessary demographics can be filled in. You will estimate the blood volume at 12 stations and once completed the data collection sheet will be placed in a sealed box.

No identifying data will be collected and the collected data will only be viewed by me and my research supervisors, this will ensure confidentiality and anonymity.

The study will be of no immediate benefit to you, but should visual estimation of blood loss be inaccurate, educational and training programs could be instituted and pictorial guides could be put up in theatre.

Please know that you are free to withdraw from the study at any time without having to provide any reason. Not partaking or withdrawing at any time will carry no penalty or repercussions of any sort.

Thank you for taking time to read this letter. If you have questions or concerns with regard to the study, you may contact the following people with your queries:

- Prof. Cleaton-Jones (Chairperson of the HREC): (011) 717 1234
- Dr. Henko van den Bergh (Researcher): 082 418 8719

Kind regards,

Henko van den Bergh.

Appendix 8 Data collection sheet

Participant no.: _____

Discipline: _________________________

Years/months of experience working in the operating theatre: _____

Please enter the estimated volume of blood on each swab against the corresponding letter below:

Station	Estimated Volume (blood volumes on swabs are in multiples of 10 ml, e.g. 20 ml, 50 ml, 130 ml)
A	ml
B	ml
C	ml
D	ml
E	ml
F	ml
G	ml
H	ml
I	ml
J	ml
K	ml
L	ml

Appendix 9 – Infection control (CMJAH and CHBAH Protocol)

1. Transmission based precautions

Standard precautions are used for the protection of all people exposed to

Hazardous Biological Agents (HBA).

1.1 Hand washing

- Wash hands after touching blood, whether or not gloves are worn.
- Use plain (Non-antimicrobial) soap for routine hand washing.
- Use antiseptic soap (Chlorhexidine scrub or Povidone Iodine scrub) to wash hands with when doing sterile procedures or to prevent and control an outbreak of infections.

1.2 Gloves

- Wear gloves (clean, intact non-sterile gloves are adequate) when touching blood or contaminated swabs.
- Change and dispose of gloves between tasks and procedures after contact with blood material and swabs.
- Remove gloves promptly after use, before touching noncontaminated material and environmental surfaces and before attending to people
- Dispose of gloves into a red plastic bag that will be placed into the medical waste box/wheelie bin.
- Wash hands immediately to avoid transfer of micro-organisms to other persons and environments.

1.3 Clothes – Scrubs

Protective clothing should be worn during use of blood products and contaminated swabs, which includes masks, eye protection, plastic aprons or gowns, or theatre scrubs.

1.4 Medical waste

- Get placed into a red plastic bag, when the bag is about twothirds full, the top of the bag is gathered, twisted and tied with an overhand knot. Care must be taken to direct the mouth of the bag away from the face when this is done to prevent the inhalation of bacterial/viral laden aerosols.
- The red plastic bag is placed into a second clean red plastic bag that is sealed and placed into the medical waste box/wheelie bin.
- The contents of the medical waste containers may not be handled or opened after closure.

1.5 Treatment of blood spills

- Cover the spill with paper to contain it, then collect the necessary equipment – red plastic bag, gloves, disinfectant (1% Sodium Hypochlorite) and paper.
- Wearing gloves wipe up spill and discard paper into red plastic bag, then poor disinfectant over the spill area and wipe up with a paper towel – discard paper into red plastic bag.
- Repeat last step once and discard gloves into red plastic bag.

This protocol has been revised to fit the material used in this study.

Appendix 10 – Swab stations and scattered plots

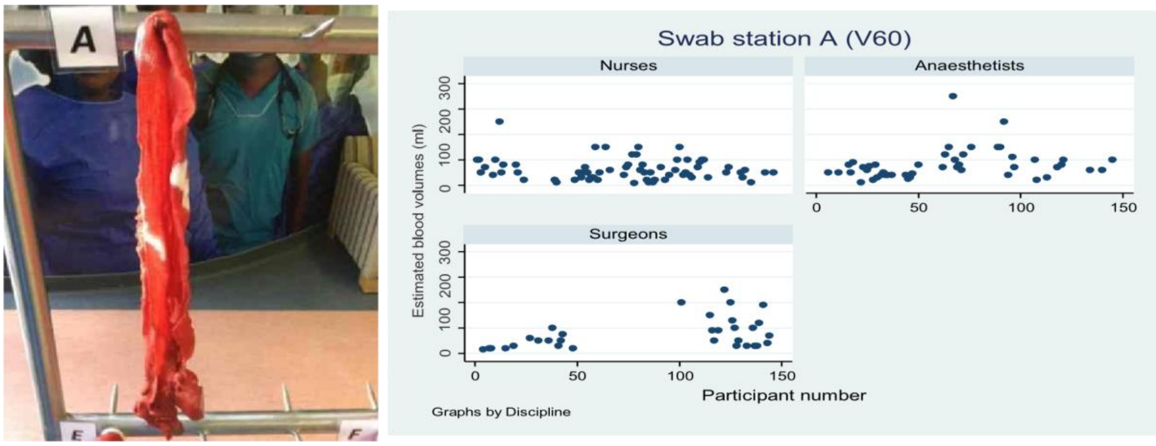

Figure 10.1 Swab station A (V60) and scattered plots of estimations

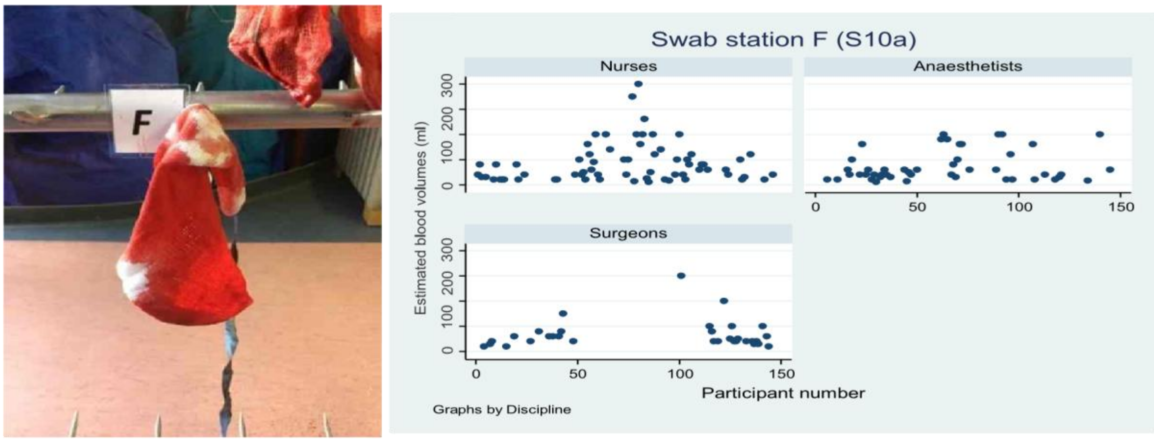

Figure 10.2 Swab station F (S10a) and scattered plots of estimations

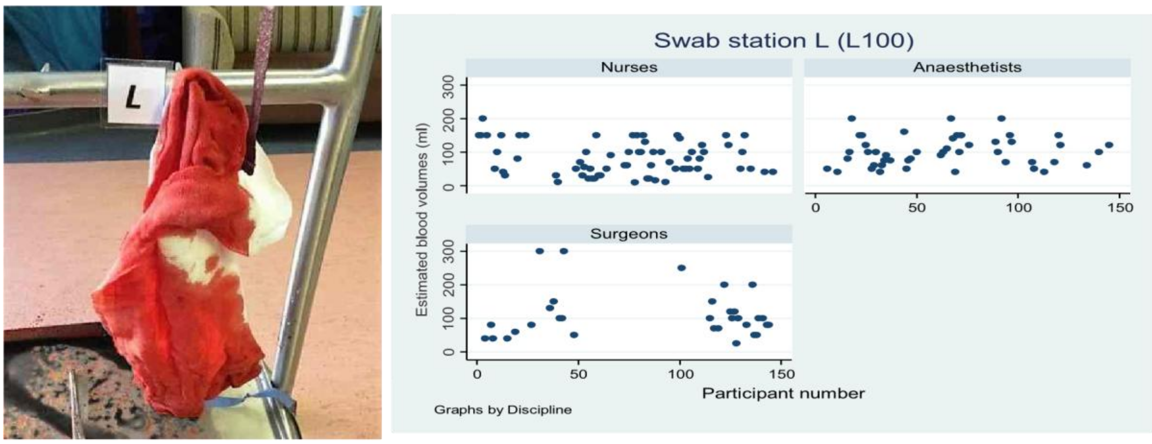

Figure 10.3 Swab station L (L100) and scattered plots of estimations