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Literature Review

Comparison of Visual Estimation of Intraoperative Blood Loss with Haemoglobin Estimation in Patients Undergoing Caesarean Section at Term

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Abstract

Background: Accurate assessment of intra-operative blood loss is an important aspect of peri-operative management of patients undergoing caesarean section and visual estimation is the most commonly used method and sometimes the only method available. Therefore, assessing the accuracy of visual estimation of blood loss compared to estimation using a point-of-care device such as the Hemocue is very relevant.

Aim and Objectives: This study compared intraoperative blood loss by visual estimation with blood loss calculated from haemoglobin (Hb) estimation using the HemoCue®201+ (AB Medical Inc Sweden).

Patients and Method: This was a prospective, double blind, non-randomized, controlled comparative study in which each patient acted as her own control. Sixty ASA physical status I or II pregnant patients at term undergoing elective caesarean section under spinal anaesthesia were enrolled into the study. In the theatre, the patients' Hb level was determined using the Hemocue prior to pre-loading with 10 ml/kg of normal saline. Spinal anaesthesia was induced in the sitting position with 2.5 ml of 0.5% hyperbaric bupivacaine. Intraoperatively, standard monitoring (Heart Rate, Blood Pressure, Respiratory Rate, Electrocardiography, peripheral oxygen saturation and temperature) was observed and recorded for each patient. At the end of skin closure, the Hb level was measured using the HemoCue and blood loss was visually estimated and documented. A modified Gross formula was used to calculate the blood loss. Blood loss was visually estimated by the researcher (anaesthetist) and then compared with the measured blood loss using HemoCue.

Results: A total of sixty patients participated in this study. The mean visual estimated blood loss and HemoCue calculated blood loss were 470 ± 221 ml and 563 ± 204 ml respectively with p-value = 0.125 (paired t-test). There was a positive correlation between both methods (r = 0.66, n = 60, p = 0.002) using Pearson's correlation. Agreement, according to Bland and Altman, indicated that the mean difference (bias) between both methods was +45 ml and discrepancy between the two methods widens when blood loss is more than 500 ml.

Conclusion: This study showed that visual estimation of intraoperative blood loss by the anesthetist did not differ significantly from Hemocue calculated blood loss during caesarean section. Visual estimation of blood loss by the anaesthetist is reliable and a useful skill especially in resource poor setting.

Keywords: *Visual Estimation; Intraoperative Blood Loss; Haemoglobin Estimation; Caesarean Section*

Introduction

Over the years, different methods have been used for the estimation of intraoperative blood loss which is an important aspect of peri-operative management of the surgical patient. Visual estimation has been the most commonly used method and sometimes the only method available for assessing intraoperative blood loss simply because it is easy, quick and convenient.

Accurate assessment of intra-operative blood loss is an important aspect of peri-operative management of patients undergoing caesarean section where blood loss is often dispersed and mixed with liquor [1]. Anaesthetists in developing countries may not have the luxury of point-of-care monitoring devices and may have to rely on visually estimated blood loss and other clinical acumen in making this decision [2]. An important step when reviewing transfusion practice is to see whether accurate assessment of blood loss is being done [3].

Several studies within sub Saharan Africa using visual estimations of blood loss in suction bottles, blood mixed with liquor in and around the operating field, counting of soaked abdominal packs and gauze reveal a high transfusion rate of up to 25.2% among women undergoing caesarean section and appreciable numbers were unnecessary transfusion [4-6]. Inaccurate blood loss estimation can lead to either over or under transfusion. Blood transfusion may be associated with adverse immunological transfusion reactions, transmission of infections, increased cost, increased peri-operative morbidity and mortality and delayed recovery from anaesthesia [7-9].

Accurate blood loss assessment minimizes the frequency of under or over transfusion of surgical patients [3]. Major haemorrhage, if left unattended to, continues to be one of the most common causes of direct maternal death in obstetric practice [10]. The anaesthetist has a role to play in the prevention and reduction of maternal mortality associated with intraoperative blood loss during caesarean section as advocated in the United Nation's Millennium Development Goals (MDG) [11].

The HemoCue is a useful medical device that can accurately determine a patient's haemoglobin level and therefore can be utilized for direct measurement of blood loss [12-14]. In 1974, Jan Lilja, a laboratory engineer, and Sven-Erik Nilsson, a computer expert, of the Kristianstad Hospital Clinical Laboratory began outlining an improved method for measuring hemoglobin, and by 1982 Leo diagnostics began selling and distributing the first hemoglobin photometers [13,14]. The Hemocue system has been in use since 1982 in the United State of America, however in 1999, it was later acquired by EQT, a private equity group in northern Europe which recorded an annual turnover exceeding $40 million USD in the same year [13]. The Confidential Enquiries into Maternal and Child Health of Great Britain recommends the perioperative use of HemoCue in aiding the management of maternal haemorrhage [15]. Therefore, assessing the accuracy of visual estimation of blood loss compared to estimation using a point-of-care device like the HemoCue will be very relevant in optimal obstetric care.

Materials and Methods

Study location

The study was carried out on pregnant women at term undergoing elective caesarean section at the University of Nigeria Teaching Hospital Enugu. It is a 700-bedded tertiary hospital located in South East Nigeria.

Ethical approval

Ethical clearance for the study was obtained from the Hospital Research and Ethics Committee (HREC) and informed written consent was also obtained from each patient recruited for the study.

After obtaining approval from the Hospital Research and Ethics Committee, and informed written consent from the patients, a total of 60 patients of American Society of Anesthesiologists (ASA) physical status I or II were enrolled into this double blind, prospective, non-randomized, controlled comparative study in which each patient acted as her own control.

Inclusion criteria

- Pregnant women at term presenting for elective caesarean section.
- ASA I or ASA II patients undergoing elective caesarean section.
- Patients for caesarean section under subarachnoid block.

Exclusion criteria

- Patient with pre-operative anaemia with haemoglobin ≤ 8 gm/L.
- Dehydrated patients.
- Patient at risk of massive intraoperative haemorrhage e.g. major placenta previa.
- Patients with severe co-morbidities e.g. severe cardio-respiratory disease, recent myocardial infarction and stroke.

Blinding

The researcher and the patients were not aware of the calculated blood loss using the HemoCue prior to the time of making visual estimate of intraoperative blood loss. However, the researcher had the responsibility to alert the attending physician whenever haemoglobin level falls ≤ 7 gm/L using the HemoCue.

All patients were seen and reviewed the evening before surgery. The patient's age, weight, indication for caesarean section, parity, and gestational age were taken and recorded. History was taken, general and systemic examination done and the patients were classified using the ASA physical health status. Routine investigations (haemoglobin concentration and urinalysis) were done and two units of blood were grouped and cross-matched for each patient. A written informed consent was obtained and patients were fasted for at least 6 hours for solids and at least 2 hours for clear fluids before the operation. Each patient received ranitidine 150 mg orally and metoclopramide 10 mg orally, the night before and on the morning of the surgery.

On the morning of surgery, the availability and functionality of the anaesthetic machine, endotracheal tubes, laryngoscopes, stilletes and suction machines were ascertained. Laryngeal mask airway, gum elastic bougie, face mask, and resuscitation drugs such as ephedrine, atropine and adrenaline were all made available in the theatre.

In the theatre, monitoring was done using a multi-parameter monitor (DASH 4000 Monitor; G.E Medical systems, USA) having electrocardiogram, pulse oximetry, Non-invasive blood pressure, and temperature monitors. The patient's baseline vital signs were taken and documented.

Intravenous access was secured using 16-guage cannula and patients were preloaded with warm normal saline (10 ml/kg) using a volumetric infusion pump (IVAC 560, San Diego, CA, USA). The patients' preoperative laboratory haemoglobin was documented and the preoperative haemoglobin (h_i) obtained prior to preloading and after preloading (h_p) using the HemoCue was also documented.

After preloading with normal saline (10 ml/kg), the patients were placed in the sitting position, while the anaesthetist scrubbed and put on sterile gown and gloves. The lumbar region was then cleaned and draped and L3 - L4 interspace identified using the iliac spines as landmarks. The skin, subcutaneous tissue and interspinous ligament were infiltrated with 2 ml of 2% lignocaine. Using a 25G pencil point (Whitacre) spinal needle passed through a 21G hypodermic needle as an introducer, the subarachnoid space was located and with drainage of clear cerebrospinal fluid 2.5 ml of 0.5% hyperbaric bupivacaine was administered into the subarachnoid space.

After injecting the hyperbaric bupivacaine into the subarachnoid space the punctured site was covered with sterile dressing and the patients were slowly returned back to the supine position with head and shoulders supported on a pillow and with a 15 degree left lateral tilt using a wedge. The vital signs were measured and recorded immediately after the spinal technique. The level of the sensory block was assessed using cotton wool soaked in alcohol until a block height of T4 - T6 was achieved, after which surgery was allowed to proceed.

Maternal vital signs and oxygen saturation were monitored at 5 minute intervals. Intravenous fluids for these patients was restricted to the initial preload (10 ml/kg) and the maintenance fluid administered to the patients using 10 ml/kg in the first one hour and 5 ml/kg in the subsequent hour and this was delivered with the aid of the infusion pump.

The blood pressure was maintained within 25% of baseline with 3 mg boluses of ephedrine when indicated. Urine output was monitored via urethral catheterization to assess fluid maintenance and adequate tissue perfusion. Total urine output was recorded for all the patients.

After skin closure the researcher visually estimated the blood loss and documented it as vf and this was followed by haemoglobin estimation by the researcher using HemoCue which was also documented as hf. The Researcher estimated the blood loss by counting the blood soaked abdominal mops and gauze pieces and multiplying them by the estimated volume of blood each would hold; fixed size mops and gauze were used. A fully soaked and dripping abdominal swab (10 × 10 inches) was taken as containing 100 ml of blood while a piece of gauze (4 × 4 inches) was assumed to contain 10ml of blood, while blood lost to suction bottles and that lost in and around the operating field mixed with liquor were estimated before and after suctioning of the liquor.

At the delivery of the foetus, intravenous oxytocin 5 IU bolus was given and an infusion of 30 IU of oxytocin in 500 ml of normal saline was administered to help maintain uterine contraction. Neonatal outcome was documented after assessment was done using Apgar score at 1 and 5 minute intervals.

The total blood loss and the duration of surgery were documented in the data collection form. At the end of the surgery, patients were taken to the recovery room and post-operative vital signs, fluid input and output were monitored and documented. In the recovery room, post-operative pain was managed using intravenous tramadol 1 mg/kg stat and intravenous ketorolac 0.5 mg/kg stat. Thereafter, pain relief was maintained according to the departmental protocol.

The blood samples for HemoCue estimation were taken from a skin prick on the thumb of the non-cannulated arm. All capillary samples were taken by the researcher. The capillary samples were taken strictly according to the manufacturer's recommendation, which includes choosing a suitable digit for sampling, making a skin puncture that will allow a ladybird size drop of blood to be expelled, drawing up the blood sample with the cuvette ensuring that the entire chamber is filled (not only the circular section) and wiping off the excess on absorbent material taking care not to siphon out the content. This sample was then placed into the HemoCue®201+ (AB Medical Inc, Angelholm. Sweden) device and the results were displayed on the screen in less than a minute. The visually estimated blood loss and time were noted.

Other information on the perioperative events including the visually estimated and HemoCue estimated blood loss was documented on a data collection form (See Appendix I). The actual blood loss was calculated from a modification of the Gross formula given below [74].

Haematocrit (Hct) derived from HemoCue = 2.953 × Hb g/dl [64,75].

$$ABL = \frac{BV\ (Hct_{(i)} - Hct_{(f)})}{Hct_{(m)}}$$

Where ABL= Actual blood loss

BV= is the blood volume calculated from the patient weight in Kg (65ml/Kg) [72].

$Hct_{(i)}$ = haematocrit initial

$Hct_{(f)}$ = haematocrit final

$Hct_{(m)}$ = the mean of the initial and final haematocrits

$$\text{Calculated blood loss using HemoCue} = \frac{BV\ (2.953 \times h_i - 2.953 \times h_f)}{2.953 \times h_m}$$

The visually estimated blood loss was designated as estimated blood loss (EBL) while the blood loss calculated from the HemoCue haemoglobin was designated as actual blood loss (ABL). The average blood loss (AVG-BL) was derived from each patient which was the mean of the actual and estimated blood loss.

Statistical analysis

Statistical Package for Social Sciences version 17.0 was used for data entry and statistical analysis. The mean, standard deviation and range were used to analyze basic demographics.

To compare blood loss assessment using visual estimation and the HemoCue test, paired t-test, Pearson's correlation and the Bland and Altman's method of assessing agreement between two methods of clinical measurement were used [76]. The Bland and Altman statistical test compares two methods of clinical measurement by plotting the difference between the two values obtained by each method against the "actual" value estimated by calculating the mean of the two values. A large difference between the two methods (mean difference) represents "bias" of one method over the other.

Result

A total of 60 parturient for elective caesarean section were recruited for this study. The ages of the parturient were between 21 - 37 years with a mean of 27.66 ± 3.13 years, their mean body weights ranged from 62 - 95 kg with a mean of 80.22 ± 5.77 kg (Table 1). The indications for caesarean section as seen in figure 1 included; cephalo-pelvic disproportion (33.33%), post datism (25%), breech presentation (8.33%), maternal request (8.33%), mal-position/mal-presentation (16.67%), oligohydramnios (8.33%). A total of 50 patients were ASA class I while the remaining 10 patients were ASA class II (Figure 2).

Variables	Mean ± SD	Range
Age (years)	27.66 ± 3.13	21 - 37
Weight (Kg)	80.22 ± 5.77	62 - 95
Gestational age (weeks)	38.43 ±1.44	37 - 41
Parity Nulliparous Multiparous Grand multiparous	 45 (75%) 15 (25%) 0 (0%)	1 - 4

***Table 1**: Demographic characteristics.*

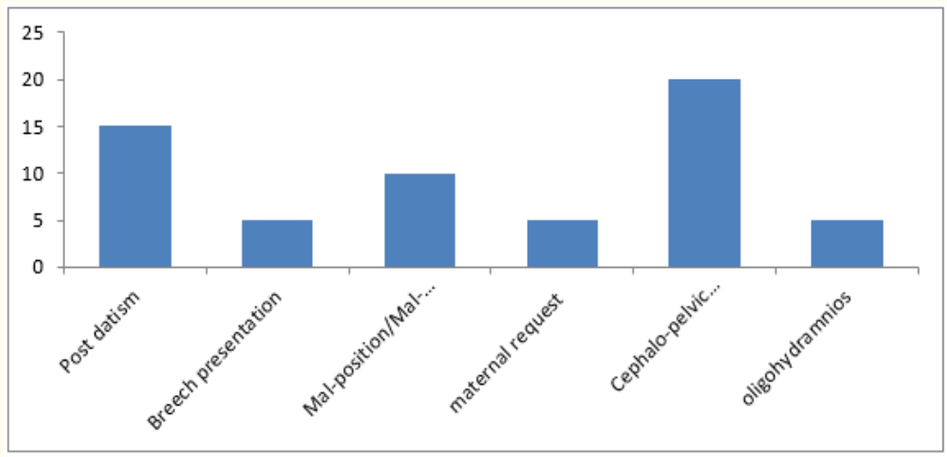

Figure 1: *Indications for caesarean section.*

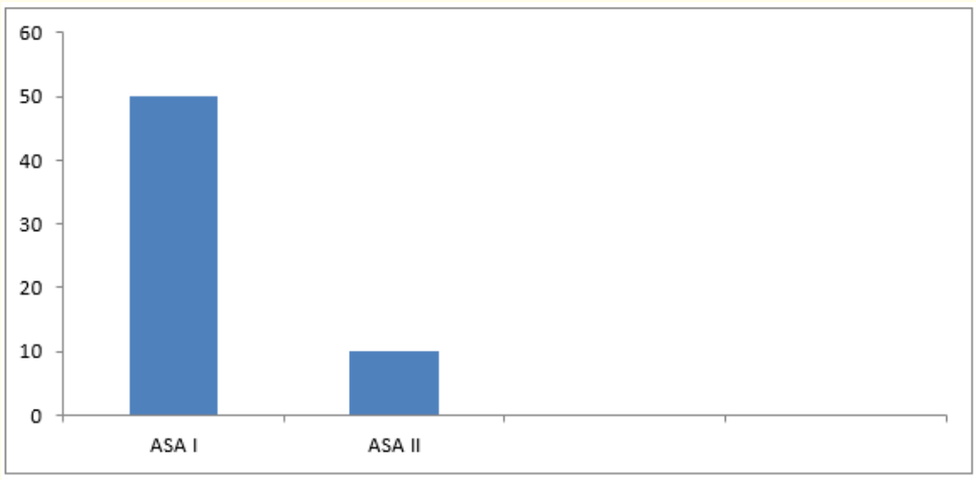

Figure 2: *Distribution of patients by ASA classification.*

The duration of surgery varied between 60 - 90 minutes with a mean of 75.22 ± 7.22 minutes. The total volume of fluid given to the patients ranged from 1200 - 1850 ml with a mean of 1555.44 ± 113.13 ml (Table 2). The relationship between laboratory haemoglobin concentration of the patients' using an auto-analyzer (GEM premier 3000) and that of Hemocue haemoglobin concentration was determined using Pearson's correlation (p = .0001, n = 60, r = 0.89) (Figure 3). This result suggests that Hemocue has a high accuracy with correlation of 0.89 when compared with a reference method (automated hematology analyzer) (Figure 3). Further comparison of the values obtained from the two methods of haemoglobin estimation was done using a paired t- test and no significant difference was observed (p value = 0.07) as seen in table 3.

Variables	Range	Mean	±SD
Volume of preload (ml)	620 - 950	850.67	± 110.21
Duration of preload (minutes)	10 - 20	14.25	± 2.08
Total volume of fluid given (ml)	1200 - 1850	1555.44	± 113.13
Duration of surgery (minutes)	60 - 90	75.22	± 7.22
Urine Output (ml)	150 - 350	170.45	± 30.45

Table 2*: Time, duration and volume of fluid given.*

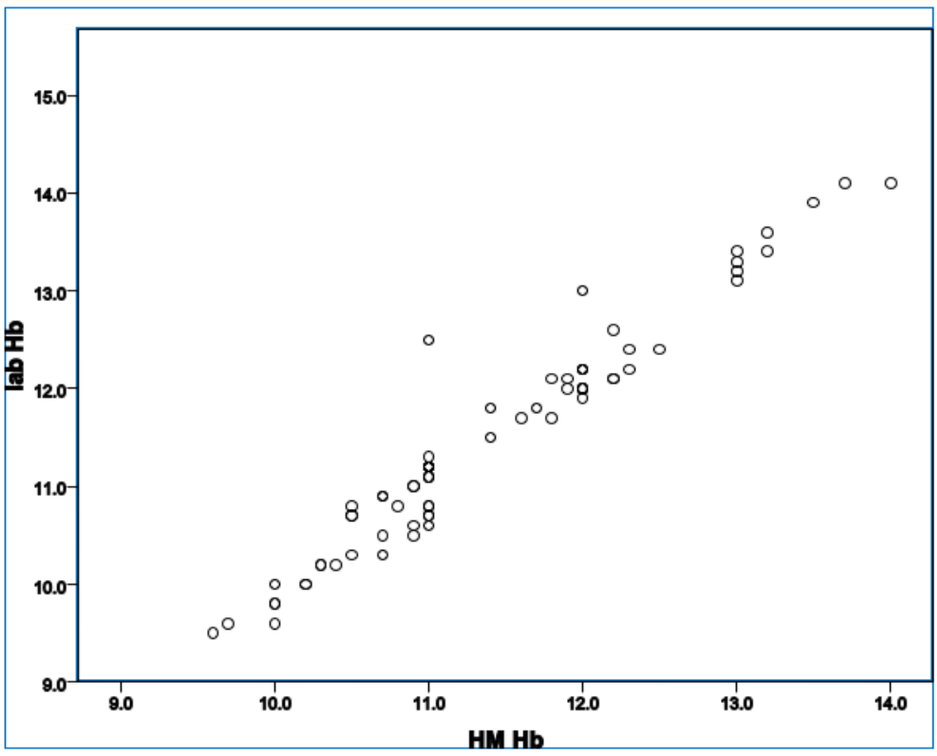

Figure 3: *A simple scatter plot of Laboratory (lab) Hb and Hemocue (HM) Hb.*

	Range	Mean ± SD	P-value	95% CI of the difference	
Laboratory Haemoglobin (g/dl)	9.5 - 14.1	11.47 ± 1.14		Lower	Upper
				0.0021	0.1424
Hemocue Haemoglobin (g/dl)	9.6 - 14.0	11.40 ± 1.01	0.07		

Table 3: *Comparison of laboratory Haemoglobin versus Hemocue haemoglobin.*

Level of significance ≤ 0.05.

The patients' mean haemoglobin using Hemocue before preloading with 10 ml/kg of normal saline over 10 - 20 minutes was 11.36 ± 0.77g/dl, and after preloading was 11.23 ± 1.15g/dl. There was a slight drop in the mean haemoglobin level but the drop was not significant (p value = 0.14, paired t-test) as seen in table 4.

The mean visual estimated blood loss for caesarean section was 470.32 ± 221.66 ml with a range of 200 - 1100 ml while the mean calculated blood loss (CBL) using HemoCue was 563.47 ± 203.53 ml with a range of 180.7 - 1074.5 ml. Visual estimation was less than Hemocue calculated blood loss (underestimation). The difference between visually estimated blood loss and calculated blood loss was not significant with a p value of 0.125 (paired t-test) (Table 5).

A Pearson product-moment correlation coefficient was computed to assess the relationship between estimated blood loss and calculated blood loss using Hemocue. There was a positive correlation between both methods (r = 0.66, n = 60, p = 0.002). A scatter plot summarizes the results (Figure 4). Overall, there was a reasonable, positive correlation between visually estimated blood loss and Hemocue calculated blood loss.

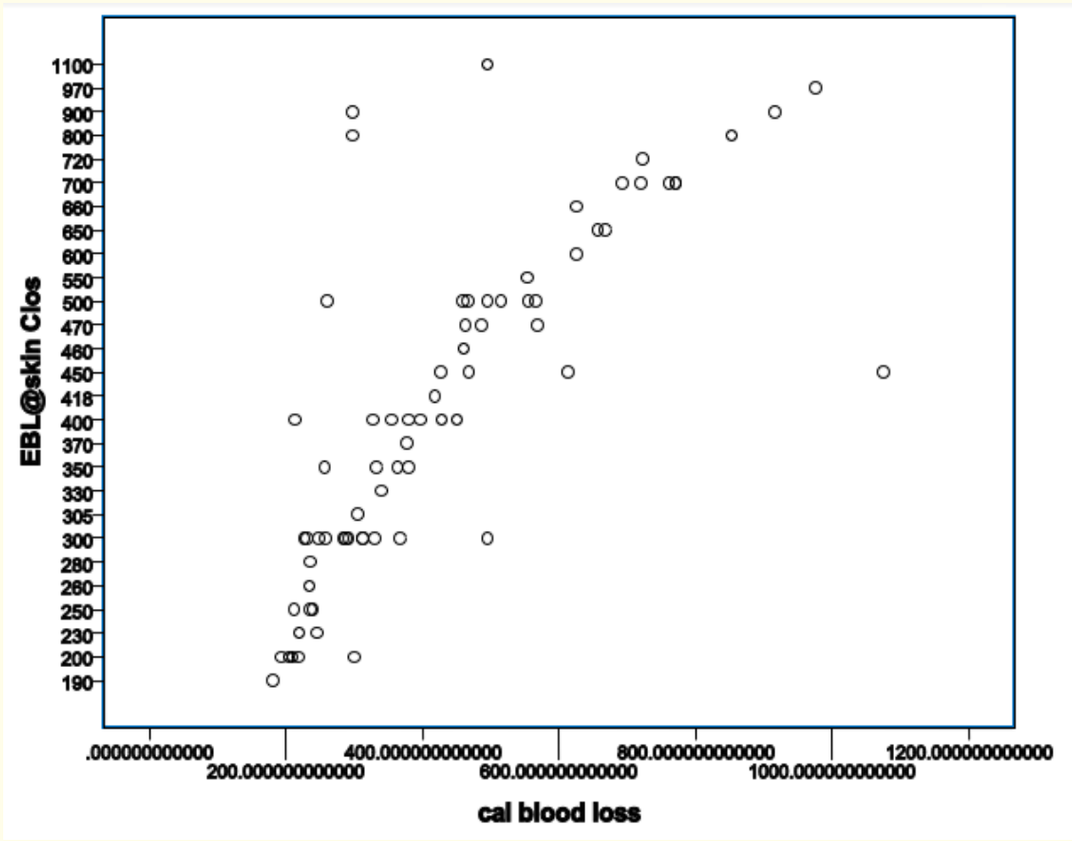

Figure 4: *A simple scatter plot of EBL and CBL.*

	Range	Mean ± SD	P-value	95% CI of the difference	
Haemoglobin before preload (g/dl)	10.0 - 12.7	11.36 ± 0.77		Lower	Upper
				0.9060	1.1514
Haemoglobin after preload (g/dl)	9.8 - 12.3	11.23 ± 1.15	0.14		

Table 4: *Effect of preload on the mean Haemoglobin using Hemocue.*

Level of significance ≤ 0.05.

Blood loss during caesarean section	Range	Mean ± SD	p-value	95% CI of the difference
Visually estimated blood loss at skin closure (ml)	200- 1100	470.32 ± 221.66		-13.65 - 102.34
HemoCue calculated blood loss at skin closure (ml)	180.7 - 1074.5	563.47 ± 203.53	0.125	

Table 5: *Visual estimated blood loss and HemoCue calculated blood loss for Caesarean Section.*

Further analysis was done using Bland and Altman statistical test. Estimated blood loss and calculated blood loss were used to determine the difference in blood loss (DIFF-BL). The average blood loss (derived from the mean of both methods of estimation) was 456.22 ± 177.46 ml (Table 6). The bias (mean difference between both methods) was negligible (+45.25 ml) and the limit of agreement (mean difference ± 2SD) between both methods was -222.20 - 275.43 ml (Table 6). The bias and limit of agreement between both methods of assessing blood loss was small and not significant enough to cause error in clinical judgment in this group of patients.

Parameter	Range	Mean ± SD	Standard error of mean	Limit of agreement (mean ± 2SD)
DIFF-BL (ml)	-624.5 - +781.6	+45.25 ± 116.16	27.55	-222.20 - 275.43
Average blood loss (ml)	202.06 - 911.58	456.22 177.46	20.44	

Table 6: *Measurement of agreement between both methods.*

To obtain the Bland-Altman plot, the difference in blood loss was plotted on the Y-axis with the average blood loss on the X-axis (Figure 5). From the plot it was observed that at average blood loss between 200 - 500 ml, the values were around the "0" point on the Y-axis which connotes good level of agreement between both methods of determining intraoperative blood loss but this scatters further away around the "0" point at average blood loss of > 500 ml which implies that as blood loss increases above 500 ml the error margin between visually estimated blood loss and Hemocue calculated blood loss widens.

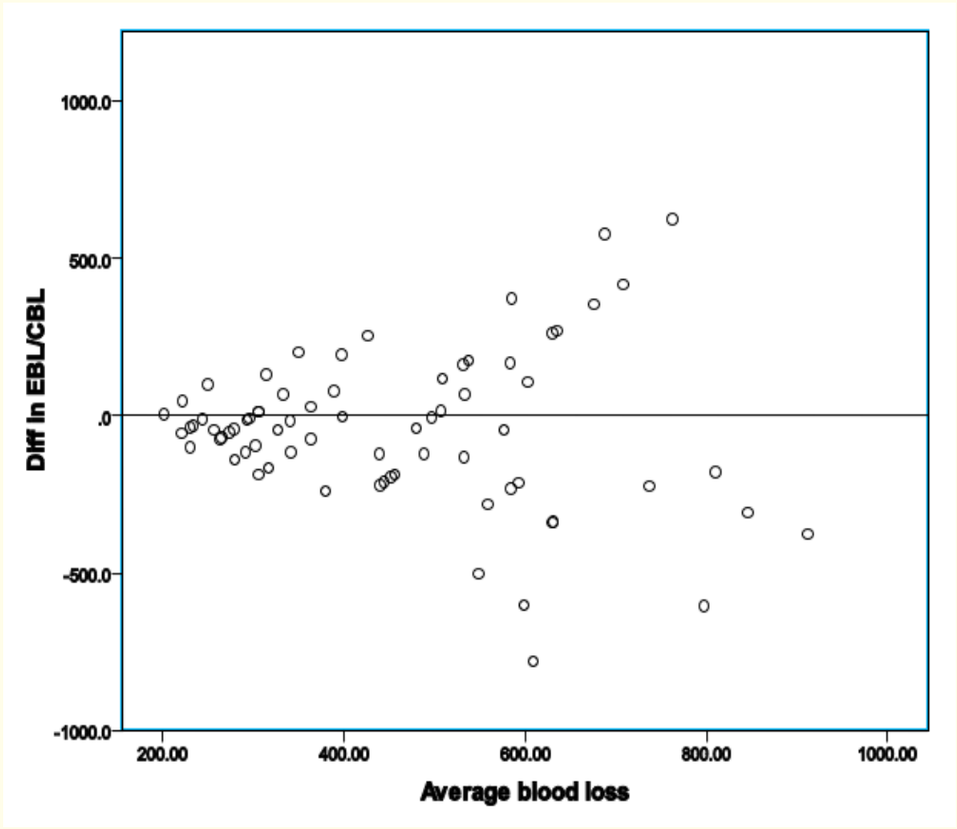

Figure 5: *Bland and Altman plot.*

The patients' vital signs trends during the surgery are reflected in figures 6-8. Systolic blood pressure decreased significantly by 16 mmHg (p = 0.001, paired t- test) while diastolic pressure decreased by 10 mmHg (p = 0.015, paired t-test) in the first 10 minutes of spinal anaesthesia, subsequently, there was a gradual rise in the systolic and diastolic pressure. In 33% (20) of the parturient, hypotension was managed with 3mg aliquots of ephedrine. No significant change in the pulse rate (p = 0.086, paired t-test) and the respiratory rate (p = 0.776, paired t-test) were observed.

Neonatal outcome was good with Apgar score in the range of 7 - 9 in 1 and 5 minute interval (Table 7).

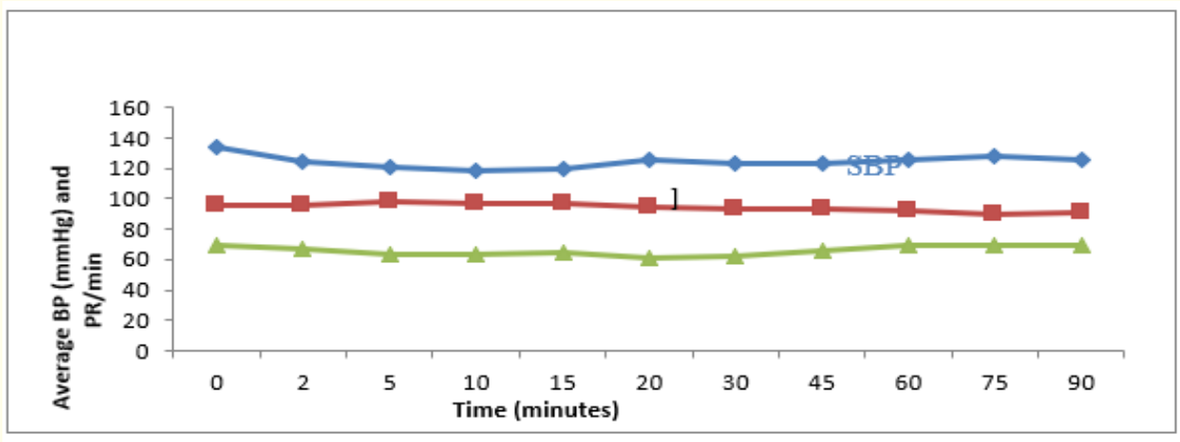

Figure 6: *Trends of haemodynamic parameters.*

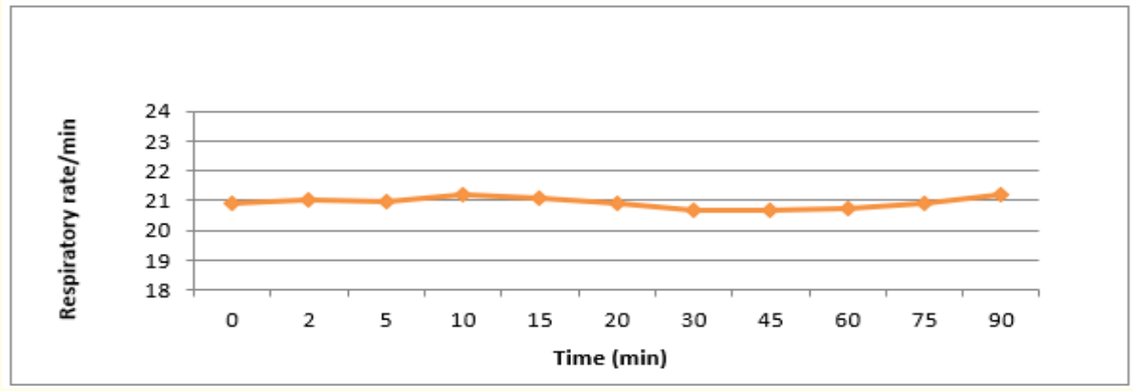

Figure 7: *Trend of Respiratory rate.*

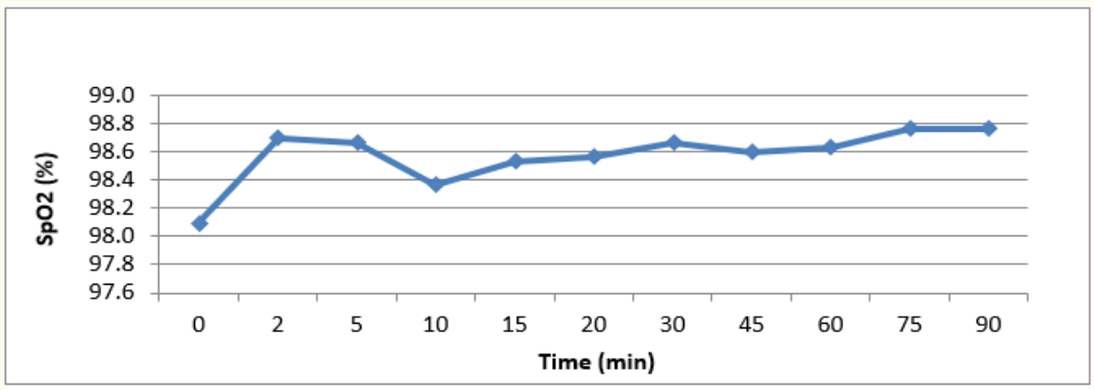

Figure 8: *Trend of SpO_2.*

Parameter	Range	Mean (SD)
Neonatal weight (kg)	2.5 - 5.5	3.08 ± 0.568
Apgar score		
1 minute	7 - 9	
5 minutes	7 - 9	

***Table 7**: Neonatal outcome.*

Discussion and Conclusion

The study revealed that visual estimation was found to be less than Hemocue calculated blood loss. However, visual estimation of intraoperative blood loss by the anaesthetist did not significantly differ from Hemocue calculated blood loss. The average blood loss using visual estimation in this study was 470 ± 221 ml with a range of 200 - 1100 ml. This finding agrees with the results of previous studies done by Duthie., *et al*. [26] and Fauzia., *et al*. [27], Duthie., *et al*. [26] in their study, observed a mean estimated blood loss of 425 ml with a range of 100 - 1300 ml during caesarean section.

In the same way, Fauzia., *et al*. [27] in their work observed that the average blood loss estimated by anaesthetist was 498 ± 176 ml while visually estimated blood loss by obstetrician was 592 ± 222 ml. In their study, the estimated blood loss by the anaesthetists were surprisingly lower than those of the obstetricians in contrast to the general belief that anaesthetists often tend to 'overestimate' blood loss [37]. Their study included both elective and emergency caesarean sections, however, the estimated blood loss by the anaesthetists corroborated with the index study which implies that there is no significant difference in blood loss during elective or emergency caesarean section [23-25].

Furthermore, Ashraf., *et al.* [23] in a study to assess blood loss during caesarean section observed that visually estimated blood loss by nurses, obstetricians and anaesthetists was within the range of 350 - 1000 ml. In their study, the anaesthetists gave the closest estimation of blood loss (mean EBL = 560 ml) when it was compared with the results obtained by weighing of swabs.

In contrast, Imarengaiye., *et al*. [77] and Oluwarotimi., *et al*. [78] in separate studies observed the mean estimated blood loss during caesarean section to be as high as 1310.8 ± 991.8 ml and 848.3 ± 736.2 ml respectively. Interestingly, both studies were retrospective in nature and were focused on evaluating blood reservation and utilization policy during caesarean section and also included patients who received intraoperative blood transfusion. This was in contrast with the index study which was a prospective study, where patients who received intraoperative blood transfusion or whose haemoglobin level dropped to ≤ 7 g/dl were excluded.

Furthermore, several anaesthetists were involved in estimating blood loss in the above studies compared to a single anaesthetist in this index study and this could have led to inter-observer bias. The researcher (anaesthetist) in the index study was solely responsible for visual estimation of blood loss so as to eliminate inter-observer variability.

There is paucity of report on the use of Hemocue in determining intraoperative blood loss during caesarean section globally. In this study, the HemoCue calculated blood loss was 563 ± 207 ml with a wide range of 181 - 1075 ml. The result is in tandem with previous work done using laboratory haematocrit values (model not reported), where the measured blood loss was within the range of 66 - 1290 ml during caesarean section with a mean of 627 ml [23].

Duthie., *et al*. [26] in a different study carried out to measure blood loss during caesarean section, reported a mean blood loss of 487 ml with a range of 164 - 1438 ml. However, the measured blood loss was done using alkaline hematin method which is different from the technique adopted in the current study. A review of articles on various methods of measuring blood loss revealed that only few published studies have quantified blood loss with acid or alkaline hematin, and there are none in developing countries [22].

In another study done to measure blood loss during caesarean section using patients' laboratory haemoglobin (model not reported), an average blood loss of 787 ± 519 ml was observed [27]. The methodology in the above study differed significantly from the index study as the final Hb check was done 48 hours after surgery and some of the patients who had received blood transfusion in the immediate post-operative period were included in the study and these could account for the discrepancy in their outcome compared to the index study.

In addition, two previous studies done by Ramadani., *et al*. [20] and Gol., *et al.* [25] using gravimetric method to measure blood loss during caesarean section revealed a mean blood loss of 669 ml and 626 ml respectively. The slight increase in their values compared to the index study could be attributed to the different methods of assessment employed by the investigators and the inclusion of patients undergoing general anaesthesia. It is well documented that measured blood loss varies with the method of assessing blood loss and there

There was no significant difference between the mean visual estimated blood loss and the mean HemoCue calculated blood loss (p = 0.125, paired t-test). The relationship between both methods of estimating blood loss was assessed using Pearson's correlation and the result showed a high correlation between both methods (r = 0.66). This finding agrees with the study done by Laarson., *et al.* [33] where he observed moderate correlation (r = 0.55) between estimated and measured blood loss in caesarean section. Similarly, Budny., *et al.* [40] in their work, established a strong positive association between calculated blood loss and visually EBL

In contrast, Naveen., *et al.* [34] compared visually EBL with laboratory calculated blood loss and found poor correlation between both methods with interclass correlation coefficient of 0.34. Their study was done on general surgery patients, neurosurgical and orthopaedic patients. In addition, more than one anaesthetist was responsible for estimation of blood loss and this could account for the disparity in their result compared to the index study.

Similarly, Abbasi., *et al.* [35] in their work reported poor correlation between visual EBL and haematocrit CBL in supratentorial craniotomy with a regression coefficient of 0.38. Their study was conducted on neurosurgery patients whose procedure lasted between 2 - 6 hours, with an average blood loss of 945 ml. The large blood loss associated with supratentorial craniotomy could account for the poor correlation between both methods as visually estimated blood loss becomes more inaccurate as blood loss increases. In addition, the use of irrigation fluid during craniotomy could also contribute to error in their estimation of blood loss.

However, the interpretation of test of significance and correlation coefficient when comparing two methods could be misleading as data which seem to be poor in agreement can produce quite high correlations [76]. Therefore, further analysis to measure the degree of agreement between both methods of clinical measurement recommended by Bland and Altman was also employed. The result showed good agreement between the two methods of assessing blood loss with a bias of + 45.25 ml. The level of agreement was better at blood loss of between 200 - 500 ml. At blood loss > 500 ml the difference between both method was between 500 - 750 ml which was too wide and represent an unacceptable margin if it should be solely relied upon for clinical judgment.

These findings corroborates with previous studies where blood loss was visually estimated with reasonable accuracy among anaesthetists and the error in clinically estimated blood loss was typically higher if the measured blood loss was more than 600 ml [31,38]. Similarly, Kavle., et al. [38] in their study found visual estimation of blood loss by Zanzibari nurse-midwives to be accurate when compared to laboratory CBL with a mean difference of 5 ml. In the above study, the mean difference increased to 62 ml when blood loss > 200 ml, a pattern that was in keeping with the finding in this index study. Furthermore, Glover, in his study had reported greater error in the estimation of larger blood losses by health professionals which was also in keeping with this study [39].

In this research, the patients' laboratory haemoglobin and Hemocue haemoglobin were compared and a high correlation was observed (r = 0.89). The observation was in keeping with several other studies which suggested that Hemocue is an accurate device in assessment of haemoglobin in obstetric patients [58,60,79]. Fabian Sanchis-Gomer., et al. [58] in their study compared HemoCue Hb 201 system with the reference method according to International Council For Standardization In Haematology (ICSH) and found a correlation of 0.99. This result reflects a near perfect relationship between both methods and further validates the accuracy of Hemocue in assessing haemoglobin level in obstetric patients.

In addition, no significant change in patients' haemoglobin level before and after preloading with normal saline was noted (p = 0.14). The result aligns with the study done by Swensen and Hahn where they observed that the associated changes in blood volume and packed cell volume are very transient and insignificant when volumes of 10 - 20 ml/kg are administered as a single loading dose as seen during caesarean section [70]. In another study corroborating the above finding, 2 - 3 litres of isotonic solution were given during caesarean section and no effect of haemodilution appeared on haematocrit levels [71].

In contrast, in another study, it was observed that hypotension was followed by increased haemodilution after a delay of as much as 15 minutes [69]. However, the study was conducted on male patients undergoing short urological procedures under epidural anaesthesia, and the difference in their patient selection and the use of extradural anaesthesia may account for the disparity in their findings.

In the index study, the total volume of fluid given to the patients was between 1200 - 1850 ml, as fluid administration was restricted to preload and fluid maintenance and intraoperative hypotension was managed with 3 mg boluses of ephedrine to minimize haemodilution from excessive fluid administration. Most of the episodes of hypotension occurred in the initial 10 minutes after subarachnoid block. 20 patients received vasopressor (ephedrine) for management of hypotension.

Caesarean section is known to be associated with varying degrees of blood loss assessed by diverse methods such as gravimetry, colorimetry, radioisotope tagging of red cells, and photometry . However, visual estimation in this study was found to be reasonably accurate with marginal error, and a greater imprecision was found with higher losses of greater than 500ml.

In conclusion, visually estimated blood loss was closely related to HemoCue calculated blood loss, and even though visually estimated blood loss was less than Hemocue calculated blood loss the margin was not significant and couldn't have led to error in clinical judgment such as over transfusion or unrecognized massive maternal haemorrhage.

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Volume 6 Issue 11 November 2020