Assessing Accuracy of Blood Loss Measurements During Cesarean Birth in a Diverse Patient Population: A Quality Improvement Study

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ABSTRACT

Background: Accurate measurement of blood loss during delivery is important for early hemorrhage detection.

Methods: We compared quantitative blood loss and estimated blood loss to calculated blood loss. We reviewed cesarean deliveries for estimated blood loss and quantitative blood loss, December 1, 2018, to December 1, 2019. A standard formula was used for calculated blood loss.

Results: Overall (n = 483), median values (m; interquartile range [IQR]) for estimated blood loss (600.0 mL; IQR 500.0–800.0) and quantitative blood loss (557.0 mL; IQR 350.0 – 824.0) were significantly lower (both *P* values < 0.001) than calculated blood loss (929.4 mL; IQR 551.5 – 1351.5). Compared to calculated blood loss, both estimated blood loss and quantitative blood loss had low sensitivity, high specificity, and low negative predictive values. Only 10 additional patients were identified as having a postpartum hemorrhage through quantitative blood loss.

Discussion: Quantitative blood loss and estimated blood loss are immediately available in clinical practice, while calculated blood loss is not and requires additional time to obtain. All methods currently available have shortcomings. Continued efforts to create a reliable tool for identifying blood loss are needed.

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BACKGROUND

Postpartum hemorrhage accounts for approximately 16% of maternal-related deaths in developed countries.[1] Measuring blood loss during and after birth for early detection of hemorrhage to prevent maternal morbidity and mortality is standard of care, and efforts are being made to improve measurement accuracy.[1] Historically, the most common way of measuring blood loss was through visual estimated blood loss. However, estimated blood loss overestimates[2] or underestimates[3,4] blood loss compared to gravimetric and colorimetric methods. More recently, maternal and obstetric committees have recommended quantitative blood loss methods. Some studies have reported quantitative blood loss to be more accurate than visual estimation,[5,6] yet others have found no statistically significant difference between quantitative blood loss and estimated blood loss.[7,8] Additionally, quantitative and estimated blood loss have been found to comparably predict the need for blood transfusion.[8]

In November 2018, our Wisconsin-based hospital started using quantitative blood loss for measuring blood loss in a diverse patient population. The primary objective of this quality improvement study was to compare the accuracy of quantitative and estimated blood loss during cesarean delivery to calculated blood loss, a patient-specific tool to measure blood loss that is not in standard use. Secondarily, we aimed to determine the sensitivity and specificity of estimated and quantitative blood loss compared to calculated blood loss for predicting hemorrhage.

METHODS

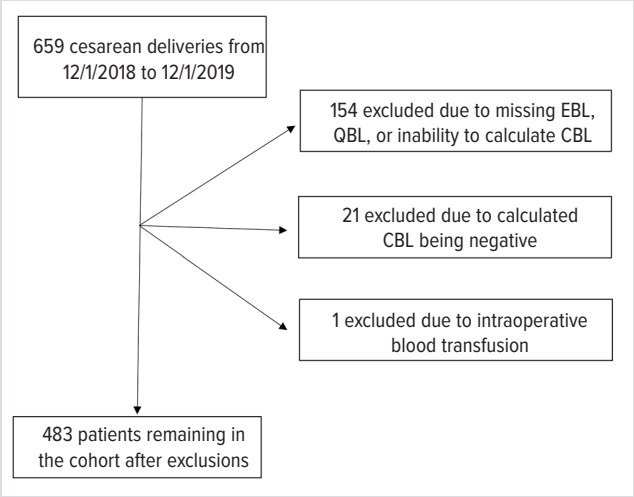
We retrospectively reviewed all pregnant patients who underwent a cesarean delivery at a mid-size, urban academic medical cen-

Table 1. Overall Demographic and Delivery Characteristics and Outcomes (n = 483)

Characteristics and Outcomes	
Age, years, median (IQR)	29.1 (24.5–33.0)
Race/ethnicity, n (%)	
Asian, non-Hispanic	38 (7.9)
Black, non-Hispanic	277 (57.3)
Hispanic	66 (13.7)
Pacific Islander, non-Hispanic	6 (1.2)
White, non-Hispanic	93 (19.3)
Other, non-Hispanic[a]	2 (0.4)
Body mass index, kg/m^2, median (IQR)	34.6 (29.8 – 40.9)
Gestational hypertension, n (%)	184 (38.1)
Multiple gestations this pregnancy, n (%)	22 (4.6)
Administration of uterotonic medications, n (%)	78 (16.1)
Number of uterotonic medications, median (IQR)	1.0 (1.0 – 2.0)
Initiation of massive transfusion, n (%)	1 (0.2)
Transfusion of blood products, n (%)	21 (4.3)
Length of hospital stay, days, median (IQR)	3.4 (2.9 – 4.4)
Post-delivery complications, n (%)	19 (3.9)
Acute kidney injury	3 (15.8)
Chorioamnionitis/endometritis	14 (73.7)
ICU admission for acute respiratory distress syndrome	1 (5.3)
Pulmonary edema	1 (5.3)
Maternal death, n (%)	0 (0.0)
Redosing of prophylactic antibiotics secondary to intraoperative blood loss, n (%)	2 (0.4)
Extended monitoring with higher level nursing care secondary to blood loss, n (%)	24 (5.0)

Abbreviations: IQR, interquartile range; ICU, intensive care unit.
[a]Other race/ethnicity includes 'unknown' and 'mixed race' as defined in our electronic medical record.

Figure 1. Flowchart for Inclusion in Final Cohort



Abbreviations: EBL estimated blood loss; QBL, quantitative blood loss; CBL, calculated blood loss.

ter in Wisconsin from December 1, 2018 to December 1, 2019. The study was determined not human subjects research by our Institutional Review Board.

Patients were included if both quantitative and estimated blood loss values were recorded. Estimated blood loss was obtained from the anesthesia log or the operative note. If estimated blood loss in the operative note did not match the anesthesia log, the study team collected the value documented by the anesthesia team, as their estimate also was based on intraoperative vital sign measurements in addition to real-time communication with the surgery team. If it was not documented in the anesthesia log, the value for estimated blood loss from the operative note was collected. Quantitative blood loss was recorded and collected from nursing flowsheets and was obtained by weighing all blood-soiled lap pads, surgical sponges, and Chux pads and subtracting their dry weight and the volume of any fluid used for irrigation. Additionally, the volume of all suction canisters was included in the calculation. Per institutional practice, only the blood suctioned after delivery of the placenta was included to exclude the volume of amniotic fluid. Hemorrhage was defined as blood loss ≥ 1000 mL.[1] We also documented the number of uterotonics used, if any, in addition to the institutional standard 30 units of oxytocin postdelivery, including additional oxytocin (beyond standard administration), misoprostol, methylergonovine, and/or 15-methyl prostaglandin F2. Postdelivery complications also were documented and defined as infection (chorioamnionitis/endometritis), acute kidney injury, pulmonary edema, acute respiratory distress syndrome, and intensive care unit admission.

To address the primary objective, patients were further excluded from the study if calculated blood loss could not be determined, if the calculation was negative, or if they received an intraoperative blood transfusion, as it would affect accuracy of the calculated blood loss. If a patient received a postoperative blood transfusion after their blood was drawn, they remained in the analysis using the hematocrit obtained prior to transfusion. Admission hemoglobin and hematocrit were used for predelivery values, unless additional hemoglobin and hematocrits were collected prior to delivery, in which case the one drawn closest to the time of delivery was used. Postdelivery hemoglobin and hematocrit were used for postdelivery values and were taken closest to the time of discharge. Use of the hemoglobin and hematocrit closest to time of discharge is considered more reflective of blood loss given the time it takes for the hemoglobin and hematocrit to equilibrate after surgery.[6] Ultimately, to determine calculated blood loss (CBL), the following formula by Stafford et al[4] was used:

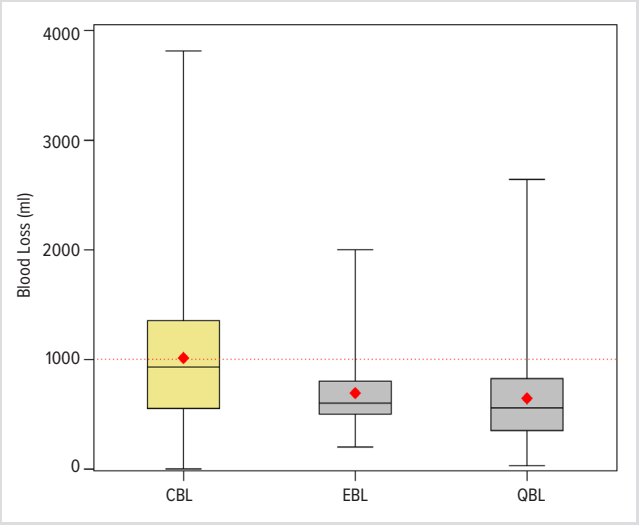
CBL = calculated blood volume x percent of blood volume lost

To determine calculated blood volume (CBV), this formula was used: CBV = 0.75 x ([maternal height (inches) x 50] + [maternal weight (pounds) x 25])

To determine percent of blood volume (%BV) lost, this formula was used: %BV lost = ([predelivery hematocrit – postdelivery hematocrit]/predelivery hematocrit)

Data were collected from the electronic medical record and

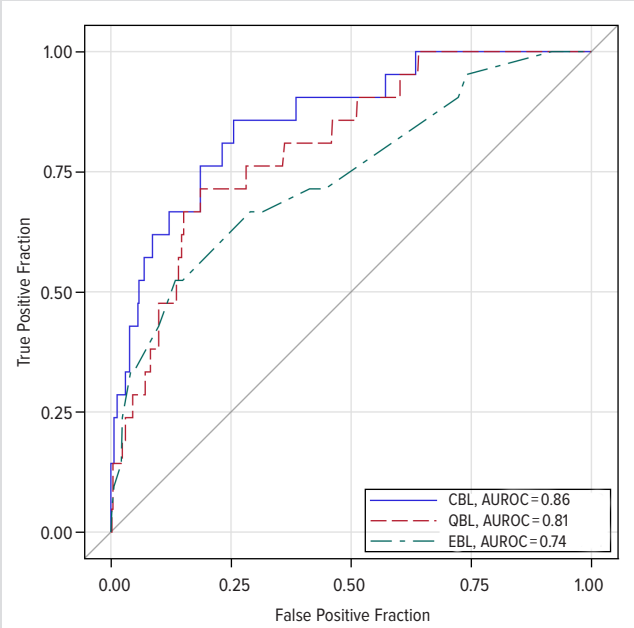
Figure 2. Box-and-Whisker Plots of the Distribution of Blood Loss Values



Abbreviations: EBL estimated blood loss; QBL, quantitative blood loss; CBL, calculated blood loss.

Median is indicated by the solid black line and mean by the red diamond. Dotted red line is set at a blood loss value of 1000 ml where 1000 ml and above indicates a hemorrhage. CBL is color-filled gold as it is considered the gold standard.

Figure 3. Receiver Operating Characteristic Curves of Blood Loss Methods Ability to Predict Blood Transfusion Need



Abbreviations: EBL estimated blood loss; QBL, quantitative blood loss; CBL, calculated blood loss; AUROC, Area Under Receiver Operating Characteristic.

Comparison of EBL, QBL, and CBLs ability to predict need for blood transfusion using estimated AUROC.

recorded in REDCap. Descriptive statistics, including frequency with percentages and median with interquartile range, were computed. Wilcoxon signed-rank test was used to compare quantitative and estimated blood loss to calculated blood loss. Box-and-whisker plots were used to describe the distributions of blood loss values. Sensitivity, specificity, positive predictive value, and negative predictive value of both quantitative and estimated blood loss in detecting postpartum hemorrhage were calculated and compared to calculated blood loss. To predict the need for blood transfusion, logistic regression and receiver operating characteristic (ROC) curves were used, and area under the ROC (AUROC) was estimated for each blood loss method. P values ≤ 0.05 were considered statistically significant. Statistical analyses were carried out using SAS Version 9.4 (SAS Institute, Cary, North Carolina).

RESULTS

A total of 659 patients underwent cesarean delivery. Following exclusion criteria, 483 patients were included in the final cohort (Figure 1). Patients predominantly had a singleton gestation (95.4%), identified as Black, non-Hispanic (57.3%), were of median age 29.1 years, and over one-third had gestational hypertension (38.1%; Table 1).

The median values for blood loss (M; interquartile range [IQR]) for estimated blood loss (600.0 mL; IQR 500.0–800.0) and quantitative blood loss (557.0 mL; IQR 350.0–824.0) were significantly lower (P<0.001 for each) than calculated blood loss (929.4 mL; 551.5–1351.5). Overall, calculated blood loss demonstrated a wider distribution of values for blood loss estimates, with a large proportion of values (43.7%, n=211) identified as postpartum hemorrhage (Figure 2). Smaller proportions of the distributions for estimated blood loss (11.4%, n=55) and quantitative blood loss (13.5%, n=65) were identified as postpartum hemorrhage (Figure 2); only 10 additional patients were identified as having a postpartum hemorrhage through use of quantitative blood loss.

When compared to calculated blood loss, estimated blood loss had low sensitivity (19.4%; 95% CI, 14.1–24.8) and high specificity (94.9%; 95% CI, 92.2–97.5). Quantitative blood loss also demonstrated low sensitivity (23.2%; 95% CI, 17.5–28.9) and high specificity (94.1%; 95% CI, 91.3–96.9). The negative predictive values for estimated blood loss (60.3%; 95% CI, 55.6–64.9) and quantitative blood loss (61.2%; 95% CI, 56.6–65.9) were also low. The positive predictive value for estimated blood loss (74.6%; 95% CI, 63.0–86.1) was similar to quantitative blood loss (75.4%; 95% CI, 64.9–85.9).

While quantitative, estimated, and calculated blood loss all predicted the need for blood transfusion (n=21, P<.001), calculated blood loss was most predictive of blood transfusion need (AUROC 0.86; 95% CI, 0.78–0.94), followed by quantitative blood loss (0.81; 95% CI, 0.72–0.89) and estimated blood loss (0.74; 95% CI, 0.62–0.86). There was no significant difference in the predictive ability of need for blood transfusion with calculated blood loss versus quantitative blood loss (difference 0.05; 95% CI -0.04 to 0.14, P=0.265) or quantitative blood loss versus estimated blood loss (0.06; -0.04 to 0.17, P=0.238); however, calculated blood loss versus estimated blood loss differed significantly (0.12; 95% CI, 0.01–0.22, P=0.027), Figure 3.

DISCUSSION

Quantitative blood loss assessment requires additional training of the labor and delivery staff, which can be time consuming and labor intensive. Like Wesley et al and Torres et al,[7,8] our quality improvement study questions the utility of quantitative blood loss compared to estimated blood loss given similar median values for blood loss between methods; further, both were significantly lower than calculated blood loss. Quantitative blood loss was only slightly more sensitive than estimated blood loss in the detection of hemorrhage, and both had similar specificity. Of greatest clinical significance, negative predictive values of both quantitative and estimated blood loss methods were similarly low. Our study demonstrated that for both estimated and quantitative blood loss, nearly 40% of hemorrhages may screen negative, falsely reassuring the medical team. Similarly to Torres et al,[8] our study also demonstrated that quantitative and estimated blood loss comparably predicted the need for blood transfusion. Given the high rate of morbidity and mortality associated with postpartum hemorrhage, a more sensitive method for the assessment of blood loss is needed.

It is important to note that this study used calculated blood loss as the "gold standard" for measuring blood loss; however, there is no gold standard method. For example, in our study patients were excluded if the calculated blood loss was negative, as this is physiologically and intellectually inaccurate. Inaccurate postdelivery hematocrit could be related to fluid shifts as expected postpartum.[9] Additionally, approximately one-third of patients in our study were diagnosed with hypertensive disease of pregnancy, which is known to cause third spacing of fluids due to deceased oncotic pressure and increased vascular permeability.[10] To account for these fluid shifts, the ideal time to measure hematocrit and allow for appropriate equilibration should be further studied for the postpartum period, as significant decreases in hematocrit postdelivery could lead to a wide range of calculated blood loss estimates, which may overestimate blood loss.

While a drop in hematocrit may provide the most accurate assessment of blood loss, it is not always available in real-time at the bedside. Further, hematocrit is not reliable in cases of ongoing blood loss (eg, cesarean birth). Therefore, a feasible and accurate method of measuring blood loss intraoperatively and immediately postoperatively must be established.

This quality improvement study aimed to evaluate a change in blood loss calculation method at a mid-size, urban academic medical center in Wisconsin. A strength of our study was the diverse patient population, including groups that are historically underrepresented in obstetric literature, such as Black and Brown birthing people. Our study was limited by data discrepancies, such as equal estimated and quantitative blood loss values and incomplete documentation of variables of interest within the electronic medical record. Despite these limitations, we were able to evaluate and analyze a fairly large sample to directly compare estimated, quantitative, and calculated blood loss among patients who underwent cesarean delivery. Even so, comparisons between estimated and quantitative blood loss to calculated blood loss are limited, as calculated blood loss accounts for additional blood loss and fluid intake postoperatively, while estimated and quantitative blood loss are used exclusively at the time of delivery.

CONCLUSIONS

This quality improvement study highlights the poor sensitivity of both estimated blood and quantitative blood loss. Given the potentially limited availability of all necessary measuring materials to determine quantitative blood loss, we recommend continued education and training efforts for staff on visual blood loss estimates at the time of delivery in addition to quantitative blood loss. This quality improvement study also calls into question the limitations of calculated blood loss and its use in clinical practice with the calculation of negative calculated blood loss values. Efforts to increase accuracy of blood loss evaluation both during and after cesarean birth are warranted.

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