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Accuracy of Estimated Blood Loss in Predicting Need for Transfusion after Delivery

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Abstract

Objective—The definition of postpartum hemorrhage (PPH) was developed more than 50 years ago. Since then, the obstetric population has changed dramatically. We sought to determine how well we estimated blood loss (EBL) and find thresholds predicting need for transfusion.

Study Design—We performed a prospective cohort study from 2010 to 2012, comparing those who needed transfusion postpartum and those who did not. EBL, calculated EBL (cEBL), and change in hematocrit were calculated for patients who did not receive transfusion, and EBL was calculated for those who did receive transfusion, stratified by delivery type. Receiver operator curves were created and optimal thresholds of EBL to predict transfusion were estimated.

Results—Among 4,804 patients, transfusion was required for 0.65% of vaginal and 8.7% of cesarean deliveries. Median EBL was higher in women requiring transfusion. A weak correlation was noted between EBL and cEBL for all deliveries. Thresholds of 500 mL blood loss for vaginal delivery and 1,000 mL for cesarean had the best predictive ability for transfusion.

Conclusion—In this modern obstetric cohort EBL is weakly correlated with cEBL, suggesting that accuracy of clinical estimates of blood loss is modest. However, EBL predicts need for transfusion, with optimal thresholds of 500 mL for a vaginal delivery and 1,000 mL in a cesarean. This validates the traditional definitions of PPH in our modern population.

Keywords

transfusion; blood; estimating; hemorrhage; postpartum

Despite advances in health care, rates of maternal death are not decreasing. More than 12 out of every 100,000 women in the United States die during pregnancy, childbirth, and the postpartum period.¹ Hemorrhage is the leading cause of maternal death, accounting for up to 30% of deaths in the past 30 years.² Rates of postpartum hemorrhage (PPH) have increased in recent years, despite improving prevention and management strategies, indicating that

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there is a gap in our knowledge.^{3,4} The definition of PPH varies in the literature but is most commonly defined as blood loss greater than 500 mL for a vaginal delivery and greater than 1,000 mL in a cesarean delivery.^{5–9} This definition was established more than 50 years ago, and since that time, the demographics of our obstetric population have changed dramatically. Women are entering pregnancy with more comorbid conditions, at increased age, and with higher body mass index (BMI).^{10–13} Therefore, little is known about what constitutes normal blood loss in vaginal and cesarean deliveries in a modern population. Even less is known about how well we estimate loss in the obstetric population and how we should optimally define PPH. Without this knowledge, it is difficult to determine when it is clinically appropriate to intervene in cases of PPH to decrease maternal morbidity and mortality. The overall objective of this study is to determine provider ability to estimate obstetric blood loss, and to isolate what thresholds predict the need for transfusion, and thus determine what should be the definition of PPH.

Materials and Methods

We performed a prospective cohort study of 5,000 consecutive women with a singleton, term pregnancy admitted for labor at a tertiary care center from 2010 to 2012. Patients presenting for scheduled cesarean deliveries were excluded. Before initiation of the study, approval was obtained from the Washington University Human Research Protection Board. In the primary study, the aim was to determine the association between fetal heart rate patterns and umbilical cord blood gas values. Data were collected for each patient including demographics, medical, obstetric, and social history. Dedicated pregnancy outcome coordinators obtained complete pregnancy outcome data including antepartum, intrapartum, and postpartum data. Included in this analysis are only those patients with complete data with respect to estimated blood loss (EBL) and pre- and postdelivery hematocrit (Hct).

Upon admission to labor and delivery, all patients received a complete blood count as per standard of care at our institution. After a vaginal delivery, a spun Hct value was determined for each patient using the average of three spun samples from a finger prick at 12 hours postpartum, a method shown to correlate well with laboratory Hct values.¹⁴ For patients who underwent cesarean delivery, a complete blood count was performed at 12 hours postoperative. Calculated EBL (cEBL) was determined using a validated method in which maternal blood volume $\{0.75 \times [(\text{maternal height in inches} \times 50) + (\text{maternal weight in pounds} \times 25)]\}$ is multiplied by percent of blood volume lost $[(\text{predelivery Hct} - \text{postdelivery Hct})/\text{predelivery Hct}]$.¹⁵ Change in Hct was calculated by taking the difference between postdelivery and predelivery Hct. cEBL and change in Hct was not calculated for patients who received a transfusion because the postdelivery Hct would not represent true blood loss. In addition, cEBL and change in Hct were not calculated for patients in whom the Hct level was higher postdelivery than predelivery, as this was considered to represent minimal blood loss with laboratory margin of error.

EBL was determined by the delivering physician in the case of a vaginal delivery and by a consensus between anesthesia and the delivering physician in a cesarean. Women who received at least 1 unit of packed red blood cells after delivery were categorized as receiving a transfusion. Patients who received only fresh frozen plasma, platelets, or cryoprecipitate

without packed red blood cells were considered not to have had a transfusion for the purposes of this study. The decision to transfuse a patient was made by the treating physician based on the individual clinical picture and was not standardized based on EBL or postpartum Hct value.

Two groups were compared, women who received a transfusion and women who did not. Baseline characteristics were compared between the two study groups using Student *t*-test or Mann–Whitney *U* test for continuous variables, and chi-square or Fisher exact test for categorical variables as appropriate. Normality was tested with the Kolmogorov–Smirnov test. Median and interquartile range of EBL, cEBL, and delta Hct were calculated for patients not receiving a transfusion, and EBL was calculated for patients receiving a transfusion, stratified by delivery type (vaginal vs. cesarean). Operative vaginal deliveries, vacuum and forceps, were included in the analysis of vaginal deliveries. A backward, stepwise linear regression model was developed for both vaginal and cesarean deliveries, to estimate cEBL based on individual patient characteristics. Pearson correlation coefficients (*r*) were calculated for the relationship between EBL and cEBL, stratified by delivery type. Receiver operator curves (ROCs) were created and area under the curve (AUC), a measure of a diagnostic test's discriminatory power, was used to estimate the overall predictive ability of EBL for transfusion for vaginal and cesarean deliveries. An AUC of 1.0 indicates a perfect test with 100% sensitivity and 100% specificity, whereas an AUC of 0.5 indicates no discriminative value above chance. Thresholds of EBL were compared for accuracy in predicting need for transfusion using the Youden index (YI) = (sensitivity + specificity) – 1. The optimal threshold was the one with the highest YI. Both positive and negative predictive values (PPV and NPV) were calculated for vaginal and cesarean deliveries. All statistical analyses were completed using STATA software package 12.0 (StataCorp, College Station, TX).

Results

Of the 5,000 women in the cohort, 4,804 women (96.1%) had complete data for EBL, and pre- and postpartum Hct and were included in the analysis; 83% (*n* = 3,969) of the women had a vaginal delivery, whereas 17% (*n* = 835) had a cesarean delivery. Transfusions were performed for 0.63% (*n* = 25) of women delivering vaginally and 8.7% (*n* = 73) of women delivering via cesarean.

At baseline, transfusions were associated with higher parity, prior cesarean delivery, higher infant birth weight, higher maximum oxytocin dosage, and lower admission Hct for women delivering vaginally. For women undergoing cesarean, transfusions were associated with higher parity and lower admission Hct. Women did not differ with respect to age, race, BMI, magnesium administration, rate of induction of labor, rate of intrapartum fever, operative delivery, or perineal laceration (Table 1).

Median and interquartile range of EBL, cEBL, and delta Hct are shown for patients not receiving a transfusion, and EBL is shown for patients receiving a transfusion, stratified by delivery type (Table 2). In women who underwent vaginal delivery, EBL was significantly higher in women who received transfusion compared with those who did not (500 [300,

1,000 mL] vs. 300 [300, 350 mL], $p < 0.001$). Similarly, for women who had a cesarean delivery, EBL was significantly higher in women who received a transfusion (1,000 [850, 1,500 mL] vs. 800 [700, 1,000 mL], $p < 0.001$). cEBL for women who did not receive a transfusion was 442 (210, 751 mL) for vaginal deliveries and 1,062 (676, 1,406 mL) for cesarean deliveries. In addition, in women who did not receive a transfusion, change in Hct was -2.6 (-1.2 , -4.7%) for vaginal and -6.0 (-3.9 , -8.3%) for cesarean deliveries. In women who did receive a transfusion, cEBL and change in Hct are not reported, as both values reflect an artificially elevated Hct level posttransfusion. Patient factors significantly associated with cEBL are listed in Table 3. Nulliparity, perineal laceration, obesity, and prior cesarean were significant factors in vaginal delivery, while only nulliparity and obesity were significant at cesarean.

A statistically significant, but weak, correlation was noted between EBL and cEBL for both vaginal ($r = 0.31$, $p < 0.001$) and cesarean ($r = 0.25$, $p < 0.001$) deliveries. The corresponding coefficients of determination (r^2), the variance of cEBL explained by EBL, were only 0.06 and 0.10 (Table 4, Figs. 1 and 2). ROCs for the ability of EBL to predict need for transfusion are shown in Figs. 3 and 4 for vaginal and cesarean deliveries, respectively. The AUC was 0.77 for vaginal deliveries and 0.78 for cesarean deliveries. The thresholds of 500 mL blood loss for vaginal delivery (sensitivity = 56%, specificity = 89%, PPV = 3.1%, NPV = 99.75%, YI = 0.45) and 1,000 mL blood loss for cesarean delivery (sensitivity = 67%, specificity = 72%, PPV = 18.6%, NPV = 95.9%, YI = 0.39) had the highest YI and thus were the best predictive of need for transfusion.

Discussion

We found that in modern obstetrics, median blood loss for women without a transfusion is 300 mL for a vaginal delivery compared with 800 mL for a cesarean delivery. Transfusion is rare among women with a vaginal delivery, occurring in less than 1/100 deliveries. Meanwhile, clinically significant hemorrhage is much more common in cesarean deliveries, with nearly 1/10 women receiving transfusion. Factors that have changed in the contemporary obstetric population, such as BMI and age, were not associated with increased risk for transfusion. However, increasing parity and lower predelivery Hct were associated with transfusion, consistent with prior studies.^{16–19} Women who received a blood transfusion after vaginal delivery were estimated to have lost twice as much blood as women who did not require a transfusion. Similarly, blood loss was 1.5 times higher among women who received a blood transfusion after cesarean delivery.

The data show that we tend to underestimate blood loss. Although the subjective measure of blood loss (EBL) was significantly correlated with an objective measure of blood loss (cEBL), the correlation was rather weak. EBL had a high predictive ability for need for transfusion, with higher specificity than sensitivity. The thresholds most predictive of a clinically significant EBL were 500 mL for a vaginal delivery and 1,000 mL in a cesarean, thus validating the traditional definitions of PPH in our modern population.

Previous studies have used a variety of methods to characterize normal blood loss at delivery and thus define PPH. In 1961, Newton et al used spectrophotometric methods on

100 women to determine normal blood loss. They concluded that average blood loss for a patient undergoing a term, singleton, vaginal delivery was 339 ± 313 mL.⁵ Then, in 1965, Pritchard studied maternal blood volume using labeled red blood cells with 150 women. This study found that maternal blood loss was 505 mL for a singleton vaginal delivery and 930 for a repeat cesarean delivery.⁶ Since the studies by Newton et al, Pritchard, and others, we have maintained the same definitions of normal and abnormal EBL.⁵⁻⁸ However, these prior studies did not report on demographics and selected only a small number of healthy, uncomplicated patients for study, making it difficult to apply their findings to current practice.

Our study exhibits many strengths over the previous literature on this subject. We use a large, prospectively collected dataset with a large number of covariates. This allows us to investigate many patient factors in a cohort of more than 4,800 women. Compared with prior data, our cohort reflects modern trends in obstetric populations with a high proportion of African American women, average BMI in the obese category, large proportion of induced labor, and higher maternal age. Another strength is our use of transfusion as a clinically relevant measure of PPH, which decreases bias compared with the sole use of subjective EBL.

Despite these strengths, our study is not without limitations. Due to the nature of a secondary analysis, we are limited to the cohort of women presenting for labor, collected for the purposes of the primary study. Therefore, our number of women undergoing cesarean delivery is only 17%, a number below average. However, with 835 women having a cesarean delivery in our study, our numbers remain robust compared with prior literature. In our study, we were unable to report cEBL for women who received a transfusion, and thus could not compare EBL to cEBL in these women. Therefore, in patients who received a transfusion, due to the inability to report cEBL, the EBL may have been underestimated which could potentially impact the thresholds of EBL for predicting transfusion. Finally, because the cohort was from a tertiary care center with a high degree of acuity, with high proportion of obese and African American women, the generalizability of our results may be limited. In addition, because our cohort was limited to patients presenting for labor, the cesarean deliveries were intrapartum and may not reflect average blood loss for prelabor cesareans. It is also important to note that in our institution, there is no formal curriculum or instruction on estimating blood loss; therefore, our results may not be generalizable to institutions who implement formal training in this area.

In summary, we found that in this modern obstetric cohort EBL is weakly correlated with cEBL, suggesting that accuracy of our clinical estimates of blood loss is modest. However, EBL predicts need for transfusion, with the thresholds of 500 mL for vaginal deliveries and 1,000 mL for cesarean deliveries having the highest predictive ability. Therefore, the traditional definition of PPH has been upheld in a modern obstetric population, reflected in a clinically relevant outcome of need for transfusion. During delivery, practitioners should continue to accurately record and be aware of the EBL. EBL should not be used in isolation to determine need for transfusion, but rather as an added tool combined with clinical signs and symptoms of anemia, especially given the low PPV of EBL for predicting transfusion. They can use the thresholds of 500 mL for vaginal and 1,000 mL for cesarean deliveries as a

general guideline for significant blood loss and possible need for transfusion. In addition, because the NPV of EBL for transfusion is high, practitioners may be reassured if EBL is less than the thresholds of 500 mL for vaginal and 1,000 mL for cesarean. However, for those with EBL above the threshold, by intervening on PPH before worsening clinical status, it may be possible to decrease maternal morbidity and mortality due to hemorrhage.

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References

1. Hoyert DL. Maternal mortality and related concepts. National Center for Health Statistics Vital Health Stat. 2007; 3(33):1–13.
2. Callaghan WM. Overview of maternal mortality in the United States. Semin Perinatol. 2012; 36(1): 2–6. [PubMed: 22280858]
3. Haeri S, Dildy GA III. Maternal mortality from hemorrhage. Semin Perinatol. 2012; 36(1):48–55. [PubMed: 22280866]
4. Callaghan WM, Kuklina EV, Berg CJ. Trends in postpartum hemorrhage: United States, 1994–2006. Am J Obstet Gynecol. 2010; 202(4):353.e1–353.e6. [PubMed: 20350642]
5. Newton M, Mosey LM, Egli GE, Gifford WB, Hull CT. Blood loss during and immediately after delivery. Obstet Gynecol. 1961; 17:9–18. [PubMed: 13728699]
6. Pritchard JA. Changes in the blood volume during pregnancy and delivery. Anesthesiology. 1965; 26:393–399. [PubMed: 14313451]
7. Brant HA. Precise estimation of postpartum haemorrhage: difficulties and importance. BMJ. 1967; 1(5537):398–400. [PubMed: 5297397]
8. Gahres EE, Albert SN, Dodek SM. Intrapartum blood loss measured with Cr 51-tagged erythrocytes. Obstet Gynecol. 1962; 19:455–462. [PubMed: 13896205]
9. American College of Obstetricians and Gynecologists. ACOG Practice Bulletin: Clinical Management Guidelines for Obstetrician-Gynecologists Number 76, October 2006: postpartum hemorrhage. Obstet Gynecol. 2006; 108(4):1039–1047. [PubMed: 17012482]
10. Knight M, Callaghan WM, Berg C, et al. Trends in postpartum hemorrhage in high resource countries: a review and recommendations from the International Postpartum Hemorrhage Collaborative Group. BMC Pregnancy Childbirth. 2009; 9:55. [PubMed: 19943928]
11. Martin J, Hamilton B, Sutton P, et al. Births: final data for 2005. National Vital Stat Rep. 2007; 56:1–103.
12. Robinson HE, O'Connell CM, Joseph KS, McLeod NL. Maternal outcomes in pregnancies complicated by obesity. Obstet Gynecol. 2005; 106(6):1357–1364. [PubMed: 16319263]
13. Sebire NJ, Jolly M, Harris JP, et al. Maternal obesity and pregnancy outcome: a study of 287,213 pregnancies in London. Int J Obes Relat Metab Disord. 2001; 25(8):1175–1182. [PubMed: 11477502]
14. McNulty SE, Torjman M, Grodecki W, Marr A, Schieren H. A comparison of four bedside methods of hemoglobin assessment during cardiac surgery. Anesth Analg. 1995; 81(6):1197–1202. [PubMed: 7486104]
15. Stafford I, Dildy GA, Clark SL, Belfort MA. Visually estimated and calculated blood loss in vaginal and cesarean delivery. Am J Obstet Gynecol. 2008; 199(5):519.e1–519.e7. [PubMed: 18639209]
16. Holm C, Langhoff-Roos J, Petersen KB, Norgaard A, Diness BR. Severe postpartum haemorrhage and mode of delivery: a retrospective cohort study. BJOG. 2012; 119(5):596–604. [PubMed: 22313728]

17. Chua SC, Joung SJ, Aziz R. Incidence and risk factors predicting blood transfusion in caesarean section. *Aust N Z J Obstet Gynaecol.* 2009; 49(5):490–493. [PubMed: 19780731]
18. Jou HJ, Hung HW, Yan YH, Wu SC. Risk factors for blood transfusion in singleton pregnancy deliveries in Taiwan. *Int J Gynaecol Obstet.* 2012; 117(2):124–127. [PubMed: 22356759]
19. Ehrental DB, Chichester ML, Cole OS, Jiang X. Maternal risk factors for peripartum transfusion. *J Womens Health (Larchmt).* 2012; 21(7):792–797. [PubMed: 22500552]

Fig. 1.
Correlation between EBL and cEBL for vaginal deliveries. cEBL, calculated estimated blood loss; EBL, estimated blood loss.

Fig. 2.
Correlation between EBL and cEBL for cesarean deliveries. cEBL, calculated estimated blood loss; EBL, estimated blood loss.

Fig. 3.
Receiver operator curve for the ability of EBL to predict need for transfusion in vaginal deliveries. EBL, estimated blood loss.

Fig. 4.

Receiver operator curve for the ability of EBL to predict need for transfusion in cesarean deliveries. EBL, estimated blood loss.

Table 1
Baseline characteristics for women who underwent transfusion versus those who did not stratified by delivery type

	Vaginal delivery		<i>p</i> -Value	Cesarean delivery		<i>p</i> -Value
	Transfusion (<i>n</i> = 25)	No transfusion (<i>n</i> = 3,944)		Transfusion (<i>n</i> = 73)	No transfusion (<i>n</i> = 762)	
Maternal age (y)	27.1 ± 6.7	25.4 ± 5.9	0.15	24.5 ± 6.8	25.9 ± 6.2	0.07
African American race (<i>n</i> = 2,557; 568)	60.0%	64.4%	0.64	74.0%	67.5%	0.25
BMI (kg/m ²)	30.5 ± 6.4	31.6 ± 7.0	0.44	34.4 ± 8.4	34.1 ± 8.1	0.77
Parity (# prior deliveries > 20 wk)	1.9 ± 2.4	1.3 ± 1.5	0.04	1.1 ± 1.8	0.7 ± 1.3	0.02
Prior cesarean (<i>n</i> = 276; 146)	24.0%	6.8%	< 0.01	15.0%	17.7%	0.57
Infant birth weight (g)	3,428 ± 571	3,224 ± 449	0.02	3,357 ± 476	3,330 ± 509	0.66
Birth weight > 4,000 g (<i>n</i> = 190; 68)	8.0%	4.8%	0.45	5.8%	8.4%	0.38
Magnesium administration (<i>n</i> = 217; 90)	8.0%	5.5%	0.58	13.7%	10.5%	0.40
Maximum oxytocin dose (units)	16.5 ± 11.4	12.6 ± 8.1	0.04	15.6 ± 10.6	14.8 ± 10.3	0.56
Induction of labor (<i>n</i> = 1,632; 490)	48.0%	41.1%	0.48	61.1%	58.4%	0.59
Intrapartum fever (<i>n</i> = 108; 90)	0.0%	2.7%	0.40	16.4%	10.2%	0.10
Admission Hct (%)	30.7 ± 4.4	34.4 ± 3.7	< 0.01	32.1 ± 4.2	34.9 ± 3.6	< 0.01
Operative delivery (<i>n</i> = 260)	16.0%	6.5%	0.06	N/A	N/A	N/A
Laceration (<i>n</i> = 2,397)	72.0%	60.3%	0.23	N/A	N/A	N/A

Abbreviations: BMI, body mass index; Hct, hematocrit.

Note: All results in this table are listed as mean ± standard deviation or percentage, respectively.

Table 2
Measures of blood loss for women receiving a blood transfusion and those who did not stratified by delivery type

	Overall	Transfusion	No transfusion	<i>p</i> -Value
Vaginal		<i>n</i> = 25	<i>n</i> = 3,996	
EBL (mL) <i>n</i> = 4,022	300 (300, 350)	500 (300, 1,000)	300 (300, 350)	< 0.001
cEBL (mL) <i>n</i> = 2,618	–	N/A	442 (210, 751)	
Delta Hct (%) <i>n</i> = 2,709	–	N/A	– 2.6 (– 1.2, – 4.7)	
Cesarean		<i>n</i> = 73	<i>n</i> = 769	
EBL (mL) <i>n</i> = 842	800 (700, 1,000)	1,000 (850, 1,500)	800 (700, 1,000)	< 0.001
cEBL (mL) <i>n</i> = 721	–	N/A	1,062 (676, 1,406)	
Delta Hct (%) <i>n</i> = 812	–	N/A	– 6.0 (– 3.9, – 8.3)	

Abbreviations: cEBL, calculated estimated blood loss; EBL, estimated blood loss.

Note: Results are in median (interquartile range).

Table 3
Linear regression equation with beta coefficient reflective of addition to constant cEBL
based on individual factors, stratified by delivery type

	Beta coefficient (mL)	p-Value
Vaginal delivery ^a		
Constant	373.3	–
Nulliparous	120.1	< 0.01
Laceration	89.5	< 0.01
Obese	67.3	< 0.01
Prior cesarean	109.3	< 0.01
Cesarean delivery ^b		
Constant	918.2	–
Nulliparous	87.8	0.04
Obese	104.3	0.02

Abbreviation: cEBL, calculated estimated blood loss.

^a Infant weight, laceration, induction, intrapartum fever, and admission Hct fell out of final model.

^b Infant weight, intrapartum fever, admission Hct, and induction fell out of final model.

Table 4
Correlation between EBL and cEBL stratified by delivery type

	<i>r</i>	<i>r</i> ²	<i>p</i> -Value
Vaginal	0.31	0.10	< 0.001
Cesarean	0.25	0.06	< 0.001

Abbreviations: cEBL, calculated estimated blood loss; EBL, estimated blood loss; *r*, correlation coefficient; *r*², coefficient of determination.