HHS Public Access

Author manuscript

Am J Perinatol. Author manuscript; available in PMC 2022 September 01.

Published in final edited form as:

Am J Perinatol. 2021 September ; 38(11): 1126–1133. doi:10.1055/s-0040-1710501.

Hemorrhage Risk Assessment on Admission: Utility for Prediction of Maternal Morbidity

Homa K. Ahmadzia, MD, MPH[1], **Jaclyn M. Phillips, MD**[2], **Rose Kleiman, BA**[1], **Alexis C. Gimovsky, MD**[1], **Susan Bathgate, MD**[1], **Naomi L.C. Luban, MD**[3], **Richard L. Amdur, MA, PHD**[4]

[1]Division of Maternal-Fetal Medicine, Department of Obstetrics and Gynecology, The George Washington University School of Medicine & Health Sciences, Washington DC

[2]Division of Maternal-Fetal Medicine, Department of Obstetrics, Gynecology and Reproductive Sciences, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania

[3]Department of Pediatrics and Pathology, The George Washington University School of Medicine & Health Sciences, Washington, District of Columbia

[4]Department of Surgery, The George Washington University School of Medicine & Health Sciences, Washington, District of Columbia Am J Perinatol

Abstract

Objective—Hemorrhage is a major cause of maternal morbidity and mortality prompting creation of innovative risk assessment tools to identify patients at highest risk. We aimed to investigate the association of hemorrhage risk assessment with maternal morbidity and to evaluate maternal outcomes after implementation of the risk assessment across hospital sites.

Study Design—We conducted a retrospective cohort analysis of a multicenter data-base including women admitted to labor and delivery from January 2015 to June 2018. The Association of Women's Health, Obstetric and Neonatal Nurses risk assessment tool was used to categorize patients as low, medium, or high risk for hemorrhage. Multivariate logistic regression was used to describe the association between hemorrhage risk score and markers of maternal morbidity and evaluate maternal outcomes before and after standardized implementations of the risk assessment tool.

Results—In this study, 14,861 women were categorized as low risk (26%), 26,080 (46%) moderate risk, and 15,730 (28%) high risk (N = 56,671 births). For women with high-risk scores, the relative risk (RR) ratio compared with low-risk women was 4.9 (RR: 95% confidence interval [CI]: 3.2–7.4) for blood transfusion and 5.2 (RR: 95% CI: 4.6–5.9) for estimated blood loss (EBL) ≥ 1,000 mL. For the second objective, 110,633 women were available for pre- and postimplementation analyses (39,027 and 71,606, respectively). A 20% reduction in rates of blood

Address for correspondence Homa K. Ahmadzia, MD, MPH, Department of Obstetrics and Gynecology, The George Washington University School of Medicine & Health Sciences, Washington, DC 20037 (hahmadzia@mfa.gwu.edu).

Note

Findings were presented at the 39th Annual SMFM Meeting, February 13–16, 2019.

Conflict of Interest

None declared.

transfusion (0.5–0.4%, $p = 0.02$) and EBL ≥ 1,000 mL (6.3–5.9%, $p = 0.014$) was observed between pre-and postimplementations of the admission hemorrhage risk assessment tool.

Conclusion—Women who were deemed high risk for hemorrhage using a hemorrhage risk assessment tool had five times higher risk for blood transfusion and EBL ≥ 1,000 mL compared with low-risk women. Given the low incidence of the outcomes explored, the hemorrhage risk assessment works moderately well to identify patients at risk for peripartum morbidity.

Keywords

hemorrhage risk assessment; maternal morbidity; obstetric hemorrhage; transfusion

Obstetrical hemorrhage remains a major cause of maternal morbidity and mortality in both the developing world and high-resource nations.[1,2] In the United States, rates of perinatal hemorrhage continue to steadily increase.[3,4] Standardized programs in the United States that aim to address maternal hemorrhage have shown promising results in increased awareness and response to hemorrhage and significant reduction in morbidity.[5,6]

In 2015, the Council on Patient Safety in Women's Health Care developed an obstetric hemorrhage safety bundle to address the maternal morbidityand mortality crisis associated with hemorrhage. The program aims to reduce the frequency of severe hemorrhage and to improve maternal outcomes by implementing evidence-based practices at birthing facilities across the United States.[7] Particular emphasis is placed on recognition and prevention of obstetric hemorrhage through antepartum and intrapartum hemorrhage risk assessment. Though many studies have identified risk factors associated with obstetric hemorrhage, existing risk calculators remain inconsistent and merely capture a fraction of patients who proceed to be affected by severe obstetric hemorrhage.[7–10]

The California Maternal Quality Care Collaborative (CMQCC) and the Association of Women's Health, Obstetric and Neonatal Nurses (AWHONN) developed a novel hemorrhage risk assessment tools aimed to identify patients at highest risk for maternal hemorrhage by classifying women as low, medium, or high risk for hemorrhage.[11] This risk assessment structure is now used and cited by the American College of Obstetricians and Gynecologists Safe Motherhood Initiative is widely implemented at the national level.[12,13] Although these risk tools are similar in design, factors included in the tools differ slightly, particularly in the medium-risk category (induction of labor, cervical ripening, polyhydramnios, stillbirth, and family history of postpartum hemorrhage are included in AWHONN's but not in CMQCC's tool). However, little data exist validating this tool for prediction of obstetric hemorrhage or the utility of this tool to impact patient outcomes.[14]

Our study aims to investigate how the use of an admission hemorrhage risk score correlates with maternal morbidity and to evaluate the potential impact of multisite implementation of this assessment on subsequent perinatal outcomes.

Materials and Methods

This is a retrospective study conducted using data from a multicenter database that included women who were admitted to labor and delivery (L&D) from January 2015 to June 2018.

Twenty hospitals were included in the database. Five hospitals had an average annual delivery volume less than 500 (25%), five had 500 to 999 (25%), nine had 1,000 to 2,999 (45%), and one had more than 3,000 (5%). The geographic distributions of the hospitals were east cost ($N = 5$; 25%), central ($N = 8$; 40%), and west coast ($N = 7$; 35%). Any patient who was admitted for delivery met criteria for this study. At the time of admission, an L&D nurse performed the hemorrhage electronic risk assessment and a risk score was automatically generated and documented in the patient electronic medical record. Patients were excluded if they had no data available for hemorrhage risk assessment or missing date of delivery. Out of 120,703 cases in the initial database, the date of delivery was missing in 10,070 cases (8.3%), so these could not be coded for birth before or after introduction of the hemorrhage risk assessment tool. When we look at cases that occurred after introduction of the hemorrhage risk assessment tool, we find that it was used in 54,877 cases (77%) and not used in 16,729 (23%).

Hemorrhage risk scores were electronically abstracted with the aid of a hospital information technology, official, and an L&D nurse. Estimated blood loss (EBL) was inputted by trained L&D nurses into electronic medical records with input from the delivering physician. All data were fully anonymized prior to accessing the information for the study and the committee waved requirement of informed consent for this retrospective analysis. Through the Office of Human Research, The George Washington University Institutional Review Boards (IRBs) approved protocols for study procedures (IRB 180249 on December 18, 2018, and IRB 061611 on July 27, 2017).

All centers involved in our study implemented universal screening using a nursing-driven hemorrhage risk assessment tool on June 1, 2016. The hemorrhage risk tool in this study categorizes patients as low, medium, or high risk for hemorrhage depending on presence, absence, and number of well-established risk factors for hemorrhage (►Table 1).

Data from the hemorrhage risk assessment tool were extracted from the database. Outcomes related to blood transfusion, EBL ≥ 1000 mL, intensive care unit (ICU) admission, chorioamnionitis, general anesthesia, oxytocin use, and cesarean delivery were evaluated in each risk group and before and after implementations. Blood transfusion was defined as administration of any amount of packed red blood cells. Demographic data were also collected. This study had two objectives (1) to evaluate the association of hemorrhage risk with actual outcomes and (2) to examine whether there was a change in patient outcomes between pre-and posttool implementations.

To evaluate the association between hemorrhage risk level and other patient variables, we used chi-square or the Fisher's exact test (when $N \leq 5$) for categorical variables and analysis of variance or the Kruskal–Wallis' test for normally distributed or skewed continuous variables, respectively. Relative risk (RR), sensitivity, specificity, positive predictive value, and negative predictive value were calculated using the standard definitions.[15] The first study objective focused on the observed association of a hemorrhage risk assessment score with perinatal outcomes, hence we did not adjust for covariates. For the second objective regarding changes in perinatal outcomes after universal hemorrhage risk tool implementation, we adjusted for any potential confounds that had any association with time

(with $p < 0.10$; pre-vs. posttool implementation, June 1, 2016) using multivariable logistic regression. SAS (version 9.4, Cary, NC) was used for data analysis, with $p < 0.05$ considered significant. Our sample had power = 0.89 to detect a difference in incidence in low-versus high-risk patients of 0.2 versus 0.4%. For the pre– posttest, our power was 0.96 to detect a difference in incidence of 0.50% pre versus 0.35% post.

Results

For the first objective, we evaluated 57,185 births with 14,885 (26%) characterized as low risk, 26,326 (46%) moderate risk, and 15,974 (28%) high risk. Maternal characteristics are summarized in ►Table 2. A total of 281 women (0.5%) received a blood transfusion and 3,717 women (6.6%) experienced EBL ≥ 1,000 mL. When comparing the high-risk cohort to the low-risk cohort, the high-risk cohort was observed to have a greater risk for blood transfusion (RR: 4.9, 95% confidence interval [CI]: 3.2–7.4) and EBL ≥ 1,000 mL (RR: 5.2, 95% CI: 4.6–5.8) (►Table 3). This effect was still observed when comparing the medium-risk cohort to the low-risk cohort; blood transfusion (RR: 2.6, 95% CI: 1.7–4.0) and EBL ≥ 1,000 mL (RR: 3.5, 95% CI: 3.1–3.9) (►Table 3). Admission to the ICU was higher when comparing high- or medium-risk cohorts with our low-risk cohort (RR: 2.4, 95% CI: 1.2–4.5 and RR: 1.9, 95% CI: 1.0–3.5, respectively). Of all women who required a blood transfusion, only 9.3% had an admission score of low risk (26/281) in comparison to 42.3% (119/281) medium risk, and 48.4% (136/281) high risk. The tool showed a sensitivity of 85%, specificity of 51%, positive predictive value of 10%, and negative predictive value of 98% for high-versus low-risk women with EBL ≥ 1,000 mL (►Table 4).

To evaluate the potential impact implementing a standardized hemorrhage risk assessment tool, we expanded our study population to include a subset of women before the protocol was in effect. For the second objective, the population consisted of 110,633 women (39,027 women included prior to implementation of the hemorrhage risk assessment and 71,606 women after). Small but significant differences were seen in the pre- and postimplementation groups for length of pregnancy, multiple gestations, and prior cesarean deliveries (►Table 2).

Rates of any blood transfusion were slightly but significantly decreased (0.5–0.4%, $p = 0.02$) after the implementation of the hemorrhage risk assessment. Deliveries with EBL ≥ 1,000 mL (6.3–5.9%, $p = 0.014$) also fell significantly after implementation. Incidence of ICU admission, chorioamnionitis, and general anesthesia however did not change overall during the time period studied. Slightly higher rates of oxytocin use (83.3–85.2%, $p < 0.0001$) and of spontaneous vaginal delivery (58.5–59.4%, $p = 0.004$) were seen from pre- to postimplementation (►Table 4).

The adjusted odds ratio of having any perinatal blood transfusion was found to be significantly reduced 0.66 (95% CI: 0.52–0.85, $p = 0.001$) after implementation of the hemorrhage risk assessment. Similarly, the adjusted odds ratio of delivery with EBL ≥ 1,000 mL was significantly lower 0.82 (95% CI: 0.76–0.88, $p < 0.0001$) after the use of the risk assessment tool. No difference in the odds ratio of a spontaneous vaginal delivery was seen after the implementation of the hemorrhage risk assessment (►Table 5).

Comment

Principle Findings

In our study, we looked specifically at the patient's risk assessment score on admission to validate the accuracy of the tool and determine if increased awareness of a patient's risk score might impact maternal outcomes. We observed a statistically significant difference in rates of obstetric hemorrhage between low-, medium-, and high-risk groups. The medium- and high-risk groups were associated with increased RR for maternal morbidity (transfusion, EBL ≥ 1,000 mL, ICU admission, and undergoing general an-esthesia). In addition, we were able to assess data on maternal outcomes before and after the risk assessment tool was implemented into hospital protocol. After implementation of the AWHONN risk assessment tool at all hospital sites, these data demonstrate that this tool works moderately well to identify patients at highest risk for obstetric hemorrhage and when implemented, may function to decrease rates of perinatal morbidity.

Discussion

Approximately 2.9% of all deliveries in the United States are complicated by significant maternal hemorrhage, with 0.4 to 1.6% of all deliveries requiring blood transfusion.[3,9,16,17] Studies suggest a temporal increase in both severe obstetric hemorrhage along with rates of maternal transfusion.[8,9,17] This has prompted development of risk assessment programs and obstetric hemorrhage care bundles to address the increasing frequency and severity of hemorrhage.[6,7,11,13] The AWHONN risk assessment tool was designed to capture low-, medium-, and high-risk individuals at three distinct time points: admission, intrapartum, and immediately postpartum.[11]

Current data support our study and suggest that tools of this caliber are able to capture a group of women with a relatively high risk of hemorrhage, but that significant hemorrhage occurs even in the absence of risk factors. Using the CMQCC risk assessment tool, Dilla et al performed a risk assessment tool validation study by retrospectively assigning hemorrhage risk scores and evaluating the differences between groups and patient outcomes. When looking at the individual risk factors comprising the risk assessment tool, they found that each risk factor was associated with a significantly increased risk of experiencing peripartum hemorrhage (with the exception morbid obesity and macrosomia).[14] The rate of hemorrhage was increased in the medium- and high-risk groups compared with low-risk group (low [0.8%]; medium [2.0%]; and high [7.3%]). However, only 22% of patients who experienced significant hemorrhage were classified in high-risk group.

Similar to our study, Shields et al found that implementation of maternal hemorrhage protocols reduced risk of blood product use per 1,000 births by ~25%.[6] A mechanism for this reduction may stem from increased awareness about patients who are at higher risk for hemorrhage by the obstetric care team. Providers may be more likely to recognize hemorrhage earlier or more readily administer hemorrhage therapy. Even though the overall incidence of perinatal transfusions were low in our study, the small, but significant difference in transfusion rate after implementation (0.5 vs. 0.4%), would likely be

synergistic when combined with other components of the safety bundle as outline by the Council on Patient Safety in Women's Health Care.

Of note, we also observed a statistically significant increased use of oxytocin after risk tool implementation, suggesting that there may have been simultaneous changes in practice of labor management or management of the third stage of labor. We recognize that this could be a temporal change in clinical practice or a downstream effect of the implementation of the hemorrhage risk assessment tool. However, we adjusted for this, along with other covariates, in examining the association of time (pre- vs. posthemorrhage assessment tool implementation) with transfusions and blood loss.

Clinical and Research Implications

Though data suggest that hemorrhage risk assessment and obstetric hemorrhage programs prove beneficial to impact maternal outcomes, it is estimated that at least 20% of academic hospitals are not routinely using obstetric hemorrhage protocols on L&D.[18] Implementing a hemorrhage risk assessment tool requires minimal training of staff on L&D and can quickly become a routine and efficient part of the workflow. Low-resource hospitals that may struggle in incorporating more time, training, or cost intensive aspects of a maternal safety bundle, would have little trouble integrating this hemorrhage risk assessment tool into their facility. This could be a cost-effective way to see modest improvements in perinatal outcomes. Additional studies on optimal timing of risk assessment implementation would be helpful in determining at which point, or points, inpatient care risk assessment most accurately predicts patient outcomes. Reassessment of risk throughout the course of the pregnancy or throughout labor may be a way to better identify patients at highest risk of hemorrhage and improve preparedness and patient counseling.

Strengths and Limitations

Strengths of this study include the large number of patients and the use of a multicenter database to capture a diverse maternal population. Importantly, our study is able to evaluate maternal outcomes before and after hospital implementations of an admission risk assessment tool. The retrospective design of our study poses several limitations. Though we have a large sample size for analysis, we recognize that our population is predominantly Caucasian with low rates of chronic hypertension and preeclampsia, which could limit generalizability of our findings. The tool used in this study categorizes women as low, medium, or high risk for hemorrhage. However, due to the existence of multiple and similar risk calculator tools (i.e., CMQCC and AWOHNN), the variables were similar but not standardized between hospitals.[13] As the hemorrhage risk scores were calculated by nurses on admission to L&D, it is possible that the score was miscalculated (e.g., a patient with a prior cesarean was categorized as low risk). However, this represents the practical use of the hemorrhage risk assessment tool and is a more accurate representation of how the tool is clinically implemented.

In addition, we are unable to determine whether the findings of decreased rates of transfusion and EBL ≥ 1,000 mL after implementation of the risk assessment tool were due to risk assessment alone or if other simultaneous factors may have contributed to this

result. There was no standardized nurse or physician training on hemorrhage at the time of risk assessment implementation and individual hospital protocols were not monitored or available for review (e.g., hospital protocol for management of low- vs. high-risk scores). While we were able to adjust for certain maternal characteristics and delivery complications, it remains unclear if hospital management of maternal hemorrhage or alternative protocols also contributed to our findings.

Conclusion

Women who scored as high risk for hemorrhage using the AWHONN hemorrhage risk assessment had five times higher risk for blood transfusion and EBL ≥ 1,000 mL compared with low-risk women. After implementation of a hemorrhage risk assessment at admission, we found a 20% reduction in rates of blood transfusion and EBL ≥ 1,000 mL. Our study demonstrates that this tool works moderately well to identify patients at highest risk for obstetric hemorrhage and when implemented, may function to decrease rates of perinatal morbidity. High hemorrhage risk scores are associated with hemorrhage-related morbidity, though more data are needed to understand how implementation of hemorrhage risk assessments impact maternal outcomes.

Acknowledgments

The authors would like to thank Nathan Bible from George Washington University Hospital for data extraction, Megan Beglin from George Washington University for aid on optimizing data extraction, and Jamil Kazma from George Washington University for aid on manuscript review and revision. There was no compensation for any of the above-acknowledged authors.

Funding

This publication was supported by Children's National KL2 Federal Funds (KL2TR001877) and award number UL1TR001876 from the NIH National Center for Advancing Translational Sciences.

References

1. Grobman WA, Bailit JL, Rice MM, et al. ; Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD) Maternal-Fetal Medicine Units (MFMU) Network. Frequency of and factors associated with severe maternal morbidity. Obstet Gynecol 2014;123(04):804–810 [PubMed: 24785608]
2. World Health Organization. WHO recommendation on tranexamic acid for the treatment of postpartum haemorrhage. 2017. Available at: https://www.who.int/reproductivehealth/publica-tions/tranexamic-acid-pph-treatment/en/. Accessed March 17, 2019
3. 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]
4. Kramer MS, Berg C, Abenhaim H, et al. Incidence, risk factors, and temporal trends in severe postpartum hemorrhage. Am J Obstet Gynecol 2013;209(05):449.e1–449.e7 [PubMed: 23871950]
5. Lappen JR, Seidman D, Burke C, Goetz K, Grobman WA. Changes in care associated with the introduction of a postpartum hemorrhage patient safety program. Am J Perinatol 2013;30(10):833–838 [PubMed: 23359234]
6. Shields LE, Wiesner S, Fulton J, Pelletreau B. Comprehensive maternal hemorrhage protocols reduce the use of blood products and improve patient safety. Am J Obstet Gynecol 2015;212(03):272–280 [PubMed: 25025944]

7. Main EK, Goffman D, Scavone BM, et al. ; National Partnership for Maternal Safety; Council on Patient Safety in Women's Health Care. National Partnership for Maternal Safety: consensus bundle on obstetric hemorrhage. Obstet Gynecol 2015;126(01):155–162 [PubMed: 26241269]
8. Ahmadzia HK, Phillips JM, James AH, Rice MM, Amdur RL. Correction: predicting peripartum blood transfusion in women undergoing cesarean delivery: a risk prediction model. PLoS One 2019;14(01):e0211360
9. Bateman BT, Berman MF, Riley LE, Leffert LR. The epidemiology of postpartum hemorrhage in a large, nationwide sample of deliveries. Anesth Analg 2010;110(05):1368–1373 [PubMed: 20237047]
10. Al-Zirqi I, Vangen S, Forsen L, Stray-Pedersen B. Prevalence and risk factors of severe obstetric haemorrhage. BJOG 2008;115(10): 1265–1272 [PubMed: 18715412]
11. Association of Women's Health, Obstetric and Neonatal Nurses (AWHONN). Postpartum Hemorrhage Project: A Multi-Hospital Quality Improvement Program. 2017. Available at: http://www.pphproject.org. Accessed March 17, 2019
12. The American College of Obstetricians and Gynecologists. Safe Motherhood Initiative. Maternal Safety Bundle for Obstetric Hemorrhage. 2015. Available at: https://www.acog.org/community/dis-tricts-and-sections/district-ii/programs-and-resources/safe-moth-erhood-initiative/obstetric-hemorrhage. Accessed March 17, 2019
13. Bingham D, Melsop K, Main E. CMQCC Obstetric Hemorrhage Hospital Level Implementation Guide. Palo Alto, CA: The California Maternal Quality Care Collaborative (CMQCC); 2010
14. Dilla AJ, Waters JH, Yazer MH. Clinical validation of risk stratification criteria for peripartum hemorrhage. Obstet Gynecol 2013; 122(01):120–126 [PubMed: 23743452]
15. Gordis L Epidemiology. Philadelphia, PA: Elsevier; 2009
16. Callaghan WM, Grobman WA, Kilpatrick SJ, Main EK, D'Alton M. Facility-based identification of women with severe maternal morbidity: it is time to start. Obstet Gynecol 2014;123(05): 978–981 [PubMed: 24785849]
17. Oyelese Y, Ananth CV. Postpartum hemorrhage: epidemiology, risk factors, and causes. Clin Obstet Gynecol 2010;53(01):147– 156 [PubMed: 20142652]
18. Kacmar RM, Mhyre JM, Scavone BM, Fuller AJ, Toledo P. The use of postpartum hemorrhage protocols in United States academic obstetric anesthesia units. Anesth Analg 2014;119(04):906–910 [PubMed: 25238236]

Key Points

- This study aimed to understand the utility of the AWOHNN hemorrhage risk assessment tool for predicting hemorrhage-related morbidity and to evaluate maternal outcomes before and after tool implementations.
- A high score using a hemorrhage risk assessment tool on admission is associated with five time loss ≥1,000 mL, compared with a low score.
- Use of a hemorrhage risk assessment tool works moderately well to identify patients at highest risk for hemorrhage-related morbidity.

Table 1

AWHONN hemorrhage risk assessment[11]

Low risk	Medium risk	High risk
• No previous uterine incision • ≦ 4 previous vaginal births • No known bleeding disorder • No history of PPH • Singleton pregnancy	• Induction of labor • > 4 prior vaginal births • Prior cesarean birth or • prior uterine incision • Large uterine fibroids • History of one previous PPH • Chorioamnionitis • Fetal demise • Morbid obesity (BMI > 35) • Estimated fetal weight > 4 kg • Family history in first-degree • relative who experienced PPH • Polyhydramnios	• Active bleeding more than bloody show • Suspected accreta or percreta • Placenta previa, low lying • Placenta • Known coagulopathy • History of more than one previous PPH • Hematocrit < 30 and other risk factors • Platelets <100K

Abbreviations: AWHONN, Association of Women's Health, Obstetric and Neonatal Nurses; BMI, body mass index; PPH, postpartum hemorrhage. Note: Two or more medium-risk factors will automatically classify you as high risk.

Table 2

Patient demographic data for objective 1 (risk assessment prediction) and objective 2 (perinatal outcomes before and after tool implementations)

Patient variables	Objective 1			*p*-Value	Objective 2		*p*-Value
	Low	Medium	High		Before implementation	After implementation	
	(*n* = 14,885)	(*n* = 26,326)	(*n* = 15,974)		(*n* = 39,027)	(*n* = 71,606)	
Delivery type							
CD	1,202 (8%)	12,773 (49%)	7,312 (46%)	<0.0001	13,406 (34%)	25,458 (36%)	<0.0001
Vaginal	13,635 (92%)	13,364 (51%)	8,490 (53%)		25,298 (65%)	45,636 (64%)	
VBAC	48 (0.3%)	189 (0.7%)	172 (1%)		232 (1%)	512 (1%)	
Race/ethnicity							
Black	2,376 (16.0%)	4,069 (14.5%)	3,453 (21.6%)	<0.0001	6,060 (16%)	12,082 (17%)	<0.0001
White	7,528 (50.6%)	14,820 (54.2%)	7,852 (49.2%)		19,551 (50%)	35,989 (50%)	
Asian	713 (4.8%)	1,097 (4.2%)	700 (4.4%)		1,452 (4%)	3,095 (4%)	
Other/unknown	4,268 (28.6%)	6,880 (26.1%)	3,969 (24.9%)		11,964 (30%)	20,440 (29%)	
Insurance							
Medicaid	4,928 (33.1%)	8,835 (33.6%)	4,924 (30.9%)	<0.0001	3,379 (9%)	22,573 (32%)	<0.0001
Private	8,304 (55.8%)	14,036 (53.3%)	9,167 (57.4%)		9,095 (23%)	38,184 (53%)	
Uninsured	401 (2.7%)	952 (3.6%)	279 (1.8%)		336 (1%)	1,990 (3%)	
Other/unknown	1,252 (8.4%)	2,503 (9.5%)	1,604 (10.0%)		26,217 (67%)	8,859 (12%)	
Marital status							
Married	7,111 (47.7%)	12,968 (49.3%)	7,845 (49.1%)	0.0007	19,102 (49%)	34,463 (48%)	<0.0001
Single	7,015 (47.1%)	11,893 (45.2%)	7,265 (45.5%)		16,123 (41%)	31,701 (44%)	
Other/unknown	759 (5.1%)	1,465 (5.5%)	864 (5.4%)		3,802 (10%)	5,442 (8%)	
Gestational diabetes	550 (3.7%)	1,775 (6.7%)	1,450 (9.1%)	<0.0001	2,022 (5%)	4,467 (6%)	<0.0001
Pregestational diabetes	71 (0.5%)	323 (1.2%)	304 (1.9%)	<0.0001	899 (2%)	2,460 (3%)	<0.0001
Chronic hypertension	77 (0.5%)	398 (1.5%)	440 (2.8%)	<0.0001	509 (1.3%)	1,069 (1.5%)	0.011
Smoking during pregnancy	636 (4.3%)	1,263 (4.8%)	811 (5.1%)	0.0033	11,257 (29%)	3,210 (4%)	<0.0001
Preeclampsia	128 (0.9%)	693 (2.6%)	647 (4.1%)	<0.0001	1,140 (3%)	1,714 (2%)	<0.0001
Interpregnancy interval <1 y	234 (1.57%)	542 (2.06%)	346 (2.17%)	<0.0001	541 (1.4%)	1,346 (1.9%)	<0.0001
Placenta previa	45 (0.03%)	104 (0.40%)	255 (1.6%)	<0.0001	220 (0.6%)	492 (0.7%)	0.014

Am J Perinatol. Author manuscript; available in PMC 2022 September 01.

Patient variables	Objective 1			*p*-Value	Objective 2		*p*-Value
	Low	Medium	High		Before implementation	After implementation	
	(*n* = 14,885)	(*n* = 26,326)	(*n* = 15,974)		(*n* = 39,027)	(*n* = 71,606)	
DIC	0 (0%)	2 (0.01%)	19 (0.03%)	<0.0001	5 (0.01%)	20 (0.03%)	0.11
History of postpartum hemorrhage	127 (0.9%)	621 (2.4%)	1,168 (7.3%)	<0.0001	252 (0.7%)	2,020 (2.8%)	<0.0001
Dinoprostone use	478 (3.2%)	2,434 (9.3%)	1,917 (12.0%)	<0.0001	3,036 (8%)	5,506 (8%)	0.59
Misoprostol use	1,098 (7.4%)	3,570 (13.6%)	2,831 (17.7%)	<0.0001	4,073 (10%)	8,736 (12%)	<0.0001
Oxytocin use	12,233 (82.2%)	23,836 (90.5%)	14,484 (90.7%)	<0.0001	15,469 (40%)	29,720 (42%)	<0.0001
Use of any antibiotics	6,333 (42.6%)	16,564 (62.9%)	10,473 (65.6%)	<0.0001	21,069 (54%)	40,026 (56%)	<0.0001
Vacuum-assisted delivery	434 (2.9%)	1,600 (6.1%)	1,154 (7.2%)	<0.0001	1,971 (5%)	3,781 (5%)	0.1
Forceps-assisted delivery	92 (0.6%)	211 (0.8%)	256 (1.6%)	<0.0001	511 (1.3%)	718 (1.0%)	<0.0001
Eclampsia	15 (0.1%)	61 (0.2%)	50 (0.3%)	0.0003	74 (0.2%)	150 (0.2%)	0.48
HELLP	3 (0.02%)	15 (0.06%)	10 (0.06%)	0.1758	17 (0.04%)	35 (0.05%)	0.7
Number of previous CD							
0	14,778 (99.3%)	23,183 (88.1%)	14, 204 (88.9%)	<0.0001	36,090 (95%)	65,806 (92%)	<0.0001
1	73 (0.5%)	1,911 (7.3%)	1,030 (6.5%)		1,267 (3%)	3,509 (5%)	
2	23 (0.2%)	868 (3.3%)	488 (3.1%)		608 (2%)	1,565 (2%)	
3+	11 (0.07%)	364 (1.4%)	252 (1.6%)		243 (1%)	726 (1%)	
Gestational age <39 wk	5,573 (37.9%)	9, 253 (35.5%)	6, 080 (38.5%)	<0.0001	12,647 (33%)	25,819 (37%)	<0.0001
Intrapartum abruption	58 (0.4%)	469 (0.8%)	299 (1.9%)	<0.0001	201 (0.8%)	556 (0.8%)	0.92
Placenta accreta	0 (0%)	3 (0.01%)	38 (0.24%)	<0.0001	28 (0.07%)	53 (0.07%)	0.89
Intrapartum bleeding	22 (0.04%)	74 (0.3%)	212 (1.3%)	<0.0001	279 (0.7%)	331 (0.5%)	<0.0001
Platelets <150,000	1,431 (9.6%)	2,723 (10.3%)	1,631 (10.2%)	<0.0001	3,795 (10%)	7,068 (10%)	0.43
Hematocrit <32%	2,135 (14.3%)	4,747 (18.0%)	294 (18.4%)	<0.0001	5,859 (15%)	11,649 (16%)	<0.0001
Parity							
0	2,434 (17.3%)	4,057 (16.0%)	2,751 (18.1%)	<0.0001	8,740 (24%)	12,390 (19%)	<0.0001
1	7,148 (50.7%)	12,411 (49.0%)	7,373 (48.5%)		19,202 (53%)	32,786 (49%)	
2	2,337 (16.6%)	4,265 (16.8%)	2,262 (14.9%)		4,022 (11%)	10,222 (15%)	
3+	2,169 (15.4%)	4,595 (18.1%)	2,802 (18.5%)		4,085 (11%)	11,002 (17%)	
Multiple gestation	14 (0.09%)	314 (1.2%)	424 (2.7%)	<0.0001	327 (0.8%)	795 (1.1%)	<0.0001

Abbreviations: CD, cesarean deliveries; DIC, disseminated intravascular coagulation; HELLP, hemolysis, elevated liver enzymes, low platelets; VBAC, vaginal birth after cesarean.

Table 3

Outcomes related to admission hemorrhage risk score and associated risk ratio (95% CI)

Outcome	Hemorrhage risk score			*p*-Value	Risk ratio (95% CI)	
	Low (*n* = 14,885)	Medium (*n* = 26,326)	High (*n* = 15,974)		Medium vs. Low	High vs. Low
Any blood transfusion	26 (0.2%)	119 (0.5%)	136 (0.9%)	<0.0001	2.6 (1.7–4.0)	4.9 (3.2–7.4)
EBL ≥1,000 mL	294 (2.0%)	1,795 (6.8%)	1,631 (10.2%)	<0.0001	3.5 (3.1–3.9)	5.2 (4.6–5.8)
ICU admission[a]	13 (0.1%)	43 (0.2%)	33 (0.2%)	0.024	1.9 (1.0–3.5)	2.4 (1.2–4.5)
General anesthesia	59 (0.4%)	249 (1.0%)	236 (1.5%)	<0.0001	2.4 (1.8–3.2)	3.7 (2.8–5.0)
Chorioamnionitis	114 (0.8%)	188 (0.7%)	345 (2.2%)	<0.0001	0.93 (0.75–1.18)	2.8 (2.3–3.5)

Abbreviations: CI, confidence interval; EBL, estimated blood loss; ICU, intensive care unit.

[a]Includes all ICU admissions.

Table 4

Sensitivity and specificity associated with hemorrhage risk assessment tool for prediction of transfusion and EBL ≥1,000 mL

	High vs. Low	Medium vs. Low	High and Medium vs. Low
Predicting any transfusion			
Sensitivity	0.84	0.82	0.91
Specificity	0.48	0.36	0.26
PPV	0.01	0.00	0.01
NPV	1.00	1.00	1.00
Prediction accuracy	0.49	0.36	0.26
Predicting EBL ≥1,000 mL			
Sensitivity	0.85	0.86	0.92
Specificity	0.50	0.37	0.27
PPV	0.10	0.07	0.08
NPV	0.98	0.98	0.98
Prediction accuracy	0.53	0.40	0.32

Abbreviations: EBL, estimated blood loss; NPV, negative predictive value; PPV, positive predictive value.

Table 5

Perinatal outcomes pre- and post-tool implementations with adjusted odds ratio (95% CI)

Outcome	Preimplementation (*n* = 39,027)	Postimplementation (*n* = 71,606)	*p*-Value	Adjusted odds ratio (95% CI)	*p*-Value
Any transfusion	202 (0.5%)	299 (0.4%)	0.02	0.66 (0.52–0.85)	0.001
EBL >1,000 mL	2,448 (6.3%)	4,229 (5.9%)	0.014	0.82 (0.76–0.88)	<0.0001
Spontaneous vaginal delivery	22,811 (58.5%)	42,497 (59.4%)	0.004	1.03 (0.93–1.15)	0.54
Chorioamnionitis	446 (1.1%)	794 (1.1%)	0.61	–	–
ICU admission	51 (0.13%)	106 (0.15%)	0.46	–	–
General anesthesia	350 (0.9%)	663 (0.9%)	0.63	–	–
Used oxytocin	32,525 (83.3%)	60,997 (85.2%)	<0.0001	0.79 (0.74–0.84)	<0.0001

Abbreviations: CI, confidence interval; EBL, estimated blood loss; ICU, intensive care unit.