Correlation between hemorrhage risk prediction score and severe maternal morbidity

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BACKGROUND: Obstetrical hemorrhage is a leading cause of severe maternal morbidity, a key indicator of a nation's healthcare delivery system and often associated with a high rate of preventability. Limited data suggest that a patient's hemorrhage risk score may be associated with risk for maternal morbidity such as severe hemorrhage, intensive care unit admission, or transfusion. Little is known regarding the relationship between hemorrhage risk score and nontransfusion-related morbidity.

OBJECTIVE: We sought to evaluate the association between a patient's California Maternal Quality Care Collaborative admission hemorrhage risk score and severe maternal morbidity.

STUDY DESIGN: This was a retrospective cohort of delivery admissions from 2018 to 2019 in a single healthcare network. Admission risk scores were assigned to each patient using the California Maternal Quality Care Collaborative criteria. Rates of transfusion- and nontransfusion-associated severe maternal morbidity were compared across low-, medium-, and high-risk strata. We defined severe maternal morbidity as the presence of any International Classification of Diseases diagnosis or procedure codes outlined by the Centers for Disease Control and Prevention, need for intensive care unit admission, or prolonged postpartum hospital length of stay. A multivariable logistic regression was used to assess the association between hemorrhage risk score and severe maternal morbidity.

RESULTS: In the overall cohort, severe maternal morbidity occurred in 2.4% (n=517) of all deliveries. Excluding cases requiring transfusion, 0.6% (n=131) of cases still had a severe maternal morbidity event. The incidence of severe maternal morbidity was 1.6% (n=264) in patients categorized as low risk for hemorrhage compared with 2.5% (n=118) and 13.6% (n=135) in patients who were categorized as medium or high risk for hemorrhage, respectively ($P<.001$). Patients classified as high risk had a significant association with both severe maternal morbidity (adjusted odds ratio, 8.8; 95% confidence interval, 7.0–11) and nontransfusion-associated severe maternal morbidity (adjusted odds ratio, 3.6; 95% confidence interval, 2.2–5.9).

CONCLUSION: In addition to predicting the risk for obstetrical hemorrhage and transfusion, our findings indicate that the California Maternal Quality Care Collaborative admission hemorrhage risk tool in addition predicts risk for transfusion- and nontransfusion-associated severe maternal morbidity. Our findings imply that despite awareness and the identification of patients at high risk for obstetrical hemorrhage on admission, significant hemorrhage-associated morbidity persisted. Our data indicate that the identification of risk alone may be insufficient to reduce morbidity and imply that further work is needed to investigate and implement new practices in response to a patient's score stratum.

Key words: hemorrhage risk prediction, obstetrical hemorrhage, severe maternal morbidity

Introduction

Obstetrical hemorrhage is a leading cause of maternal morbidity and mortality.[1–3] Rising rates and severity of obstetrical hemorrhage are thought to directly contribute to increasing rates of severe maternal morbidity (SMM),[4–6] a key indicator of a nation's healthcare delivery system. SMM is defined as unintended outcomes related to labor and delivery that cause significant short-term or long-term health consequences.[4,7] Data from the National Inpatient Sample demonstrate a more than 200% increase in SMM in the period from 1993 to 2014, primarily driven by an increase in blood transfusions. After exclusion of blood transfusions, a reduced, but important increase in SMM of 20% was still observed.[4]

Recently, maternal morbidity and mortality review committees and retrospective case reviews have identified hemorrhage as an important preventable contributor to SMM.[8–12] The degree of preventability associated with hemorrhage has prompted the development and utilization of obstetrical care bundles in an effort to mitigate the consequences of severe hemorrhage. One important component of a hemorrhage care bundle includes a hemorrhage risk prediction tool. The most notable example is the California Maternal Quality Care Collaborative (CMQCC)'s hemorrhage risk prediction tool, which stratifies women by hemorrhage risk at the time of their delivery admission. Since the development of the CMQCC's hemorrhage risk prediction tool and the subsequent widespread adoption, a validated hemorrhage risk prediction tool is now mandated in all labor and delivery units nationwide.[13] Limited data suggest that implementation of this tool may improve patient outcomes and reduce the rates of hemorrhage and/or transfusion secondary to enhanced recognition and response.[14,15] Understanding the cohort at highest risk for SMM is paramount to the identification of clinically relevant measures and implementation of programs aimed at improving the quality of care and maternal outcomes. Given the significant relationship between obstetrical hemorrhage and SMM, we sought to evaluate the association between CMQCC hemorrhage risk prediction score and SMM.

Methods

We performed a retrospective cohort analysis of delivery admissions from 10 hospitals within a single healthcare network from 2018 to 2019. Data were

Cite this article as: Phillips JM, Hacker F, Lemon L, et al. Correlation between hemorrhage risk prediction score and severe maternal morbidity. Am J Obstet Gynecol MFM 2021;3:100416.

2589-9333/$36.00

http://dx.doi.org/10.1016/j.ajogmf.2021.100416

AJOG MFM at a Glance

Why was this study conducted?

This study aimed to investigate the relationship between a commonly used hemorrhage risk prediction tool and the occurrence of severe maternal morbidity (SMM).

Key findings

Patients who were categorized as medium or high risk for hemorrhage experienced higher rates of SMM. A high-risk score for hemorrhage was associated with risk for both hemorrhage-associated and hypertensive-associated morbidity.

What does this add to what is known?

Hemorrhage risk prediction tools predict both transfusion-associated and non-transfusion-associated SMM. Identifying risk alone is insufficient to mitigate the risk for morbidity.

available from the University of Pittsburgh Medical Center's clinical data warehouse (CDW). The CDW stores all quantitative data documented in the electronic health records and contains data generated from International Classification of Diseases, Tenth Revision (ICD-10) diagnosis and procedure codes, billing codes, and Cerner-specific delivery forms.

An admission hemorrhage risk score was retrospectively assigned to each patient using the CMQCC criteria. The CMQCC admission hemorrhage risk score classifies women as at low, medium, or high risk for postpartum hemorrhage based on patient risk factors (Table 1). ICD-10 diagnosis codes and quantitative data from the CDW were used to generate the admission CMQCC risk score. We were unable to obtain specific data regarding the "history of postpartum hemorrhage," which is required to assign a medium-risk CMQCC score, because it cannot reliably be extracted from larger administrative databases with ICD-10 diagnosis codes.[16] Obstetrical hemorrhage was identified by ICD-10 diagnosis codes and was assigned at the discretion of individual providers at our institution. Our institution generally utilizes the American College of Obstetricians and Gynecologists' (ACOG) definition to diagnose clinically significant obstetrical hemorrhage. Importantly, the ACOG updated the definition of obstetrical hemorrhage in 2017 to blood loss greater than or equal to 1000 mL regardless of delivery mode. This change occurred before the start of this study, making the definition of hemorrhage consistent across the study period.[17]

Consistent with previous large cohort studies involving SMM identification through administrative databases, SMM in our analysis was defined by any of the following: any Centers for Disease Control and Prevention (CDC) ICD diagnosis or procedure code indicators, intensive care unit admission, or prolonged postpartum hospital length of stay (>3 standard deviations from the mean for mode of delivery).[18–21] The CDC lists 21 unique ICD diagnosis or procedure code indicators that qualify for the diagnosis SMM (Table 2).[4] Blood transfusion was defined as either occurring during the delivery hospitalization or not and we were unable to determine the severity of bleeding or number of units transfused owing to limitations in the ICD diagnosis coding. New recommendations from the ACOG and the Society of Maternal-Fetal Medicine joint Consensus on Severe Maternal Morbidity suggests that transfusion alone is not a sufficient criterion to qualify as SMM.[7] Therefore, we analyzed a subgroup of SMM cases in which cases of transfusion were excluded. Cause-specific SMM was otherwise determined by evaluating the frequencies of individual ICD diagnostic or procedure codes.

Maternal demographics and delivery characteristics were compared between cases with and without SMM. In our cohort, pregnancy-associated hypertension is defined by the complete spectrum of pregnancy-associated hypertension and includes women with mild hypertensive disease (such as gestational hypertension and preeclampsia without severe features) and women with severe disease (such as preeclampsia with severe features or eclampsia). The rates of SMM were calculated for each CMQCC risk category and compared using chi-square or Fisher's exact tests. Logistic regression was used to estimate the risk for transfusion and SMM across CMQCC risk categories. We used theory-based causal diagrams to identify delivery site, insurance status, age, and race as potential confounders. CMQCC scores were assigned and data were analyzed using Stata Statistical Software release 16 (College Station, TX).[22] Our institution's Quality Improvement Review Committee approved our study procedures as a quality improvement project (#2831 on 9/12/2020) and was exempt from institutional review board approval.

Results

Our study included 28,254 delivery admissions from January 1, 2018 through December 31, 2019. Patients were excluded if they had no data available for hemorrhage risk score calculation (n=2169) or if baseline maternal demographic data were missing (n=4242), leaving 21,843 patients in the cohort for analysis. In the overall cohort, 2.4% (n=517) of deliveries had an SMM event. Transfusion-associated SMM occurred in 1.8% (n=386) of the cases. When excluding cases with transfusion, 0.6% (n=131) of cases experienced an SMM event. The CMQCC admission hemorrhage risk tool categorized 16,184 (74%) patients as low risk, 4664 (21%) as medium risk, and 995 (5%) as high risk for hemorrhage.

Table 3 demonstrates significantly higher rates of advanced maternal age, government-assisted insurance, non-Hispanic Black race, preexisting medical conditions, preterm birth, and multiple

TABLE 1
Criteria for assigning the CMQCC admission hemorrhage risk score

CDC diagnosis or procedure
Intensive care unit admission
Hysterectomy
Acute respiratory distress syndrome
Acute renal failure
Sepsis
Shock
Disseminate intravascular coagulation
Pulmonary edema
Air and thrombotic embolism
Severe anesthesia complications
Eclampsia
Cardiac conversion
Puerperal cerebrovascular disorders
Amniotic fluid embolism
Ventilation
Sickle cell crisis
Acute myocardial infarction
Heart failure
Cardiac arrythmia
Aneurysm
Temporary tracheostomy

CDC, Centers for Disease Control and Prevention; *CMQCC*, California Maternal Quality Care Collaborative.

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TABLE 2
List of SMM indicators based on CDC ICD diagnosis or procedure codes

Low risk	Medium risk	High risk
No previous uterine incision	Previous CD or uterine surgery	Placenta previa, low-lying placenta
Singleton pregnancy	Multiple gestation	Suspected placenta accreta spectrum
≤4 previous vaginal births	>4 previous vaginal births	Hematocrit <30 with other risk factors
No bleeding disorder	Chorioamnionitis	Platelets <100,000
No history of PPH	History of PPH	Active bleeding on admission
	Large uterine fibroids	Known coagulopathy

CD, cesarean delivery; *CDC*, Centers for Disease Control and Prevention; *ICD*, International Classification of Diseases; *PPH*, postpartum hemorrhage; *SMM*, severe maternal morbidity.

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gestations among patients with SMM. This relationship was consistent regardless of transfusion status. There was no significant difference in the rates of pregnancy-associated hypertension and gestational diabetes between cases with and without SMM. We observed a trend among women with nontransfusion-associated SMM in which a higher proportion of patients had advanced maternal age (28% vs 23%; *P*=.11), obesity (36% vs 32%; *P*=.33), and identified as non-Hispanic Back race (31% vs 26%; *P*=.05). However, the presence of preexisting chronic hypertension was significantly higher in the nontransfusion-associated SMM cohort (18% vs 10%; *P*=.001) than in the overall SMM cohort. Patients with SMM had significantly higher rates of cesarean deliveries than women without SMM. However, the rates of cesarean delivery were similar between patients with nontransfusion- and transfusion-associated SMM (Table 3).

As the hemorrhage risk score increased, we observed higher rates SMM both when including and excluding transfusion in the definition of SMM. The rate of SMM was only 1.6% (n=264) among patients categorized as low risk for hemorrhage compared with 2.5% (n=118) and 13.6% (n=135) among patients who were categorized as medium or high risk for hemorrhage, respectively (*P*<.001) (Figure). Importantly, this association remained even after excluding transfusion from the SMM diagnostic criteria. The unadjusted incidence of nontransfusion-associated SMM occurred in 0.5%, 0.7%, and 2.3% of patients classified as low, medium, or high risk for hemorrhage, respectively (*P*<.001) (Figure).

Using low risk as the referent population and controlling for age, race, site of delivery, and insurance status, we demonstrated that a score of medium or high risk for hemorrhage on the CMQCC admission risk tool is a consistent and significant predictor of risk for SMM (Table 4). Transfusion was an important driver of this association. We observed a 10-fold higher odds of receiving a transfusion among patients classified as high risk when compared with patients classified as low risk (adjusted odds ratio [aOR], 10.9; 95% confidence interval [CI], 8.6−14.0). However, patients classified as high risk also had a significant association with SMM with inclusion (aOR, 8.8; 95% CI, 7.0−11) and exclusion (aOR, 3.6; 95% CI, 2.2−5.9) of transfusion. A designation of medium risk on the CMQCC admission hemorrhage risk tool was associated with SMM overall (aOR, 1.5; 95% CI, 1.2−1.9), but was not found to be significantly associated with nontransfusion-associated SMM (aOR, 1.3; 95% CI, 0.86−2.0).

In addition, we explored CDC ICD-specific indicators to further understand the association between nontransfusion-associated SMM and a designation of high risk on the CMQCC admission hemorrhage risk tool. The dominant indicators in this population are related to hemorrhage-associated morbidity (Table 5). Peripartum hysterectomy and disseminated intravascular coagulation (DIC) comprised 40% and 20% of the cases of nontransfusion-associated SMM, respectively. Five of these hysterectomies were planned (25%) owing to placenta accreta spectrum, whereas 3 were unplanned owing to hemorrhage (n=2; 10%) and infection (n=1; 5%). Other prevalent indicators in this population were acute renal failure (n=3; 15%), pulmonary edema (n=2; 10%), and sepsis (n=2; 10%). Acute renal failure and pulmonary edema were all secondary to preeclampsia.

TABLE 3
Maternal demographic and delivery data stratified by SMM and transfusion status

		SMM (n=517)		SMM no transfusion (n=131)	
Demographics	No SMM (n=21,326)	n (%)	*P* value[a]	n (%)	*P* value[b]
Advanced maternal age (>35 y)	3742 (18)	119 (23)	.001	37 (28)	.001
Race					
Non-Hispanic White	16,317 (77)	349 (67)		87 (66)	
Non-Hispanic Black	3429 (16)	132 (26)	<.001	40 (31)	<.001
Other	1580 (7)	36 (7)		4 (3)	
Insurance status					
Private	12,929 (61)	279 (54)	.002	66 (50)	.02
Government-assisted	8397 (39)	238 (46)		65 (50)	
Pregestational					
Diabetes	219 (1)	15 (3)	<.001	7 (5)	<.001
Hypertension	982 (5)	50 (10)	<.001	23 (18)	<.001
Obesity BMI >35 kg/m^2	6207 (29)	167 (32)	.11	47 (36)	.09
Primiparous	9004 (42)	248 (48)	.01	65 (50)	.09
Twin pregnancy	356 (2)	36 (7)	<.001	5 (4)	.07
Gestational age at delivery					
<32 wk	316 (1)	38 (7)		10 (8)	
>32 and <37 wk	1649 (8)	107 (21)	<.001	30 (23)	<.001
>37 wk	19,361 (91)	372 (72)		91(69)	
Pregnancy-associated hypertension	1202 (6)	35 (7)	.27	9 (7)	.54
Gestational diabetes	1708 (8)	45 (9)	.57	10 (8)	.88
Admission hemoglobin					
<8 g/dL	25 (0.1)	24 (5)	<.001	2 (2)	.01
>8 and <10 g/dL	1001 (5)	96 (19)	<.001	12 (9)	.02
Admission platelets					
<70 per μL	16 (0.08)	9 (2)	<.001	0 (0)	.9
<100 per μL	138 (0.65)	21 (4)	<.001	6 (5)	<.001
Mode of delivery					
Vaginal	15,388 (72)	181 (35)	<.001	56 (43)	<.001
Cesarean	5938 (28)	336 (65)	<.001	75 (57)	<.001

BMI, body mass index; *SMM*, severe maternal morbidity.

[a] *P* values represent no SMM cohort compared with SMM cohort; [b] *P* values represent no SMM cohort compared with SMM no transfusion cohort.

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TABLE 4
Odds of SMM stratified by CMQCC hemorrhage risk score

CMQCC score	SMM	Transfusion	Nontransfusion SMM
Unadjusted OR (95% CI)			
Low	Ref	Ref	Ref
Medium	1.6 (1.3–1.9)	1.6 (1.2–2.1)	1.5 (0.98–2.2)
High	9.5 (7.6–11.8)	11.2 (8.8–14.3)	4.2 (2.6–6.9)
Adjusted[a] OR (95% CI)			
Low	Ref	Ref	Ref
Medium	1.5 (1.2–1.9)	1.6 (1.2–2.1)	1.3 (0.86–2.0)
High	8.8 (7.0–11)	10.9 (8.6–14.0)	3.6 (2.2–5.9)

CI, confidence interval; *CMQCC*, California Maternal Quality Care Collaborative; *OR*, odds ratio; *SMM*, severe maternal morbidity.

[a] Adjusted for delivery site, insurance status, age, race (factors not included in hemorrhage risk model).

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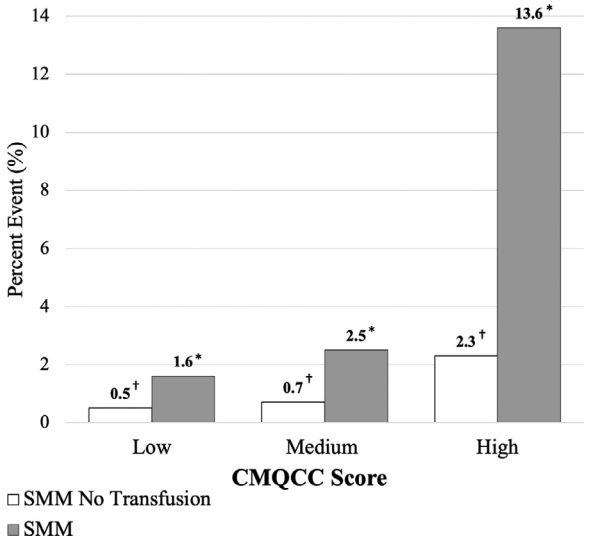
FIGURE
Rate of SMM stratified by CMQCC hemorrhage risk score



Rate is displayed with SMM including and excluding transfusion. The *asterisk* and *dagger* represent significant differences across CMQCC risk categories using chi-square testing.

CMQCC, California Maternal Quality Care Collaborative; *SMM*, severe maternal morbidity.

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TABLE 5
Top ICD-10 codes for nontransfusion-associated, cause-specific SMM in patients who scored as high risk on the CMQCC

Cause-specific ICD-10 code	SMM no transfusion, n=20	Percentage
Peripartum hysterectomy	8	40
Disseminated intravascular coagulation	4	20
Acute renal failure	3	15
Pulmonary edema	2	10
Sepsis	2	10

CMQCC, California Maternal Quality Care Collaborative; *ICD-10*, International Classification of Diseases, Tenth Revision; *SMM*, severe maternal morbidity.

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Discussion

Principal findings

Our findings once again demonstrate the known association between CMQCC admission hemorrhage risk score and transfusion and, in addition, provides evidence that the hemorrhage risk score is associated with both transfusion- and nontransfusion-associated SMM. This finding highlights that the utility of a commonly used hemorrhage risk prediction tool extends beyond hemorrhage prediction and can provide insight into a patient's risk for an SMM event. Specifically, scoring as high risk for hemorrhage on the CMQCC admission hemorrhage risk prediction tool was associated with transfusion- and nontransfusion-associated hemorrhage morbidity such as hysterectomy, DIC, and sequalae of pregnancy-associated hypertensive disease such as pulmonary edema and acute renal failure. A classification as medium risk was associated with transfusion-associated SMM, but no relationship between a medium-risk score and nontransfusion-associated SMM was observed. Thus, this important tool for hemorrhage risk prediction should in addition be recognized to have a secondary function to identify patients at risk for SMM.

Results

Utilization of the hemorrhage risk score not only predicts the occurrence of hemorrhage, but also the occurrence of hemorrhage-associated morbidity such as transfusion, hysterectomy, or coagulopathy.[14] Similar to previous work, we found that patients who were scored as medium or high risk for hemorrhage had significantly higher odds of receiving a transfusion compared with low-risk patients.[14,16,23] Using the CDC criteria for SMM, transfusion has been documented as the most prevalent indicator for SMM.[4,18] As expected, transfusion was a driving factor for the association of hemorrhage risk score with SMM in our study. However, using only administrative ICD codes to identify transfusion has significant limitations because a patient can screen positive for SMM after only receiving 1 unit of blood. More recent guidelines for transfusion suggested that the presence or absence of transfusion alone is not a sufficient indicator for SMM. Rather, the quantity and type of product transfused should be considered in making the diagnosis of SMM.[7]

Interestingly, rates of pregnancy-associated hypertension did not differ significantly across hemorrhage risk classification or between cases with and without SMM. We speculate that this was because of the inability to differentiate mild from severe hypertensive disease within this subgroup. However, we found a higher probability of hypertensive-associated morbidity in patients who were scored as high risk for hemorrhage on the CMQCC hemorrhage risk prediction tool. We postulate that this finding could be because of some overlap in risk factors associated with both hypertensive disease and hemorrhage,

including multiple gestation and abnormal placentation.

Clinical implications

In an effort to better understand and reduce the rates of maternal mortality, the focus of obstetrical research now includes SMM as an important measure of maternal health.[24] Here we demonstrate a strong association between a commonly used hemorrhage risk prediction tool and SMM. From a public health perspective, these tools are already implemented at national level and can be used not only to predict the risk for hemorrhage, but also to predict the risk for both transfusion- and nontransfusion-associated morbidity. This highlights the opportunity to improve practices and protocols in response to when a patient is classified as high risk for hemorrhage. Examples of protocol enhancements could include increased awareness with a multidisciplinary discussion of hemorrhage risk score, patient optimization before delivery, or promoting earlier use of uterotonics, among others. Importantly, developing new tools aimed at risk stratification of patient cohorts at high risk for SMM may enhance clinical response and improve patient care in these rare events.

Research implications

A significant body of research exists in which common risk factors are evaluated and various screening modalities for SMM are validated.[9,18,24–28] At this time, there is no simple or standardized screening tool for SMM. We found that the CMQCC hemorrhage risk prediction tool can provide insight into a patient's risk for SMM. A high score is most strongly associated with hemorrhage-associated morbidity such as transfusion, peripartum hysterectomy, and DIC. However, the score in addition functions to predict the occurrence of nontransfusion-associated SMM. Future work aimed at evaluating the association between individual risk factors and transfusion-associated and nontransfusion-associated morbidity could be used to better understand the relationship between SMM and CMQCC and to identify risk factors specifically associated with morbidity. Importantly, further work is needed to develop a practical and generalizable screening tool for all-cause SMM that can be universally adopted at a national level.

Strengths and limitations

Our study has several strengths. Using a large and modern cohort, we evaluated the association between a commonly used hemorrhage risk assessment tool and SMM, a rare clinical event. This cohort was large enough to evaluate trends in both transfusion- and nontransfusion-associated SMM across hemorrhage risk strata. In addition, we were able to comment on trends in cause-specific etiologies of SMM owing to the size of our cohort. However, the CDC definition of SMM utilizes administrative data primarily comprising ICD diagnosis and procedure codes. Existing data suggest that this screening method is reasonable, but can overestimate the incidence of SMM.[18,29] Our study has several other important limitations. At our institution, we prospectively utilize a validated hemorrhage risk score that is similar to the CMQCC score, but different in that it generates a score based on weighted risk factors.[30] Because our hemorrhage prediction tool is institution specific, we chose to use criteria from a nationally recognized hemorrhage risk score that has greater generalizability. The CMQCC hemorrhage risk score was retrospectively assigned to patients using quantitative laboratory values and ICD diagnosis and procedure codes. In addition, we limited this analysis to the CMQCC admission hemorrhage risk score. Because risk for hemorrhage can escalate throughout the delivery process owing to development of intrapartum or postpartum risk factors, we may not capture this dynamic process. Importantly, we recognize that our analysis regarding the small cohort of women with nontransfusion-associated SMM is limited by the small sample size, but does provide some descriptive insight into this tool and patient population. In addition, this dataset is limited to delivery hospitalizations and does not allow comment on SMM that occurred following postpartum hospital discharge. As mentioned previously, owing to limitations in ICD coding, we were unable to determine the quantity or type of product transfused.

Conclusions

In addition to predicting the risk for obstetrical hemorrhage and transfusion, our findings indicate that the CMQCC admission hemorrhage risk tool has utility for predicting the risk of an SMM event. A classification as high risk for hemorrhage performed well at predicting SMM that was unrelated to transfusion alone. Our data reinforce the importance of consistently using this tool for every patient at the time of delivery admission. The CMQCC tool is already utilized at a national level. Our study findings have important implications for the management of obstetrical patients admitted for delivery. A patient's risk score can be used as an opportunity to enhance preparedness to prevent an SMM event or to intervene early to mitigate morbidity. ■

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Received Mar. 15, 2021; revised May 20, 2021; accepted May 26, 2021.

The authors report no conflict of interest.

This study received no financial support.

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