

Original Research

Severe maternal morbidity in the periviable period stratified by mode of delivery: a retrospective cohort study

Amanda Baucom, MD, MBA¹, Robert Rossi, MD², Megan Jiang, BS, BA³

¹ Maternal Fetal Medicine, University of Cincinnati, ² Maternal Fetal Medicine, University of Cincinnati, ³ University of Cincinnati

Keywords: Periviable birth, maternal morbidity, cesarean section

<https://doi.org/10.54053/001c.132284>

North American Proceedings in Gynecology & Obstetrics

Vol. 4, Issue 1, 2025

Objective

We sought to characterize the rate and type of severe maternal morbidity (SMM) among patients who delivered in the periviable period (20 0/7 through 25 6/7 weeks of gestation) and then to further stratify results by mode of delivery (cesarean versus vaginal).

Design

Single center retrospective cohort study of patients at the University of Cincinnati Medical Center delivering within the periviable between 2012 through 2021.

Methods

Maternal demographic and social factors, preexisting maternal co-morbidities, obstetric characteristics, interventions, and SMM were collected by three abstractors via manual chart review. SMM was defined according to ACOG's example list. Differences in SMM between mode of delivery were compared using t-test and chi square analysis. Fisher's exact test was used to compare counts equal to or less than 5.

Main Outcome Measures

Our primary outcome was the rate and type of severe maternal morbidity among patients who delivered in the periviable period. Our secondary outcome was this SMM stratified by mode of delivery.

Results

There were 338 periviable births among 289 patients during the study period. 152 (52.6%) underwent cesarean and 137 (47.4%) delivered vaginally. Overall rate of SMM among periviable births was 19.0%. The individuals delivered via cesarean section had higher rates of SMM (30.9% vs 5.8%, $p < 0.001$, aOR 3.9, 95% CI 1.1-14.3).

Conclusions

One in five patients who delivered in the periviable period experienced a severe maternal morbidity, with almost a 4-fold higher risk among cesarean births compared to vaginal.

INTRODUCTION

Severe maternal morbidity (SMM) affects more than 50,000 patients per year or approximately 2% of all deliveries in the United States, with steadily increasing frequency ("Severe Maternal Morbidity in the United States," n.d.). The etiology for this increase is unknown, but may be secondary to changes in the overall health of the population ("Severe Maternal Morbidity in the United States," n.d.; Hinkle, Sharma, and Kim 2012; Fisher et al. 2013; Campbell et al. 2013; Small et al. 2012). We previously demonstrated that premature delivery, and in particular, periviable birth (defined as delivery between 20 0/7 through 25 6/7 weeks of

gestation) (Hinkle, Sharma, and Kim 2012), is associated with high rates of maternal morbidity (17.2%: periviable births, 5.1%: preterm births, and 2.7%: term births) (Rossi and DeFranco 2018).

This high rate of maternal morbidity is likely due to a combination of underlying maternal medical co-morbidities, obstetric complications, and obstetric interventions that are associated with periviable birth (American College of Obstetricians and Gynecologists 2017). The American College of Obstetricians and Gynecologists and the Society for Maternal-Fetal Medicine acknowledge in the Obstetric Care Consensus, "Periviable Birth," that while some obstetric interventions aimed at optimizing neonatal outcomes pose little risk to the patient, others, including classical ce-

sarean delivery, may result in significant short-term and long-term maternal morbidity for uncertain neonatal benefit (American College of Obstetricians and Gynecologists 2017). Despite this cautionary guideline, periviable cesarean rates have increased over time (Stoll, Hansen, Bell, et al. 2010; Costeloe et al. 2012; Ancel, Goffinet, and EPIPAGE 2 Writing Group 2014; Rossi, Hall, and DeFranco 2019).

There is a paucity of research on the prevalence and type of SMM in the periviable period, particularly the association between cesarean utilization and SMM. In this study, we sought to characterize the rate and type of SMM among patients who delivered in the periviable period and the association between cesarean and these adverse maternal outcomes.

METHODS AND MATERIALS

We performed a single-center retrospective cohort study of all periviable births occurring at the University of Cincinnati Medical Center from 2012 to 2021. The protocol for this study was approved by the Human Subjects Institutional Board Review at the University of Cincinnati Medical Center. Periviable birth was defined as livebirth occurring between 20 0/7 - 25 6/7 weeks of gestation. Pregnancies that resulted in fetal demise were excluded, consistent with prior literature (Reddy et al. 2015; Romagano et al. 2020). Data were collected and managed using REDCap electronic data capture tools hosted at University of Cincinnati (Harris et al. 2009).

Our primary objective was to determine SMM rate among patients who delivered in the periviable period. SMM was defined using the Gold Standard Severe Maternal Morbidity guidelines established by Main et al (American College of Obstetricians and Gynecologists 2016) and published in the Obstetric Care Consensus No.5 "Severe Maternal Morbidity: Screening and Review." (Main et al. 2016) This list of 37 maternal morbidity indicators is organized into the following SMM categories: hemorrhage, hypertension/neurologic, renal, sepsis, pulmonary, cardiac, intensive care unit/invasive monitoring, surgical, bladder, and bowel complications, and anesthesia complications (Box S1). In cases of multifetal births, the number of SMM was counted once per mother.

The secondary objective was to compare the rate and risk of composite SMM between vaginal and cesarean delivery groups to determine the association between periviable cesarean utilization and SMM. Differences in maternal demographic, social, medical, obstetric, and delivery characteristics were compared between patients who underwent cesarean and vaginal birth. These differences were compared using t-test and chi square analysis, for continuous and categorical data, respectively. Fisher's exact test was used to compare counts ≤ 5 . Mann-Whitney U test was applied for nonparametric testing. Variables with significant differences in bivariate analyses were selected to perform a multivariate logistic regression for estimation of the adjusted odds (aOR) of composite SMM in cesarean verses vaginal delivery. This regression model was constructed us-

ing a backward selection process. As outcome events were rare and there were significant demographic and obstetrical differences between mode of delivery in pretest bivariate comparisons, the number of variables selected was limited to 10 events per variable according to Peduzzi et al to avoid overfitting the model (Peduzzi et al. 1995, 1996). Variables selected for the adjusted model included maternal race, pregnancy induced hypertensive disease, chronic hypertension, delivery indication, pregestational diabetes, and gestational age at delivery.

We then stratified the patients by delivery indication and performed a subgroup analysis. Groups included 1) maternal-indicated (delivery due to maternal illness, pregnancy induced hypertensive disease, or other maternal condition negatively impacted by pregnancy), 2) fetal-indicated (delivery due to fetal distress, non-reassuring fetal testing, cord prolapse, spontaneous preterm labor, or other fetal indication), or 3) dual-indicated (delivery due to both maternal and fetal condition including antepartum hemorrhage secondary to abruption, placenta previa or accreta, or chorioamnionitis). Multivariate logistic regression was performed for each indication group to estimate the aOR of cesarean delivery and composite SMM. Lastly a qualitative analysis, in which the maternal delivery and neonatal record were reviewed for all patients who had an SMM. This was performed by the 3 abstractors (MJ, AB, and RR) to assign likelihood of cesarean causing SMM (causative, likely, possibly, not causative) and likelihood of cesarean mitigating SMM (yes, possibly, no) for each case among patients categorized as "fetal" or "maternal" indicated delivery. These assignments are shown in Table S1 and S2.

Significant differences were defined as comparisons with probability value of <0.05 and 95 percent confidence interval not inclusive of the null value of 1.0. Statistical analyses were performed using STATA Release 15 software (StataCorp, College Station, TX).

RESULTS

Of 462 periviable deliveries during the study period, 124 were fetal demises, leaving 338 livebirths among 289 patients. 52.6% (n=152) underwent cesarean delivery (Figure 1). Individuals for both modes of delivery were similar in age, race/ethnicity, parity, body mass index (kg/m^2), substance/tobacco use, and socioeconomic status (Table 1). The individuals delivered via cesarean section had higher rates of medical co-morbidities including hypertensive disease both chronic and pregnancy-induced, pregestational diabetes, and admissions for fetal growth restriction or hypertensive complications. The individuals who underwent a cesarean section were hospitalized longer (9.7 ± 7.2 vs 5.7 ± 5.0 days, $p < 0.001$) and had longer latency from admission until delivery if admitted for preterm premature rupture of membranes (PPROM) (14.4 ± 9.1 vs 6.7 ± 10.5 days, $p = 0.032$) (Table 2).

Patients who underwent cesarean section were more likely to receive other obstetric interventions such as antenatal steroids and magnesium for fetal neuroprotection. Cesarean deliveries also had a longer latency between ad-

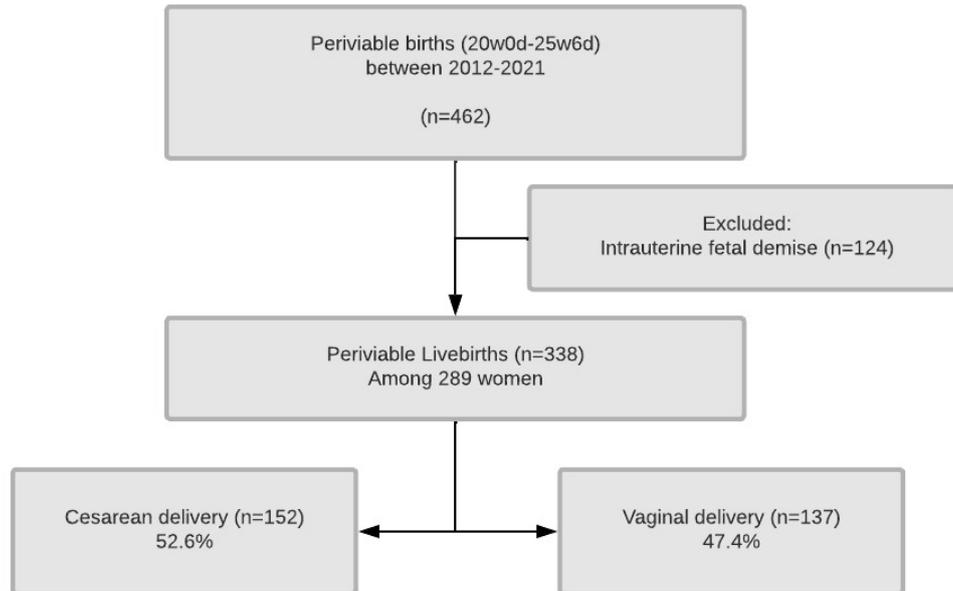


Figure 1. Flow diagram of study population

Table 1. Baseline Maternal Characteristics of Births at 20 0/7 – 25 6/7 weeks

Characteristic	Total Pregnancies (n=289)	Cesarean delivery (n=152)	Vaginal delivery (n=137)	p-value
Maternal Age (years)	27.8±6.2	28.2±6.5	27.4±5.9	0.293
Advanced maternal age (≥35 y/o)	44 (15.2)	27 (17.8)	17 (12.4)	0.206
Maternal Race/ethnicity				
Asian	8 (2.8)	4 (50.0)	4 (50.0)	0.201
Hispanic	8 (2.8)	3 (37.5)	5 (62.5)	
Non-Hispanic Black	119 (41.2)	59 (49.6)	60 (50.4)	
Non-Hispanic White	136 (47.1)	80 (58.8)	56 (41.2)	
Other	18 (6.2)	6 (33.3)	12 (66.7)	
Nulliparous	99 (40.6)	49 (38.9)	50 (42.4)	0.580
Maternal BMI (kg/m ²) ⁺	29.1 (25.1, 36.4)	30.5 (23.6, 38.0)	28.8 (25.4, 35.6)	0.631
Obese (BMI>30.0 kg/m ²)	155 (53.6)	89 (58.6)	66 (48.2)	0.077
Tobacco Use	56 (20.0)	28 (18.8)	28 (21.4)	0.603
Substance abuse	46 (15.9)	24 (15.8)	22 (16.1)	0.950
Medicaid insurance	163 (56.6)	94 (61.8)	69 (50.7)	0.058
Married	121 (42.8)	71 (47.3)	50 (37.6)	0.098

Data are n (%), mean ± standard deviations, or median (interquartile range)

BMI – body mass index

⁺Mann-Whitney U test

mission and delivery resulting in deliveries at later gestational ages. Individuals delivered via cesarean section were more likely to deliver due to fetal distress (30.9 vs 2.2%, $p<0.001$) and hypertensive disease of pregnancy (15.8 vs 2.2%, $p<0.001$) compared to vaginal deliveries. There was a higher incidence of fetal malpresentation in the individuals who delivered via cesarean section (Table 3).

Among the 289 patients, 19.0% (n=55) experienced ≥ 1 SMM event. Because some patients had multiple events, the composite rate of SMM events was 52.2 per 100 patients (n=151 events). The most observed SMM categories were hypertensive/neurologic (11.1%), ICU-related (5.5%), hemorrhage (4.8%), and pulmonary (4.2%) morbidities. Composite SMM rate was significantly higher in cesarean deliv-

Table 2. Baseline Obstetric Characteristics of Births at 20 0/7 – 25 6/7 weeks

Characteristic	Total Pregnancies (n=289)	Cesarean delivery (n=152)	Vaginal delivery (n=137)	p-value
Prior preterm Birth (<37 w)	66 (22.9)	36 (23.8)	30 (21.9)	0.695
Prior cesarean delivery	54 (19.1)	30 (20.4)	24 (17.7)	0.555
Interpregnancy interval (<12 months)	41 (15.5)	21 (15.1)	20 (16.0)	0.842
Hypertensive disease				
Chronic HTN	64 (22.2)	47 (30.9)	17 (12.4)	<0.001
Gestational HTN	1 (0.7)	1 (0.7)	1 (0.7)	1.000
Preeclampsia	14 (4.8)	9 (5.9)	5 (3.7)	0.369
Superimposed preeclampsia	21 (7.3)	20 (13.2)	1 (0.7)	<0.001
HELLP syndrome	4 (1.4)	4 (2.6)	0 (0)	0.124
Eclampsia	1 (0.4)	1 (0.7)	0 (0)	1.000
Any pregnancy induced HTN	42 (16.3)	35 (25.9)	7 (5.7)	<0.001
Pregestational diabetes	16 (5.5)	14 (9.2)	2 (1.5)	0.004
Cerclage placed in pregnancy	27 (9.5)	13 (8.8)	14 (10.3)	0.665
Indication for admission				
Hypertensive disease	35 (12.1)	30 (19.7)	5 (3.7)	<0.001
Maternal, other	16 (5.5)	12 (7.9)	4 (2.9)	0.075
Vaginal bleeding, previa	15 (5.2)	11 (7.2)	4 (2.9)	0.116
Vaginal bleeding, abruption	12 (4.2)	5 (3.3)	7 (5.1)	0.439
Vaginal bleeding, other	24 (8.3)	8 (5.3)	16 (11.7)	0.048
Preterm labor	112 (38.8)	40 (26.3)	72 (52.6)	<0.001
PPROM	75 (26.0)	34 (22.4)	41 (29.9)	0.143
Cervical insufficiency	27 (9.3)	19 (12.5)	8 (5.8)	0.052
Fetal growth restriction	14 (4.8)	13 (8.6)	1 (0.7)	0.002
Abnormal fetal testing	12 (4.2)	10 (6.6)	2 (1.5)	0.038
Fetal, other	7 (2.4)	5 (3.3)	2 (1.5)	0.452
Days admitted prior to delivery (days) ⁺	2 (1,5)	3 (1,6)	1(0,3)	0.002
Maternal length of hospitalization (days) ⁺	6 (4,10)	8 (5,11)	4 (3,6)	<0.001
Length of latency if PPRM (days) ⁺	2(1,7)	3(1,8)	1 (1,5)	0.101

Data are n (%), mean ± standard deviations, or median (interquartile range)

HTN – hypertension, HELLP – hemolysis, elevated liver enzymes, and low platelets, PPRM – pre-labor preterm rupture of membranes

⁺Mann-Whitney U test

eries for both the number of patients who experienced ≥1 event (30.9 vs 5.8%, p<0.001) and the number of events per 100 patients (83.6 vs 17.5, p<0.001). By category, the cesarean deliveries had higher rates of hypertensive/neurologic (20.4 vs 0.7%, p<0.001) and ICU/invasive monitoring (9.2 vs 1.5%, p=0.004). Patients who delivered via cesarean had higher rates of continuous infusion of anti-hypertensive agents (15.1 vs 0.7%, p<0.001), administration of IV anti-hypertensives for >48 hours after delivery (13.8 vs 0%, p<0.001), and HELLP syndrome or disseminated intravascular coagulation (6.6 vs 0%, p=0.002). Cesarean deliveries had lower rates of retained placenta (0.7 vs 14.7%, p<0.001) and subsequent D&C (0 vs 10.9%, p<0.001) but higher rates of postpartum endometritis (7.3 vs 1.5%, p=0.022). In the

multivariable logistic regression model, cesarean delivery during the periviable period was associated with an increased risk of composite SMM (adjusted RR 6.6, 95% CI 2.2-19.9) as shown in [Table 3](#).

When categorized by delivery indication, 11.1% (n=32) of patients were delivered for maternal indications, 74.7% (n=216) for fetal indications, and 14.2% (n=41) for dual indications. In all three subgroups, SMM rate was higher in cesarean delivery compared to vaginal (maternal: 92.6 vs 20.0%, p<0.002; fetal: 14.4 vs 5.4%, p=0.025; dual: 33.3 vs 5.0%, p=0.045). The association between cesarean and SMM was highest among patients who delivered for maternal indications (unadjusted OR 50.0, CI 3.6-668.3) compared to fetal (unadjusted OR 3.0, CI 1.1-8.0) and dual indications

Table 3. Obstetric interventions, Delivery characteristics, and Severe Maternal Morbidities

Characteristic	Total Pregnancies (n=289)	Cesarean delivery (n=152)	Vaginal delivery (n=137)	p-value
Tocolytic therapy	147 (50.9)	84 (55.3)	63 (46.0)	0.115
GBS antibiotic prophylaxis	107 (37.0)	63 (41.5)	44 (32.1)	0.101
Magnesium for fetal neuroprotection	184 (63.7)	129 (84.9)	55 (40.2)	<0.001
Latency antibiotics if PPROM (n=75)	51 (68.0)	29 (85.3)	22 (53.7)	0.003
Expectant management of preeclampsia	28 (9.7)	26 (17.1)	2 (1.5)	<0.001
Antenatal corticosteroids	202 (69.9)	138 (90.8)	64 (46.7)	<0.001
Fetal monitoring	162 (56.1)	115 (75.7)	47 (34.3)	0.001
Delivery characteristics				
Gestational age at delivery (wks) ⁺	24 (23, 25)	25 (24,25)	23 (22, 25)	0.002
Type of uterine incision			Type of vaginal birth	
Low transverse		43 (28.3)	Spontaneous	109 (82.6)
Low vertical		1 (0.7)	Breech SVD	38 (28.4)
Classical		103 (67.8)	VBAC	23 (17.4)
High transverse		3 (2.0)		
Other		2 (1.3)		
Fetal growth restriction	42 (15.6)	36 (24.8)	6 (4.8)	<0.001
Birthweight (g)	590±179	623±154	552±198	<0.001
Fetal presentation				
Cephalic	156 (54.7)	61 (40.4)	95 (70.9)	<0.001
Breech	93 (32.6)	70 (46.4)	23 (17.2)	
Transverse	34 (11.9)	19 (12.6)	15 (11.2)	
Other	2 (0.7)	1 (0.7)	1 (0.8)	
Delivery Indication				
Hypertensive disease of pregnancy	27 (9.3)	24 (15.8)	3 (2.2)	<0.001
Cord prolapse	7 (2.4)	6 (4.0)	1 (0.7)	0.124
Chorioamnionitis	30 (10.4)	13 (8.6)	17 (12.4)	0.283
Vaginal bleeding, previa	4 (1.4)	4 (2.6)	0 (0)	0.124
Vaginal bleeding, accreta	2 (0.7)	2 (1.3)	0 (0)	0.500
Vaginal bleeding, abruption	11 (3.8)	6 (4.0)	5 (3.7)	1.000
Vaginal bleeding, other	3 (1.0)	2 (1.3)	1 (0.7)	1.000
Spontaneous preterm labor	146 (50.5)	38 (25.0)	108 (78.8)	<0.001
Maternal condition, other	3 (1.0)	2 (1.3)	1 (0.7)	1.000
Fetal condition, other	15 (5.2)	13 (8.6)	2 (1.5)	0.007
Fetal distress	50 (17.3)	47 (30.9)	3 (2.2)	<0.001
Maternal illness	6 (2.1)	4 (2.6)	2 (1.5)	0.687
Estimated Blood Loss (mL) at delivery	618±432	884±382	316±432	<0.001
Total Blood Loss (mL) at delivery	686±474	913±424	431±394	<0.001
Maternal Morbidities				

Characteristic	Total Pregnancies (n=289)	Cesarean delivery (n=152)	Vaginal delivery (n=137)	p-value
Obstetrical Hemorrhage				
Hemorrhagic SMM (patients)*	14 (4.8)	8 (5.3)	6 (4.4)	0.727
Hemorrhagic SMM (events) †	21 (7.3)	15 (9.9)	6 (4.4)	0.073
Postpartum hemorrhage	65 (22.5)	29 (19.1)	36 (26.3)	0.143
PPH > 4 units prbc	7 (2.4)	6 (4.0)	1 (0.7)	0.124
PPH > 2 prbc/ffp	2 (0.7)	2 (1.3)	0 (0)	0.499
PPH resulting in ICU admission	1 (0.4)	1 (0.7)	0 (0)	1.000
Bakri balloon	3 (1.0)	1 (0.7)	2 (1.5)	0.605
Uterine artery ligation	4 (1.4)	4 (2.6)	0 (0)	0.124
B-Lynch	1 (0.4)	0 (0)	1 (0.7)	0.474
Bakri or B-Lynch + 2 units prbc	2 (0.7)	1 (0.7)	1 (0.7)	1.000
Requiring operation	2 (0.7)	1 (0.7)	1 (0.7)	1.000
Blood transfusion	33 (11.4)	21 (13.8)	12 (8.8)	0.177
Retained placenta	21 (7.4)	1 (0.7)	20 (14.7)	<0.001
D&C for retained placenta	14 (5.1)	0 (0)	14 (10.9)	<0.001
EBL > 1 L	34 (11.8)	24 (15.8)	10 (7.4)	0.027
Unplanned hysterectomy	3 (1.0)	3 (2.0)	0 (0)	0.249
Uterine rupture	1 (0.4)	1 (0.7)	0 (0)	0.342
Hypertension/Neurologic				
Hypertensive/Neurologic SMM (patients)*	32 (11.1)	31 (20.4)	1 (0.7)	<0.001
Hypertensive/Neurologic SMM (events) †	62 (21.5)	60 (39.5)	2 (1.5)	<0.001
Eclamptic Seizure or Status Epilepticus	3 (1.0)	3 (2.0)	0 (0)	0.249
Continuous infusion of anti-HTN agents	24 (8.3)	23 (15.1)	1 (0.7)	<0.001
IV anti-HTN > 48 hours after delivery	21 (7.3)	21 (13.8)	0 (0)	<0.001
Non-responsiveness or Loss of Vision	1 (0.4)	1 (0.7)	0 (0)	1.000
Severe Liver Injury	3 (1.0)	2 (1.3)	1 (0.7)	1.000
HELLP or DIC	10 (3.5)	10 (6.6)	0 (0)	0.002
Renal				
Renal SMM (patients)*	3 (1.0)	3 (2.0)	0 (0)	0.249
Renal SMM (events) †	3 (1.0)	3 (2.0)	0 (0)	0.249
Oliguria	1 (0.4)	1 (0.7)	0 (0)	1.000
AKI (2.0 or double baseline)	3 (1.0)	3 (2.0)	0 (0)	0.249
Sepsis				
Sepsis SMM (patients)*	9 (3.1)	6 (3.9)	3 (2.2)	0.506
Sepsis SMM (events) †	14 (4.8)	9 (5.9)	5 (3.6)	0.368
Sepsis	8 (2.8)	5 (3.3)	3 (2.2)	0.726
Septic Shock	1 (0.4)	1 (0.7)	0 (0)	1.000
Infection with pulmonary complications	5 (1.7)	3 (2.0)	2 (1.5)	1.000
Bacteremia	4 (1.4)	2 (1.5)	2 (1.3)	1.000
Endometritis	13 (4.6)	11 (7.3)	2 (1.5)	0.022
SPT	1 (0.4)	1 (0.7)	0 (0)	1.000

Characteristic	Total Pregnancies (n=289)	Cesarean delivery (n=152)	Vaginal delivery (n=137)	p-value
Pulmonary				
Pulmonary SMM (patients)*	12 (4.2)	8 (5.3)	4 (2.9)	0.386
Pulmonary SMM (patients) †	13 (4.5)	9 (5.9)	4 (2.9)	0.264
ARDS/PNA/Edema	8 (2.8)	4 (2.6)	4 (2.9)	1.000
Ventilation	3 (1.0)	3 (2.0)	0 (0)	0.249
Pulmonary Embolism	1 (0.4)	1 (0.7)	0 (0)	1.000
DVT	1 (0.4)	1 (0.7)	0 (0)	1.000
Cardiac				
Cardiac SMM (patients)*	2 (0.7)	2 (1.3)	0 (0)	0.500
Cardiac SMM (events) †	3 (1.0)	3 (2.0)	0 (0)	0.249
Cardiac disease admitted to ICU	1 (0.4)	1 (0.7)	0 (0)	1.00
Arrhythmia medication	1 (0.4)	1 (0.7)	0 (0)	1.000
Arrhythmia	1 (0.4)	1 (0.7)	0 (0)	1.000
Intensive care Unit/Invasive monitoring				
ICU SMM (patients)*	16 (5.5)	14 (9.2)	2 (1.5)	0.004
ICU SMM (events) †	21 (7.3)	19 (12.5)	2 (1.5)	<0.001
ICU admission	15 (5.2)	13 (8.6)	2 (1.5)	0.007
Central line	6 (0)	6 (4.0)	0 (0)	0.031
Surgical, bladder, or bowel complications				
Surgical complication SMM (patients)*	6 (2.1)	5 (3.3)	1 (0.7)	0.218
Surgical complication SMM (events) †	7 (2.4)	6 (3.9)	1 (0.7)	0.124
Bowel/bladder injury	2 (0.7)	2 (1.3)	0 (0)	0.500
Ileus	2 (0.7)	1 (0.7)	1 (0.7)	1.000
Internal hematoma	1 (0.4)	1 (0.7)	0 (0)	1.000
SSI	2 (0.7)	2 (1.3)	0 (0)	0.500
Anesthesia Complications				
Anesthesia complications SMM (patients)*	7 (2.4)	3 (2.0)	4 (2.9)	0.711
Anesthesia complications SMM (events) †	7 (2.4)	3 (2.0)	4 (2.9)	0.711
Total spinal anesthesia	1 (0.4)	1 (0.7)	0 (0)	1.000
Epidural hematoma	2 (0.7)	1 (0.7)	1 (0.8)	1.000
Aspiration pneumonia	4 (1.4)	1 (0.7)	3 (2.2)	0.348
Other complications				
Postpartum readmission	6 (2.1)	5 (3.3)	1 (0.7)	0.218
Postpartum psychosis	1 (0.4)	1 (0.7)	0 (0)	1.000
Total SMM				
Composite SMM (patients)*	55 (19.0)	47 (30.9)	8 (5.8)	<0.001
Composite SMM (events) †	151(52.2)	127 (83.6)	24 (17.5)	<0.001
Cesarean association with SMM	Crude OR (95% CI)	aOR (95% CI)		

Characteristic	Total Pregnancies (n=289)	Cesarean delivery (n=152)	Vaginal delivery (n=137)	p-value
Composite SMM (patients)*	7.2 (3.3-15.9)	6.6 (2.2-19.9)		

Data are n (%), mean ± standard deviations, or median (interquartile range)

GBS – group B streptococcus, PPRM – pre-labor preterm rupture of membranes, SVD – spontaneous vaginal delivery, VBAC – vaginal birth after cesarean

*Patients with at least 1 SMM event

†Total number of SMM events per cohort (events/100 patients)

aRR – adjusted relative risk.

Italicized: individual severe maternal morbidities included in the composite of SMM (defined in Box.1).

Adjusted model included covariates: maternal age, pregnancy induced hypertensive disease, chronic hypertension, delivery indication, obesity, Medicaid insurance, maternal race, gestational age at delivery.

*Mann-Whitney U test

(unadjusted OR 9.5, CI 1.0-86.3). However, these results should be interpreted with caution due to imprecise estimates.

A qualitative analysis was performed by the 3 abstractors (MJ, AB, and RR) of each patient who experienced SMM and their hospitalization to assign the likelihood of causality (causative, likely, possibly, not causative) between SMM and the mode of delivery. Among 15 patients who delivered for fetal indications and experienced SMM, 7 were deemed either causative, likely, or possibly causative (Table S1). Of these 15, 40% (n=6) had ≥1 SMM event. Four of these patients experienced SMM events that can be definitively tied to their cesarean section (prolonged postoperative ileus, bladder injury, small bowel injury). Only 1 had a permanent morbidity, unplanned hysterectomy in an otherwise healthy patient. In 8 patients, cesarean was determined to have either mitigated or possibly mitigated the SMM event. Comparatively, among patients who delivered for maternal indications (n=25), there were no cases where the cesarean delivery was deemed possibly causative. In all 25 of these patients, the cesarean delivery was determined to have possibly mitigated the SMM event (Table S2).

DISCUSSION

MAIN FINDINGS

We found that nearly one in five patients who deliver in the periviable period experience an SMM event. When stratified based on mode of delivery, the cesarean deliveries experienced significantly higher rates of SMM compared to the vaginal deliveries (30.9 vs 5.8%, aOR 3.9, 95% CI 1.1-14.3, p<0.001). In subgroup analysis of delivery method separated by delivery indication (maternal vs fetal vs dual), 96.2 % of patients who underwent a cesarean section experienced an SMM. Despite higher rates of SMM among patients who delivered by cesarean, a detailed review of SMM cases among those delivered for fetal and maternal indications revealed cesarean as causative in a minority of cases and perhaps mitigated SMM in many cases.

INTERPRETATION

The decision to offer to an obstetric intervention in the periviable period requires equipoise between associated maternal risks and degree of expected neonatal benefit. These clinical decisions should be taken in context of the

newborn's overall prognosis, which changes substantially with increasing gestational age at delivery. There are no randomized controlled trials comparing modes of delivery in the periviable period, however there are limited retrospective studies including our own with mixed conclusions (Romagano et al. 2020; Harris et al. 2009; American College of Obstetricians and Gynecologists 2016; Main et al. 2016; Peduzzi et al. 1995, 1996; Tucker Edmonds et al. 2015; Czarny et al. 2021; Reddy et al. 2012; Lee and Gould 2006; Wylie et al. 2008). As such, the Obstetric Care Consensus titled "Periviable Birth" recommends against routine utilization of cesarean for the indication of periviable birth alone (American College of Obstetricians and Gynecologists 2017). Blanc et al performed a meta-analysis and systematic review of SMM risk with cesarean periviable birth and found increased risk of SMM if delivered at < 26 weeks (aOR 1.65, 95% CI 1.52-1.78). Romagano et al performed a retrospective cohort study of maternal morbidity between 23-28 weeks and found composite maternal morbidity of 42% vs 45% in the individuals who delivered vaginally compared to cesarean (aOR 1.00, 95% CI 0.27-3.64) (Romagano et al. 2020). Their higher rate of reported maternal morbidity (Jiang 19.0% vs Romagano (23+0 – 25+6 weeks) 60.5%) is likely due to their inclusion of any blood transfusion, hemorrhage, chorioamnionitis, and prolonged hospital stay in the composite morbidity rate; indicators which are not considered severe morbidity by the gold standard.^{13,16}

As the causal pathway to SMM among patients delivering in the periviable period is highly complex with varying degrees of input from underlying maternal medical comorbidities (i.e. renal disease, preexisting hypertension), obstetric complications (i.e. preeclampsia), and iatrogenic sources (i.e. surgical complications), it is not possible to assume that cesarean delivery necessarily resulted in an SMM event. We conducted a case-by-case review of the 15 patients who delivered via cesarean for fetal indications and who also experienced ≥1 SMM event. It is unsurprising that, among the 4 patients with SMM events that can be definitively tied to their cesarean, the events all fall under the category of surgical, bladder, or bowel complications. There were 3 patients whose SMM events (postoperative sepsis, ICU admission, pulmonary edema) could potentially be related to cesarean, but the causative relationship was less clear. The majority of SMM events in this subgroup were obstetric complications rather than cesarean morbidity. Events in these patients included difficult to control hypertension requiring multiple doses of IV antihyperten-

sives, HELLP syndrome, uterine rupture, placental abruption, and antepartum pulmonary embolism which were not caused by cesarean section, as they preceded the operation. In patients with hypertensive events, it is possible that cesarean mitigated further SMM by expediting delivery and preventing worsening of hypertensive disorders of pregnancy. In the patient with uterine rupture, cesarean was necessary to control maternal hemorrhage and reduce further SMM.

We also conducted a case-by-case review of the 25 patients who delivered via cesarean sections for maternal indications who also experienced ≥ 1 SMM event. Within these 25 patients, cesarean section was not determined to be causative of SMM but rather may have mitigated SMM after extensive review of maternal records. Based on these results, we cannot establish a consistent causal relationship between use of cesarean section and the increased rate of SMM in the periviable period. In some cases, primarily those with fetal indications for cesarean delivery, it is likely that the SMM experienced was a direct result of surgical intervention. In other cases, use of cesarean section likely mitigated further SMM by expediting delivery in an already ill parturient. Therefore, based on this case-by-case review, the association between cesarean and SMM appears nuanced, complex, and may modify SMM risk both positively and negatively.

STRENGTHS AND LIMITATIONS

Strengths of this study include the use of a large contemporary database from a single center that provides only high-level maternal care (level IV) and is one of two centers providing high level neonatal care (level III) within a large geographical region serving both metropolitan and surrounding rural areas. The scope of maternal morbidity evaluated is extensive and incorporated a validated criteria for defining SMM (Main et al. 2016). Additionally, this data provides insight and knowledge for providers on the common types of SMM encountered with periviable delivery and allows more informed counseling for at-risk patients.

Our results are limited by retrospective design and inability to determine causality between mode of delivery and SMM. There are also clinical scenarios in which cesarean may have mitigated SMM, which we are unable to measure reliably. We attempted to address these issues by providing a detailed account of individual SMMs among deliveries and performing secondary analyses stratifying by delivery indication and qualitative assessment of the SMM cause in relation to delivery mode. Additionally, this study was conducted using a cohort of deliveries occurring at a single, tertiary academic center, which may make our findings less generalizable to other populations in different areas. There is also a possibility for potential inaccuracies in reporting of data variables, or complete lack of reporting, which is especially true for emergent deliveries. To limit inaccurate or missing data, all records were abstracted by the same 3

reviewers (MJ, AB, RR) during a period in which one electronic medical reporting system was utilized.

CONCLUSIONS

One in five patients who delivered in the periviable period experienced a severe maternal morbidity. Utilization of cesarean among those delivering within the periviable period was associated with higher rate of severe maternal morbidity. The higher rate of SMM was likely attributed to the underlying maternal condition and obstetric complications rather than the mode of delivery and, in many cases, cesarean may have mitigated further SMM. Additionally, more research is needed to examine other obstetric interventions geared at prolonging a pregnancy for fetal benefit at the expense of maternal health, and how these impact neonatal and maternal outcomes.

ACKNOWLEDGMENT AND DISCLAIMER

This study includes data provided by the Center for Disease Control and Prevention, National Vital Statistics System, which should not be considered an endorsement of this study or its conclusions. No funding was obtained in support of this study.

CORRESPONDING AUTHOR

Megan Jiang BS, BA.
University of Cincinnati College of Medicine
Department of Obstetrics and Gynecology
Medical Sciences Building, Room 4555
231 Albert Sabin Way
Cincinnati, OH 45267-0526
Office phone: 513-558-8448
Mobile phone: 513-502-2261
Fax: (513) 558-3558
Email address: jiangm5@mail.uc.edu

FINANCIAL DISCLOSURE

The authors did not report any potential conflicts of interest.

CONTRIBUTIONS TO AUTHORSHIP

RR conceived of the project. RR, MJ, and AB were involved in experimental design. MJ, AB, and RR abstracted data from manual chart review and created the database. RR performed statistical analysis. RR and MJ interpreted data. MJ wrote the original draft of the manuscript. RR, MJ, ED, and AB edited and revised the manuscript.

Submitted: December 02, 2024 EDT. Accepted: March 11, 2025 EDT. Published: March 01, 2025 EDT.



This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CCBY-NC-ND-4.0). View this license's legal deed at <https://creativecommons.org/licenses/by-nc-nd/4.0> and legal code at <https://creativecommons.org/licenses/by-nc-nd/4.0/legalcode> for more information.

REFERENCES

- American College of Obstetricians and Gynecologists. 2016. "Severe Maternal Morbidity: Screening and Review. Obstetric Care Consensus No. 5." *Obstet Gynecol* 128:e54-60. <https://doi.org/10.1097/AOG.0000000000001642>.
- . 2017. "Periviable Birth. Obstetric Care Consensus No. 6." *Obstet Gynecol* 130:e187-99. <https://doi.org/10.1097/AOG.0000000000002352>.
- Ancel, P. Y., F. Goffinet, and EPIPAGE 2 Writing Group. 2014. "EPIPAGE 2: A Preterm Birth Cohort in France in 2011." *BMC Pediatr* 14 (April):97. <https://doi.org/10.1186/1471-2431-14-97>.
- Campbell, K. H., D. Savitz, E. F. Werner, C. M. Pettker, D. Goffman, C. Chazotte, et al. 2013. "Maternal Morbidity and Risk of Death at Delivery Hospitalization." *Obstet Gynecol* 122 (3): 627-33. <https://doi.org/10.1097/AOG.0b013e3182a06f4e>.
- Costeloe, K. L., E. M. Hennessy, S. Haider, F. Stacey, N. Marlow, and E. S. Draper. 2012. "Short Term Outcomes after Extreme Preterm Birth in England: Comparison of Two Birth Cohorts in 1995 and 2006 (the EPICure Studies)." *BMJ* 345 (December):e7976. <https://doi.org/10.1136/bmj.e7976>.
- Czarny, H. N., B. Forde, E. A. DeFranco, E. S. Hall, and R. M. Rossi. 2021. "Association between Mode of Delivery and Infant Survival at 22 and 23 Weeks of Gestation." *Am J Obstet Gynecol MFM* 3 (4): 100340. <https://doi.org/10.1016/j.ajogmf.2021.100340>.
- Fisher, S.C., S.Y. Kim, A.J. Sharma, R. Roachat, and B. Morrow. 2013. "Is Obesity Still Increasing among Pregnant Patients? Prepregnancy Obesity Trends in 20 States, 2003-2009." *Prev Med* 56 (6): 372-78. <https://doi.org/10.1016/j.yjmed.2013.02.015>.
- Harris, P. A., R. Taylor, T. Robert, P. Jonathon, N. Gonzalez, and J. G. Conde. 2009. "Research Electronic Data Capture (REDCap) - A Metadata-Driven Methodology and Workflow Process for Providing Translational Research Informatics Support." *J Biomed Inform* 42 (2): 377-81. <https://doi.org/10.1016/j.jbi.2008.08.010>.
- Hinkle, S. N., A. J. Sharma, and S. Y. Kim. 2012. "Prepregnancy Obesity Trends among Low-Income Patients, United States, 1999-2008." *Matern Child Health J* 16 (7): 1339-48. <https://doi.org/10.1007/s10995-011-0898-2>.
- Lee, H.C., and J.B. Gould. 2006. "Survival Advantage Associated with Cesarean Delivery in Very Low Birth Weight Vertex Neonates." *Obstet Gynecol* 107:97-105. <https://doi.org/10.1097/01.AOG.0000192400.31757.a6>.
- Main, E. K., A. Abreo, J. McNulty, W. Gilbert, C. McNally, D. Poeltler, et al. 2016. "Measuring Severe Maternal Morbidity: Validation of Potential Measures." *Am J Obstet Gynecol* 214:643.e1-10. <https://doi.org/10.1016/j.ajog.2015.11.004>.
- Peduzzi, P. N., J. Concato, T. R. Holford, and A. R. Feinstein. 1995. "The Importance of Events per Independent Variable in Multivariable Analysis, II: Accuracy and Precision of Regression Estimates." *J Clin Epidemiol* 48:1503-10. [https://doi.org/10.1016/0895-4356\(95\)00048-8](https://doi.org/10.1016/0895-4356(95)00048-8).
- Peduzzi, P. N., J. Concato, E. Kemper, T. R. Holford, and A. R. Feinstein. 1996. "A Simulation Study of the Number of Events per Variable in Logistic Regression Analysis." *J Clin Epidemiol* 49:1373-79. [https://doi.org/10.1016/S0895-4356\(96\)00236-3](https://doi.org/10.1016/S0895-4356(96)00236-3).
- Reddy, U. M., M. M. Rice, W. A. Grobman, J. L. Bailit, R. J. Wapner, M. W. Varner, et al. 2015. "Serious Maternal Complications after Early Preterm Delivery (24-33 Weeks' Gestation)." *Am J Obstet Gynecol* 213 (4): 538.e1-9. <https://doi.org/10.1016/j.ajog.2015.06.064>.
- Reddy, U. M., J. Zhang, L. Sun, Z. Chen, T. N. K. Raju, and S. K. Laughon. 2012. "Neonatal Mortality by Attempted Route of Delivery in Early Preterm Birth." *Am J Obstet Gynecol* 207:117.e1-8. <https://doi.org/10.1016/j.ajog.2012.06.023>.
- Romagano, M. P., O. Fofah, J. J. Apuzzio, S. F. Williams, and L. Gittens-Williams. 2020. "Maternal Morbidity after Early Preterm Delivery (23-28 Weeks)." *Am J Obstet Gynecol MFM* 2 (3): 100125. <https://doi.org/10.1016/j.ajogmf.2020.100125>.
- Rossi, R. M., and E. A. DeFranco. 2018. "Maternal Complications Associated with Periviable Birth." *Obstet Gynecol* 132 (1): 107-14. <https://doi.org/10.1097/AOG.0000000000002690>.
- Rossi, R. M., E. Hall, and E. A. DeFranco. 2019. "Contemporary Trends in Cesarean Delivery Utilization for Live Births Between 22 0/7 and 23 6/7 Weeks of Gestation." *Obstet Gynecol* 133 (3): 451-58. <https://doi.org/10.1097/AOG.0000000000003106>.
- "Severe Maternal Morbidity in the United States." n.d. Division of Reproductive Health, National Center for Chronic Disease Prevention and Health Prevention. Accessed February 10, 2020. <https://www.cdc.gov/reproductivehealth/maternalinfanthealth/severematernalmorbidity.html>.
- Small, M. J., A. H. James, T. Kershaw, B. Thames, R. Gunatilake, and H. Brown. 2012. "Near-Miss Maternal Mortality: Cardiac Dysfunction as the Principal Cause of Obstetric Intensive Care Unit Admissions." *Obstet Gynecol* 119 (2 Pt 1): 250-55. <https://doi.org/10.1097/AOG.0b013e31824265c7>.
- Stoll, B. J., N. I. Hansen, E. F. Bell, et al. 2010. "Neonatal Outcomes of Extremely Preterm Infants from the NICHD Neonatal Research Network." *Pediatrics* 126 (3): 443-56. <https://doi.org/10.1542/peds.2009-2959>.
- Tucker Edmonds, B. T., F. McKenzie, M. Macheras, S. K. Srinivas, and S. A. Lorch. 2015. "Morbidity and Mortality Associated with Mode of Delivery for Breech Periviable Deliveries." *Am J Obstet Gynecol* 213 (1): 70.e1-70.e12. <https://doi.org/10.1016/j.ajog.2015.03.002>.

Wylie, B. J., L. L. Davidson, M. Barta, and S. D. Reed.
2008. "Method of Delivery and Neonatal Outcome in
Very Low-Birthweight Vertex-Presenting Fetuses."
Am J Obstet Gynecol 198:640.e1-7. [https://doi.org/
10.1016/j.ajog.2007.12.038](https://doi.org/10.1016/j.ajog.2007.12.038).

SUPPLEMENTAL MATERIALS

Table S1. Cases of Severe Maternal Morbidity Among Deliveries for Fetal Indications

Cases	Record ID	Gestational week	Indication for cesarean	SMM type	Cesarean causative of SMM event	Cesarean mitigated SMM event
1	46	24w	Stat: Cat 3 tracing, SI preE, thrombocytopenia	Difficult to control HTN requiring multiple IV doses	No	Possibly
2	56	25w	Stat: Fetal bradycardia, HELLP syndrome	HELLP syndrome, Difficult to control HTN requiring multiple IV doses, possible eclamptic seizure, abruption	No	Possibly
3	83	24w	Stat: 10 cm dilated, footling breech	Prolonged postoperative ileus, NGT	Yes	No
4	92	24w	Urgent: Cat 2-3 tracing SI preE, FGR w/REDF	Difficult to control HTN requiring multiple IV doses	No	Possibly
5	97	25w	Urgent: Non-reassuring FHM, preE, FGR w/ eUAPI	Difficult to control HTN requiring multiple IV doses	No	Possibly
6	105	24w	Stat: PTL, footling breech	Postoperative sepsis, ICU admission	Possibly	No
7	203	25w	Stat: cord prolapse, PTL	Antepartum pulmonary embolism	No	No
8	227	24w	Stat: PTL, cord prolapse	Bladder injury	Yes	No
9	252	24w	Stat: PTL, cord prolapse, breech	Postoperative sepsis, ICU admission, pulmonary edema, pelvic abscess, IR drained	Likely	No
10	296	24w	Stat: fetal bradycardia, PTL, abruption, DKA	Uterine rupture, cervicovaginal extension, uterine artery laceration w/ O'Leary ligation, obstetric hemorrhage	No	Yes
11	313	24w	Urgent: NRFWB, placenta percreta	ICU admission, Small bowel injury/repair, cesarean hysterectomy	Yes	Yes
12	366	25w	Urgent: NRFWB, SI preE, FGR REDF	Difficult to control HTN requiring multiple IV doses	No	Possibly
13	390	25w	Stat: NRFWB, FGR REDF, SI PreE	Difficult to control HTN requiring multiple IV doses	No	Possibly
14	446	24w	Stat: PPROM, cord prolapse	Postoperative maternal arrhythmia, ICU admission	Possibly	No
15	458	24w	Stat: PPROM, fetal bradycardia	PPH, bladder injury/repair, unplanned hysterectomy, ICU admission, post op DVT	Yes	No

Table S2. Cases of Severe Maternal Morbidity Among Deliveries for Maternal Indications

Cases	Record ID	Gestational week	Indication for cesarean	SMM type	Cesarean causative of SMM event	Cesarean mitigated SMM event
1	6	25w	Urgent: HELLP syndrome, FGR w/ AEDF, breech	HELLP syndrome, Difficult to control HTN requiring multiple IV doses	No	Possibly
2	52	23w	Urgent: HELLP syndrome, breech	HELLP syndrome, Difficult to control HTN requiring multiple IV doses	No	Possibly
3	78	24w	Urgent: HELLP syndrome, FGR w/ REDF, breech	HELLP syndrome	No	Possibly
4	82	24w	Urgent: HELLP syndrome, respiratory failure, avoid prolonged IOL	HELLP syndrome, pulmonary edema requiring non-rebreather mask ventilation, ICU admission, sepsis, disseminated viral infection, oliguria, Lasix diuresis	No	No
5	91	24w	Emergent: IOL for chorioamnionitis w/ARDS, IOL failed 2/2 NRFHT remote from delivery, respiratory failure	Pulmonary edema, ICU admission, ventricular tachycardia	No	Possibly
6	96	24w	Urgent: preE with SF, FGR, uncontrolled severe range BP, avoid prolonged IOL	Difficult to control HTN requiring multiple IV doses	No	Possibly
7	104	24w	Urgent: HELLP syndrome, worsening transaminitis, BPs, avoid prolonged IOL	HELLP syndrome, Difficult to control HTN requiring multiple IV doses	No	Possibly
8	113	24w	Urgent: preE SF, thrombocytopenia, hypoxia, avoid prolonged IOL	Pulmonary edema, respiratory failure requiring Lasix diuresis, Difficult to control HTN requiring multiple IV doses	No	Possibly
9	162	23w	Urgent: preE with SF, developing HELLP syndrome, di/di twins with FGR, prior cesarean x 1, avoid prolonged IOL	Difficult to control HTN requiring multiple IV doses	No	Possibly
10	179	24w	Urgent: preE w/SF, multifetal gestation, malpresentation of twin A	Difficult to control HTN requiring multiple IV doses	No	Possibly
11	235	23w	Non-urgent: PreE w/SF, FGR w/ REDF, prior cesarean	Difficult to control HTN requiring multiple IV doses	No	Possibly
12	244	24w	Emergent: HELLP syndrome with severe DIC	HELLP syndrome Difficult to control HTN requiring multiple IV doses	No	Possibly
13	281	25w	Emergent: HELLP	HELLP syndrome, difficult to	No	Possibly

Cases	Record ID	Gestational week	Indication for cesarean	SMM type	Cesarean causative of SMM event	Cesarean mitigated SMM event
			Syndrome	control HTN requiring IV doses		
14	285	24w	Non-urgent: HELLP Syndrome	HELLP Syndrome	No	Possibly
15	302	25w	Urgent: PreE w/ SF, FGR with aEDF	Difficult to control HTN requiring multiple IV dosages	No	Possibly
16	304	24w	Urgent: PreE w/ SF	Pulmonary Edema	No	Possibly
17	334	24w	Urgent: PreE w/ SF	Difficult to control HTN requiring multiple IV dosages	No	Possibly
18	344	24w	Urgent: PreE w/ SF	Difficult to control HTN requiring multiple IV dosages	No	Possibly
19	359	23w	Urgent: HELLP syndrome	HELLP Syndrome	No	Possibly
20	372	24w	Emergent: Superimposed preE w/ SF, FGR w/ REDF	HELLP Syndrome	No	Possibly
21	386	25w	Emergent: PreE w/ SF	Difficult to control HTN requiring multiple IV dosages	No	Possibly
22	387	25w	Emergent: PreE w/ SF	HELLP Syndrome	No	Possibly
23	409	24w	Emergent: PreE w/ SF	Eclampsia	No	Possibly
24	422	24w	Emergent: PreE w/ SF	Difficult to control HTN requiring multiple IV dosages	No	Possibly
25	462	23w	Emergent: PreE w/ SF	Pulmonary Edema	No	Possibly

Box S1. Main et al. Validation of severe maternal morbidity measures. Am J Obstet Gynecol 2016.

Severe maternal morbidity
Hemorrhage
Obstetric hemorrhage with ≥4 units of red blood cells transfused
Obstetric hemorrhage with 2 units of red blood cells and 2 units of fresh frozen plasma transfused (without other procedures or complications), if not judged to be “over- exuberant” transfusion
Obstetric hemorrhage with <4 units of blood products transfused and evidence of pulmonary congestion that requires >1 dose of Lasix
Obstetric hemorrhage with return to operating room for any major procedure (excludes dilation)
Any emergency/unplanned peripartum hysterectomy, regardless of number of units transfused (includes all placenta accretas)
Obstetric hemorrhage with uterine artery embolization, regardless of number of units transfused
Obstetric hemorrhage with uterine balloon or uterine compression suture placed and 2-3 units of blood products transfused
Obstetric hemorrhage admitted to intensive care unit for invasive monitoring or treatment (either medication or procedure; not just observed overnight)
Hypertension/neurologic
Eclamptic seizure(s) or epileptic seizures that were “status”
Continuous infusion (intravenous drip) of an antihypertensive medication
Non-responsiveness or loss of vision, permanent or temporary (but not momentary), documented in physician’s progress notes
Stroke, coma, intracranial hemorrhage
Preeclampsia with difficult to control severe hypertension (>160 systolic blood pressure or >110 diastolic blood pressure) that requires multiple intravenous doses and/or persistent ≥48 hours after delivery
Liver or subcapsular hematoma or severe liver injury admitted to the intensive care unit (bilirubin >6 or liver enzymes >600)
Multiple coagulation abnormalities or severe hemolysis, elevated liver enzymes, and low platelet count (HELLP) syndrome
Renal
Diagnosis of acute tubular necrosis or treatment with renal dialysis
Oliguria treated with multiple doses of Lasix
Creatinine ≥2.0 in a patient without preexisting renal disease OR a doubling of the baseline creatinine in a patient with preexisting renal disease
Sepsis
Infection with hypotension with multiple liters of intravenous fluid or pressors used (septic shock)
Infection with pulmonary complications such as pulmonary edema or acute respiratory distress syndrome
Pulmonary
Diagnosis of acute respiratory distress syndrome, pulmonary edema, or postoperative pneumonia
Use of a ventilator (with either intubation or noninvasive technique)
Deep vein thrombosis or pulmonary embolism
Cardiac
Preexisting cardiac disease (congenital or acquired) with intensive care unit admission for treatment
Peripartum cardiomyopathy
Arrhythmia that requires >1 dose of intravenous medication but not intensive care unit admission
Arrhythmia that requires intensive care unit with further treatments
Intensive care unit/invasive monitoring
Any intensive care unit admission that includes treatment or diagnostic or therapeutic procedure
Central line or pulmonary catheter used to monitor a complication
Surgical, bladder, and bowel complications
Bowel or bladder injury during surgery beyond minor serosal tear
Small bowel obstruction, with or without surgery during pregnancy/postpartum period
Prolonged ileus for ≥4 days
Anesthesia complications

Severe maternal morbidity
Total spinal anesthesia
Aspiration pneumonia
Epidural hematoma