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Association Between Severe Maternal Morbidity and Psychiatric Illness Within 1 Year of Hospital Discharge After Delivery

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OBJECTIVE: To estimate whether severe maternal morbidity is associated with increased risk of psychiatric illness in the year after delivery hospital discharge.

METHODS: This retrospective cohort study used International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes within Florida's Healthcare Cost and Utilization Project's databases. The first liveborn singleton delivery from 2005 to 2015 was included; women with ICD-9-CM codes for psychiatric illness or substance use disorder during pregnancy were excluded. The exposure was ICD-9-CM codes during delivery hospitalization of severe maternal morbidity, as per the Centers for Disease Control and Prevention. The primary outcome was ICD-9-CM codes in emergency department encounter or inpatient admission within 1 year of hospital discharge of composite psychiatric morbidity (suicide attempt, depression, anxiety, posttraumatic stress disorder, psychosis, acute stress reaction, or adjustment disorder). The secondary outcome was a composite of ICD-9-CM codes for substance use disorder. We compared women with severe maternal morbidity with those without severe maternal morbidity using multivariable logistic regression adjusting for sociodemographic factors and medical comorbidities. Cox proportional hazard models identified the highest risk period after hospital discharge for the primary outcome.

RESULTS: A total of 15,510 women with severe maternal morbidity and 1,178,458 without severe maternal morbidity were included. Within 1 year of hospital discharge, 2.9% (n=452) of women with severe maternal morbidity had the primary outcome compared with 1.6% (n=19,279) of women without severe maternal morbidity, resulting in an adjusted odds ratio (aOR) 1.74 (95% CI 1.58–1.91). The highest risk interval was within 4 months of discharge (adjusted hazard ratio [adjusted HR] 2.53 [95% CI 2.05–3.12]). Most severe maternal morbidity conditions were associated with higher risk of postpartum psychiatric illness. Women with severe maternal morbidity had nearly twofold higher risk of postpartum substance use disorder (170 [1.1%] vs 6,861 [0.6%]; aOR 1.91 [95% CI 1.64–2.23]).

CONCLUSION: Though absolute numbers were modest, severe maternal morbidity was associated with increased risk of severe postpartum psychiatric morbidity and substance use disorder. The highest period of risk extended to 4 months after hospital discharge.

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Severe maternal morbidity, historically described only as a "near miss" for peripartum maternal mortality,[1] has increased by 45% in the United States from 2006 to 2015.[2] Severe maternal morbidity recently has been formally defined using a composite by the Centers for Disease Control and Prevention (CDC) including indices of both severe peripartum medical conditions such as eclampsia or sepsis and procedures such as blood transfusion or hysterectomy performed during delivery hospitalization.[3] Severe maternal morbidity has been associated with maternal mortality, increased hospital costs, and prolonged delivery hospitalizations.[4] In addition, having severe maternal morbidity during delivery has been identified as a risk factor for postpartum emergency department (ED) encounters for medical care[5] and postpartum inpatient readmission.[6]

Childbirth is known to be a potent trigger for the onset of psychiatric illness,[7,8] and various factors, ranging from unexpected cesarean delivery[9] to miscarriage,[10] stillbirth,[11–13] and perception of negative or traumatic birth experience[14] have been associated with increased risk of psychiatric illness after delivery. Although severe maternal morbidity is, by definition, life-threatening and there is a clear association between adverse life events and new-onset postpartum psychiatric morbidity,[15] the effect of severe maternal morbidity on postpartum psychiatric illness remains unclear. The only published data available from the United States are limited by small sample size and self-disclosure of "pregnancy complications," of which nearly 75% were first trimester miscarriage.[16] To shed light on the potential association between severe maternal morbidity and postpartum psychiatric morbidity in the United States, large, population-based studies are needed that use robust clinician-generated diagnoses for both severe maternal morbidity and psychiatric conditions.

Using a state database, we aimed to determine the incidence of presentation for acute psychiatric care in the ED or inpatient hospital in the year after hospital discharge from delivery of a liveborn singleton and to ascertain whether having severe maternal morbidity during delivery was associated with increased risk of acute psychiatric illness within 1 year of hospital discharge compared with deliveries without severe maternal morbidity. We hypothesized that liveborn singleton deliveries with severe maternal morbidity would be associated with increased risk of psychiatric morbidity in the year after hospital discharge when compared with deliveries without severe maternal morbidity.

METHODS

We conducted a retrospective cohort study using the Florida State Inpatient Database and Emergency Department Database of the Agency for Healthcare Research and Quality Healthcare Cost and Utilization Project[17] from 2005 to 2015, including all in-hospital deliveries from the fourth quarter of 2005 through December 31, 2014. The Inpatient and ED databases were linked at a patient-level using a visit linkage variable (VisitLink) in tandem with a timing variable (DaysToEvent)[17]; as such, we could include multiple hospital or ED visits in Florida across time while adhering to Healthcare Cost and Utilization Project privacy regulations.[17] Deliveries in females aged 13–54 years were identified using a validated algorithm that uses International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) diagnosis and procedure codes.[18] For study purposes, the index delivery was defined as the first delivery within the database during the study timeframe, regardless of parity or subsequent deliveries; the duration of postpartum follow-up was defined as 365 days after hospital discharge. Only the index delivery was included for analysis. Deliveries were restricted to liveborn singletons (ICD-9-CM codes 650 or V270). Women whose index deliveries were coded as both liveborn singletons and stillbirth 23 weeks of gestation or more (ICD-9-CM codes 656.40, 656.41, and V271), or multiple gestation (ICD-9-CM codes 651.00, 651.01, 651.10, 651.11, 651.20, 651.21, V272.2–V27.7) were excluded from analysis because stillbirth[19,20] and multiple gestation[21] have each been associated with increased risk of postpartum psychiatric morbidity, which would have confounded our analyses. Patients who were listed as male were excluded, as were women who did not reside in Florida because their long-term outcomes may not be captured in our database. In addition, women coded during an inpatient hospitalization or ED encounter in the 252 days (9 months, a proxy for pregnancy) before hospital discharge of the index delivery for any condition within the primary and secondary composite outcomes were excluded from analysis owing to preexisting psychiatric morbidity or substance use disorder. Sociodemographic data analyzed included age, race–ethnicity (non-Hispanic black, non-Hispanic white, Hispanic, and other), and payer (private, public, or other). We also identified and analyzed underlying maternal medical comorbidities and maternal conditions present at delivery using a previously validated maternal comorbidity index[4] (Appendix 1, available online at http://links.lww.com/AOG/B508). Tobacco use was not included in our study population as this variable has been shown to be under-coded in the Healthcare

Cost and Utilization Project database overall and within the state of Florida specifically.[22]

The primary exposure was the CDC's severe maternal morbidity composite (Box 1); the individual indices were extracted using ICD-9-CM diagnosis and procedure codes as defined by the CDC[3] (Appendix 2, available online at http://links.lww.com/AOG/B508). Owing to concerns that blood transfusion was under-coded because of variations in coding practices between hospitals,[23] secondary exposures included the individual indices within the severe maternal morbidity composite.

Because the Healthcare Cost and Utilization Project database includes admission and discharge dates for all patients but does not include delivery date for all women with normal spontaneous vaginal delivery, outcomes were extracted from the day after index delivery hospital discharge through 365 days after discharge. The primary outcome was an ICD-9-CM code during a postpartum ED presentation or readmission to an inpatient hospital for psychiatric illness, defined as a condition within the psychiatric morbidity composite. Our primary outcome combined psychiatric composites that have been previously used in the obstetric literature,[8,10,11,15,24] including suicide attempt, depression, anxiety, psychosis, posttraumatic stress disorder (PTSD), acute stress reaction, and adjustment disorder. The secondary outcome was a substance use disorder composite, including alcohol or recreational drug use or dependence, obtained using the Elixhauser comorbidity algorithm, a dichotomous categorization of ICD-9-CM code-based morbidity that has been well-validated for administrative datasets.[25] The ICD-9-CM codes for each condition within the primary and secondary outcomes are included in Appendix 3, available online at http://links.lww.com/AOG/B508. Only the first ED presentation or hospital admission meeting our primary or secondary outcome definition during the time interval was included as an outcome. Coding for either primary or secondary diagnoses of any condition within each composite during a postpartum encounter was included as an outcome. Women could have both the primary and secondary outcome if they had codes for conditions in both composites during the same ED or hospital encounter but having ICD-9-CM coding for one outcome excluded women from being eligible for the other outcome at subsequent encounters. Patients included in each composite outcome may have had more than one diagnosis within the composite but were only counted once per composite.

Demographic and baseline clinical data were compared between women with severe maternal morbidity compared with without severe maternal morbidity using the X^2 test or Fisher exact test for categorical variables as appropriate. Observations were censored by the first of the following conditions: 365 days interval after the index delivery hospital discharge, death, or subsequent hospitalization coded for pregnancy. The first subsequent hospitalization coded for pregnancy was identified using ICD-9-CM diagnosis and procedure codes for pregnancy-related conditions or delivery after the index delivery (Appendix 3, http://links.lww.com/AOG/B508). Unadjusted logistic regression was conducted for all primary and secondary outcomes. In addition, multivariable logistic regression analyses were conducted for all conditions within the psychiatric and substance use disorder composites that had more than 50 women with severe maternal morbidity coded for that individual outcome. Multivariable logistic regression analyses were adjusted for differences between sociodemographic and medical factors of women with compared with without severe maternal morbidity during delivery hospitalization that were identified to be statistically significant: age, race–ethnicity, payer, income quartile

Box 1. Medical Conditions in the Centers for Disease Control and Prevention's Severe Maternal Morbidity Composite

Medical Condition

- Acute myocardial infarction
- Aneurysm
- Acute renal failure
- Adult respiratory distress syndrome
- Amniotic fluid embolism
- Cardiac arrest or ventricular fibrillation
- Conversion of cardiac rhythm
- Disseminated intravascular coagulation
- Eclampsia
- Heart failure or arrest during surgery or procedure
- Puerperal cerebrovascular disorders
- Pulmonary edema or acute heart failure
- Severe anesthesia complications
- Sepsis
- Shock
- Sickle cell disease with crisis
- Air and thrombotic embolism
- Hysterectomy
- Temporary tracheostomy
- Ventilation
- Blood transfusion

Data from Centers for Disease Control and Prevention. Severe maternal morbidity indicators and corresponding ICD codes during delivery hospitalizations. Available at: https://www.cdc.gov/reproductivehealth/maternalinfanthealth/smm/severe-morbidity-ICD.htm. Retrieved May 10, 2018.

by ZIP code, mode of delivery, and maternal medical comorbidities. Sickle cell disease and eclampsia were conditions included within the severe maternal morbidity composite, but some ICD-9-CM codes used for these conditions were also included within the morbidity composite; thus, we were unable to adjust for Sickle cell disease or eclampsia in the multivariable models. Demographic data missing from the database was recoded as an indicator variable to ensure all patients were included in the multivariable analyses. A two-sided $P<.05$ was considered statistically significant in all analyses. Owing to Healthcare Cost and Utilization Project restrictions designed to preserve patient privacy, counts less than 11 for an exposure were presented as n <11 and counts less than 11 for an outcome were reported as "–."

Additional prespecified analyses were performed to further evaluate our findings. First, the risks of the primary and secondary outcomes were compared with each of the individual conditions within the severe maternal morbidity composite to identify whether specific morbidities were associated with increased risk of postpartum psychiatric illness or substance use disorder or dependence. Unadjusted logistic regression was conducted for all conditions within the severe maternal morbidity composite. In addition, multivariable logistic regression analyses were conducted for blood transfusion and for the severe maternal morbidity composite excluding blood transfusion. Second, we conducted Cox proportional hazard ratios to examine the association between stillbirth (and term live birth) and the primary outcome over the 12-month follow-up period. The log-rank test was used to compare survival functions. The proportional hazards assumption was assessed by significance testing of a time-dependent interaction. In anticipation that the risk of postpartum psychiatric morbidity was not consistent during the year-long follow-up period, additional Cox proportional hazard models were created to explore the highest risk window for postpartum psychiatric morbidity in clinically relevant intervals: the 12-month follow-up period was to be divided into 6-, 4-, and 3-month intervals if needed. Once significance testing of a time-dependent interaction showed the proportional hazards assumption was not violated, the Heaviside unit step function was used to accommodate for variations in time-dependent interactions in the follow-up period.[26] Third, we tested whether significant interactions existed between independent variables within the primary logistic model. Fourth, we re-defined our outcomes to include only hospital admissions alone (ie, excluding ED encounters) to analyze the effect of severe maternal morbidity on postpartum psychiatric morbidity severe enough to require inpatient psychiatric care.

Lastly, we conducted several sensitivity analyses. First, we re-defined the exclusion period for preexisting psychiatric comorbidity as 2 years before the index delivery to exclude women with significant psychiatric illness who did not have any acute events during their pregnancy (ie, only deliveries from 2007 to 2014 were included). Second, we excluded women who had medical comorbidities identified during their delivery hospitalization as medical comorbidities alone[27] or in combination[28] have been associated with increased risk of depression or PTSD.[29] Thus, we could ensure medical comorbidities were not confounding the association between severe maternal morbidity and postpartum psychiatric morbidity. Third, we removed psychosis as both an exclusion for a preexisting psychiatric morbidity and as a condition within the primary composite outcome. This was done because, although psychosis has been described as a mood disorder in the obstetric literature,[8,15,30] it is categorized as a psychotic disorder in the *Diagnostic and Statistical Manual of Mental Disorders, 5th Edition.*[31]

The study was exempted from review by the Washington University in St. Louis Human Research Protection Office because the Healthcare Cost and Utilization Project data consist of limited datasets with no personally identifiable information. SAS 9.3 was used for all analyses.

RESULTS

A total of 1,229,835 patients with liveborn singleton pregnancies were identified: 16,408 (1.3%) deliveries with severe maternal morbidity and 1,213,427 (98.7%) deliveries without severe maternal morbidity. Eight hundred ninety-eight deliveries with severe maternal morbidity (5.5%) and 34,969 deliveries without severe maternal morbidity (2.9%) were excluded owing to prior psychiatric morbidity or substance use disorder. Appendix 4, available online at http://links.lww.com/AOG/B508, compares the conditions identified during the index pregnancy or during the index delivery hospitalization that resulted in exclusion from analysis. After excluding for preexisting psychiatric illness and prior ED visits or inpatient admissions for substance use disorder, the final analytic population of liveborn singleton pregnancies included 15,510 deliveries with severe maternal morbidity and 1,178,458 deliveries without severe maternal morbidity.

Sociodemographic and obstetric characteristics for women with severe maternal morbidity during delivery compared with those without severe

Table 1. Comparison of Baseline Characteristics of Women Without Coding for Preexisting Psychiatric Illness in the 9 Months Before Delivery of Liveborn Singleton Neonates for Women With Severe Maternal Morbidity Compared With Those Without Severe Maternal Morbidity

Characteristic	With SMM (n=15,510)	Without SMM (n=1,178,458)	Unadjusted OR (95% CI)	*P*
Maternal age at delivery (y)				
Younger than 18	724 (4.7)	45,356 (3.9)	1.30 (1.20–1.40)	
18–34	11,779 (76.0)	958,429 (81.3)	Reference	
35–39	2,216 (14.3)	138,162 (11.7)	1.31 (1.25–1.37)	
40 or older	791 (5.1)	36,511 (3.1)	1.76 (1.64–1.90)	
Race–ethnicity*				
White	6,318 (41.3)	596,251 (51.3)	Reference	
Black	5,060 (33.1)	252,952 (21.8)	1.89 (1.82–1.96)	
Latina	2,937 (19.2)	236,875 (20.4)	1.17 (1.12–1.22)	
Other	982 (6.4)	76,112 (6.5)	1.22 (1.14–1.30)	
Insurance type				
Private	6,636 (42.8)	573,882 (48.7)	Reference	
Public	8,355 (53.9)	568,966 (48.3)	1.27 (1.23–1.31)	
Other	519 (3.3)	35,610 (3.1)	1.26 (1.15–1.38)	
Income quartile, based on ZIP code†				
1 (poorest)	4,825 (35.9)	308,826 (31.5)	1.37 (1.29–1.46)	
2	4,174 (31.1)	301,272 (30.7)	1.21 (1.14–1.29)	
3	3,143 (23.4)	258,898 (26.4)	1.06 (1.00–1.13)	
4 (wealthiest)	1,284 (0.6)	112,351 (11.4)	Reference	
Mode of delivery				
Spontaneous vaginal	4,700 (30.3)	685,947 (58.2)	Reference	
Operative vaginal	629 (4.1)	52,226 (4.6)	1.69 (1.56–1.84)	
Cesarean	10,181 (65.6)	438,285 (37.2)	3.30 (3.27–3.51)	
Maternal comorbidities‡				
Maternal comorbidity composite	8,777 (56.6)	351,002 (29.8)		<.001
Pulmonary hypertension	124 (0.8)	209 (0.02)		<.001
Placenta previa	617 (4.0)	6,046 (0.5)		<.001
Preeclampsia or gestational hypertension without severe features	2,311 (14.9)	86,575 (7.4)		<.001
Preeclampsia with severe features	2,618 (16.9)	16,617 (1.4)		<.001
Chronic kidney disease	241 (1.6)	2,279 (0.2)		<.001
Chronic hypertension	929 (6.0)	23,320 (2.0)		<.001
Ischemic heart disease	15 (0.1)	118 (0.01)		<.001
Congenital heart disease	60 (0.4)	960 (0.08)		<.001
Sickle cell disease	617 (4.0)	6,046 (0.5)		<.001
Systemic lupus erythematosus	77 (0.5)	1,269 (0.1)		<.001
Human immunodeficiency virus	124 (0.8)	2,984 (0.3)		<.001
Cardiac valvular disease	272 (1.8)	7,749 (0.7)		<.001
Chronic congestive heart failure§	—	0 (0.0)		<.001
Asthma	677 (4.4)	32,844 (2.8)		<.001
Preexisting diabetes mellitus	294 (1.9)	10,034 (0.9)		<.001
Gestational diabetes mellitus	1,014 (6.5)	63,408 (5.4)		<.001
Obesity	1,115 (7.2)	49,036 (4.2)		<.001
Cystic fibrosis§	—	99 (0.01)		.8
Previous cesarean delivery	2,476 (16.0)	134,809 (11.4)		<.001

SMM, severe maternal morbidity; OR, odds ratio.
Data are n (%) unless otherwise specified.
* Missing data from 213 deliveries with SMM and 16,268 deliveries without SMM.
† Missing data from 2,084 deliveries with SMM and 197,111 deliveries without SMM.
‡ Data from Bateman B, Mhyre JM, Hernandez-Diaz S, Huybrechts KF, Fischer M, Creanga A, et al. Development of a comorbidity index for use in obstetric patients. Obstet Gynecol 2013;122:957–65.
§ Unable to report (fewer than 11 women).

maternal morbidity during delivery are shown in Table 1. Women with severe maternal morbidity during delivery were significantly older and more likely to have cesarean delivery, be black, and have public insurance. Among those with available income data, women with severe maternal morbidity were

significantly more likely to be in the two poorest income quartiles by ZIP code compared with women without severe maternal morbidity. They were also more likely to have medical comorbidities.

Primary and secondary outcomes are shown in Table 2 stratified by deliveries with severe maternal morbidity compared with without severe maternal morbidity and adjusted for maternal age, race–ethnicity, insurance type, income quartile by ZIP code, and maternal medical-comorbidities. After singleton live-birth deliveries without severe maternal morbidity, 1.6% of women (n=19,279) received primary or secondary diagnosis codes for psychiatric illness within 1 year of hospitalization discharge, during either ED presentations (n=12,328) or hospital admissions (n=7,041). The risk of readmission or ED encounter with coding for psychiatric illness was nearly 75% higher after deliveries with severe maternal morbidity (n=452 [2.9%] with 222 admissions and 230 ED visits; adjusted odd ratios [aOR] 1.74 , 95% CI 1.58–1.91; risk attributable to severe maternal morbidity: 1.3%). Depression and anxiety were the most common psychiatric morbidities, and the risk was significantly higher among deliveries with severe maternal morbidity compared with without severe maternal morbidity for both conditions (aOR 1.86, 95% CI 1.60–2.16 for depression, with 0.6% risk attributable to severe maternal morbidity; aOR 1.78, 95% CI 1.56–2.03 for anxiety, with 0.7% risk attributable to severe maternal morbidity). Overall, with the exception of suicide attempt and acute stress reaction, severe maternal morbidity was associated with significantly higher risk of presenting for each individual condition within the primary psychiatric outcome. Women also had nearly two times higher risk of being coded for drug or alcohol use or dependence in an inpatient admission or ED encounter in the year after delivery with severe maternal morbidity than without severe maternal morbidity (168 [1.1%] vs 6,856 [0.6%]; aOR 1.89 , 95% CI 1.62–2.21; 0.5% risk attributable to severe maternal morbidity). Of note, a higher proportion of women who had severe maternal morbidity had their follow-up period censored because of death within 365 days of discharge from delivery compared with those who did not have severe maternal morbidity (n=330 [2.18%] vs n=243 [0.02%]).

Cox proportional hazard ratios were used to examine the association between severe maternal morbidity and the primary outcome over the 12-month follow-up period. The proportional hazards assumption was violated for the 12-month ($P<.001$) and 6-month ($P=.003$) follow-up periods but not

Table 2. Risk of Psychiatric Morbidity Coded During an Emergency Department Visit or Hospitalization Within 1 Year of Delivery of a Liveborn Singleton Neonate for Women With Intrapartum Severe Maternal Morbidity Compared With Those Without Intrapartum Severe Maternal Morbidity Among Women Without Preexisting Psychiatric Conditions

Outcome	With SMM (n=15,510)	Without SMM (n=1,178,458)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)*	Attributable Risk Due to SMM (%)
Composite psychiatric morbidity	452 (2.9)	19,279 (1.6)	1.81 (1.64–1.98)	1.74 (1.58–1.91)	1.3
Suicide attempt†	—	552 (0.05)	0.69 (0.29–1.66)	‡	—
Depression	186 (1.2)	7,533 (0.6)	1.89 (1.63–2.19)	1.86 (1.60–2.16)	0.6
Anxiety	230 (1.5)	9,573 (0.8)	1.84 (1.61–2.10)	1.78 (1.56–2.03)	0.7
Psychosis	95 (0.6)	4,575 (0.4)	1.58 (1.29–1.94)	1.52 (1.24–1.87)	0.2
PTSD	11 (0.07)	330 (0.03)	2.53 (1.39–4.62)	‡	0.04
Acute stress reaction	14 (0.09)	622 (0.05)	1.71 (1.01–2.91)	‡	0.04
Adjustment disorders	34 (0.2)	827 (0.07)	3.13 (2.22–4.41)	‡	0.13
Composite substance use	168 (1.1)	6,856 (0.6)	1.90 (1.65–2.24)	1.89 (1.62–2.21)	0.5
Drug use and dependence	136 (0.9)	5,261 (0.5)	1.99 (1.69–2.38)	1.98 (1.67–2.36)	0.4
Alcohol use and dependence	50 (0.3)	2,330 (0.2)	1.63 (1.23–2.16)	‡	0.1

SMM, severe maternal morbidity; OR, odds ratio; PTSD, posttraumatic stress disorder.
Data are n (%) unless otherwise specified.
* Adjusted for maternal age, race–ethnicity, insurance type, income quartile by ZIP code, mode of delivery, and maternal medical comorbidities. Adjusted ORs calculated for conditions within the composite in which more than 50 women received codes (‡ not calculated).
† Unable to report (fewer than 11 women had this psychiatric morbidity).

violated when follow-up was limited to the first 4 months (P=.2). After adjusting for maternal age, race–ethnicity, insurance status, and income quartile by ZIP code, we found a statistically significant association between severe maternal morbidity compared with no severe maternal morbidity and the development of the primary outcome for the first 4 months after hospital discharge (adjusted hazard ratio of 2.53 [95% CI 2.05–3.12]).

Multivariable analyses testing whether significant interactions between independent variables existed in the primary outcome's model are shown in Appendix 5, available online at http://links.lww.com/AOG/B508. The P values for interactions were not statistically significant for payer type or mode of delivery (P=.07 and P=.05, respectively) but were statistically significant for race–ethnicity (P=.003), income quartile by ZIP code (P<.001), and maternal comorbidities (P<.001). After adjusting for other variables, postpartum psychiatric morbidity was twice as likely among women with private insurance or who were aged 35–39 years who had severe maternal morbidity as those with private insurance or who were aged 35–39 years who did not have severe maternal morbidity (aOR 1.99 [95% CI 1.66–2.38] for private insurance; aOR 2.04 [95% CI 1.55–2.68] for age 35–39 years). Similarly, women who were black or Latina who had severe maternal morbidity were twice as likely to have postpartum psychiatric morbidity than black or Latina women who did not have severe maternal morbidity (aOR 1.97 [95% CI 1.67–2.33] for black women; aOR 2.17 [95% CI 1.71–2.745 for Latina women]). Lastly, women who had primary or secondary diagnosis codes during delivery hospitalization of at least one condition within the maternal morbidity composite were nearly twice as likely as those who did not to have postpartum psychiatric morbidity (aOR 1.91 [95% CI 1.66–2.20]).

Table 3 presents the risk of postpartum psychiatric morbidity adjusted by whether the delivery did or did not have individual conditions within the severe maternal morbidity composite. The majority of severe maternal morbidity indices, including blood transfusion, were associated with increased risk of ED visit or hospitalization coded for acute psychiatric illness in the year after delivery. Some of the more common conditions within the severe maternal morbidity composite were associated with increased risk of postpartum psychiatric morbidity, including acute renal failure and adult respiratory distress syndrome (unadjusted OR 3.87 [95% CI 2.72–5.51] with 4.4% risk attributable to severe maternal morbidity; unadjusted OR 3.67 [95% CI 2.81–4.80] with 4.1% risk attributable to severe maternal morbidity; respectively). Other conditions, including acute myocardial infarction and temporary tracheostomy occurred rarely but were associated with particularly high risk for postpartum psychiatric morbidity during an ED or inpatient hospitalization.

The risk of the substance use disorder outcome adjusted for each condition within the severe maternal morbidity composite is presented in Table 4. The majority of severe maternal morbidity conditions, including blood transfusion, were associated with increased risk of coding for substance use disorder during presentation in the ED or inpatient hospitalization coded within 1 year after discharge from delivery hospitalization. Some of the more common conditions within the severe maternal morbidity composite were associated with high risk of the substance use disorder composite, including sepsis (unadjusted OR 4.20 [95% CI 2.86–6.15]) and pulmonary edema (unadjusted OR 2.41 [95% CI 1.60–3.62]).

Subgroup and sensitivity analyses are shown in Appendices 6–19, available online at http://links.lww.com/AOG/B508. When presentations to the ED were excluded, the association between postpartum psychiatric morbidity and severe maternal morbidity remained significant (Appendices 6 and 7, http://links.lww.com/AOG/B508). Overall, the risk of being coded for any of the conditions within the psychiatric composite condition during a postpartum inpatient hospitalization was 2.36 times higher after a delivery with severe maternal morbidity compared with without severe maternal morbidity (n=230 [1.5%] vs 7,041 [0.6%]; aOR 2.36 [2.07–2.70]). Excluding women who received ICD-9-CM codes during ED visits or inpatient admissions for 2 years before delivery hospitalization for the primary or secondary outcomes (Appendices 8–11, http://links.lww.com/AOG/B508) or who had any comorbidities within our maternal comorbidity composite[4] (Appendices 12–15, http://links.lww.com/AOG/B508) did not significantly change our results. Removing psychosis as a condition for exclusion and from the primary outcome composite did not significantly change the findings (Appendices 16–19, http://links.lww.com/AOG/B508).

DISCUSSION

In this large retrospective cohort study, we provide insight into the incidence of year-long postpartum psychiatric morbidity in women with liveborn singleton pregnancies with and without severe maternal morbidity. In women without severe maternal morbidity, presentation to the ED or admission to the

Table 3. Risk of an Emergency Department Encounter or Hospitalization Within 1 Year of Delivery of a Liveborn Singleton Neonate Coded for Psychiatric Morbidity for Women With Intrapartum Severe Maternal Morbidity Compared With Those Without Intrapartum Severe Maternal Morbidity Among Women Without Psychiatric Illness in the 9 Months Before Delivery

	Composite Psychiatric Morbidity				
	With SMM	Without SMM (n=1,178,458)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)*	Attributable Risk Due to SMM (%)
Overall SMM composite (n=15,510)	452 (2.9)	19,279 (1.6)	1.81 (1.64–1.98)	1.74 (1.58–1.91)	1.3
Transfusion (n=9,780)	267 (2.7)	19,464 (1.6)	1.68 (1.49–1.90)	1.60 (1.41–1.81)	1.1
Composite SMM without transfusion (n=5,730)	185 (3.2)	19,546 (1.6)	2.00 (1.72–2.31)	1.94 (1.67–2.25)	1.6
Acute myocardial infarction† (n=28)	—	—	7.14 (2.16–23.66)	‡	—
Aneurysm (n=11)	0 (0.0)	19,731 (1.7)	—	‡	0.0
Acute renal failure (n=541)	33 (6.1)	19,711 (1.7)	3.87 (2.72–5.51)	‡	4.4
Adult respiratory distress syndrome (n=983)	57 (5.8)	19,674 (1.7)	3.67 (2.81–4.80)	‡	4.1
Amniotic fluid embolism† (n=51)	—	—	1.19 (0.16–8.62)	‡	—
Cardiac arrest or ventricular fibrillation† (n=104)	—	—	3.01 (1.23–7.38)	‡	—
Conversion of cardiac arrhythmia† (n=209)	—	—	2.37 (1.17–4.80)	‡	—
Disseminated intravascular coagulation (n=2,552)	47 (1.8)	19,684 (1.7)	1.12 (0.84–1.49)	‡	0.1
Eclampsia (n=1,137)	46 (4.1)	19,685 (1.7)	2.51 (1.87–3.38)	‡	2.4
Heart failure or arrest during surgery or procedure† (n=167)	—	—	2.22 (0.98–5.01)	‡	—
Puerperal cerebrovascular disorder (n=359)	18 (5.0)	19,713 (1.7)	3.14 (1.96–5.05)	‡	3.3
Pulmonary edema or acute heart failure (n=618)	24 (3.9)	19,707 (1.7)	2.41 (1.60–3.62)	‡	2.2
Severe anesthesia complication† (n=218)	—	—	2.27 (1.12–4.60)	‡	—
Sepsis (n=426)	28 (6.6)	19,703 (1.7)	4.20 (2.86–6.15)	‡	4.9
Shock (n=314)	13 (4.1)	19,718 (1.7)	2.57 (1.48–4.48)	‡	2.4
Sickle cell disease with crisis (n=212)	29 (13.7)	19,702 (1.7)	9.44 (6.38–13.98)	‡	12.0
Air and thrombotic embolism† (n=197)	—	—	3.18 (1.69–6.02)	‡	—
Hysterectomy (n=879)	22 (2.5)	19,709 (1.7)	1.53 (1.00–2.33)	‡	0.8
Temporary tracheostomy† (n=43)	—	—	11.58 (5.15–26.02)	‡	—
Ventilation† (n=101)	—	—	1.82 (0.58–5.75)	‡	—

SMM, severe maternal morbidity; OR, odds ratio.
Data are n (%) unless otherwise specified.
* Adjusted for maternal age, race–ethnicity, insurance type, income quartile by ZIP code, mode of delivery, and maternal medical comorbidities. Adjusted ORs calculated for SMM composite, blood transfusion alone, and SMM composite without blood transfusion (‡ not calculated).
† Unable to report (less than 11 women had the primary psychiatric outcome).

hospital for either acute psychiatric care or management of drug or alcohol use or dependence was not uncommon within 1 year of delivery hospitalization discharge (1.6% and 0.6%, respectively). However, the risk was higher for both the psychiatric morbidity composite and substance use disorder composite when deliveries with severe maternal morbidity were compared with those without severe maternal morbidity, though the absolute numbers and risk attributable to severe maternal morbidity were both modest. We also identified specific conditions within the severe maternal morbidity composite–both common

Table 4. Risk of an Emergency Department Encounter or Hospitalization Within 1 Year of Delivery of a Liveborn Singleton Neonate Coded for Substance Use for Women With Intrapartum Severe Maternal Morbidity Compared With Those Without Intrapartum Severe Maternal Morbidity Among Women Without Preexisting Psychiatric Illness in the 9 Months Before Delivery

	Composite Substance Use Morbidity				
	With SMM	Without SMM (n=1,178,458)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)*	Attributable Risk Due to SMM (%)
Overall SMM composite (n=15,510)	168 (1.1)	6,856 (0.6)	1.90 (1.65–2.24)	1.89 (1.62–2.21)	0.5
Transfusion (n=9,780)	98 (1.4)	6,926 (0.6)	1.72 (1.41–2.10)	1.69 (1.38–2.07)	0.8
Composite SMM without transfusion (n=5,730)	70 (1.2)	6,954 (0.6)	2.18 (1.72–2.76)	2.17 (1.71–2.75)	0.6
Acute myocardial infarction† (n=28)	0 (0.0)	7,024 (0.6)	—	‡	0.0
Aneurysm (n=11)	0 (0.0)	7,024 (0.6)	—	‡	0.0
Acute renal failure (n=541)	—	—	3.87 (2.72–5.51)	‡	—
Adult respiratory distress syndrome (n=983)	14 (1.4)	7,010 (0.6)	2.44 (1.44–4.14)	‡	0.8
Amniotic fluid embolism† (n=51)	0 (0.0)	7,024 (0.6)	—	‡	0.0
Cardiac arrest or ventricular fibrillation† (n=104)	—	—	1.64 (0.23–11.76)	‡	—
Conversion of cardiac arrhythmia† (n=209)	—	—	2.46 (0.79–7.70)	‡	—
Disseminated intravascular coagulation (n=2,552)	19 (0.7)	7,005 (0.6)	1.27 (0.81–1.99)	‡	0.1
Eclampsia† (n=1,137)	—	—	1.05 (0.50–2.20)	‡	—
Heart failure or arrest during surgery or procedure† (n=167)	0 (0.0)	7,024 (0.6)	—	‡	0.0
Puerperal cerebrovascular disorder† (n=359)	—	—	1.43 (0.46–4.44)	‡	—
Pulmonary edema or acute heart failure (n=618)	15 (2.4)	7,009 (0.6)	2.41 (1.60–3.62)	‡	1.8
Severe anesthesia complication† (n=218)	—	—	0.78 (0.11–5.55)	‡	—
Sepsis† (n=426)	—	—	4.20 (2.86–6.15)	‡	—
Shock† (n=314)	—	—	1.63 (0.52–5.08)	‡	—
Sickle cell disease with crisis (n=212)	25 (11.8)	6,999 (0.6)	22.67 (14.93–34.44)	‡	10.4
Air and thrombotic embolism† (n=197)	—	—	1.73 (0.43–6.98)	‡	—
Hysterectomy† (n=879)	—	—	1.55 (0.77–3.12)	‡	—
Temporary tracheostomy† (n=43)	—	—	4.02 (0.55–29.24)	‡	—
Ventilation† (n=101)	—	—	5.18 (1.65–16.34)	‡	—

SMM, severe maternal morbidity; OR, odds ratio.

* Adjusted for maternal age, race–ethnicity, insurance type, income quartile by ZIP code, mode of delivery, and maternal medical comorbidities. Adjusted ORs calculated for SMM composite, blood transfusion alone, and SMM composite without blood transfusion (‡ not calculated).

† Unable to report (fewer than 11 women had at least one condition within the substance use composite).

(adult respiratory distress syndrome) and rare (acute myocardial infarction)–that were associated with increased risk of psychiatric morbidity and substance use disorder. Lastly, we identified that the highest risk of postpartum psychiatric morbidity was in the first 4 months after hospital discharge from delivery with severe maternal morbidity compared with without severe maternal morbidity (adjusted hazard ratio 2.53 [95% CI 2.05–3.12]), suggesting that access to medical and mental health care is needed beyond the six-week postpartum period traditionally covered by public health insurance.

Our findings support prior studies. First, similar to our findings, demographic factors such as race–ethnicity,

payer status, and income have been associated with increased odds of postpartum readmission or ED presentation overall[4,6,32] and specifically for psychiatric morbidity including postpartum depression,[7] PTSD,[16] or a composite of psychiatric conditions.[8] Second, our findings support one prior population-wide study analyzing the association between severe maternal morbidity and physician-diagnosed postpartum psychiatric illness[33] as well as smaller studies describing the association between severe maternal morbidity and patient-reported psychological symptoms.[34,35] Third, the increased risk within our study population of postpartum psychiatric illness and specific conditions within the severe maternal morbidity composite support prior data suggesting that patients have increased risk of longstanding residual depression after tracheostomy,[36] surviving acute myocardial infarction,[37] or diagnosis of adult respiratory distress syndrome.[38]

Lastly, the finding that postpartum psychiatric morbidity was not uncommon after delivery of a liveborn singleton without severe maternal morbidity aligns with recent data that routine deliveries and postpartum periods are powerful stimulants for psychiatric illness,[7,8] particularly depression and anxiety.[30] The association with severe maternal morbidity and increased risk of psychiatric illness reinforces the growing body of literature suggesting that unanticipated obstetric events such as unplanned cesarean delivery,[9] miscarriage,[10] or stillbirth[11–13] increase the risk of psychiatric morbidity above that of baseline. Taken together, these findings should encourage clinicians to heed the American College of Obstetricians and Gynecologists' recent recommendations to not only screen all women for depression and anxiety after delivery[30] but also provide individualized care with additional in-person visits as needed for 3 months postpartum[39] and throughout the interpregnancy interval.[40]

More specifically, our findings have significant public health ramifications. Though the absolute number of women with risk attributable to severe maternal morbidity was modest, women who have severe maternal morbidity have a significantly increased risk of postpartum psychiatric morbidity for a year after hospital discharge from their delivery, and that this risk was highest in the first 4 months. Women with increased risk of severe maternal morbidity were nonwhite, in the lowest income quartiles by ZIP code, and had public insurance, which often discontinues at 6 weeks postpartum. Thus, women at higher risk for severe maternal morbidity may be left without access to medical or psychiatric care during the highest risk time for acute psychiatric morbidity, which extends for months after their hospital discharge. Our findings suggest that public insurance should extend medical and mental health benefits beyond 6 weeks postpartum, particularly for women with severe maternal morbidity during delivery.

Furthermore, our identification of specific morbidities within the severe maternal morbidity composite and specific maternal demographic factors that were associated with significantly increased risk of acute postpartum psychiatric illness and substance use disorder lays the groundwork for the development of a novel clinical calculator used to predict patients' risk of developing postpartum psychiatric morbidity based on their personal risk factors.

Our study offers several strengths. First, the data are derived from a comprehensive all-payer database that includes nearly all inpatient admissions and ED presentations to a hospital in the state of Florida for nearly a decade, increasing the generalizability of our results. Second, we linked the Healthcare Cost and Utilization Project ED and inpatient databases to more accurately exclude women with antepartum psychiatric morbidity and identify postpartum outcomes until 1 year after hospital discharge from delivery, which provides a longer postpartum follow-up period than prior North American studies.[5,41] Third, our study population was restricted to liveborn singletons, which decreased the potential for confounding given both stillbirth[13,19] and multiple gestation[21] are associated with increased risk of postpartum psychiatric morbidity. Fourth, our ICD-9-CM coding has been validated for all critical variables included in this analysis, including deliveries,[18] psychiatric morbidity,[8,15] drug and alcohol use and dependence,[25] maternal medical comorbidities,[4] and severe maternal morbidity,[3] strengthening our findings.

Lastly, our multiple sensitivity analyses tested the robustness of the association between severe maternal morbidity and psychiatric illness by varying potential confounders. For example, a recent meta-analysis concluded that, compared with adults who are black, have government insurance, or are lower income, those who are white, have private insurance, and higher income are less likely to use ED services[42]; this mirrors the sociodemographic differences in our study population among women with and without severe maternal morbidity. To eliminate a potential confounder–ED visit utilization variation by demographic factors–we excluded ED encounters as an

outcome, and the association between severe maternal morbidity and postpartum psychiatric morbidity strengthened. Similarly, though nearly one third of nonmaternal and nonneonatal hospitalizations in the United States in 2012 included diagnosis codes of mental or substance use disorders,[43] psychiatric and substance use disorder diagnoses may be under-coded in Healthcare Cost and Utilization Project.[44,45] However, extending the exclusion period for antepartum psychiatric or substance use disorder morbidity to 2 years before delivery increased the likelihood that women with psychiatric morbidity were identified and excluded from our analyses without significantly changing the association between severe maternal morbidity and postpartum psychiatric morbidity.

Nevertheless, limitations to our study should be considered. First, as with any retrospective study, causality cannot be established. Furthermore, the unadjusted and adjusted odds ratios (aORs) for most of our findings are less than 4, which is within the zone of potential bias.[46] Thus, though our findings persisted in multiple sensitivity analyses, the relatively weak association we found between severe maternal morbidity and our primary outcome could be the result of a type I error. Second, Healthcare Cost and Utilization Project's database does not contain gestational age or neonatal outcomes, which may confound our results given Neonatal Intensive Care Unit admission is a risk factor for postpartum depression and anxiety.[47] Third, because women who had severe maternal morbidity are more likely to have prolonged delivery hospitalizations,[48] our follow-up period of 1 year after hospital discharge was more likely to extend beyond 1-year of delivery for women with severe maternal morbidity compared with those without severe maternal morbidity, potentially leading to ascertainment bias. Fourth, women who had severe maternal morbidity had higher rates of death within 1 year of hospital discharge, which may confound our findings because women censored because of death could not have either outcome. Fifth, we limited identification of comorbidities to the delivery hospitalization, which may have decreased our ability to identify all comorbidities within our study population.

Lastly, the Healthcare Cost and Utilization Project databases include only inpatient admissions and visits to hospital EDs. The lack of outpatient data potentially affects our results in two ways. Women with preexisting psychiatric illness who remained stable in the outpatient setting would not have been excluded in our analyses despite their increased risk of postpartum psychiatric illness.[30] However, this exclusion likely resulted in nondifferential misclassification because women with well-controlled psychiatric illness are not thought to have increased risk of severe maternal morbidity during delivery.[30] Conversely, the lack of outpatient data means that we could not capture women who developed new-onset postpartum psychiatric morbidity or drug or alcohol use disorder who were managed entirely in the outpatient setting. Given that the majority of postpartum psychiatric morbidity is managed in the outpatient setting,[30] our analyses may underestimate the prevalence of postpartum psychiatric morbidity. However, it is impossible to determine whether this underestimation biases our results toward or against the null. More research is needed in a validated database that combines inpatient and outpatient medical care to determine the true prevalence of postpartum psychiatric morbidity.

In conclusion, we found that postpartum psychiatric illness and substance use disorder within 1 year of hospital discharge occurs significantly more often among women who suffer intrapartum severe maternal morbidity during delivery of a liveborn singleton compared with those who do not have severe maternal morbidity, though the absolute numbers and risk attributable to severe maternal morbidity were both modest. We also identified specific conditions within the severe maternal morbidity composite such as acute myocardial infarction and temporary tracheostomy that were associated with high risk of postpartum psychiatric illness and substance use disorder or dependence. These findings suggest that additional psychosocial support—as well as access to medical and mental health care—should be available to all women in the year after delivery, particularly those with intrapartum severe maternal morbidity in the first 4 months after hospital discharge.

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