

Severe Maternal Morbidity Among Delivery and Postpartum Hospitalizations in the United States

William M. Callaghan, MD, MPH, Andreea A. Creanga, MD, PhD, and Elena V. Kuklina, MD, PhD

OBJECTIVES: To propose a new standard for monitoring severe maternal morbidity, update previous estimates of severe maternal morbidity during both delivery and postpartum hospitalizations, and estimate trends in these events in the United States between 1998 and 2009.

METHODS: Delivery and postpartum hospitalizations were identified in the Nationwide Inpatient Sample for the period 1998–2009. International Classification of Diseases, 9th Revision codes indicating severe complications were used to identify hospitalizations with severe maternal morbidity and related in-hospital mortality. Trends were reported using 2-year increments of data.

RESULTS: Severe morbidity rates for delivery and postpartum hospitalizations for the 2008–2009 period were 129 and 29, respectively, for every 10,000 delivery hospitalizations. Compared with the 1998–1999 period, severe maternal morbidity increased by 75% and 114% for delivery and postpartum hospitalizations, respectively. We found increasing rates of blood transfusion, acute renal failure, shock, acute myocardial infarction, respiratory distress syndrome, aneurysms, and cardiac surgery during delivery hospitalizations. Moreover, during the study period, rates of postpartum hospitalization with 13 of the 25 severe complications examined more than doubled, and the overall mortality during postpartum hospitalizations increased by 66% ($P < .05$).

CONCLUSIONS: Severe maternal morbidity currently affects approximately 52,000 women during their delivery hospitalizations and, based on current trends, this burden is expected to increase. Clinical review of identified cases of severe maternal morbidity can provide an opportunity to identify points of intervention for quality improvement in maternal care.

(*Obstet Gynecol* 2012;120:1029–36)

DOI: <http://10.1097/AOG.0b013e31826d60c5>

LEVEL OF EVIDENCE: III

More than four million women give birth in the United States each year, nearly all of them in hospitals, making the delivery of neonates the most common reason for hospitalization.¹ Some women face severe morbidity such as hemorrhage, embolism, acute renal failure, stroke, acute myocardial infarction, and other complications. Although conditions contributing to severe morbidity are rare, when applied to the large cohort of birthing women, these conditions often result in high direct medical cost, extended length of hospitalization, and long-term rehabilitation. Severe maternal morbidity is also a matter of concern for health care provider teams who are involved in the care and treatment of women during and after pregnancy and an organized national approach for the reduction of maternal morbidity and mortality has recently been called for.² As a first step, tracking severe maternal morbidity is essential for assessment of resource allocation and identification of priorities in research as well as in development of guidelines and protocols for obstetric care. Although prevention and management can be challenging, it has been suggested that focusing a lens on severe maternal morbidity can provide clinically relevant measures for quality of maternal care.^{2,3}

Reports from national administrative hospital discharge data using International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM)

From the Division of Reproductive Health and the Division of Heart Disease and Stroke Prevention, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia.

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Corresponding author: William M. Callaghan, MD, MPH, Centers for Disease Control and Prevention, 4770 Buford Highway NE, Mailstop K-23, Atlanta, GA 30341; e-mail: WCallaghan@cdc.gov.

Financial Disclosure

The authors did not report any potential conflicts of interest.

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ISSN: 0029-7844/12



diagnosis and procedure codes suggest that severe complications during delivery hospitalizations in the United States are many times more common than maternal deaths.^{4,5} However, these reports used different databases and had some differences in definitions of severe morbidity. Moreover, little consideration has been given to severe maternal morbidity during postpartum hospitalizations. A recent report concerning hospital readmissions after delivery revealed a readmission rate within 6 weeks of delivery of approximately 1%; uterine and wound infections and hypertension were the most frequent reasons for readmission, although there were also high rates of admission for cholecystitis, pneumonia, and appendicitis.⁶ Several recent nationwide studies have demonstrated that a substantial proportion of pregnancy-related hospitalizations for cardiomyopathy and chronic cardiac disease were identified in the postpartum period.^{7,8}

In an effort to present a more comprehensive picture, we sought to update national estimates of severe maternal morbidity rates using the most recently available data for delivery and postpartum hospitalizations. Moreover, we aimed to rectify previous discrepancies in definitions and propose a standard for population-based monitoring of severe maternal morbidity using readily available administrative databases.

PATIENTS AND METHODS

The Nationwide Inpatient Sample is the largest all-payer hospital inpatient care database in the United States. One of a family of databases and software tools developed as part of the Healthcare Cost and Utilization Project, the Nationwide Inpatient Sample is sponsored by the Agency for Healthcare Research and Quality in partnership with state-level data collection organizations to provide national estimates for inpatient care.⁹ The Nationwide Inpatient Sample is a stratified sample of approximately 20% of all community hospitals in the United States, with hospitals selected using five characteristics: rural or urban location, number of beds, region, teaching status, and ownership. The database includes all discharges from selected hospitals and provides information on five to eight million discharges from an average of 1,000 hospitals each year. Each discharge record has the potential to list 15 ICD-9-CM diagnoses and 15 ICD-9-CM procedures. Each record is weighted to account for the complex sampling and when weights are applied during analysis, nationwide estimates can be derived. Because the data are publicly available and do not contain direct personal identifiers, this study was

exempt from review by the Centers for Disease Control and Prevention institutional review boards.¹⁰

Our analysis consisted of all delivery and postpartum hospitalizations for the period 1998–2009. The delivery hospitalizations were identified using a previously published algorithm, which incorporates ICD-9-CM diagnosis codes for an outcome of delivery, diagnosis-related groups delivery codes, and ICD-9-CM procedure codes for selected delivery-related procedures.¹¹ This method has been shown to improve the accuracy of identifying deliveries, especially those to women with severe morbidity. Postpartum hospitalizations were identified using the fifth digit=4 in ICD-9-CM codes for primary or secondary diagnosis, an ICD-9-CM code V24 for any listed diagnosis, postpartum diagnosis-related group codes (376 or 377 for the 1998–2007 period, 776 or 769 for the 2008–2009 period), or all of these.

The delivery hospitalizations with severe morbidity were identified by using condition-specific ICD-9-CM codes. The list of these ICD-9-CM diagnosis and procedure codes was developed on the basis of previously proposed conceptual models and frameworks for identification of severe maternal morbidity in the United States.^{4,5} Briefly, these constructs relied less on being assigned a specific diagnosis and more on having ICD-9-CM diagnosis and procedure codes indicating that a specific severe complication occurred. We placed less reliance on traditional obstetric ICD-9-CM codes because they are largely nonspecific with regard to severity. In this report, we aimed to revise and update this list by identifying additional severe morbidity conditions that are not captured by our previous lists of ICD-9-CM codes for severe complications. To achieve this, line listings of ICD-9-CM diagnosis and procedure codes for all pregnancy and postpartum discharge records with in-hospital mortality that did not have any of our previously used severe morbidity ICD-9-CM codes were reviewed by two investigators (W.M.C. and E.V.K.) independently. The association of codes with in-hospital mortality became a new criterion to consider the diagnosis or procedure as an indicator of severe morbidity. Each investigator developed a list of ICD-9-CM codes that were not on our original list that could potentially be used as an indicator for severe morbidity. Finally, the two lists of codes proposed by each investigator were merged into one list, and a master list of severe maternal morbidity ICD-9-CM codes was arrived at by consensus. The following eight severe morbidity indicators were added to our list of 17 severe morbidities: sickle cell anemia with crisis; intracranial injuries; internal injuries of the thorax, abdomen, and pelvis;



aneurysm; operations on the heart and pericardium; cardiac monitoring; temporary tracheostomy; and conversion of cardiac rhythm.

Among all hospitalizations with ICD-9-CM codes for selected categories of severe morbidity, hospitalizations with in-hospital mortality and transfer were hierarchically classified as hospitalizations with severe complications regardless of the length of stay. In-hospital mortality and transfer status were identified using the variable “died during hospitalization” and “disposition of patient” or “admission source” in the Nationwide Inpatient Sample. Because ICD-9-CM codes at discharge might be used to indicate an historical condition or a “ruled out” condition, we considered length of stay in assigning a hospitalization as representing severe maternal morbidity. Similar to the methodology applied in our previous studies, we reclassified hospitalizations with severe morbidity and an implausibly short length of stay as hospitalizations without severe morbidity to obtain the most conservative estimates.^{4,5} Short length of hospital stay was defined as length of stay less than the 90th percentile as calculated separately for vaginal, primary, and repeat cesarean deliveries. Reclassification based on length of stay was not applied to delivery hospitalizations with severe complications identified by procedure codes (eg, hysterectomy, blood transfusion, ventilation) or codes for postpartum hospitalizations.

All statistical analyses were conducted using Stata 12 and adjusted for the complex study design of the Nationwide Inpatient Sample using Taylor’s linearization method.¹² As a result of a small size of hospitalizations for some rare severe morbidities, we report rates per 10,000 deliveries by 2-year intervals for each severe complication among delivery and postpartum hospitalizations. The Cuzick nonparametric test for trend across ordered groups was used to assess the statistical significance of changes in mortality ratios over time.¹³ Overall severe morbidity rates were calculated using women who had at least one indication of severe morbidity as the numerator. Finally, we calculated in-hospital proportionate mortality for each severe morbidity examined by dividing the number of deaths for each severe morbidity by the total number of hospitalizations with a discharge status of death. Because delivery and postpartum hospitalizations resulting in mortality are extremely rare, the estimates for mortality were reported for the entire time period (1998–2009). Moreover, cause-specific mortality cases with less than 10 unweighted observations or for which the relative standard error of the estimate was greater than 30% were not reported because of unreliability of the estimate resulting from small numbers of cases.

RESULTS

We identified 49,346,974 delivery and 738,124 postpartum hospitalizations that occurred during 1998–2009. Among these hospitalizations, we identified 597,920 with severe maternal morbidity: 493,397 during delivery and 104,523 during postpartum hospitalizations.

In the period 2008–2009, for every 10,000 delivery hospitalizations, there were 129 delivery hospitalizations and 29 postpartum hospitalizations with at least one severe complication (Tables 1 and 2). Compared with 1998–1999, severe complications during delivery hospitalizations increased by 75% ($P<.05$) and during postpartum hospitalizations by 114% ($P<.05$). An ICD-9-CM code indicating receipt of a blood transfusion was the leading reason for being classified as having severe morbidity across all time periods for both delivery and postpartum hospitalizations.

For delivery hospitalizations, there were increases in many complications, most notably for acute renal failure, shock, thrombotic pulmonary embolisms, respiratory distress syndrome, acute myocardial infarction, blood transfusion, aneurysms, and operations on the heart and pericardium; rates of postpartum hospitalizations with 13 of the 25 severe complications examined more than doubled during the study period. The only decreases occurred for delivery hospitalizations associated with ICD-9-CM codes for severe anesthesia complications, pulmonary edema, and eclampsia. There were no significant decreases for any category of severe complications for postpartum hospitalizations.

For delivery hospitalizations with severe complications, the in-hospital proportionate mortality ranged from less than 1% for sickle cell anemia to 33.2% for respiratory distress syndrome (Table 3). Two fifths of the women who died during the delivery hospitalization required mechanical ventilation, and one third of them received a blood transfusion. Also of note, 28.6%, 13.8%, and 9.4% of these women required cardiac rhythm conversion, a heart or pericardium operation, or cardiac monitoring, respectively. By comparison, more than half (53.3%) of all deaths during postpartum hospitalizations were among women with a respiratory distress syndrome diagnosis and 31.5% among women with acute renal failure (Table 3). Proportionate mortality for severe complications such as cardiac arrest or ventricular fibrillation, shock, sepsis, disseminated intravascular coagulopathy, and cerebrovascular disorders were all in excess of 20%. Approximately three in four women who died postpartum while hospitalized were



Table 1. Rates (Standard Errors) of Selected Severe Complications During Delivery Hospitalizations per 10,000 Delivery Hospitalizations: United States, 1998–2009 (n=49,346,974)

Condition	1998–1999	2000–2001	2002–2003	2004–2005	2006–2007	2008–2009	P*	% Increase
Acute renal failure	2.29 (0.16)	1.99 (0.12)	2.61 (0.14)	2.77 (0.16)	3.55 (0.17)	4.52 (0.14)	<.05	97.26
Cardiac arrest or ventricular fibrillation	0.51 (0.06)	0.46 (0.05)	0.49 (0.06)	0.66 (0.06)	0.60 (0.06)	0.63 (0.06)	.14	22.89
Heart failure during procedure or surgery	11.12 (0.50)	9.25 (0.64)	10.37 (0.54)	10.66 (0.66)	9.77 (0.50)	9.92 (0.54)	.48	–10.75
Shock	1.50 (0.10)	1.30 (0.10)	1.52 (0.10)	1.86 (0.12)	2.16 (0.12)	3.01 (0.14)	<.05	100.66
Sepsis	3.14 (0.20)	2.45 (0.15)	2.68 (0.16)	2.57 (0.15)	2.77 (0.15)	3.08 (0.17)	.85	–1.96
Disseminated intravascular coagulation	9.20 (0.33)	8.88 (0.34)	9.81 (0.36)	9.97 (0.52)	11.09 (0.52)	12.46 (0.72)	<.05	35.46
Amniotic fluid embolism	0.40 (0.05)	0.50 (0.05)	0.40 (0.05)	0.44 (0.05)	0.35 (0.05)	0.36 (0.05)	.17	–8.88
Thrombotic embolism	0.81 (0.09)	1.07 (0.09)	1.29 (0.10)	1.39 (0.10)	1.49 (0.10)	1.39 (0.09)	<.05	71.83
Puerperal cerebrovascular disorders	1.94 (0.13)	1.79 (0.11)	2.01 (0.13)	2.12 (0.12)	2.08 (0.12)	1.69 (0.10)	.95	–12.75
Severe anesthesia complications	1.91 (0.14)	1.43 (0.11)	1.43 (0.11)	1.08 (0.09)	1.11 (0.08)	0.74 (0.06)	<.05	–61.27
Pulmonary edema	2.11 (0.16)	2.01 (0.15)	1.61 (0.15)	1.80 (0.20)	1.49 (0.13)	1.44 (0.12)	<.05	–31.76
Adult respiratory distress syndrome	3.56 (0.18)	3.39 (0.17)	3.93 (0.19)	4.49 (0.18)	4.90 (0.21)	6.24 (0.32)	<.05	75.41
Acute myocardial infarction	0.11 (0.03)	0.20 (0.03)	0.18 (0.03)	0.24 (0.04)	0.22 (0.04)	0.20 (0.04)	<.17	79.35
Eclampsia	6.34 (0.29)	5.92 (0.28)	5.79 (0.35)	6.01 (0.37)	5.19 (0.21)	4.80 (0.18)	.06	–24.33
Blood transfusion	34.04 (1.47)	42.59 (1.75)	55.07 (2.02)	71.05 (2.86)	84.83 (2.36)	96.38 (2.84)	<.05	183.15
Ventilation	4.73 (0.19)	4.75 (0.20)	5.36 (0.22)	5.71 (0.23)	5.59 (0.21)	6.32 (0.28)	<.05	33.55
Hysterectomy	7.36 (0.28)	7.41 (0.28)	7.76 (0.29)	8.14 (0.30)	8.27 (0.30)	9.11 (0.36)	<.05	23.73
Sickle cell anemia with crisis [†]	0.92 (0.10)	0.72 (0.09)	0.73 (0.08)	0.93 (0.12)	0.86 (0.10)	0.58 (0.07)	.48	–36.45
Intracranial injuries [†]	0.13 (0.03)	0.12 (0.03)	0.17 (0.04)	0.19 (0.04)	0.10 (0.02)	0.09 (0.02)	.28	–33.37
Internal injuries of thorax, abdomen, and pelvis [†]	0.64 (0.07)	0.52 (0.06)	0.73 (0.07)	0.78 (0.08)	0.68 (0.07)	0.55 (0.07)	.75	–14.10
Aneurysm [†]	0.02 (0.01)	0.04 (0.02)	0.04 (0.01)	0.08 (0.02)	0.09 (0.02)	0.06 (0.02)	.07	194.73
Operations on heart and pericardium [†]	2.63 (0.13)	3.53 (0.72)	3.26 (0.13)	3.98 (0.15)	4.44 (0.32)	4.60 (0.30)	<.05	74.96
Cardio monitoring [†]	2.26 (0.26)	3.47 (1.08)	2.00 (0.68)	2.48 (0.89)	1.21 (0.42)	0.93 (0.08)	.11	–58.80
Temporary tracheostomy [†]	0.22 (0.04)	0.21 (0.04)	0.21 (0.04)	0.21 (0.04)	0.21 (0.04)	0.26 (0.04)	.71	19.75
Conversion of cardiac rhythm [†]	0.53 (0.06)	0.52 (0.06)	0.58 (0.06)	0.59 (0.06)	0.61 (0.06)	0.63 (0.06)	<.05	18.25
At least one complication	73.82 (1.65)	78.59 (1.86)	91.24 (2.23)	106.33 (3.74)	116.86 (2.93)	129.08 (3.34)	<.05	74.86
In-hospital mortality	1.05 (0.09)	0.75 (0.07)	0.86 (0.08)	0.78 (0.07)	0.80 (0.06)	0.66 (0.06)	.18	–37.45

* Cuzick nonparametric test-for-trend across ordered groups was used to assess the statistical significance of changes over time.

[†] Conditions and procedures identified based on review of coded discharge abstracts where discharge status was listed as died during hospitalization.

mechanically ventilated, one in four received a blood transfusion, and one in five had either cardiac surgery or required cardiac rhythm conversion.

DISCUSSION

The contemporary evaluation of severe maternal morbidity using standardized nationwide hospital

discharge data in the United States is challenging because there is a lack of a standardized classification and definitions for these complications.^{4,5,14–17} We have attempted to provide a comprehensive list of indicators for use in ongoing monitoring of severe maternal morbidity for health care institutions, states, and regions and at the national level. The availability



Table 2. Rates (Standard Errors) of Selected Severe Complications During Postpartum Hospitalizations per 10,000 Delivery Hospitalizations: United States, 1998–2009 (N=738,124)

Condition	1998–1999	2000–2001	2002–2003	2004–2005	2006–2007	2008–2009	P*	% Increase
Acute renal failure	0.48 (0.06)	0.72 (0.08)	1.02 (0.10)	1.13 (0.11)	1.53 (0.12)	2.17 (0.11)	<.05	351.11
Cardiac arrest or ventricular fibrillation	0.12 (0.03)	0.17 (0.03)	0.22 (0.04)	0.17 (0.03)	0.18 (0.04)	0.41 (0.07)	.08	244.85
Heart failure during procedure or surgery	0.98 (0.08)	1.10 (0.09)	1.34 (0.10)	1.39 (0.11)	1.58 (0.10)	1.86 (0.14)	<.05	89.53
Shock	0.40 (0.05)	0.60 (0.07)	0.75 (0.07)	0.86 (0.08)	1.02 (0.08)	1.40 (0.16)	<.05	250.06
Sepsis	1.42 (0.10)	1.42 (0.10)	1.86 (0.12)	2.38 (0.13)	2.69 (0.14)	3.53 (0.21)	<.05	148.81
Disseminated intravascular coagulation	1.19 (0.11)	1.27 (0.13)	1.68 (0.13)	1.91 (0.13)	1.73 (0.12)	2.18 (0.18)	<.05	82.87
Thrombotic embolism	1.33 (0.11)	1.35 (0.10)	2.29 (0.13)	2.64 (0.14)	2.88 (0.15)	3.57 (0.19)	<.05	168.63
Puerperal cerebrovascular disorders	1.51 (0.12)	1.94 (0.13)	2.28 (0.15)	2.46 (0.14)	2.37 (0.14)	3.13 (0.22)	<.05	107.45
Severe anesthesia complications	0.30 (0.05)	0.18 (0.03)	0.20 (0.04)	0.18 (0.04)	0.22 (0.04)	0.25 (0.05)	.95	-17.80
Pulmonary edema	0.42 (0.06)	0.42 (0.05)	0.49 (0.06)	0.49 (0.06)	0.43 (0.06)	0.58 (0.08)	.08	38.34
Adult respiratory distress syndrome	1.07 (0.10)	1.35 (0.11)	1.71 (0.12)	2.00 (0.13)	2.45 (0.15)	3.01 (0.18)	<.05	181.74
Acute myocardial infarction	0.18 (0.03)	0.28 (0.05)	0.32 (0.05)	0.33 (0.05)	0.40 (0.05)	0.42 (0.06)	<.05	131.24
Eclampsia	1.76 (0.12)	2.01 (0.12)	2.28 (0.14)	2.70 (0.16)	2.69 (0.14)	2.90 (0.18)	<.05	64.52
Blood transfusion	3.48 (0.21)	4.67 (0.26)	6.22 (0.29)	7.82 (0.31)	8.74 (0.36)	9.89 (0.38)	<.05	184.32
Ventilation	1.19 (0.11)	1.42 (0.11)	1.81 (0.14)	2.04 (0.15)	2.14 (0.15)	2.57 (0.18)	<.05	116.33
Hysterectomy	0.88 (0.08)	0.89 (0.08)	1.10 (0.09)	1.16 (0.09)	1.04 (0.08)	1.19 (0.11)	.06	35.74
Sickle cell anemia with crisis	0.09 (0.03)	0.10 (0.02)	0.13 (0.03)	0.34 (0.06)	0.33 (0.06)	0.40 (0.11)	<.05	345.10
Intracranial injuries	0.08 (0.02)	0.04 (0.02)	0.08 (0.02)	0.13 (0.03)	0.08 (0.02)	0.08 (0.03)	.45	5.26
Internal injuries of thorax, abdomen, and pelvis	0.21 (0.04)	0.13 (0.03)	0.16 (0.03)	0.28 (0.05)	0.18 (0.03)	0.15 (0.03)	.85	-28.39
Aneurysm	0.03 (0.01)	0.04 (0.02)	0.01 (0.01)	0.03 (0.01)	0.03 (0.01)	0.06 (0.03)	.46	88.47
Operations on heart and pericardium	0.80 (0.08)	1.17 (0.11)	1.64 (0.12)	1.83 (0.15)	1.96 (0.13)	2.47 (0.15)	<.05	209.01
Cardio monitoring	0.53 (0.07)	0.48 (0.07)	0.38 (0.05)	0.43(0.07)	0.48 (0.08)	0.31 (0.06)	.12	-40.76
Temporary tracheostomy	0.09 (0.03)	0.12 (0.03)	0.10 (0.02)	0.21 (0.04)	0.23 (0.04)	0.24 (0.05)	<.05	164.65
Conversion of cardiac rhythm	0.06 (0.02)	0.08 (0.02)	0.13 (0.03)	0.13 (0.03)	0.12 (0.03)	0.30 (0.06)	.07	407.25
At least one complication	13.59 (0.42)	15.42 (0.46)	19.54 (0.56)	22.61 (0.61)	24.45 (0.63)	29.03 (0.68)	<.05	113.60
In-hospital mortality	0.26 (0.04)	0.24 (0.04)	0.29 (0.05)	0.30 (0.05)	0.32 (0.04)	0.43 (0.06)	<.05	66.10

* Cuzick nonparametric test-for-trend across ordered groups was used to assess the statistical significance of changes over time.

of 12 years of nationwide hospital discharge data and review of ICD-9-CM codes associated with deaths during delivery and postpartum hospitalizations allowed us to expand the list of severe morbidities from previously published reports and to uncover indicators that might have been missed under frameworks solely based on codes indicating body system failures. Although our study confirmed that fatal outcomes are rare among delivery and postpartum hospitalizations, linking severe complications to in-hospital maternal mortality for 25 and 18 indicators of severe morbidity during delivery and postpartum hospitalizations, respectively, contributes to the validation of our proposed list of severe morbidities. In addition, we identified severe maternal morbidity for women who were admitted postpartum and demonstrated not only that

there is a substantial burden of morbidity among these women, but also that it is increasing.

As in previous reports^{4,5} blood transfusion was the most common indicator of severe maternal morbidity. This is consistent with the general increase in postpartum hemorrhage in the population¹⁸ as well as the increase in hysterectomy at delivery hospitalization. Although delivery hospitalizations with blood transfusions had large increases over time, delivery hospitalizations with ICD-9-CM codes for acute renal failure, shock, acute respiratory distress syndrome, acute myocardial infarction, and aneurysms all increased by more than 75% between 1998–1999 and 2008–2009; although absolute rates of severe complications were low for postpartum hospitalizations, 13 indicators of severe morbidity at least doubled.



Table 3. In-Hospital Proportionate Mortality During Delivery and Postpartum Hospitalizations With Selected Severe Complications: United States, 1998–2009

Condition	Delivery Hospitalizations (n=4,012 Deaths)		Postpartum Hospitalizations (n=1,592 Deaths)	
	n	% (Standard Error)	n	% (Standard Error)
Acute renal failure	697	17.37 (1.38)	501	31.47 (2.60)
Cardiac arrest or ventricular fibrillation	1,214	30.26 (1.61)	388	24.37 (2.40)
Heart failure during procedure or surgery	571	14.23 (1.22)	125	7.85 (1.52)
Shock	756	18.84 (1.37)	423	26.57 (2.47)
Sepsis	579	14.43 (1.23)	387	24.31 (2.40)
Disseminated intravascular coagulation	992	24.73 (1.51)	351	22.05 (2.32)
Amniotic fluid embolism	407	10.14 (1.06)	—	—
Thrombotic embolism	269	6.70 (0.87)	140	8.79 (1.59)
Puerperal cerebrovascular disorders	446	11.12 (1.10)	442	27.76 (2.50)
Severe anesthesia complications	134	3.34 (0.63)	34	2.14 (0.80)
Pulmonary edema	58	1.45 (0.42)	45	2.83 (0.93)
Adult respiratory distress syndrome	1,332	33.20 (1.68)	848	53.27 (2.80)
Acute myocardial infarction	105	2.62 (0.57)	58	3.64 (1.04)
Eclampsia	127	3.16 (0.61)	69	4.34 (1.14)
Blood transfusion	1,340	33.39 (1.68)	424	26.63 (2.48)
Ventilation	2,430	60.57 (1.72)	1,218	76.51 (2.38)
Hysterectomy	443	11.04 (1.10)	56	3.52 (1.05)
Sickle cell anemia with crisis	39	0.97 (0.34)	—	—
Intracranial injuries	145	3.60 (0.65)	—	—
Internal injuries of thorax, abdomen, and pelvis	198	4.94 (0.76)	27	1.69 (0.75)
Aneurysm	—	—	—	—
Operations on heart and pericardium	553	13.78 (1.21)	317	19.91 (2.24)
Cardio monitoring	377	9.40 (1.11)	182	11.43 (1.78)
Temporary tracheostomy	115	2.87 (0.58)	96	6.03 (1.34)
Conversion of cardiac rhythm	1,146	28.56 (1.61)	311	19.54 (2.22)

—, Cells with fewer than 10 unweighted observations are not reported.

Unexpectedly, we found a dramatic increase in cardiac surgery during delivery and postpartum hospitalizations. This was uncovered after we linked hospitalizations with in-hospital mortality to their ICD-9-CM discharge codes. We do not have information to understand the circumstances or indications for surgery in a meaningful way, and there is likely a role that trauma played as an indication. However, other major surgical procedures also likely associated with trauma such as intracranial injuries and internal injuries (including those to thorax) did not increase over time. This suggests that cardiac surgery during pregnancy and the postpartum is increasing, a notion that is consistent with the apparent increased severity of cardiovascular disease in pregnancy⁸ and the recently reported increase in cardiovascular disease as a cause of pregnancy-related mortality.¹⁹ Similarly, the decrease in severe complications of anesthesia is in line with the decrease in pregnancy-related mortality from anesthesia complications.²⁰

During the same study period, increases in the U.S. cesarean delivery rate and in the proportion of pregnant women with chronic conditions,^{8,21,22} postpartum

hemorrhage,¹⁸ obesity,²³ multiple births, and advanced maternal age²⁴ have been documented. Against the backdrop of increases in numbers of women with high-risk conditions, a call for returning the “M” to maternal-fetal medicine has been made.² Given this context, a more nuanced review of cases is needed to identify modifiable risks and develop best practices to deal with risks that might not be modifiable. Approximately 5,600 women died during a delivery or postpartum hospitalization during the period covered in this report. Although deaths are the most tragic events in obstetrics, our estimates suggest that severe maternal morbidity is on the order of 100 times more common. On an annual basis, with approximately 4,000,000 births in the United States, 129 episodes of severe maternal morbidity will affect approximately 52,000 women. Expanding the focus to what lies below the tip of the iceberg is needed, and we offer a comprehensive construct as a starting point for investigation. The information provided in this report has the potential to be used for clinical reviews, development of quality-of-care indicators, and identifying future research priorities in obstetrics.



The results of our study should be considered in light of the following limitations. First, although our identification of severe complications was based on an algorithm that uses ICD-9-CM codes and several data-driven criteria such as in-hospital mortality, transfer from or to another health care facility, and length of hospital stay, we were unable to fully assess the severity of these conditions. Hospital-based administrative databases that make up the Nationwide Inpatient Sample are primarily used for billing, and hence are subject to errors of omission and commission by medical coders as well as changes over time in coding practices. For example, we found that the average number of ICD-9-CM codes for all delivery and all postpartum hospitalizations increased from 3.6 and 2.9 to 4.6 and 4.5 between 1998–1999 and 2008–2009, respectively. However, the increasing number of postpartum hospitalizations in our study suggests that at least some increase in severe morbidity is the result of the increase in the number of hospitalizations with true morbidity rather than the result of the increase in the number of ICD-9-CM codes per admission. Moreover, administrative data do not provide details regarding sociodemographic or clinical obstetrical risk factors for severe maternal morbidity. Although identifying women according to the indications of severe complications may result in misclassification, the error likely will affect sensitivity rather than specificity as has been demonstrated in validation studies of hospital discharge data.^{25–27} However, the number of cases identified, especially at hospital and local levels, will be small and using medical records to review the clinical courses will serve to validate the proposed indicators and identify points of intervention for preventable complications.¹⁷

In conclusion, we present an overview of trends in severe maternal morbidity, update previous reports, and propose a new standard for monitoring severe maternal morbidity that remains open to emerging issues in obstetrical care and management. Our findings suggest a substantial increase in severe complications for delivery and postpartum hospitalizations from 1998–1999 to 2008–2009, particularly as indicated by the growing rates for blood transfusions, acute renal failure, shock, acute myocardial infarction, respiratory distress syndrome, aneurysms, and cardiac surgery during delivery hospitalizations.

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rev 1/2010

