OBSTETRICS

Identification of severe maternal morbidity during delivery hospitalizations, United States, 1991-2003

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OBJECTIVE: This investigation aimed to identify pregnancy complications and risk factors for women who experienced severe maternal morbidity during the delivery hospitalization and to estimate severe maternal morbidity rates.

STUDY DESIGN: We used the National Hospital Discharge Survey for 1991-2003 to identify delivery hospitalizations with maternal diagnoses and procedures that indicated a potentially life-threatening diagnosis or life-saving procedure.

RESULTS: For 1991-2003, the severe maternal morbidity rate in the United States was 5.1 per 1000 deliveries. Most women who were classified as having severe morbidity had an ICD-9-CM code for transfusion, hysterectomy, or eclampsia. Severe morbidity was more common at the extremes of reproductive age and for black women, compared with white women.

CONCLUSION: Severe maternal morbidity is 50 times more common than maternal death. Understanding these experiences of these women potentially could modify the delivery of care in healthcare institutions and influence maternal health policy at the state and national level.

Key words: pregnancy complication, severe maternal morbidity, surveillance

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Maternal morbidity, broadly defined, encompasses physical and psychologic conditions that result from or are aggravated by pregnancy that have an adverse effect on the woman's health. Maternal morbidity includes a broad spectrum of severity and can include complications and conditions that are associated with any pregnancy outcome. Although there is no established way to identify what maternal conditions to consider as morbidity, extending maternal health surveillance to include the identification and review of pregnancy complications and the factors that are associated with them has the potential to improve maternal health by providing information to influence the delivery of health services and health policy.

Some previous frameworks for measuring maternal morbidity in the United States have been constructed with antenatal hospitalizations as a proxy for maternal morbidity[1,2]; others have used all pregnancy-related complications during delivery hospitalizations.[3] Neither of these frameworks for maternal morbidity has taken into account the severity of illness. A scoring system that used a hospital-based clinical database to identify the most severe morbidity (so-called "near miss" morbidity) performed well,[4] but the information that is needed to obtain the score usually is not readily available, unless an institution has a specialized perinatal databases or a state collects healthcare use data beyond that based on International Classification of Disease 9th Revision, Clinical Modification (ICD-9-CM) codes. Recently, investigators in Canada grouped ICD-9-CM discharge diagnosis codes and Canadian Classification of Diagnostic, Therapeutic, and Surgical Procedure codes to identify women who likely experienced severe morbidity during their delivery hospitalization.[5]

Whereas the severity of morbidity is a continuum, several reasons suggest the importance of focusing on the severe end of the spectrum. Severe morbidity has a greater effect on the woman's health and poses greater risks to her immediate and lifelong well-being. Identifying women who experienced severe maternal morbidity provides cases for review of care and offers the opportunity to better understand the continuum of severity and the factors that are associated with preventability. Thus, as we attempt to expand maternal health surveillance beyond death at the institutional, state, and national level, it would be useful to be able to use readily available information to identify women with severe morbidity during pregnancy. Using national data, we have identified a group of routinely collected ICD-9-CM discharge and procedure codes that we believe indicate significant complications of pregnancy.

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MATERIALS AND METHODS

We used information from the National Hospital Discharge Survey (NHDS) for the years 1991-2003 to identify delivery hospitalizations. This time period was chosen because it reflected the most recent design of the survey and encompassed a large number of deliveries, thereby allowing for exploration of trends in relatively rare events. The NHDS is conducted annually by the Centers for Disease Control and Prevention's National Center for Health Statistics, and its design is described in detail elsewhere.[6] In brief, the National Center for Health Statistics collects data on inpatient use from short-stay, noninstitutional, and nonfederal hospitals in the United States. The NHDS uses a 3-stage sampling design: geographic primary sampling units, hospitals within primary sampling units, and discharges within hospitals. The data are weighted to represent national inpatient hospitalizations; each observation is weighted according to its probability of being sampled. From 1991-2003, a mean of 464 hospitals (range, 426-494) provided information on approximately 300,000 discharges per year.[6-12] For each discharge, the NHDS collects basic demographic information and characteristics of hospitalizations such as length of stay, an ICD-9-CM–coded primary diagnosis, up to 6 additional ICD-9-CM diagnoses, and up to 4 ICD-9-CM procedure codes. Approximately 25% of discharges in the NHDS have no information about race. A previous study showed that hospitals that did not report race were likely to have a higher proportion of white discharges than hospitals that reported race.[13] Hospital characteristics that are collected include region and size. The NHDS samples hospital discharges and not persons. However, because a woman can be hospitalized only once for a delivery and our analysis focused on delivery hospitalizations, the woman was the unit of analysis for this project. This study analyzed deidentified unlinked data and was exempt from institutional review board review.

Delivery hospitalizations were identified by the ICD-9-CM code V27, which designates the outcome of a delivery in the primary diagnosis field. As a conceptual basis for severe maternal morbidity, we considered ways that ICD-9-CM diagnosis and procedure codes could indicate that a woman was likely to have had a significant, potentially life-threatening illness or an event during her delivery hospitalization. Although we did not ignore specific diagnoses, our framework placed less emphasis on obstetric diagnosis codes, which in many instances are nonspecific and do not indicate the severity of the condition, and placed a greater emphasis on diagnosis and procedure codes that reflect that a severe complication occurred during the delivery hospitalization. For example, the diagnosis code for severe preeclampsia (642.5) was not deemed to be sufficient to designate a woman as having severe morbidity. Although this diagnosis includes the term *severe*, there are several ways to meet the definition requirements of severe preeclampsia; therefore, there is a very broad spectrum of severity that is embedded in this diagnosis code.[14] However, regardless of whether a woman had the code for severe preeclampsia, if she had a code that indicated an event that occurred as a likely consequence of severe preeclampsia (such as a cerebrovascular accident, a blood transfusion, or artificial ventilation), she was designated as having had severe morbidity.

We selected ICD-9-CM codes that we believed indicated severe morbidity or were a consequence of severe morbidity. Indicators of severe morbidity based on diagnosis and procedure codes were determined a priori according to a previously published conceptual model,[15] the framework reported for Canada,[5] and a review by 2 medical epidemiologists (W.M.C., C.J.B.) of all codes that are within and outside of the pregnancy chapter of ICD-9-CM. These conditions and procedures and the associated ICD-9-CM codes are shown in the Appendix.

Initially, all women who had at least 1 of the selected ICD-9-CM codes were considered to be potential cases of severe morbidity. Then, in an effort to address potential coding errors, we excluded from further analysis women with a very short length of stay, which we believed was clinically inconsistent with the severe morbidity diagnosis. We restricted the analysis to women with a hospital stay of at least 3 days (2 days being the median length of stay among women who delivered) or who had been transferred to another facility after delivery. Women who had at least 1 of the selected ICD-9-CM codes and a length of stay of at least 3 days or a postpartum transfer were considered to have had severe maternal morbidity for the analysis of detailed morbidities, maternal characteristics, and hospital characteristics.

The severe maternal morbidity rate was defined as the number of women who met our severe morbidity criteria per 1000 deliveries. Severe maternal morbidity rates were tabulated by maternal and hospital characteristics that were available in the NHDS. Imposing a minimum length-of-stay requirement affected the prevalence of severe morbidity. Thus, we calculated severe morbidity rates for a range of minimum length of stays (1-7 days) to explore the effect of this inclusion criterion. We also tested whether the severe morbidity rate had changed over the 14 years of observation with the use of a weighted least-squares test for trend based on a 2-sided z test. To calculate accurate estimates for standard errors and to account for the complex sampling design of the NHDS, all of the analyses were performed with SUDAN (RTI International, Research Triangle Park, NC) statistical software.

RESULTS

From 1991 through 2003, the NHDS contained 423,480 sampled records in which a delivery was indicated by the presence of a V27 code in the primary diagnosis field; the sample represented 50.6 million deliveries when the appropriate weighting was applied. In the same time period, there were 2235 discharge records for delivery hospitalizations with a length of stay of at least 3 days and at least 1 diagnosis or procedure code that met the severe maternal morbidity criteria; these records represent approximately 257,000 women when weighted. The severe morbidity rate for the period

TABLE 1
Severe morbidity during delivery hospitalization, according to severe morbidity category, United States, 1991-2003

Severe morbidity category	Delivery discharges with indicated diagnosis (n)[a]	Severe morbidity with indicated diagnosis (%)[b]	Standard error of the %
Acute renal failure	6,000	2.5	0.43
Liver failure	[c]	[c]	[c]
Respiratory failure	17,000	6.7	0.58
Obstetric shock	4,000	1.5	0.36
Cerebrovascular accident	6,000	2.5	0.57
Pulmonary embolism	2,000	0.8	0.17
Amniotic fluid embolism	[c]	[c]	[c]
Eclampsia	36,000	14.0	1.56
Septicemia	11,000	4.1	0.68
Complications of anesthesia	12,000	4.6	0.69
Cardiac events/procedures	20,000	7.6	1.00
Mechanical ventilation	11,000	4.2	0.71
Transfusion	125,000	48.4	1.98
Hysterectomy	31,000	11.9	0.92
Invasive hemodynamic monitoring	5,000	1.8	0.35
TOTAL	291,000		

[a] Counts of discharges are weighted to account for NHDS sampling and represent national estimates rounded to the nearest 1000. Sum of delivery discharges with an indicated diagnosis (291,000) exceeds the number of women with ≥1 severe morbidity diagnoses (257,000).

[b] Percentage of severe morbidity sums to >100, because some women had diagnoses that placed them in >1 severe morbidity category.

[c] The number of sampled discharges was <30, which was considered to be unreliable. These discharges are included in the aggregate measure of severe morbidity.

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was 5.1 per 1000 deliveries (95% CI, 4.7-5.5). Because a woman could have had a condition in >1 severe morbidity category, the total count of morbidity indicators exceeds the total number of women with any severe morbidity. Likewise, the sum of the percentages of severe morbidity by category across all categories exceeds 100 (Table 1). Most of the women who met our severe morbidity criteria were included because they had an ICD-9-CM code for transfusion, hysterectomy, or eclampsia (Table 1). Women at a greater risk of severe morbidity were at the extremes of age, African American, resided in the South or the Northeast, and gave birth by cesarean section (Table 2).

The severe morbidity rate increased during the period from 1991-2003; the severe morbidity rate was 4.5 per 1000 deliveries from 1991-1994, 4.7 per 1000 deliveries from 1995-1998; and 5.9 per 1000 deliveries from 1999-2003 ($z = 2.84$; P for test of trend = .002; Figure 1). To further understand this trend, we examined the severe morbidity rate over time, particularly focusing on the potential role of transfusion codes for the identification of cases. We stratified deliveries with severe morbidity into 3 groups: those with only a code for transfusion, those without a code for transfusion, and those with a code for transfusion and at least 1 other of the selected codes. From 1991-2003 there was a statistically significant increase in the proportion of women who had an ICD-9-CM code for blood transfusion during their delivery hospitalization ($P = .009$). The rate of severe morbidity not identified by transfusion did not change over the time period.

Our construct of severe morbidity includes the length of hospital stay and requires that the length of stay exceed the national median length of stay (2 days). Figure 2 demonstrates the impact of this decision on the calculated severe morbidity rate. Among women who had a severe pregnancy complication code, most had a delivery hospitalization of <1 week. Imposing longer length-of-stay requirements on the definition of severe morbidity resulted in substantial decreases in the severe morbidity rate.

COMMENT

Deaths of women as a consequence of pregnancy in the United States have been likened to "the tip of the iceberg"; that is, for every death, there are many women who have significant complications of pregnancy, labor, and delivery. During the period 1991-2003, we found that 5 of every 1000 women who delivered had at least 1 indicator of a severe complication during their delivery hospitalization. For every maternal death, approximately 50 women experience severe morbidity, which means that approximately 20,000

TABLE 2
Severe morbidity rates according to maternal characteristics, hospital size, geographic region, and cesarean delivery, United States, 1991-2003

Variable	Severe morbidity rate (per 1000 deliveries)	Standard error of severe morbidity rate	Relative risk	95% CI
Total	5.1	0.2		
Age (y)				
10-19	6.5	0.61	1.40	1.09-1.70
20-29	4.6	0.26	Reference	
30-39	5.2	0.28	1.11	0.94-1.28
40-59	7.7	1.31	1.67	1.08-2.25
Race[a]				
White	4.4	0.28	Reference	
Black	8.5	0.54	1.95	1.60-2.29
Other	4.7	0.72	1.06	0.72-1.41
Beds in hospital (n)[b]				
<100	4.9	0.90	1.11	0.66-1.55
100-299	4.4	0.39	Reference	
300-499	4.7	0.37	1.07	0.82-1.32
>500	5.5	0.38	1.25	0.97-1.52
Region				
Northeast	5.7	0.49	1.41	1.10-1.71
Midwest	4.1	0.28	Reference	
South	6.0	0.40	1.47	1.13-1.81
West	4.2	0.20	1.04	0.84-1.24
Cesarean delivery				
Yes	14.1	0.68	6.06	5.02-7.09
No	2.3	0.17	Reference	

[a] Race data are missing from 24.7% of the discharge records.

[b] Eleven percent of the discharge records are missing the number of beds in the hospital.

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women each year are affected. The severe maternal morbidity rate increased during the early years of the 21st century, primarily because of an increase in the rate of transfusion.

The recent effort by Wen et al[5] to identify and monitor severe maternal morbidity closely reflects our proposed framework. Using a hospital discharge database for 7 provinces that accounted for >70% of the deliveries in Canada, they developed categories of severe morbidity using ICD-9-CM–coded diagnoses and procedures. They found an overall severe morbidity rate of 4.4 per 1000 deliveries from 1991-2001. However, there are several important differences between their analysis and ours. Wen et al selected their severe morbidity ICD-9-CM codes based on the most common codes for women in their database who died from pregnancy complications. Because we used the NHDS, a sample of hospital discharges that contains few pregnancy-related deaths, we could not directly link women who died during their delivery hospitalization to the coded cause of death. However, we did select codes that were based on the causes of pregnancy-related deaths in the United States[16] and our understanding of the clinical courses for those women.

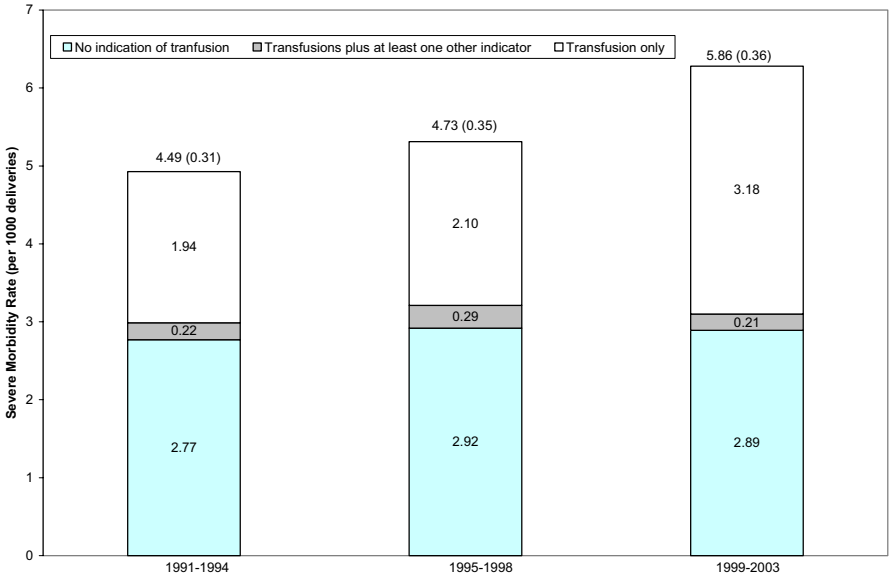
We also did not include 2 codes that the Canadian group considered as indicators of severe morbidity. "Other complications of obstetric surgery and procedures" (ICD-9-CM code 669.4) was the most common severe morbidity (24%) in the Canadian report. Although the code 669.4 mentions cardiac arrest and cerebral anoxia as examples of complications for which the code could be used, the Canadian group named the indicator for that code "Cardiac arrest or failure or cerebral anoxia after obstetric surgery." In the early stages of our analysis, for a

sample of discharges with a 669.4 code, we reviewed all of the additional diagnostic and procedure codes. We found that most of the women with the code 669.4 had short hospitalizations, were discharged alive, and had little evidence of comorbidities. For example, ileus was a common comorbidity used in combination with 669.4 and cesarean section. The few exceptions to this had more specific cardiac codes (eg, cardiac arrest) in addition to 669.4, and our algorithm would have identified these. "Uterine rupture" was the third most common severe morbidity that was found by the Canadian group. Because previous work suggests that the accuracy of the ICD-9-CM codes for uterine rupture is low,[17] we did not consider uterine rupture in and of itself as a severe morbidity and assumed that a clinically significant rupture would require a blood transfusion or a hysterectomy.

The prominent influence of blood transfusion in indicating severe maternal morbidity highlights the major contribution of obstetric hemorrhage to maternal morbidity and death. Other studies that used different frameworks and definitions for severe maternal morbidity found similar large contributions for severe hemorrhage to the overall severe morbidity rate.[18-22] In the Canadian report, the importance of transfusion as a prominent indicator of severe maternal morbidity is demonstrated by the fact that it was the second leading cause of severe morbidity after the nonspecific code 669.4 (Other complications of obstetric surgery and procedures).[5] Although the Canadian report suggested a decreasing trend in transfusion, an Australian report documented increasing rates of postpartum hemorrhage and transfusion among women with hemorrhage during similar time periods.[23] However, without a better understanding of how administrative coding occurs, we cannot exclude the possibility that there may be a more permissive attitude toward blood transfusions among obstetricians in recent years or differences in coding practices.

ICD-9-CM codes have several limitations when used to identify many specific conditions and, more so, when an attempt is made to determine the severity of the condition. We avoided the use of most of the conventional obstetric ICD-9-CM diagnosis codes because they lack specificity and because most of the codes do not indicate severity. Many potentially severe complications are coded under broad headings that are based on the body system that was affected and not the specific conditions. For example,

FIGURE 1
Severe morbidity rate



Severe morbidity rate per 1000 deliveries (standard error) over time, by the presence or absence of blood transfusions. Weighted least-squares test for trend in "transfusion only" rate; $z = 2.37$; $P = .009$.

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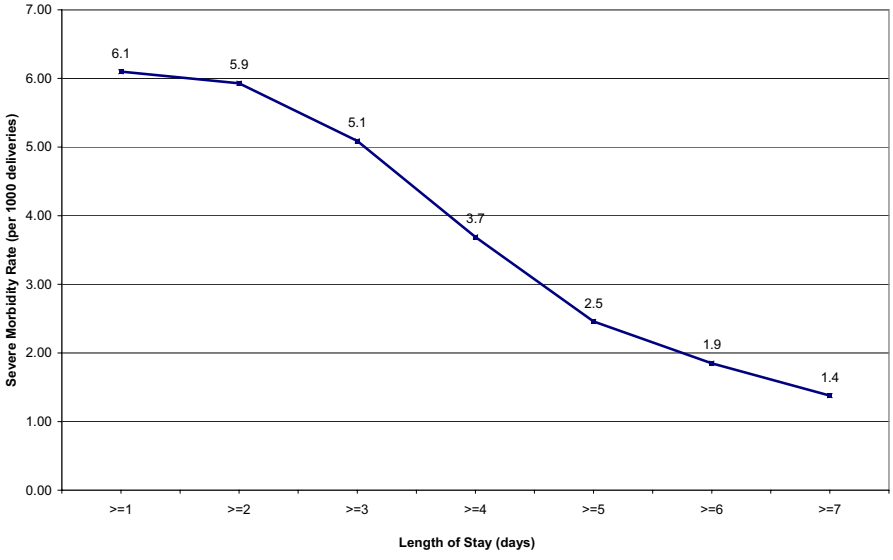
FIGURE 2
Effect of varying the length of stay criterion on the severe morbidity rate



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acute fatty liver of pregnancy, a potentially fatal complication, is represented by the same ICD-9-CM code (646.7) as icterus gravidarum. As such, we relied on other indicators of severity over and above simply meeting the definition requirements of a condition or a syndrome.

Coded administrative data may also be inaccurate and, therefore, misleading when an attempt is made to identify women with severe maternal morbidity. For example, we found codes for severe events, such as stroke and amniotic fluid embolism, for women who were discharged alive and who had implausibly short hospital stays. It is possible that the codes were incorrect or that the length-of-stay status was incorrect. We imposed a length-of-stay requirement of at least 3 days to at least partially account for these discrepancies and presented data to demonstrate how increasing the length of stay affects the overall severe morbidity rate. However, some misclassification certainly has occurred. In addition, it is possible that some women were coded as discharged alive when, in fact, they died during hospitalization or they were transferred to another health care facility. Such inconsistencies can be resolved only through validation studies. Objectively, validation can establish whether the ICD-9-CM code truly indicates that a condition was present or that a procedure was performed. Although this particular set of ICD-9-CM codes has not been validated for delivery hospitalizations, validation studies of comorbidity codes for obstetric hospitalizations generally have reported low-to-good sensitivities and reasonable-to-high specificities or positive predictive values.[24-26] Therefore, if the same holds for the codes presented here, our construct may represent an underestimation of the magnitude of severe maternal morbidity. On the other hand, subjective validation involves a judgment about whether the woman truly had severe morbidity. We encourage such research to validate and improve this construct for monitoring severe maternal morbidity.

In his recent proposal for an agenda on patient safety in obstetrics and gynecology, Pearlman[27] calls for measures of quality that go beyond rates of vaginal and cesarean birth. Identifying cases of severe maternal morbidity, understanding the factors that lead to adverse events, and taking informed action to improve systems can have a profound effect on how the process of care occurs.[28,29] Review of cases of severe maternal morbidity may also reveal success stories in that nonpreventable complications may have been kept from progressing to a greater degree of severity or death. Such information can provide valuable insight into best practices.

The usefulness of monitoring severe maternal morbidity extends beyond the level of healthcare facilities. Similar to the national analysis presented here, states can use their hospital discharge databases to determine severe morbidity rates at the state level and for specific hospitals, towns, cities, and perinatal regions. Moreover, states with the capacity to link their hospital discharge databases with birth certificates can take advantage of additional information that is available on birth certificates (such as maternal race and obstetric characteristics) to enhance their analyses. As perinatal regionalization expands to consider maternal requirements for advanced levels of care, information about the distribution and determinants of severe maternal morbidity can inform policy decisions that promote appropriate referral for care of the pregnant woman and her fetus.

Maternal death is the traditional sentinel event in obstetrics, an event that signals the need for a careful search for ways to prevent future deaths. However, maternal deaths are rare in the United States, and improvement of the quality of care in contemporary times requires that the concept of sentinel event be expanded. The identification of women who experience severe adverse events during their delivery hospitalizations and a review of their care is a natural extension of pregnancy-related death surveillance. Acknowledging the limits of coded discharge data, we propose a simple method for the identification of cases of severe maternal morbidity as a first step for monitoring trends at the local, state, and national level and for the review of quality of care in individual institutions or perinatal regions. ■

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APPENDIX

Severe morbidity group, description of diagnosis or procedure, and ICD-9-CM codes for severe maternal morbidity

Morbidity group	Description of diagnosis or procedure	ICD-9-CM code
Diagnosis-based groups		
Acute renal failure	Acute renal failure	584
	Renal failure unspecified	586
	Acute renal failure after labor and delivery	669.30,2,4
Liver failure	Acute and subacute necrosis of the liver	570
Respiratory failure	Acute pulmonary edema	518.4
	Pulmonary insufficiency after trauma and surgery	518.5
	Acute respiratory failure	518.81,2,4
	Respiratory arrest	799.1
Obstetric shock	Obstetric shock	669.10,1,2,3,4
Cerebrovascular accident	Subarachnoid hemorrhage	430
	Intracerebral hemorrhage	431
	Other and unspecified intracranial hemorrhage	432
	Occlusion and stenosis of precerebral arteries	433
	Occlusion of cerebral arteries	434
	Acute, but ill-defined, cerebrovascular disease	436
	Cerebral venous thrombosis (pregnancy specific)	671.50,1,2,3,4
	Cerebrovascular disorders in the puerperium	674.00,1,2,3,4
Pulmonary embolism	Obstetric air embolism	673.00,1,2,3,4
	Obstetric blood clot embolism	673.20,1,2,3,4
	Obstetric septic and pyemic embolism	673.30,1,2,3,4
	Other pulmonary embolism	673.80,1,2,3,4
	Iatrogenic pulmonary embolism and infarction	415.11
	Other pulmonary embolism and infarction	415.19
Amniotic fluid embolism	Amniotic fluid embolism	673.10,1,2,3,4
Eclampsia	Eclampsia	642.60,1,2,3,4

(Cont'd)

Morbidity group	Description of diagnosis or procedure	ICD-9-CM code
Septicemia	Septicemia	038
Complications of anesthesia	Obstetric codes for complications of anesthesia	668.00,1,2,3,4
		668.10,1,2,3,4
		668.21,1,2,3,4
Procedure-based groups		
Cardiac events/procedures	Heart failure	428
	Cardiomyopathy	425
	Cardiac arrest	427.5
	Acute myocardial infarction	410
	Conversion of cardiac rhythm (includes cardiopulmonary resuscitation)	99.60, 99.62, 99.62, 99.63, 99.64, 99.69
Mechanical ventilation	Continuous ventilation, unknown duration	96.70
	Continuous ventilation $<$96 hr	96.71
	Continuous ventilation $\geq$96 hr	96.72
Transfusion	Other transfusion of whole blood	99.03
	Transfusion of packed cells	99.04
Hysterectomy	Subtotal abdominal hysterectomy	68.3
	Total abdominal hysterectomy	68.4
	Other and unspecified hysterectomy	68.9
Invasive hemodynamic monitoring	Circulatory monitoring	89.60-64