Severe Obstetric Morbidity in the United States: 1998–2005

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OBJECTIVE: To examine trends in the rates of severe obstetric complications and the potential contribution of changes in delivery mode and maternal characteristics to these trends.

METHODS: We performed a cross-sectional study of severe obstetric complications identified from the 1998–2005 Nationwide Inpatient Sample of the Healthcare Cost and Utilization Project. Logistic regression was used to examine the effect of changes in delivery mode and maternal characteristics on rates of severe obstetric complications.

RESULTS: The prevalence of delivery hospitalizations (per 1,000) complicated by at least one severe obstetric complication increased from 0.64% (n=48,645) in 1998–1999 to 0.81% (n=68,433) in 2004–2005. Rates of complications that increased significantly during the study period included renal failure by 21% (from 0.23 to 0.28), pulmonary embolism by 52% (0.12 to 0.18), adult respiratory distress syndrome by 26% (0.36 to 0.45), shock by 24% (0.15 to 0.19), blood transfusion by 92% (2.38 to 4.58), and ventilation by 21 % (0.47 to 0.57). In logistic regression models, adjustment for maternal age had no effect on the increased risk for these complications in 2004–2005 relative to 1998–1999. However, after adjustment for mode of delivery, the increased risks for these complications in 2004–2005 relative to 1998–1999 were no longer significant, with the exception of pulmonary embolism (odds ratio 1.30) and blood transfusion (odds ratio 1.72). Further adjustment for payer, multiple births, and select comorbidities had little effect.

CONCLUSION: Rates of severe obstetric complications increased from 1998–1999 to 2004–2005. For many of these complications, these increases were associated with the increasing rate of cesarean delivery.
(Obstet Gynecol 2009;113:293–9)

LEVEL OF EVIDENCE: III

Because maternal mortality is an uncommon albeit devastating event in the United States, the research agenda in obstetric epidemiology has broadened over the past decade to include maternal morbidity as an important measure of maternal health.[1] Although indicators of maternal morbidity during labor and delivery are included in the U.S. Department of Health and Human Services Healthy People 2010 objectives, comprehensive population-based information on severe obstetric complications remains very limited.[2] Examination of severe or "near-miss" complications remains a valuable clinical and epidemiologic adjunct to maternal death reviews as a means of identifying major problems in obstetric care that may be amenable to interventions.[1]

According to data from other national studies, rates of cesarean delivery have increased from 21.2% in 1998 to 31.1% in 2005.[2,3] Because cesarean delivery is a major abdominal surgery that may be associated with different risks of complications compared with vaginal deliveries, the increase in cesarean deliveries may also influence maternal morbidity rates.[4–6] The objective of this study was to examine trends in rates of severe obstetric complications, and the contribution of changes in cesarean delivery rates and mater-

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The authors thank Pooja Bansil for programming assistance. The findings and conclusions in this report are those of the authors and do not necessarily represent the view of the Centers for Disease Control and Prevention or the Eunice Kennedy Shriver *National Institute of Child Health and Human Development, National Institutes of Health, Bethesda, Maryland.*

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Financial Disclosure
The authors did not report any potential conflicts of interest.

ISSN: 0029-7844/09

Table 1. International Classification of Diseases, 9th Revision Complication Codes Used to Describe Severe Maternal Morbidity in the United States, 1998–2005, Nationwide Inpatient Sample

Complications	International Classification of Diseases, 9th Revision, Clinical Modification Codes
Pregnancy	
Diabetes	250.00–250.33, 250.40–250.93, 775.1, 648.0, 648.8
Hypertension	401.0, 401.1, 401.9, 402.00–405.99, 437.2, 642.0–642.9
Multiple births	651, V27.2, V27.3, V27.4, V27.5, V27.6, V27.7
Previous cesarean delivery	654.2x
Labor and delivery	
Renal failure	669.3, 584
Heart failure	669.4, 427.5, 428.1, 428.21, 428.31, 428.41, 997.1
Pulmonary embolism	673, 415.1x
Pulmonary edema	518.4, 428.1
Adult respiratory distress syndrome	518.5, 518.81, 518.82, 518.84, 799.1
Puerperal cerebrovascular disorders	674.0, 671.5, 430, 431, 436, 432.x, 433.x, 434.x, 437.x, 997.2, 999.2
Deep venous thrombosis	671.3, 671.4, 671.9, 451.x, 452, 453.x
Disseminated intravascular coagulation	286.6, 286.9, 666.3
Shock	669.1, 998.0 (postoperative shock), 995.0 (other anaphylactic shock), 995.4 (shock due to anesthesia), 785.5x (shock without mention trauma)
Sepsis	038.0–038.9, 995.91, 995.92
Severe anesthesia complications	668.0, 668.1, 668.2
Procedures	
Cesarean delivery	74.0, 74.1, 74.2, 74.4, 74.99
Blood transfusion	99.00–99.09
Hysterectomy	68.3–68.9
Ventilation	93.90, 96.01–96.05, 96.7x

nal age to these trends, during this recent period of rising cesarean delivery rates.

MATERIALS AND METHODS

We used data from the Nationwide Inpatient Sample (NIS) of the Healthcare Cost and Utilization Project (HCUP), a federal-state-industry partnership sponsored by the Agency for Healthcare Research and Quality.[7] The NIS is the largest all-payer inpatient care database in the United States and uses discharges from the sampled hospitals to produce nationwide estimates. The number of states participating in the NIS ranged from 22 in 1998 to 37 in 2005; the sampling frame for the 2005 NIS is a sample of hospitals that comprises approximately 90% of all hospital discharges in the United States. Details of the sampling strategy are described elsewhere.[7] The weighted nationwide annual estimates of the total number of discharges from all U.S. hospitals ranged from 34,874,001 in 1998 to 39,163,834 in 2005. Because the NIS excludes data elements that could directly or indirectly identify individuals, this research was determined to be exempt by the institutional review board of the Centers for Disease Control and Prevention.

Our analysis included all 1998–2005 delivery hospitalizations. To identify delivery hospitalizations, we used a combination of delivery-related diagnosis and procedure International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes as described in detail elsewhere.[8] Hospitalization records were excluded if their discharge summary contained ICD-9-CM codes for hydatidiform mole (630), other abnormal product of conception (631), ectopic pregnancy (633), or abortion (632, 634, 635, 636, 637, 638, 639, and 69.01, 69.51, 74.91, 75.0).

We assessed severe/"near-miss" maternal morbidity using the WHO method of disease-based and management-based groups.[9] The disease-based group consisted of severe anesthesia complications, renal failure, heart failure, puerperal cerebrovascular disorders, obstetric pulmonary embolism, pulmonary edema, adult respiratory syndrome, deep venous thrombosis, disseminated intravascular coagulation, sepsis, and shock. The management-based group included hysterectomy, blood transfusions, and ventilation.

First, we identified hospitalizations with severe obstetric complications using condition-specific ICD-9 codes. Second, we used mortality, transfer from or to another health care facility, and length of stay as criteria to distinguish between hospitalizations with severe complications and hospitalizations with preex-

isting conditions. Because hospitalizations with mortality or transfer may have a short length of stay, we considered them as hospitalizations with severe complications regardless of the length of stay. Among the remaining hospitalizations, we reclassified hospitalizations with short length of stay (defined as hospitalizations with length of stay less than 90th percentile calculated separately for vaginal, primary, and repeat cesarean deliveries) as hospitalizations without severe complications unless ventilation or hysterectomy were also included. The percent of excluded hospitalizations ranged from 10.7% to 46.4% for renal failure and complications of anesthesia, respectively, when this criterion was applied. The ICD-9-CM codes for pregnancy and labor/delivery complications included in the study are listed in Table 1.

Because we planned to conduct trend analyses, all changes in ICD-9-CM codes documented by the National Center for Health Statistics that took place during the period of study were assessed and included in our coding algorithm.[10] The only substantive changes documented were for codes for sepsis in 2002 and codes for cardiomyopathy that have been expanded into a specific code; thus, we could not investigate trends in rates of cardiomyopathy. In-hospital mortality was identified using the variable "died during hospitalization" in the HCUP data system.

The unit of analysis was a delivery hospitalization, not an individual. We performed two types of testing: a linear trend in prevalence of severe labor/delivery complications as well as in prevalence of other potential determinants of the complications across the four intervals (1998–1999, 2000–2001, 2002–2003, and 2004–2005) and a difference in the prevalence of severe labor/delivery complications between each 2-year interval adjusted for other factors. Although we reported linear trends for all four intervals, we showed prevalence and difference in the prevalence only for 1998–1999 and 2004–2005. We used orthogonal polynomial coefficients that are calculated recursively according to the method of Fisher and Yates for linear trend testing.[11] The significance level used to test linear trends was set at 99% (ie, $P = .01$ threshold). We applied logistic regression to examine the changes in rates of severe obstetric complications between 1998–1999 and 2004–2005.

We reported prevalence and examined the trend in prevalence of age groups, insurance status, mode of delivery, and prevalence of selected pregnancy complications from 1998–1999 to 2004–2005. We also reported overall rates of each complication as well as rates of each complication by age group or mode of delivery per 1,000 deliveries and assessed their trend by four 2-year intervals.

Table 2. Maternal Characteristics Among Delivery Hospitalizations for 1998–1999 and 2004–2005 From the Nationwide Inpatient Sample

Characteristics	Percent	
	1998–1999 (N=7,605,289)*	2004–2005 (N=8,409,938)
Age (y)		
Younger than 20	12.60	10.22
20–34	74.30	74.98
Older than 34	13.10	14.80
Payer		
Medicaid/Medicare	34.61	41.00
Private insurance	58.63	53.16
Self-pay	6.26	5.68†
Mode of delivery		
Vaginal	74.52	67.84
Vaginal after cesarean	3.96	1.57
Repeat cesarean	7.97	12.71
Primary cesarean	13.55	17.88
Pregnancy conditions		
Multiple birth	1.52	1.79
Hypertension‡	2.06	2.83
Diabetes‡	3.92	5.44

* Data for 2000–2001 and 2002–2003 is not shown, linear trend across 1998–1999, 2000–2001, 2002–2003, and 2004–2005 are assessed by calculating orthogonal polynomial coefficients according to the method of Fisher and Yates.

† *P* for linear trends >.05; for all other variables in the table, *P* for linear trends <.0001.

‡ Includes gestational and nongestational condition.

Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated to estimate the risk of each severe obstetric complication in three time intervals (2000–2001, 2002–2003, 2004–2005) relative to 1998–1999. Only results for 2004–2005 are presented. Sequential models were constructed with maternal age only, mode of delivery only, both maternal age and mode of delivery, and a full model also including other potential determinants of severe obstetric complications to assess the effect of each factor or group of factors on the relationship between time period (2004–2005 compared with 1998–1999) and the occurrence of each severe obstetric complication. In addition to maternal age and mode of delivery, we also investigated selected pregnancy conditions and hospital characteristics (region [Northwest, Midwest, South, West], location [rural/urban], teaching status [yes/no], and bed size [small, medium, large]) as potential predictors or covariates of obstetric complications. Because some states do not report race/ethnicity information to HCUP, we did not include this variable in the analysis.[7]

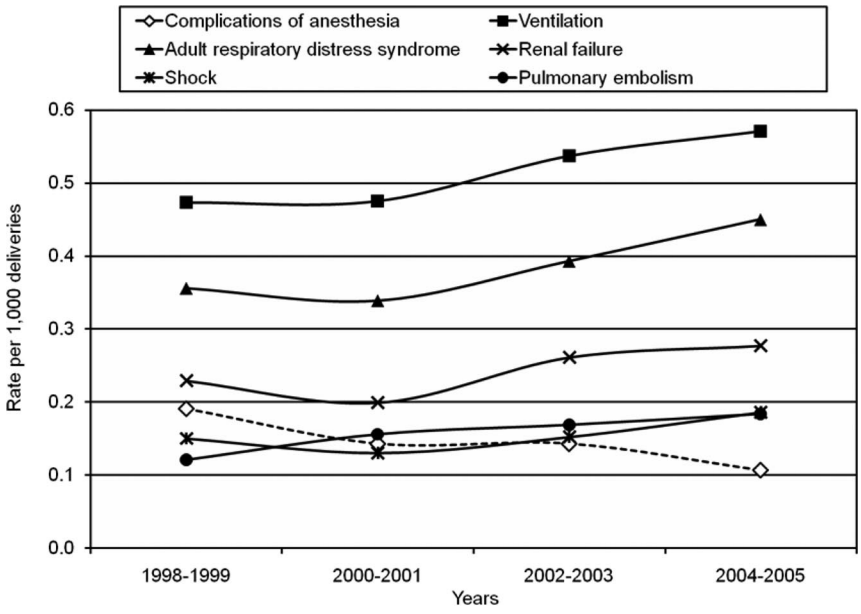

Fig. 1. Severe complications with significant linear trends in the United States between 1998 and 2005. Data from the National Inpatient Sample.
Kuklina. Severe Obstetric Morbidity, United States. Obstet Gynecol 2009.

We used SAS 9.1 software (SAS Institute Inc., Cary, NC) to manage data and used SAS-callable SUDAAN 9.0 software (RTI International, Research Triangle, NC) to account for the multistage probability sampling design. Thus, all results are based on the weighted estimates of delivery hospitalizations in the United States during the period of study. All programming was independently duplicated by a second analyst.

RESULTS

During the study period, there were an estimated 32,276,863 delivery discharge records. Proportions of demographic characteristics and codes for selected pregnancy complications in 1998–1999 and 2004–2005 are shown in Table 2. Delivery hospitalizations in 2004–2005 compared with 1998–1999 were characterized by an increase in the proportion of older women and women on Medicaid/Medicare. An increase in the proportion of hospitalizations with multiple births, hypertension, diabetes, and cesarean delivery was also observed.

The prevalence of delivery hospitalizations complicated by at least one severe obstetric complication increased from 0.64% (n=48,645) in 1998–1999 to 0.81% (n=68,433) in 2004–2005. The rate of in-hospital mortality among all delivery hospitalizations was 0.1 and 0.08 per 1,000 deliveries in 1998–1999 and 2004–2005, respectively. The highest rate of in-hospital mortality, in the range of 54–100 per 1,000

Table 3. Rates of Selected Obstetric Complications per 1,000 Deliveries by Age and Mode of Delivery for 1998–99 and 2004–05 From the Nationwide Inpatient Sample*†

	Renal Failure		Pulmonary Embolism		Adult Respiratory Distress Syndrome	
	1998–99	2004–05	1998–99	2004–05	1998–99	2004–05
Overall	0.23	0.28*	0.12	0.18*	0.36	0.45*
Age (y)						
Younger than 20	0.15	0.23	0.07	0.21*	0.38	0.49*
20–34	0.21	0.25*	0.11	0.16*	0.31	0.38*
Older than 34	0.42	0.45	0.20	0.27	0.59	0.77*
Mode of delivery						
Vaginal	0.12	0.11	0.07	0.09	0.15	0.15
Vaginal birth after cesarean	0.14	0.07	0.07	0.12	0.15	0.19
Repeat cesarean delivery	0.25	0.28	0.25	0.25	0.45	0.59
Primary cesarean delivery	0.87	0.93	0.35	0.49*	1.50	1.50

* Data for 2000–20001 and 2002–2003 are not shown; linear trend across 1998–1999, 2000–2001, 2002–2003, and 2004–2005 are assessed by calculating orthogonal polynomial coefficients according to the method of Fisher and Yates.
† *P* for linear trends <.05.

deliveries, was observed among hospitalizations with ventilation, pulmonary embolism, shock, adult respiratory distress syndrome, and renal failure. There were an estimated 2,760 hospitalizations with in-hospital mortality during the 1998–2005 years. During the same time period, in comparison, there were an estimated 227,333 hospitalizations with at least one disease-based or management-based severe morbidity.

Blood transfusions and heart failure were among the severe conditions with rates greater than 1.0 case per 1,000 deliveries. Severe complications of anesthesia, pulmonary edema, pulmonary embolism, and shock were among the rarest conditions, with rates less than 0.2 cases per 1,000 deliveries. There was no evidence of a statistically significant change in the rates of the following complications over the study period: heart failure (P=.43), puerperal cerebrovascular disorders (P=.46), pulmonary edema (P=.11), deep venous thrombosis (P=.37), disseminated intravascular coagulation (P=.08), and sepsis (P=.07). The rate of hysterectomy increased, but this increase had only borderline significance (P=.045). Severe complications with significant linear trends (P<.01) during the period of study are shown in Figure 1. In contrast to the increasing linear trends for renal failure, pulmonary embolism, adult respiratory syndrome, shock, blood transfusions (data are not shown), and ventilation, the linear trends for severe complications of anesthesia were decreasing.

Rates of both adult respiratory syndrome and blood transfusion increased significantly from 1998–1999 to 2004–2005 within each age group (Table 3). Additionally, there was a pattern of increasing rates of each complication with increasing age. Rates of blood transfusion increased significantly within each mode of delivery. Significant increases were observed for pulmonary embolism and shock among primary cesarean deliveries. Generally, rates of complications were higher in repeat or primary cesarean deliveries than in vaginal deliveries or vaginal deliveries after cesarean.

During the study period, there was a greater than 20% increase in rates of renal failure, respiratory distress syndrome, shock, and ventilation, a 52% increase in rates of pulmonary embolism, and a 92% increase in rates of blood transfusion (Table 4). Conversely, there was a decrease of more than 40% in rates of severe complications of anesthesia. Adjustment for age had little effect on the observed changes in severe morbidity in 2004–2005 compared with 1998–1999. In contrast, adjustment for mode of delivery explained almost all increases in the estimated risk of renal failure, adult respiratory syndrome, and ventilation, whereas it explained only roughly one half of the increase in the risk of shock, one third of the increase in the risk of pulmonary embolism, and only one fifth of the increase in the risk of blood transfusion. Further, it did not explain any of the decrease in the risk of complications of anesthesia. Adjustment for age and delivery mode simultaneously as well as further adjustment for payer, multiple births, diabetes, and hypertension had little effect on any results.

DISCUSSION

The contemporary evaluation of severe obstetric morbidity in the United States is challenged by the lack of a specific surveillance system with confirmed cases as well as the relatively infrequent number of events. We

Shock		Blood Transfusion		Ventilation		Complication of Anesthesia	
1998–99	2004–05	1998–99	2004–05	1998–99	2004–05	1998–99	2004–05
0.15	0.19*	2.38	4.58*	0.47	0.57*	0.19	0.11*
0.08	0.09	2.84	5.79*	0.35	0.62*	0.20	0.13
0.13	0.17*	2.15	4.08*	0.43	0.49*	0.17	0.10*
0.32	0.35	3.29	6.28*	0.85	0.93	0.29	0.15*
0.11	0.09	1.49	2.83*	0.18	0.16	0.07	0.06
0.24	0.16	2.26	4.46*	0.15	0.26	0.18	0.08
0.24	0.30	5.07	7.03*	0.75	0.75	0.43	0.13*
0.32	0.48*	5.78	9.50*	2.02	2.04	0.72	0.29*

Table 4. Adjusted Odds Ratios and (95% Confidence Intervals) for Severe Obstetric Complications in 2004–2005 Compared With 1998–1999, Nationwide Inpatient Sample

Adjusted for	Renal Failure	Pulmonary Embolism	Adult Respiratory Distress Syndrome
Crude	1.21(1.02–1.44)	1.52 (1.25–1.86)	1.26 (1.11–1.43)
Age only	1.19 (1.00–1.42)	1.50 (1.23–1.84)	1.25 (1.10–1.42)
Mode of delivery only	1.02 (0.86–1.22)	1.30 (1.06–1.59)	1.04 (0.92–1.18)
Age and mode of delivery	1.01 (0.85–1.21)	1.29 (1.05–1.58)	1.04 (0.92–1.18)
Mode of delivery, age, and other factors*	0.92 (0.78–1.09)	1.23 (1.00–1.50)	0.96 (0.85–1.08)

* Adjusted for payer, multiple births, diabetes, and hypertension.

used the largest hospital discharge data set available to examine coding for these conditions over time as the rate of cesarean delivery rose, and limited the cases to include only those that had a long length of stay. We found an approximately 20% increase in rates of renal failure, respiratory distress syndrome, shock, and ventilation and an approximately 50% and 90% increase in pulmonary embolism and blood transfusions, respectively, from 1998–1999 to 2004–2005. Maternal age did not seem to contribute substantively to these increases in risk. In contrast, increasing rates of cesarean delivery seemed to explain the observed change over time for renal failure, respiratory distress syndrome, and ventilation. Changes in cesarean delivery rate, although only partially, also contributed to the increases in shock, pulmonary embolism, and blood transfusions.

Only a few population-based studies for comparison are available. Our rates of management-based complications (0.06–0.5%) are within the range reported by other studies (0.01–2.99%).[9] The rates of severe complications, with exception for rates of severe anesthesia, reported in our study are higher than rates reported from the Discharge Abstract Database collected by the Canadian Institute for Health Information.[12] Although differences exist in several definitions of severe complications, the results on the increasing trends in adult respiratory distress syndrome, pulmonary edema, embolisms, and ventilation are consistent between this and our study. Sharply increasing trends of blood transfusion in our study may reflect the growing trends in general population that started in 1997.[13,14] Finally, one report on severe morbidity using the National Hospital Discharge Survey examined similar ICD-9-CM codes but summarized the data from 1991 to 2003, due to the small sample size.[15]

The results of our study should be considered in the light of the following limitations: First, our identification of severe complications is based on ICD-9-CM codes and data-driven criteria, such as in-hospital mortality transfer from or to another health care facility and length of stay. We were unable to confirm the severity of conditions by using medical records. Second, lack of information on race and body mass index precluded us from adjusting these confounders. Marked racial disparity in maternal morbidity and mortality has been reported in previous studies.[16–18] In addition, although we adjusted for changes in prevalence of diabetes and hypertension, the contribution of growing trends in obesity to increasing trends in maternal morbidity requires future investigation by more specific indicators such as body mass index.

A surveillance system for rare obstetric complications has been implemented in the United Kingdom.[19] Case reports are collected prospectively from each hospital on a monthly basis. Only conditions with rates less than 0.5 per 1,000 deliveries and a significant contribution to maternal morbidity and mortality are surveyed. The development of a national surveillance system for severe obstetric complications in the United States may improve the ascertainment, monitoring, and classification of these complications and potentially identify modifiable risk factors.

In conclusion, our analysis demonstrated that the increasing trend in rates of several severe complications among delivery hospitalizations is paralleled by the increasing rate of cesarean delivery. The independent increase in rates of pulmonary embolism is of concern because, although extremely rare, it is the most common direct cause of maternal mortality in the United States.[20] Future studies on the major risk factors for this complication, other than age and mode of delivery, such as multiparity, obesity, and/or chronic disease, may shed light on these trends. Our results do not demonstrate causality, so it is important that future studies or surveillance be undertaken to confirm and further investigate the contribution of changes in obstetric practice and other modifiable

Shock	Blood Transfusion	Ventilation	Complication of Anesthesia
1.24 (1.03–1.48)	1.92 (1.68–2.20)	1.21 (1.08–1.35)	0.56 (0.45–0.70)
1.20 (1.00–1.44)	1.92 (1.68–2.20)	1.20 (1.07–1.34)	0.56 (0.45–0.69)
1.09 (0.91–1.30)	1.72 (1.50–1.97)	0.98 (0.88–1.10)	0.47 (0.37–0.58)
1.04 (0.86–1.26)	1.72 (1.50–1.98)	0.98 (0.87–1.09)	0.47 (0.37–0.58)
1.03 (0.86–1.23)	1.63 (1.43–1.85)	0.91 (0.82–1.01)	0.45 (0.36–0.56)

factors to any increases in severe obstetric complications described here.

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