

OBSTETRICS

Maternal death in the 21st century: causes, prevention, and relationship to cesarean delivery

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OBJECTIVE: We sought to examine etiology and preventability of maternal death and the causal relationship of cesarean delivery to maternal death in a series of approximately 1.5 million deliveries between 2000 and 2006.

STUDY DESIGN: This was a retrospective medical records extraction of data from all maternal deaths in this time period, augmented when necessary by interviews with involved health care providers. Cause of death, preventability, and causal relationship to mode of delivery were examined.

RESULTS: Ninety-five maternal deaths occurred in 1,461,270 pregnancies (6.5 per 100,000 pregnancies.) Leading causes of death were complications of preeclampsia, pulmonary thromboembolism, amniotic fluid embolism, obstetric hemorrhage, and cardiac disease. Only 1 death was seen from placenta accreta. Twenty-seven deaths (28%) were deemed preventable (17 by actions of health care personnel and

10 by actions of non-health care personnel). The rate of maternal death causally related to mode of delivery was 0.2 per 100,000 for vaginal birth and 2.2 per 100,000 for cesarean delivery, suggesting that the number of annual deaths resulting causally from cesarean delivery in the United States is about 20.

CONCLUSION: Most maternal deaths are not preventable. Preventable deaths are equally likely to result from actions by nonmedical persons as from provider error. Given the diversity of causes of maternal death, no systematic reduction in maternal death rate in the United States can be expected unless all women undergoing cesarean delivery receive thromboembolism prophylaxis. Such a policy would be expected to eliminate any statistical difference in death rates caused by cesarean and vaginal delivery.

Key words: cesarean delivery, maternal death, quality of care

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Maternal death rates in the United States have remained constant for several decades.¹ This may be due to a stagnation in quality improvement with respect to maternal death or a masking of improved quality by demographic

changes or the appearance of newer diseases or more virulent forms of established diseases. Alternately, improved overall quality of maternal care may be masked by the rising rate of cesarean delivery, given the known association of these procedures with increased rates of maternal death.^{2,3}

In a review of all maternal deaths among almost 1.5 million deliveries within 124 hospitals in the last 6 years, we sought to answer the following questions: (1) what are the causes of maternal death in the years since 2000; (2) to what extent are such deaths preventable by improved individual quality of care; (3) to what extent is cesarean delivery causally, as opposed to associatively related to maternal death; and (4) are there systematic changes in the delivery of obstetric health care that might have an impact on the maternal death rate in the United States?

Dec. 31, 2006, in facilities of the nation's largest health care delivery system, the Hospital Corporation of America. This system has hospitals providing obstetric services in 20 states, from New England to Florida and California to Alaska and includes primary, secondary, and tertiary level hospitals, including 2 academic medical centers. Previous analysis of cesarean and operative vaginal delivery rates from this system suggests a patient population roughly representative of that of the United States as a whole.^{4,5,6} When necessary to clarify the chain of events leading to death or qualifications of the treating providers (3 cases), medical record information was supplemented by interviews with involved providers. Maternal deaths were identified by examining cases of death that fell within diagnosis-related groups 370-375, 378, 380, 381, 383, and 384, as identified in a central electronic hospital discharge database. This population included pregnant pa-

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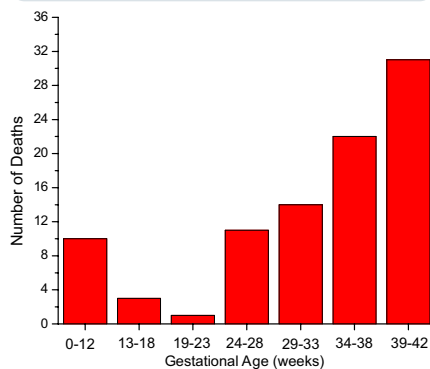
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MATERIALS AND METHODS

We examined medical records of all maternal deaths between Jan. 1, 2000, and

FIGURE
Relationship of maternal deaths to gestational age



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tients with cardiac arrest that occurred outside the hospital who were pronounced dead on arrival.

Primary data extraction from medical records was carried out by a single physician author using a standardized data collection form. When the extracted data made clear the issue of preventability and causal relationship to mode of delivery (eg, maternal suicide), only the extracted data were reviewed by all authors. Where there was a potential question as to either preventability or relationship of death to mode of delivery (eg, a death from hemorrhage after hospital admission), pertinent medical records were reviewed by 2 authors (16 cases). Agreement between the 2 reviewers was obtained in all cases.

Judgments regarding causal relationship of mode of delivery to death were reached by asking the following question: "Had the patient delivered by the alternative route (vaginal vs cesarean), all other details remaining the same prior to delivery, would the death probably have been avoided?" If the answer was affirmative, death was attributed to route of delivery. This decision did not involve a judgment regarding the appropriateness of the route of delivery in an individual case. A case was judged as potentially preventable if adherence to current standards of care would likely have avoided the death.

This project was carried out as part of a system-wide quality improvement ini-

tiative aimed at identifying causes of maternal death within our system and development of improved processes to prevent such events. However, institutional review board permission for publication was obtained. Standard descriptive statistics and the Fisher's exact test were used for data analysis.

RESULTS

There were 95 maternal deaths in a total population of 1,461,270 births (6.5 per 100,000 births). Median maternal age of women who died was 29 years (range 13-42), median parity was 1 (range 0-6), 43 patients (45%) were white, 26 (27%) African American, 19 (20%) Hispanic, and 7 (8%) were of Asian ethnicity. Gestational age at the time of death is detailed in the Figure. Forty-five deaths (47%) were classified as direct obstetric deaths, 32 (33%) as indirect obstetric deaths, and 18 (20%) as nonobstetric deaths.

Fourteen patients (15%) had known preexisting medical conditions that caused or contributed to their death. Four of these had underlying cardiac conditions, 2 had chronic hypertension, 2 had human immunodeficiency virus/acquired immunodeficiency syndrome, 2 had known ethanol abuse, 2 had epilepsy, and 1 patient each had malignancy and diabetes. In each case, the ultimate cause of death was a recognized complication of this condition. Eighteen patients (19%) including 1 woman with ectopic pregnancy were not delivered, either because of early gestational age (10 patients first trimester and 5 patients weeks 13-19) or fetal demise after viability (3 patients). Two women died following dilatation and curettage associated with spontaneous abortion.

Causes of death are as outlined in Table 1. Seventeen deaths (18%) were judged to have been preventable with more appropriate medical care. Categories of these deaths were as follows: postpartum hemorrhage (8), preeclampsia (5), medication error (3), and infection (1). The ethnic distribution of preventable deaths was as follows: white, 9 (53%); African American, 5 (29%); Hispanic, 3 (18%). This is not significantly different from the general population of

TABLE 1
Causes of maternal death

Cause of death	Number	%
Complications of preeclampsia	15	16
Amniotic fluid embolism	13	14
Obstetric hemorrhage	11	12
Cardiac disease	10	11
Pulmonary thromboembolism	9	9
Nonobstetric infection	7	7
Obstetric infection	7	7
Accident/suicide	6	6
Medication error or reaction	5	5
Ectopic pregnancy	1	1
Other	11	12
Total	95	100

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maternal deaths seen in this study. Ten deaths (11%) were judged to have been preventable but were due to actions or inactions of nonmedical persons. Categories of these deaths were as follows: motor vehicle accident (2), antepartum suicide (2), ethanol abuse (2), and lack of compliance or failure to access medical care (4).

Deaths in relation to mode of delivery are outlined in Table 2. Four deaths were felt to have been directly caused by cesarean delivery. In 3 cases (all primary cesareans), death was due to hemorrhage from bleeding vessels injured during surgery. In 1 case of repeat cesarean delivery, death was due to sepsis secondary to surgical injury to the bowel during the operation. Two deaths were felt to be causally related to vaginal delivery: 1 case of hemorrhagic death associated with uterine inversion and 1 case of rupture of an unrecognized berry aneurysm during labor. In contrast, in 12 cases of death related to preeclampsia, 3 because of hemorrhage and 1 due to sepsis (a total of 17% of deaths), death was felt to have been potentially preventable had a cesarean delivery or an earlier cesarean delivery been performed. In 20 of 58 deaths associated with cesarean delivery (35%), the operative procedure was a perimor-

tem procedure performed following maternal cardiac arrest. None of these deaths was attributable to the cesarean itself.

Nine patients died from pulmonary thromboembolism: 6 following primary cesarean delivery, 1 following repeat cesarean delivery, and 2 following vaginal birth. None of these women had received peripartum thromboembolism prophylaxis in the form of either fractionated or unfractionated heparin or pneumatic compression devices. In Table 3, excess maternal deaths because of pulmonary embolism in patients undergoing cesarean delivery were causally attributed to the cesarean delivery.

COMMENT

The maternal mortality rate observed in approximately 1.5 million pregnancies over the past 6 years within our health care system was 6.3 per 100,000, about 30% lower than that reported nationally in the United States over the past several decades.¹ Whether this represents a difference in the health care rendered in the Hospital Corporation of America system, differences in data collection methodology or reflects a very recent national trend cannot be ascertained, pending future publication of complete national data since 2000. However, frequencies of various causes of death are fairly consistent with older death- and birth certificate-derived data reported from the United States as a whole.¹

Because our series of more than a million pregnancies involved both subspecialist review of pertinent medical records and, when necessary, interviews with health care providers, we believe this consistency validates the functional accuracy of cruder but more efficient techniques of determining cause of maternal death utilizing matching death and birth certificate data. Our series is also unique in that we were able to distinguish between pulmonary thromboembolism and amniotic fluid embolism (either on the basis of autopsy or clinical presentation), conditions generally grouped together in other series despite the fact that their only similarity is semantic, rather than pathophysiologic.⁷

TABLE 2

Association of route of delivery with maternal death

Delivery type	Number of procedures	Number of deaths	Frequency of death (per 100,000 procedures)
Vaginal	1,003,173	17	1.7
Primary cesarean	282,632	46	16.3
Repeat cesarean	175,465	12	7.4
Total cesarean	458,097	58	12.7
Not delivered/dilatation and curettage	na	20	na
Total	1,461,270	95	6.5 ^a

For vaginal birth vs total cesarean, vaginal birth vs primary cesarean, and vaginal birth vs repeat cesarean, $P < .001$. For primary cesarean vs repeat cesarean, $P = .01$.

^a Deaths per 100,000 pregnancies.

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Only 15% of maternal deaths were related to preexisting medical conditions. Thus, most deaths will occur in women who are classified as being at low risk for death at the beginning of pregnancy. As demonstrated in the Figure, few maternal deaths occurred in the second trimester relative to either the first or third trimester. In the third trimester, we saw a progressive increase in the number of deaths as the pregnancy progressed. Because relatively few deaths were causally attributed to delivery, this pattern suggests that advancing pregnancy beyond the second trimester progressively increases the chance of maternal death. This finding emphasizes the importance of clinical vigilance, even in apparently normal pregnancies, and supports the current practice of increased frequency

of prenatal visits in late pregnancy from the standpoint of maternal health, irrespective of fetal considerations.

In a review in North Carolina, Berg et al⁸ determined 40% of maternal deaths to be preventable, compared with 28% in our population. The difference appears to be related to the criteria used to judge preventability; whereas these authors considered deaths potentially prevented by broad changes in the health care system and public health infrastructure, we considered as preventable only those deaths that could have been avoided, by either different individual actions or system changes within specific facilities, given the health care system as it actually exists today.

Judgments regarding preventability of maternal death will, by their very nature

TABLE 3

Causal relationship between route of delivery and maternal death

Delivery type	Number of procedures	Number of deaths causally related to route of delivery	Frequency of deaths causally related to route of delivery (per 100,000 procedures)
Vaginal	1,003,173	2	0.20
Primary cesarean	282,632	7	2.5
Repeat cesarean	175,465	2	1.1
Total cesarean	458,097	9	2.0
Total	1,461,270	20	1.4

For vaginal birth vs total cesarean and vaginal birth vs primary cesarean, $P < .001$. For vaginal birth vs repeat cesarean, $P = 0.12$. For primary cesarean vs repeat cesarean, $P = .50$. For vaginal delivery vs primary, repeat, and total cesarean delivery, excluding pulmonary embolism deaths preventable with universal prophylaxis, $P = .07$, $P = .38$, $P = .08$.

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be subjective; it is possible that some of those deaths deemed preventable would have occurred, even with the most expert care, and some deemed nonpreventable might have been avoided, given more expert analysis of clinical presentation using observations or clinical nuances not apparent in the medical record. Nevertheless, we feel the unique experience of the authors of this study in dealing with critically ill pregnant women would allow meaningful observations in this regard, within the limitations mentioned above.⁹ Whereas any precise figures regarding frequencies of preventable deaths must be viewed with caution, it is clear that the majority of maternal deaths in the United States are not preventable, given the present understanding of pathophysiology and current standards of clinical care.

The most common preventable errors in preeclampsia management leading to maternal death involved inattention to blood pressure control and signs or symptoms of pulmonary edema. The most common preventable errors involving postpartum hemorrhage deaths involved inadequate surgical hemostasis; in all of these cases, however, more prompt attention to clinical signs of hemorrhage and associated hypovolemia would also have avoided death.

Despite expressed concern for a rising rate of placenta accreta associated with the increasing cesarean delivery rate, we saw only 1 death from placenta accreta in almost 1.5 million deliveries, even with a cesarean rate in our facilities at or above the national average during this period of time.⁴ Thus, the feared increase in maternal deaths because of placenta accreta does not appear to have materialized. This may be due to increased prenatal recognition of placenta accreta from ultrasound imaging and heightened awareness, which has resulted in appropriate prenatal, intraoperative, and postoperative measures being taken.^{10,11}

Given the relative frequencies of cesarean and vaginal deliveries, we would have expected at most 1 death from pulmonary embolism in both the primary and repeat cesarean delivery groups if the risk of such embolism were unrelated to mode of delivery. Because of the known

general causative relationship between major surgical procedures and venous thrombotic disease and the well-documented specific increase in venous thrombotic disease among women undergoing cesarean delivery, we believe it reasonable to causally attribute the 5 additional deaths from pulmonary embolism (4 in the primary cesarean delivery and 1 in the repeat cesarean delivery groups) to the cesarean itself¹²⁻¹⁴ (Table 3).

Our data demonstrated a significant positive association between cesarean delivery and maternal death (Table 2), confirming previous observations.^{2,3} In examining such an association, however, it is critical to avoid confounding by indication. Importantly, we found that cesarean delivery is only rarely causative (as defined in *Materials and Methods*): in most cases, death was related to the indication for cesarean delivery rather than to the operation itself. The risk of death caused by the operation of cesarean delivery is approximately 2 per 100,000 cesareans, compared with 0.2 per 100,000 deaths caused by vaginal birth. This difference is statistically significant ($P < .001$.) and translates into approximately 20 deaths caused by cesarean delivery annually in the United States.

In virtually every population of adult surgical patients, venous thromboembolism is reduced by a factor of approximately 70% with either medical or mechanical thromboprophylaxis.^{12,15-19} Although specific data in this regard are not available for pregnant women, there is no evidence to suggest that such measures would be less efficacious in this population. If one assumes similar efficacy in pregnant women, 5 of the 7 deaths because of pulmonary embolism in women undergoing cesarean delivery would have been prevented had a policy of universal use of medical or mechanical thromboprophylaxis for patients undergoing cesarean been in place during these years. This would reduce the mortality rate attributed causally to cesarean delivery to 0.9 per 100,000, or approximately 9 deaths annually in the United States and would eliminate the statistical difference in deaths causally attributed

to cesarean, compared with vaginal birth (Table 3).

Similar findings were reported in a smaller comparison of planned cesarean and planned vaginal delivery and were postulated in a review of the subject from the years 1975-2001.^{20,21} These studies contrast with a report from The Netherlands of deaths from 1983 to 1992 using different criteria for assessing causation, in which the risk of death attributed to cesarean delivery was higher.²²

Some maternal deaths can clearly be prevented by better individual care. However, given the categories of death observed and the diversity of conditions within broad categories such as cardiac death or infection, it would appear that a systematic reduction in maternal mortality rate in the United States can be achieved only through the prevention of preeclampsia or amniotic fluid embolism or a reduction in pulmonary embolism deaths. Because no form of management is currently believed to reduce the risk of either of the first 2 conditions, our data would suggest the latter as the only reasonable target for large scale intervention. Following recognition of increased maternal deaths because of thromboembolism in the United Kingdom and a widespread failure of clinicians to follow existing prophylaxis guidelines based on identified risk factors, an expert panel in that country advocated universal prophylaxis for all women undergoing cesarean delivery.²³

Given recent documentation of extremely poor compliance of obstetricians in the United States with a broad array of practice guidelines, there is little reason to believe that development of such risk-based guidelines for thromboprophylaxis would be efficacious in a country with a less tightly managed health care system.²⁴ In addition, a strategy of universal thromboprophylaxis has been shown to be cost effective under a wide range of circumstances in the United States.¹² Mechanical sequential compression devices and both fractionated and unfractionated heparin have been shown to be effective in this regard.¹⁸⁻²⁰

In obstetrics, the common use of conduction anesthesia and the potential for

catastrophic epidural hematomas would suggest that mechanical sequential compression devices may be a better option for most women undergoing cesarean delivery.²¹ These should be instituted prior to surgery and continued until the patient is ambulatory. It is unclear whether simple graduated compression stockings provide sufficient protection against thromboembolism in patients with no other risk factors undergoing cesarean delivery.

Women with any 1 of many additional risk factors beyond pregnancy and cesarean delivery would clearly fall into a category in which simple graduated compression stockings would be insufficient for optimal thromboembolism prophylaxis.¹⁸⁻²⁰ This includes operative time greater than 30-45 minutes, something that cannot be determined preoperatively, when prophylaxis must be instituted to be effective.

We conclude that most maternal deaths in the United States are not preventable and occur in women who begin pregnancy without significant risk factors for death. We confirm previous observations regarding the association of cesarean delivery with maternal death but found a much smaller causative relationship between the 2. With appropriate universal thromboembolism prophylaxis, our data suggest the excess risk of death because of cesarean delivery may be virtually eliminated, and the overall risk of death attributable to this operation would be less than 1 per 100,000. Given the potential for bleeding complications with methods of neuraxial anesthesia commonly used for cesarean delivery, we are in the process of

implementing a policy of universal pneumatic compression device use for all women undergoing cesarean delivery in our system. ■

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