

Pregnancy-Related Mortality in California

Causes, Characteristics, and Improvement Opportunities

Elliott K. Main, MD, Christy L. McCain, MPH, Christine H. Morton, PhD, Susan Holtby, MPH, and Elizabeth S. Lawton, MHS

OBJECTIVE: To compare specific maternal and clinical characteristics and contributing factors among the five leading causes of pregnancy-related mortality to develop focused clinical and public health prevention programs.

METHODS: California pregnancy-related deaths from 2002–2005 were identified with enhanced surveillance using linked birth and death certificates. A multidisciplinary committee reviewed medical records, autopsy reports, and coroner reports to determine cause of death, clinical and demographic characteristics, chance to alter outcome, contributing factors (at health care provider, facility, and patient levels), and quality improvement opportunities. The five leading causes of death were compared with each other and with the overall California birth population.

RESULTS: Among the 207 pregnancy-related deaths, the five leading causes were cardiovascular disease, preeclampsia or eclampsia, hemorrhage, venous thromboembolism, and amniotic fluid embolism. Among the leading causes of death, we identified differing patterns for race, maternal age, body mass index, timing of death, and method of delivery. Overall, there was a good-to-strong chance to

alter the outcome in 41% of deaths, with the highest rates of preventability among hemorrhage (70%) and preeclampsia (60%) deaths. Health care provider, facility, and patient contributing factors also varied by cause of death.

CONCLUSION: Pregnancy-related mortality should not be considered a single clinical entity. Reducing mortality requires in-depth examination of individual causes of death. The five leading causes exhibit different characteristics, degrees of preventability, and contributing factors, with the greatest improvement opportunities identified for hemorrhage and preeclampsia. These findings provide additional support for hospital, state, and national maternal safety programs.

(*Obstet Gynecol* 2015;125:938–47)

DOI: 10.1097/AOG.0000000000000746

LEVEL OF EVIDENCE: II

The past century has seen remarkable progress in improving the safety of childbirth in the United States. Maternal mortality fell from 850 per 100,000 live births in 1900 to 7.7 per 100,000 in 1997.¹ Over the past 20 years, however, this decline has reversed.² The 2009 U.S. pregnancy-related mortality rate was 17.8 deaths per 100,000 live births, above that of other high-resource countries.^{2,3} This rise has prompted a renewed focus at national and state levels to examine the causes and contributing factors of maternal death and improve public health and clinical practice.^{4,5}

Most previous studies of pregnancy-related deaths have included demographic and limited clinical information but did not compare specific causes of death for factors other than preventability.^{3,6–8} Studies focused on a single cause of pregnancy-related mortality often were based on administrative data sets with limited access to clinical records and unable to identify improvement opportunities.^{9–11} One of every eight U.S. births occurs in California, resulting in more than 500,000 annual deliveries with extensive racial and ethnic diversity. The California

From the California Maternal Quality Care Collaborative, Stanford University, Palo Alto, California Pacific Medical Center, San Francisco, the Public Health Institute, Santa Cruz, the Department of Family and Community Medicine, University of California, San Francisco, School of Medicine, San Francisco, and the Maternal, Child and Adolescent Health Division, Center for Family Health, California Department of Public Health, Sacramento, California.

This project was made possible by Federal Title VMCH block grant funding from the California, Department of Public Health (CDPH), Maternal Child and Adolescent Health (MCAH) Division.

The authors thank the California Pregnancy-Associated Mortality Review Committee for their careful case reviews and Dr. Connie Mitchell, Deputy Director, CDPH Center for Family Health, and Dr. Shabbir Ahmad, Chief, MCAH Epidemiology, Assessment, and Program Development, for their ongoing support of the California Pregnancy-Associated Mortality Review project.

Corresponding author: Elliott K. Main, MD, CMQCC, Stanford University, 1265 Welch Road, MS 5415, Palo Alto, CA 94305; e-mail: main@cmqcc.org.

Financial Disclosure

The authors did not report any potential conflicts of interest.

© 2015 by The American College of Obstetricians and Gynecologists. Published by Wolters Kluwer Health, Inc. All rights reserved.

ISSN: 0029-7844/15



Department of Public Health sponsored the California Pregnancy-Associated Mortality Review in 2006 using its public health authority to collect all relevant medical records and administrative reports for each maternal death. California's large population-based sample, together with enhanced case ascertainment and detailed medical record review, provides a unique opportunity to compare major causes of pregnancy-related mortality and identify improvement opportunities.

MATERIALS AND METHODS

The California Pregnancy-Associated Mortality Review used a previously described enhanced surveillance methodology that links maternal death certificates to neonatal birth and fetal death certificates and screens autopsy and coroner reports to identify all deaths occurring during, or within a year of, pregnancy, defined as pregnancy-associated deaths.¹² Using a case series design, we examined California pregnancy-related deaths, a subset of pregnancy-associated deaths, for the years 2002–2005. Pregnancy-related deaths are defined as the “death of a woman while pregnant or within one year of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by her pregnancy or its management, but not from accidental or incidental causes.”¹³ The World Health Organization now considers all deaths from suicide during pregnancy or within 42 days postpartum as pregnancy-related.¹⁴ During the California Pregnancy-Associated Mortality Review pilot period, we determined that it was not possible to assess preventability and contributing factors of suicide cases without access to mental health records and have excluded them from this analysis.

Prepregnancy weight, height, parity, delivery type, and gestational age at delivery were collected from the medical record. Maternal race and country of birth were identified from the birth certificate. A woman's body mass index (BMI, calculated as weight (kg)/[height (m)]²) was considered “prepregnancy” if recorded before 10 weeks of gestation. Population-based comparisons were made using the California Birth and Death Statistical Master Files (California Birth Cohort) for demographic data and the Maternal Infant Health Assessment, an annual representative statewide survey of more than 13,000 women, for prepregnancy obesity.

The California Pregnancy-Associated Mortality Review Committee included nearly two dozen experts from nursing, obstetrics, maternal-fetal medicine, midwifery, cardiology, anesthesiology, emergency medicine, public health, and sociology. Committee

members reviewed deidentified case summaries with detailed synopses of hospital and outpatient medical records from the prenatal period up to the death as well as autopsy and coroner reports. The California Pregnancy-Associated Mortality Review Committee determined the causes of death, contributing factors, chance to alter the outcome, and opportunities for quality improvement for each case.¹²

Causes of death were categorized into 12 diagnosis groups, one of which was “other.”¹² These categories mirrored those used by the Centers for Disease Control and Prevention and the U.K. Confidential Enquiry to allow for external comparisons.^{3,15} In participants with two or more major diagnoses, we chose the underlying disease process that initiated the cascade toward death. Through consensus, the California Pregnancy-Associated Mortality Review Committee assessed the chance to alter the fatal outcome as 1) strong, 2) good, 3) some, or 4) none. The case was considered to have a strong or good chance to have had an altered outcome (preventable) if specific and feasible actions had been implemented that might have changed the course of the woman's disease trajectory and potentially prevented the death. Examples of specific and feasible actions included: treatment of severe hypertension among women who died from intracranial hemorrhage; timely recognition and treatment of postpartum hemorrhage among women with massive blood loss and coagulopathy; or provision of perioperative venous thromboembolism prophylaxis when major risk factors were apparent among women who developed fatal pulmonary emboli. The California Pregnancy-Associated Mortality Review Committee also identified health care provider, facility, and patient factors contributing to the death. Health care provider factors include actions involving diagnosis, treatment, and communication processes. Facility factors include systems-level processes involving policies, nursing knowledge, or infrastructure. Patient factors include circumstances, risk factors, or health behaviors contributing to the cause of death. Also identified were quality improvement opportunities, defined as alternative approaches to recognition, diagnosis, treatment, or follow-up, that, if implemented, may have led to better patient care or a better outcome.

Data analyses were conducted using IBM SPSS Statistics 20.0. Unadjusted statistical differences ($P < .05$) among the five leading causes of death were compared by the Pearson χ^2 and Fisher's exact test for categorical variables and the univariate analysis of variance based on estimated marginal means with Bonferroni's post hoc statistics or the Mann-Whitney



Table 1. Pregnancy-Related Mortality Rates per 100,000 Live Births* Among All Causes of Death by Race–Ethnicity, California, 2002–2005

Race–Ethnicity	Cause of Death					
	Cardiovascular Disease		Preeclampsia or Eclampsia		Obstetric Hemorrhage	
	n	Rate (95% CI)	n	Rate (95% CI)	n	Rate (95% CI)
Hispanic	17	1.6 (0.8–2.3)	24	2.2 (1.3–3.1)	9	0.8 (0.3–1.4)
Foreign-born	8	1.2 (0.4–2.0)	18	2.6 (1.4–3.8)	5	1.0 (0–2.0)
U.S.-born	9	2.3 (0.8–3.7)	6	1.5 (0.3–2.7)	4	—
White	11	1.7 (0.7–2.7)	6	0.9 (0.2–1.7)	7	1.1 (0.3–1.9)
African American	19	16.3 [†] (9.0–23.7)	5	4.3 (0.5–8.1)	2	—
Other	2	—	1	—	2	—
All races	49	2.3 (1.6–2.9)	36	1.7 (1.1–2.2)	20	0.9 (0.5–1.3)
% of all pregnancy-related deaths	23.7		17.4		9.7	

CI, confidence interval.

Rates for fewer than five deaths not calculated as a result of instability.

* Number of pregnancy-related deaths divided by total number of live births with known race–ethnicity (N=2,138,551) per California Birth Statistical Master File (2002–2005) multiplied by 100,000.

[†] Pregnancy-related mortality rate differs significantly from all other racial and ethnic groups ($P<.001$).

U test for continuous variables, depending on data distributions. The California Department of Public Health Committee for the Protection of Human Subjects approved all project protocols and materials. The Stanford University and Public Health Institute institutional review boards exempted analysis of deidentified data on deceased persons.

RESULTS

From 2002–2005, there were 2,163,457 live births and 732 pregnancy-associated deaths in California; 207 of these deaths were determined to be pregnancy-related. We analyzed the five leading causes—cardiovascular disease, preeclampsia or eclampsia (referred hereafter as simply preeclampsia), hemorrhage, venous thromboembolism, and amniotic fluid embolism, which represented nearly 70% of the pregnancy-related deaths ($n=143$) in the study period. Other causes of pregnancy-related death included cerebrovascular accidents, sepsis from multiple nonobstetric sources, anesthesia complications, and various other medical diagnoses, each affecting one to three women.

Table 1 shows cause-specific pregnancy-related mortality rates among the 2002–2005 deaths by race–ethnicity. Cardiovascular disease was the leading cause, with a pregnancy-related mortality rate of 2.3 deaths per 100,000 live births. Cardiovascular disease deaths included those attributed to cardiomyopathies ($n=33$) and other cardiovascular causes ($n=16$). Overall, African American women comprised 6% of the births yet 39% of cardiovascular disease deaths and 22% of all pregnancy-related deaths. This translates

into an almost 10-fold higher risk of cardiovascular disease death (pregnancy-related mortality rate of 16.3 deaths per 100,000 live births) and more than a fourfold risk overall compared with other racial and ethnic groups (relative risk 4.2, confidence interval 3.0–5.8).

The leading causes of pregnancy-related mortality had differing distributions of maternal age, parity, and gestational age at delivery (Table 2). Of the California birth cohort, 41% were 30 years or older compared with 67% of preeclampsia deaths, 75% of hemorrhage deaths, and 78% of amniotic fluid embolism deaths ($P<.001$), whereas the age distribution of women who died of cardiovascular disease and venous thromboembolism mirrored that of the California birth cohort.

Women who died of preeclampsia were more likely than women who died of the other four causes to be primiparous (44% compared with 21%, $P<.01$) but their rate of primiparity was similar to the California birth cohort. Women who died from hemorrhage, venous thromboembolism, and amniotic fluid embolism were more likely to be grand multiparous than the California birth cohort ($P<.01$). Women who died of preeclampsia (61%), hemorrhage (50%), venous thromboembolism (40%), and cardiovascular disease (32.6%) were more likely to have delivered preterm (less than 37 weeks of gestation) than the California birth cohort (11%) ($P<.001$). Almost all (94%) who died from amniotic fluid embolism delivered at term, differing from the other four causes ($P<.05$).



Cause of Death							
Venous Thromboembolism		Amniotic Fluid Embolism		All Other Causes		All Causes of Death	
n	Rate (95% CI)	n	Rate (95% CI)	n	Rate (95% CI)	n	Rate (95% CI)
9	0.8 (0.3–1.4)	6	0.6 (0.1–1.0)	28	2.6 (1.6–3.5)	93	8.5 (6.8–10.3)
4	—	5	1.0 (0–2.0)	13	1.9 (0.9–2.9)	53	7.7 (5.6–9.7)
5	1.3 (0.2–2.3)	1	—	15	3.7 (1.8–5.6)	40	10.0 (6.9–13.1)
6	0.9 (0.2–1.7)	4	—	16	2.5 (1.3–3.7)	50	7.8 (5.6–10.0)
5	4.3 (0.5–8.1)	5	4.3 (0.5–8.1)	10	8.6 (3.3–13.9)	46	39.5 [†] (28.1–50.9)
0	—	3	—	10	3.4 (1.3–5.6)	18	6.2 (3.3–9.0)
20	0.9 (0.5–1.3)	18	0.8 (0.5–1.2)	64	3.0 (2.3–3.7)	207	9.7 (8.4–11.0)
9.7		8.7		30.9		100	

Women who died were significantly more likely to be obese (BMI 30 or higher) before pregnancy than the Maternal Infant Health Assessment population (30% compared with 16%, respectively, $P < .05$) (Fig. 1). An even greater difference was found in the percent of extremely obese (BMI 40 or higher) women (10% compared with 2%, $P < .05$). Women who died of cardiovascular disease were more likely to be obese than those who died of preeclampsia or amniotic fluid embolism ($P < .05$). Women who died of venous thromboembolism were more likely to be obese than those who died of preeclampsia, hemorrhage, and amniotic fluid embolism ($P < .01$). At the time of delivery, of the 58% obese women who died from venous thromboembolism, half were extremely obese.

The median time interval between delivery and death varied by cause (Fig. 2). Amniotic fluid embolism and hemorrhage deaths were more likely than venous thromboembolism and cardiovascular disease deaths to occur during labor or within 1 day of delivery ($P < .05$). Cardiovascular disease deaths occurred significantly later (median 9 days) than amniotic fluid embolism, hemorrhage, and preeclampsia deaths ($P < .001$) largely as a result of cardiomyopathy deaths, which occurred up to 5 months postpartum. The short time interval from delivery to death for women with preeclampsia reflected the high percentage of these deaths with hypertension-related hemorrhagic stroke (58%). The extreme outliers represented women with multiorgan failure or brain injury, which resulted in prolonged hospitalization before death.

Cesarean delivery was the most frequent mode of delivery among the five leading causes of pregnancy-related death (67%) (Table 2), as would be expected because more than half of the cesarean deliveries were emergent or perimortem. The exception was among

patients with venous thromboembolism, in whom 64% were repeat cesarean deliveries, only two were emergent, and none were perimortem. Of the women with BMIs 40 or higher who died of venous thromboembolism, 89% delivered by cesarean ($n = 14$).

With the exception of amniotic fluid embolism, the frequency of labor induction was similar among the major causes of pregnancy-related mortality. Of the women who died of amniotic fluid embolism, 53% were induced compared with 21% of women who died from the other major causes ($P < .01$).

For hemorrhage deaths, the underlying processes were evenly attributed to placental issues (previa, accreta, and retained placenta) (35%), uterine lacerations or rupture (35%), and atony, with or without coagulopathy (30%).

Overall, 41% of pregnancy-related deaths had a good-to-strong chance of preventability, and nearly 90% had at least “some” chance; however, the leading causes showed considerable variation (Fig. 3). Hemorrhage and preeclampsia were significantly more likely than cardiovascular disease and amniotic fluid embolism deaths to have had a good-to-strong chance of preventability, estimated at 70% and 60%, respectively. No amniotic fluid embolism deaths had a good-to-strong chance, differing from all other causes of death ($P < .001$), but 83% of amniotic fluid embolism deaths had at least some chance of preventability.

The California Pregnancy-Associated Mortality Review Committee identified specific contributing factors to guide quality improvement opportunities. Each patient may have had multiple contributing factors. Health care provider factors were the most common type of contributor identified for all five leading causes of death (Fig. 4A) and were particularly



Table 2. Maternal Age, Parity, Gestational Age, and Mode of Delivery Among Major Causes of Pregnancy-Related Death, California, 2002–2005

Maternal Characteristics	Major Causes of Pregnancy-Related Death					California Birth Cohort*
	Cardiovascular Disease	Preeclampsia or Eclampsia	Obstetric Hemorrhage	Venous Thromboembolism	Amniotic Fluid Embolism	
Maternal age (y)						
Younger than 30	25 (51)	12 (33) [†]	5 (25) [†]	11 (55)	4 (22) [†]	1,254,394 (59)
30–40	22 (45)	18 (50)	13 (65)	8 (40)	13 (72) [†]	840,868 (39)
Older than 40	2 (4)	6 (17) [†]	2 (10) [†]	1 (5)	1 (6)	46,005 (2)
Parity [‡]						
1	13 (27)	16 (44)	3 (15) [†]	3 (15) [†]	3 (17)	838,417 (39)
2–4	31 (63)	16 (44)	13 (65)	14 (70)	10 (56)	1,197,427 (56)
5 or more	5 (10)	4 (11)	4 (20) [†]	3 (15) [†]	5 (28) [†]	103,498 (5)
Gestational age (wk) at delivery or demise						
Less than 32	8 (16) [†]	6 (17) [†]	5 (25) [†]	—	—	35,901 (2)
32–36	8 (16)	16 (44) [†]	5 (25) [†]	8 (40) [†]	1 (6)	175,788 (9)
37 or greater	33 (67) [†]	14 (39) [†]	10 (50) [†]	12 (60) [†]	17 (94)	1,797,342 (90)
Mode of delivery [§]						
Vaginal	22 (46)	6 (17)	9 (45)	4 (22)	5 (29)	NA
Cesarean (total)	26 (54)	29 (83)	11 (55)	14 (78)	12 (71)	NA
Circumstances of cesarean delivery (% of all deliveries)						
Planned or scheduled	3 (6)	1 (3)	2 (10)	4 (22)	—	NA
Unplanned or labor	13 (27)	7 (20)	1 (5)	8 (44)	4 (24)	NA
Crash or emergent [¶]	4 (8)	19 (54)	6 (30)	2 (11)	5 (29)	NA
Perimortem or undergoing cardiopulmonary resuscitation	6 (13)	2 (6)	2 (10)	—	3 (18)	NA
Total	49	36	20	20	18	2,141,619

NA, not applicable.

Data are n (%) or n.

Some percentages do not equal 100 as a result of rounding.

* Limited to women with known age, parity, and gestational age within the California Birth Cohort.

[†] Proportion of deaths differs significantly from the California Birth Cohort, $P < .01$.

[‡] Parity=number of pregnancies 20 weeks of gestation or greater regardless of outcome; most recent pregnancy at time of death included.

[§] Five women died before delivery and were excluded from mode of delivery analysis.

^{||} Women who died of preeclampsia or eclampsia were more likely than those who died of cardiovascular disease or hemorrhage to have had a cesarean delivery.

[¶] Women who died of preeclampsia or eclampsia, amniotic fluid embolism, or hemorrhage were more likely than those who died of cardiovascular disease or venous thromboembolism to have had a crash or emergent cesarean delivery ($P < .05$).

common for preeclampsia and hemorrhage, consistent with their higher degree of preventability. The most common health care provider factor was delayed response to clinical warning signs followed by ineffective care. Of note, among women who died from venous thromboembolism after cesarean delivery, only one received any form of mechanical or medical prophylaxis.

Hemorrhage was associated with the most facility factors identified (Fig. 4B), with inadequate staff knowledge (42%), systems issues (ie, lack of massive transfusion protocols) (30%), and coordination of care (ie, delays in blood product administration) (30%) the most common specific factors.

Patient-related factors, particularly underlying medical conditions and obesity, were most



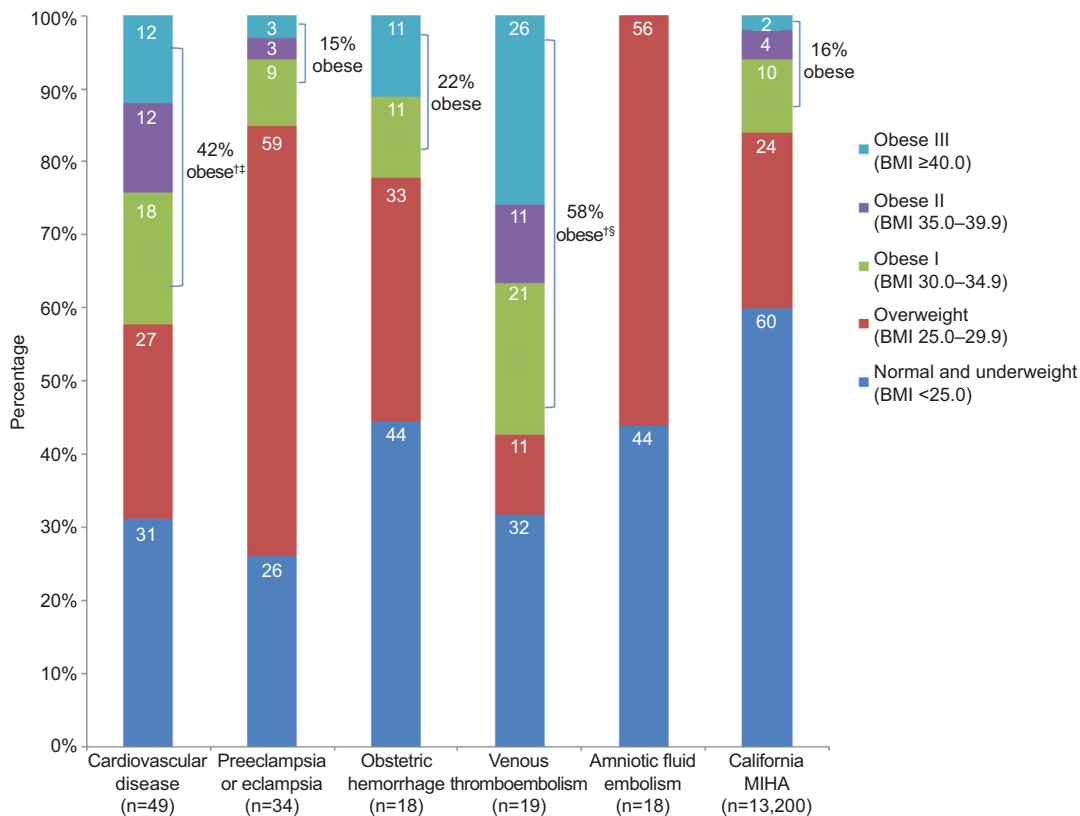


Fig. 1. Prepregnancy body mass index (BMI) among major causes of pregnancy-related death (n=138*), California, 2002–2005. *BMI data were missing for five women. [†]Significantly differs from Maternal Infant Health Assessment (MIHA) ($P<.05$). [‡]Significantly differs from preeclampsia and amniotic fluid embolism deaths ($P<.05$). [§]Significantly differs from preeclampsia or eclampsia, hemorrhage, and amniotic fluid embolism deaths ($P<.01$).

Main. *Pregnancy-Related Mortality in California. Obstet Gynecol* 2015.

commonly identified among cardiovascular disease and venous thromboembolism cases (Fig. 4C). The leading patient factors among preeclampsia deaths were delays in seeking care (42%), underlying medical conditions (39%), and presumed lack of knowledge regarding the severity of a symptom or condition (39%). Frequent patient factors among hemorrhage deaths were delays in seeking care (40%) and refusal of blood products among Jehovah's Witness adherents (20%).

DISCUSSION

This report demonstrates the clinical heterogeneity among pregnancy-related deaths in California and has important implications for medical and public health efforts. This is a large study examining U.S. pregnancy-related mortality analysis with both enhanced ascertainment and full medical record reviews. We identified significant differences among the five leading causes of pregnancy-related death when compared with each other or with the California birth

population for race, age, parity, gestational age, BMI, timing of death, induction, and delivery method. Our findings point to specific actions to improve clinical recognition and response for each cause of death described subsequently.

Cardiovascular disease was the most common cause of pregnancy-related death in California. This is consistent with recent U.S. and U.K. analyses but differs from France, where obstetric hemorrhage is most prevalent.^{3,15,16} Race and obesity were strong risk factors for cardiovascular disease deaths, whereas advanced maternal age was not. The cardiovascular disease pregnancy-related mortality rate for African American women was nearly 10 times higher than any other racial or ethnic group, and women who died of cardiovascular disease were more than three times as likely to be obese than the California population. African American and obese women seeking preconception care should be counseled on how to moderate their cardiovascular disease risk, including attaining a healthy weight before pregnancy.



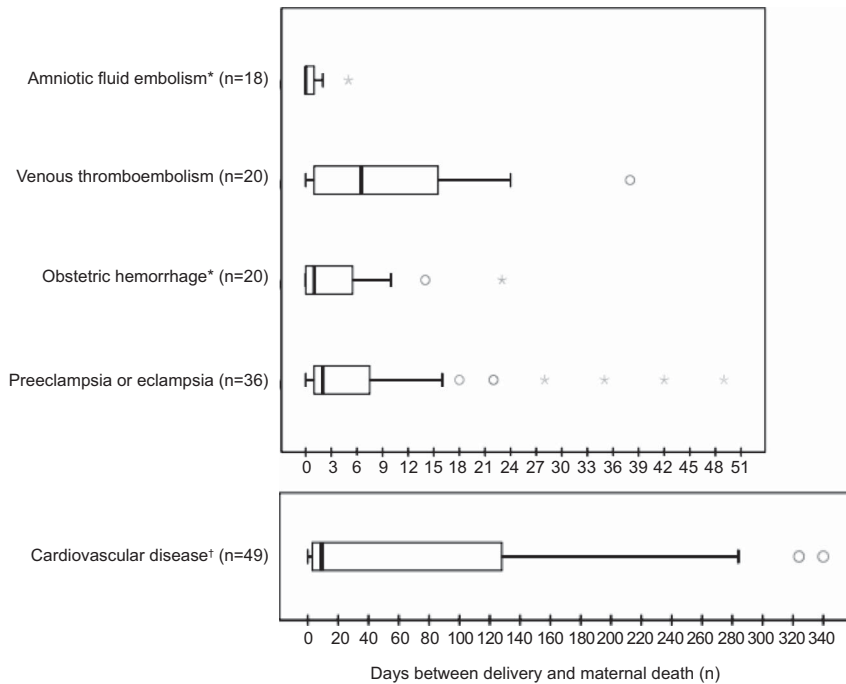


Fig. 2. Timing of death among major causes of pregnancy-related death (n=143), California, 2002–2005. Boxes represent the 25th to 75th centile ranges. Vertical lines indicate the median. Whiskers represent the 10th and 90th centile limits, with outliers shown beyond (circles and stars). *Significantly closer to delivery than venous thromboembolism and cardiovascular disease deaths ($P < .05$). †Significantly further from delivery than amniotic fluid embolism, hemorrhage, and preeclampsia or eclampsia ($P < .001$).

Main. *Pregnancy-Related Mortality in California. Obstet Gynecol 2015.*

Preeclampsia deaths were most common among foreign-born Hispanic and African American women and were associated with early gestational age, consistent with studies demonstrating the increased severity of early-onset preeclampsia.¹⁷ This cause of death was deemed one of the most preventable, with high rates of delayed response to symptoms and vital signs, ineffective control of hypertension, inadequate staff knowledge around blood pressure management, misdiagnosis, and lack of continuity of care. Patient factors included lack of understanding of warning signs and delays in seeking care. These findings reinforce the ongoing work to promote better

clinical recognition and response to preeclampsia and eclampsia. Recently, the California Maternal Quality Care Collaborative, Hospital Corporation of America, and the American College of Obstetricians and Gynecologists released guidelines and quality improvement tool kits with standardized approaches to recognize and treat severe hypertension and to increase awareness of atypical clinical presentations and patient education.^{17–19}

Hemorrhage deaths occurred among women who were significantly older, multiparous, of normal weight, and who had premature births. In this study, 35% of hemorrhage deaths were related to placental

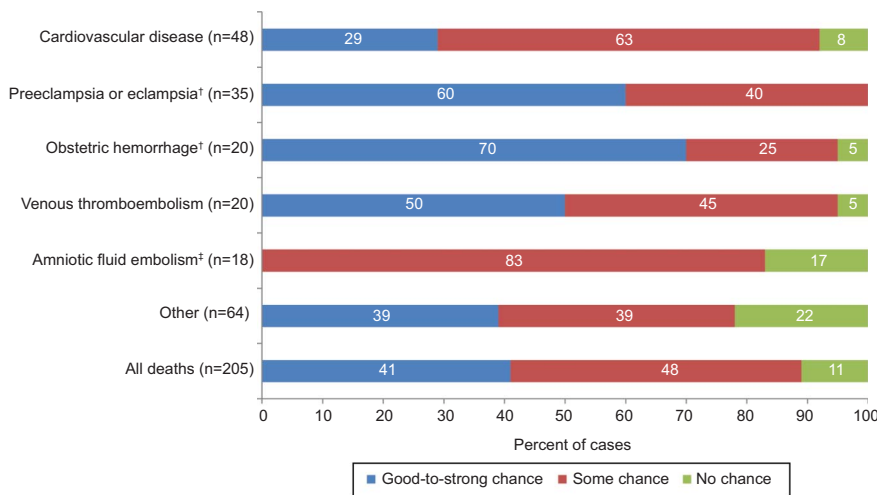
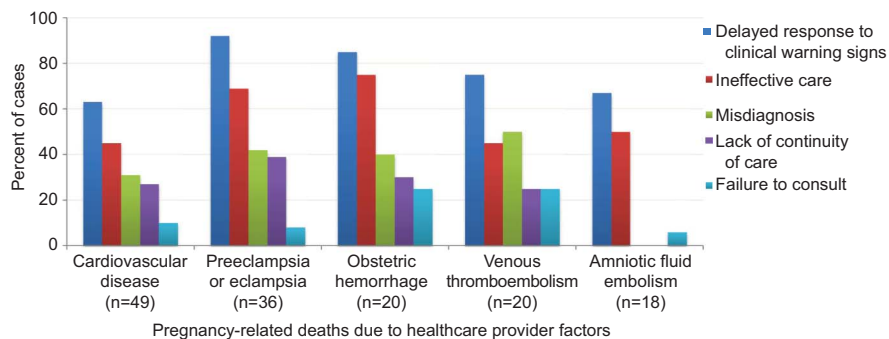


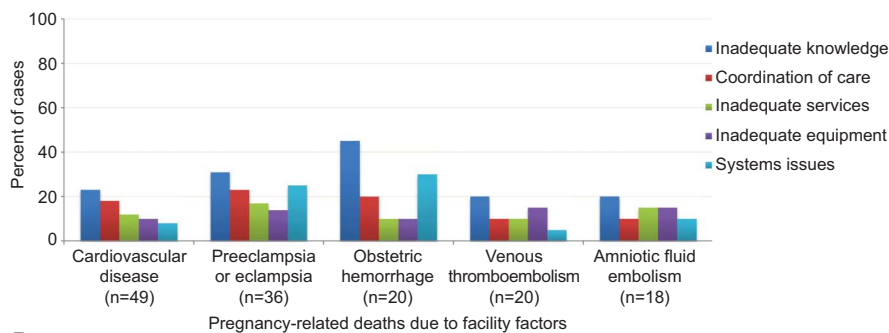
Fig. 3. Chance to alter outcome among major causes of pregnancy-related death (n=205*), California, 2002–2005. *The California Pregnancy-Associated Mortality Review Committee was unable to determine preventability in one cardiovascular disease death and one eclampsia death. †Significantly more likely to have good-to-strong chance than cardiovascular disease deaths and amniotic fluid embolism deaths. *Significantly less likely to have good-to-strong chance than all causes.

Main. *Pregnancy-Related Mortality in California. Obstet Gynecol 2015.*

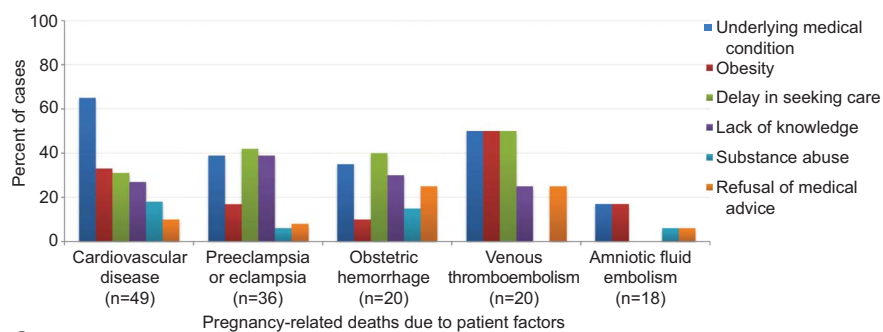




A



B



C

Fig. 4. Contributing factors among major causes of pregnancy-related death, California, 2002–2005. Health care provider factors (A), facility factors (B), and patient factors (C).

Main. *Pregnancy-Related Mortality in California. Obstet Gynecol* 2015.

complications compared with 16% found in an earlier national study.⁹ We found high rates of preventability among hemorrhage deaths, similar to other research.⁶ We identified very high rates of health care provider factors, including delayed response to clinical warning signs, ineffective medication, and inadequate blood product utilization. Hemorrhage deaths had the highest rates of facility contributing factors. U.K. and French reviews noted 66% of hemorrhage cases involved suboptimal care among health care providers and facilities.^{15,16} Recent studies indicate that standardized approaches to obstetric hemorrhage reduce serious morbidity.^{20,21}

Venous thromboembolism pregnancy-related mortality rates were highest in African American women, obese women, and among women who had repeat

cesarean deliveries. Half of the venous thromboembolism deaths were highly preventable, with strong improvement opportunities related to appropriate venous thromboembolism prophylaxis and improved responses to clinical warning signs. The United Kingdom noted a similar relationship with obesity and cesarean delivery, whereas France noted 61% had suboptimal care.^{15,16} Currently, the U.S. maternity care and safety community is discussing recommendations for additional approaches for prevention of venous thromboembolism based on risk factors beyond universal sequential compression devices at cesarean delivery.⁴

Women who died from amniotic fluid embolism presented largely in their 30s, were more likely to be multiparas, and to have term births. Other



population-based reviews also found amniotic fluid embolisms to be less common among first births.^{22,23} Our findings differ from earlier studies in that we found no association between amniotic fluid embolism deaths and obesity nor with risk factors such as forceps delivery, multiple gestation, or placenta previa.²⁴

Labor induction is a controversial risk factor for amniotic fluid embolism; several studies note a positive association,^{22,23} whereas others do not.^{24,25} With access to the full medical record, we found that 53% of women who died from amniotic fluid embolism were induced, twice that of any other cause and much higher than the population induction rate (21.5%).²⁶ These cases presented catastrophically, with the shortest time to death among all causes. However, recent studies of amniotic fluid embolism survivors suggest that massive transfusion protocols with copious coagulation factors and intensive cardiovascular support may improve survival rates.²⁵

Our study has limitations. Despite California having more than 500,000 annual births and subsequently a relatively large cohort of deaths over the 4-year study period, small numbers have limited statistical power when analyzing specific causes or performing multivariate analysis. Access to medical records was a major strength; however, judgments on preventability, contributing factors, and improvement opportunities were limited to information documented in the chart. Such data do not provide a full picture of patient and health care provider perspectives on decision-making, quality care, or the role of social determinants in health care utilization. We also had limited information on hospital-level data such as policies, procedures, or staffing, which may have contributed to some deaths.

State maternal mortality reviews identify public health and clinical efforts to reduce pregnancy-related mortality and morbidity. These reviews are valuable even in states with low numbers of maternal deaths to identify locally important improvement opportunities and develop ongoing surveillance.⁵ Our findings illustrate the need for public health interventions aimed at helping all women understand and recognize their risks and attain optimal prepregnancy health and weight. These findings also underscore the need for focused approaches to improve care such as hospital-based safety bundles for hemorrhage, preeclampsia, and venous thromboembolism prevention as well as comprehensive programs for patient education, communication, and teamwork development. Reversing increases in maternal mor-

ality and severe morbidity requires the combined efforts of public health, clinical and hospital leaders, and their institutions.

REFERENCES

1. Centers for Disease Control and Prevention. Achievements in public health, 1900–1999: healthier mothers and babies. *MMWR Morb Mortal Wkly Rep* 1999;48:849–58.
2. Kassebaum NJ, Bertozzi-Villa A, Coggeshall MS, Shackelford KA, Steiner C, Heuton KR, et al. Global, regional, and national levels and causes of maternal mortality during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2014;384:980–1004.
3. Creanga A, Berg C, Syverson C, Seed K, Bruce FC, Callaghan WM. Pregnancy-related mortality in the United States, 2006–2010. *Obstet Gynecol* 2015;125:5–12.
4. D’Alton ME, Main EK, Menard MK, Levy BS. The national partnership for maternal safety. *Obstet Gynecol* 2014;123:973–7.
5. Goodman D, Stampfel C, Creanga AA, Callaghan WM, Callahan T, Bonzon E, et al. Revival of a core public health function: state- and urban-based maternal death review processes. *J Womens Health (Larchmt)* 2013;22:395–8.
6. Berg CJ, Harper MA, Atkinson SM, Bell EA, Brown HL, Hage ML, et al. Preventability of pregnancy-related deaths—results of a state-wide review. *Obstet Gynecol* 2005;106:1228–34.
7. Schutte JM, Steegers EA, Schuitemaker NW, Santema JG, de Boer K, Pel M, et al. Rise in maternal mortality in the Netherlands. *BJOG* 2010;117:399–406.
8. Tucker ML, Berg CJ, Callaghan WM, Hsia J. The black-white disparity in pregnancy-related mortality from 5 conditions: differences in prevalence and case-fatality rates. *Am J Public Health* 2007;97:247–51.
9. Chichakli LO, Atrash HK, MacKay AP, Musani AS, Berg CJ. Pregnancy-related mortality in the United States due to hemorrhage: 1979–1992. *Obstet Gynecol* 1999;94:721–5.
10. MacKay AP, Berg CJ, Atrash HK. Pregnancy-related mortality from preeclampsia and eclampsia. *Obstet Gynecol* 2001;97:533–8.
11. Whitehead SJ, Berg CJ, Chang J. Pregnancy-related mortality due to cardiomyopathy: United States, 1991–1997. *Obstet Gynecol* 2003;102:1326–31.
12. Mitchell C, Lawton E, Morton C, McCain C, Holtby S, Main E. California Pregnancy-Associated Mortality Review: mixed methods approach for improved case identification, cause of death analyses and translation of findings. *Matern Child Health J* 2013;18:518–26.
13. Berg C, Daniel I, Atrash H, Zane S, Bartlett L. Strategies to reduce pregnancy-related deaths: from identification and review to action. Atlanta (GA): Centers for Disease Control and Prevention; 2001.
14. WHO Working Group on Maternal Mortality and Morbidity Classification. WHO application of ICD-10 to deaths during pregnancy, childbirth and the puerperium. Geneva (Switzerland): World Health Organization; 2012.
15. Cantwell R, Clutton-Brock T, Cooper G, Dawson A, Drife J, Garrod D, et al. Saving mothers’ lives: reviewing maternal deaths to make motherhood safer: 2006–08. The eighth report on confidential enquiries into maternal deaths in the United Kingdom. *BJOG* 2011;118(suppl 1):1–203.



16. Saucedo M, Deneux-Tharoux C, Bouvier-Colle MH; French National Experts Committee on Maternal Mortality. Ten years of confidential inquiries into maternal deaths in France, 1998–2007. *Obstet Gynecol* 2013;122:752–60.
17. ACOG Task Force on Hypertension in Pregnancy. Hypertension in pregnancy: report of the American College of Obstetricians and Gynecologists' Task Force on Hypertension in Pregnancy. *Obstet Gynecol* 2013;122:1122.
18. Clark SL, Christmas JT, Frye DR, Meyers JA, Perlin JB. Maternal mortality in the United States: predictability and the impact of protocols on fatal postcesarean pulmonary embolism and hypertension-related intracranial hemorrhage. *Am J Obstet Gynecol* 2014;211:32.e1–9.
19. Druzin M, Shields LE, Peterson NL, Cape V. Improving health care response to preeclampsia. In: California Maternal Quality Care Collaborative, editor. California maternal quality care collaborative toolkit to transform maternity care. Palo Alto (CA): Developed under contract #11-10006 with the California Department of Public Health MCAH Division; 2013.
20. Shields LE, Smalarz K, Reffigee L, Mugg S, Burdumy TJ, Propst M. Comprehensive maternal hemorrhage protocols improve patient safety and reduce utilization of blood products. *Am J Obstet Gynecol* 2011;205:368.e1–8.
21. Lyndon A, Lagrew D, Shields LE, Melsop K, Bingham D, Main EK. Improving health care response to obstetric hemorrhage. In: California toolkit to transform maternity care. Palo Alto (CA): Developed under contract #08-85012 with the California Department of Public Health; Maternal Child and Adolescent Health Division; 2010.
22. Knight M, Berg C, Brocklehurst P, Kramer M, Lewis G, Oats J, et al. Amniotic fluid embolism incidence, risk factors and outcomes: a review and recommendations. *BMC Pregnancy Childbirth* 2012;12:7.
23. Kramer MS, Rouleau J, Liu S, Bartholomew S, Joseph KS; Maternal Health Study Group of the Canadian Perinatal Surveillance System. Amniotic fluid embolism: incidence, risk factors, and impact on perinatal outcome. *BJOG* 2012;119:874–9.
24. Abenhaim HA, Azoulay L, Kramer MS, Leduc L. Incidence and risk factors of amniotic fluid embolisms: a population-based study on 3 million births in the United States. *Am J Obstet Gynecol* 2008;199:49 e1–8.
25. Clark SL. Amniotic fluid embolism. *Obstet Gynecol* 2014;123:337–48.
26. VitalStats. Atlanta (GA): National Center for Health Statistics: Centers for Disease Control and Prevention; 2010.

Rapid Review Process at *Obstetrics & Gynecology*

At *Obstetrics & Gynecology*, most authors receive their first decision (reject or revise) within 30 days of submission. Our online submission process also enables most authors to submit and publish a manuscript within 6 months or less. Between January 2014 and September 2014, an average of 96% of unsolicited manuscripts (excluding case reports) were published within 6 months or less.

To take advantage of the rapid review process and submit your research, please visit <http://ong.editorialmanager.com>.

rev 3/2015

