Maternal mortality

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Purpose of review
This review summarizes recent developments in maternal mortality surveillance, and draws from recent confidential mortality reports to suggest ways the anesthesiologist can contribute to safer systems of care.

Recent findings
Maternal mortality rates appear to be static in much of the developed world, but are increasing in the USA. While improvements in ascertainment explain some of these trends, deferred childbearing, increasing population rates of coexisting disease, multifetal pregnancy, and emerging infections also contribute. Risk is markedly elevated among certain racial and ethnic minorities, due to a confluence of factors that includes behavior, biology, environmental exposures, social circumstances, and the quality of clinical care. Approximately 30–40% of maternal deaths are potentially preventable, and recent maternal mortality reviews suggest specific strategies that may improve outcomes for women suffering from the most common causes of death: cardiovascular disease, hemorrhage, hypertensive disorders of pregnancy, venous thromboembolism, infection, and other medical conditions.

Summary
A growing number of countries and organizations have established systems for comprehensive maternal death surveillance and confidential review to ensure that each death counts and that the lessons learned are widely disseminated to improve future maternal safety.

Keywords
maternal mortality, obstetric hemorrhage, preeclampsia, racial disparity, venous thromboembolism

INTRODUCTION

In 2000, the United Nations announced a goal to reduce maternal mortality by 75% between 1990 and 2015. Whereas global progress has been encouraging (with a 34% reduction worldwide from 546 000 maternal deaths in 1990 to 358 000 in 2008) [1▪], improvements in the developed world have been limited. Rates have actually risen in several countries, most dramatically in the USA [1▪–3▪]. As the 2015 deadline approaches, a growing number of countries have established systems for comprehensive maternal death surveillance and confidential enquiries to ensure that each death counts and that the lessons learned are widely disseminated to improve future maternal safety. This review aims to summarize recent developments in maternal mortality surveillance, and to draw from recent confidential review reports to suggest ways the anesthesiologist can contribute to safer systems of care.

WHICH CASES COUNT?

For the purpose of international comparison, the World Health Organization (WHO) defines maternal death as 'the death of a woman while pregnant or within 42 days of the end of pregnancy, from any cause related to or aggravated by the pregnancy or its management' [1▪]. In much of the developed world, the official count is generated from death certificates, based on International Classification of Disease (ICD) codes that designate an obstetric cause of death. Traditional surveillance focused on direct deaths – 'those resulting from obstetric complications of the pregnant state from interventions, omissions, incorrect treatment, or from a chain of events resulting from the above' [1▪]. Recent evidence suggests that the majority of deaths in the developed world are actually indirect deaths 'resulting from previous existing disease or disease that developed during pregnancy and not

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KEY POINTS

- Maternal mortality is increasing in the USA, due, in part, to not only improved ascertainment, but also delayed childbearing, increasing rates of coexisting disease, especially hypertension and cardiovascular disease, and emerging infections.
- Cardiovascular disease is now the leading cause of maternal mortality in both the USA and the UK.
- Attention to venous thromboembolism prophylaxis appears to be one of the most effective strategies to reduce maternal mortality in the developed world.

due to direct obstetric causes, but aggravated by the physiologic effects of pregnancy' [4▪▪,5▪▪,6].

Indirect deaths may be missed if nonobstetric codes populate the death certificate, especially when death occurs early in gestation or late in the postpartum period. Compared with previous classification systems, ICD-10 improved ascertainment of indirect deaths because it added a specific code for late maternal death (i.e. after 42 days and up to a full year after the end of pregnancy), and expanded codes for indirect deaths. Changes in coding and ascertainment are believed to explain the entire increase in the Canadian Maternal Mortality Ratio (MMR) from 4.7 in 1996–1998 to 7.2 in 2005–2007 [7]. In the USA, the transition from ICD-9 to ICD-10 increased case ascertainment by 27.5% from 7.5 during the years 1995–1998 to 9.6 for the years 1999–2002 (Table 1) [8].

Maternal mortality surveillance is fragmented in the USA where the certification of death is the legal responsibility of individual states. To improve ascertainment, the US Center for Disease Control established the Pregnancy Mortality Surveillance System (PMSS) in 1986. The PMSS recommends mandatory reporting, electronic linkage between women's death certificates and birth certificates, a pregnancy check-box on the death certificate, and a two-stage ascertainment procedure to first identify all pregnancy-associated deaths that occur during pregnancy and up to a full year after the end of pregnancy, and then to manually review all available records to distinguish pregnancy-related deaths from those that appear to be coincidental. Two-stage surveillance procedures have been estimated to increase ascertainment of maternal deaths by 19–90% in various regions [10]. The pregnancy-related mortality ratio (PRMR) is larger than the MMR because the ascertainment procedures are more comprehensive, and because the PRMR includes both early maternal deaths (e.g. during pregnancy and up to 42 days after the end of pregnancy) and late maternal deaths (Table 1).

A 'pregnancy check-box' on the death certificate increases ascertainment of maternal mortality by approximately 60% [11▪▪]. The 2003 revision of the US Standard Certificate of Death introduced questions about pregnancy status (Table 2). By

Table 1. US maternal mortality ratio and pregnancy-related mortality ratio by year

Year	Live-births	NCHS MMR	PMSS PRMR
1995	3899589	7.1	11.3
1996	3891494	7.6	11.3
1997	3880894	8.4	12.9
1998	3941553	7.1	12.0
1995–1998		7.5	11.9
1999	3959417	9.9	13.2
2000	4058814	9.8	14.5
2001	4025933	9.9	14.7
2002	4021726	8.9	14.1
1999–2002		9.6	14.1
2003	4089950	12.1	16.8
2004	4112052	13.1	15.2
2005	4138349	15.1	15.4
2006	4265555	13.3	–
2007	4316233	12.7	–
2003–2007		13.3	15.8

MMR, maternal mortality rate; NCHS, National Center for Health Statistics; PMSS, Pregnancy Mortality Surveillance System; PRMR, pregnancy-related mortality ratio. MMR is limited to those deaths occurring within 42 days of delivery, based on obstetric codes documented on the maternal death certificate. Data from [5▪▪,9].

2005, 17 states adopted the standard death certificate pregnancy questions (representing 29% of all live-births nationally). In these states the 2005 MMR was 19.7 deaths per 100 000 live-births and the PRMR was 22.3 [11▪▪]. The US National Center for Health Statistics declined to publish the 2008 MMR, given concerns that only 31 states (representing 57% of all births) had added the standard pregnancy check-box to the state death certificate [12,13]. All but two states (North Carolina and Mississippi) are scheduled to adopt the standard pregnancy questions by 2013 [13].

The MMR in the USA appears to be increasing above and beyond improvements in ascertainment [14▪▪]. Even among states that did not add any questions about pregnancy to the death certificate, the MMR increased 23% between 2003 and 2005 [11▪▪]. Moreover, increases in severe maternal morbidity mirror the increases in maternal mortality [15–19]. Specifically, rates of peripartum mechanical ventilation, adult respiratory distress syndrome, renal failure, shock, pulmonary embolism, and blood transfusion all increased in the USA between 1998 and 2005 [17].

WHY DO WOMEN DIE?

The leading cause of maternal death in both the USA and the UK is currently cardiovascular disease. Table 3 presents cause-specific mortality ratios for five countries. Given the rarity of maternal death, and variation in ascertainment and categorization procedures, comparisons between countries are not necessarily valid. Nevertheless, the table provides general information as to which causes most frequently lead to death. These appear to be hypertensive disorders of pregnancy, hemorrhage, venous thromboembolism, infection, cardiovascular disease, and other medical disease. Anesthesia-related maternal death is relatively rare, with airway disasters the leading cause of deaths from general anesthesia, and high neuraxial block the leading cause of death from neuraxial anesthesia [4▪▪,5▪▪,6,22▪▪,23].

Table 2. Recommended standard pregnancy check-box, US Standard Certificate of Death, 2003 Revision

If female:
Not pregnant within past year
Pregnant at the time of death
Not pregnant, but pregnant within 42 days of death
Not pregnant, but pregnant 42 days to 1 year before death
Unknown if pregnant within past year

Reprinted from the U.S. standard Certificate of Death. Available at www.cdc.gov/nchs/data/dvs/DEATH11-03final-ACC.pdf (retrieved January 18, 2012).

WHY ARE RATES INCREASING?

Delayed childbearing plays a significant role in increasing maternal risk. Between 1980 and 2003, the percentage of mothers aged 35 years or more increased from 5 to 14.2% in the USA [24], and from 5.2 to 20% in the Netherlands [2▪]. Advancing maternal age increases risk for obesity, coexisting disease, hypertensive disorders of pregnancy, amniotic fluid embolism, venous thromboembolism, cesarean delivery, and maternal hemorrhage [5▪▪,25–28].

Multifetal pregnancy is associated with both advanced maternal age and maternal mortality from a variety of causes, including amniotic fluid embolism, venous thromboembolism, hemorrhage, hypertensive disorders of pregnancy, infection, cardiomyopathy, and indirect deaths [29]. The twin birth rate increased 70% in the USA between 1980 and 2009, from 1.9 to 3.3% of all births [30▪]. One-third of this increase may be explained by spontaneous twinning among older women; the remainder is attributed to assisted reproductive technology [30▪]. In 2009, more than 20% of deliveries by women aged 45 years and older was for a twin [30▪].

Both chronic hypertension and pregnancy-associated hypertension have become more common [31▪,32], and both increase risk of maternal death, particularly from preeclampsia and cerebrovascular complications. Whereas chronic hypertension alone increases risk for maternal death during the admission for delivery [adjusted odds ratio (aOR) 6.2], the combination with chronic renal disease (aOR 27.0) or collagen vascular disease (aOR 88.8) is particularly detrimental [31▪].

Population levels of obesity increased through the 1980s and 1990s, but appear to have stabilized in the USA at 32% of all women aged 20–39 years [25], and women enter pregnancy with comparable rates of obesity [33]. Obesity is associated with thromboembolism, cardiovascular disorders, hypertensive disorders of pregnancy, postpartum uterine atony, and failure to rescue from severe maternal morbidity [4▪▪,34▪,35▪].

Rates of cardiovascular disease in pregnancy continue to increase, specifically rates of congenital heart disease, cardiac dysrhythmias, cardiomyopathy, and congestive heart failure [36▪]. Whereas 1.4% of the delivering population in the USA has some form of chronic heart disease, this population experiences 28% of in-hospital maternal deaths [36▪,37▪]. Adult congenital heart disease has

Table 3. Cause-specific mortality ratios for five countries

	USA	UK	Netherlands	New Zealand	France
Years	1998–2005	2006–2008	1993–2005	2006–2009	2004–2006
Live-births	32347794	22911493	2557208	255208	4651163
Overall mortality ratio	14.5	11.4	12.1	15.3	8.6
Hypertensive disorders of pregnancy	1.79	0.83	3.5	1.6	0.84
Obstetric hemorrhage	1.81	0.65	1.1	1.2	1.91
Ectopic and first trimester	0.58	0.26	0.2	–	0.28
Antepartum	0.46	0.17	0.8	–	0.37
Postpartum	0.77	0.22	–	–	1.03
Genital tract trauma/uterine rupture	–	0	0.1	–	0.24
Venous thromboembolism	1.48	0.79	1.6	0.8	0.86
Amniotic fluid embolism	1.09	0.57	0.4	3.1	1.14
Infection	1.55	1.63	1.1	3.2	0.34
Genital tract or postpartum sepsis	–	1.13	0.7	0.8	0.26
Nonobstetric sepsis/infections	–	0.48	0.4	2.4	0.30
Cardiovascular disease	3.48	2.31	1.6	–	0.88
Cardiomyopathy	1.68	0.57	0.2	0.4	0.13
Other cardiovascular disease	1.80	1.74	1.4	–	0.75
Cerebrovascular disease	0.92	1.27	0.6	0.4	0.88
Other medical disease	1.92	2.14	1.0	3.5	0.80
Anesthesia	0.17	0.31	0.1	–	0.15

USA – Cause-specific mortality ratio includes deaths during pregnancy and up to 1 year after the end of pregnancy per 100 000 live-births. Data from [5▪▪]. UK – Cause specific mortality ratio includes deaths during pregnancy and up to 1 year after the end of pregnancy per 100 000 pregnancies lasting at least 20 weeks gestation. Data from [4▪▪]. Netherlands – Cause-specific mortality ratio includes deaths during pregnancy and up to 42 days after the end of pregnancy per 100 000 live-births. Data from [2▪]. New Zealand – Cause-specific mortality ratio includes deaths during pregnancy and up to 42 days after the end of pregnancy per 100 000 pregnancies lasting at least 20 weeks gestation. Other cardiovascular disease included in other medical disease. Data from [20▪▪]. France – Cause-specific mortality ratio includes deaths during pregnancy and up to 1 year after the end of pregnancy per 100 000 live-births. Data from [21▪].

increased 43% among delivering women in the USA, and more than 40% of these women deliver in community hospitals rather than tertiary centers [38▪].

Emerging infections contribute to the burden of maternal mortality. Globally, HIV/AIDS accounts for about 10% of all maternal deaths [3▪]. In the UK, genital tract sepsis, primarily attributed to ascending group A streptococcal infection, emerged as the leading cause of direct maternal death in 2006–2008 [4▪▪]. Whether this trend may be attributed to increasing virulence or a larger population prevalence of risk factors that increase susceptibility is unknown.

Cesarean deliveries in the USA increased 60% between 1996 and 2009, from 20.7 to 32.9% [32]. Cesarean delivery has been associated with maternal death in observational studies [39]. Mechanisms include surgical hemorrhage, venous thromboembolism, perioperative infection, abnormal placentation in subsequent pregnancies, and anesthetic complications. Nevertheless, chart reviews of individual cases and confidential enquiry reports suggest that deaths directly attributed to cesarean delivery are relatively rare, accounting for 1.3% of maternal deaths in the Netherlands [2▪], and 4.2% of deaths during the hospitalization for delivery in a large hospital network in the USA [40]. This last review actually suggested that in 17% of cases, cesarean delivery or earlier cesarean delivery may have potentially saved the mother's life [40].

IS RISK INCREASED FOR MINORITY WOMEN?

In the USA, African–American women face a PRMR that is 3.5-fold higher than white women. Risk increases disproportionately as black women age, such that the PRMR for black women over age 39 years is 166 per 100 000 live-births [5▪▪]. Racial disparities in maternal mortality and severe maternal morbidity persist after controlling for differences in maternal age, socioeconomic status, and medical comorbidities [14▪▪,19,41▪,42].

Evidence of racial and ethnic disparities is not limited to the USA. In the Netherlands, 29% of

women who died were immigrants, and substandard care was found to be more frequent in this population. In the UK, maternal mortality rates are increased among asylum seekers, women of Black African and Black Caribbean origin, women from disadvantaged socioeconomic backgrounds, and non-English speakers [4▪▪,35▪]. Significant regional variation has been identified in France, with increased risk noted for women delivering in Paris (aOR 1.6) and the overseas districts (aOR 3.5) compared with the rest of continental France [43▪].

Differences in behavior, biology, environmental conditions, social circumstances, and the quality of clinical care can all contribute to disparities in outcomes for racial and ethnic minorities [4▪▪,43▪,44▪▪]. Population rates of chronic hypertension and obesity are significantly higher in African–American women than white women [25]. Whereas rates of preeclampsia, eclampsia, abruption, and postpartum hemorrhage are relatively comparable between white and black Americans, the case-fatality ratios for all of these conditions are four-fold higher in African–American women [45]. Black African women in the UK also appear to be particularly susceptible to severe preeclampsia, and preeclampsia-related mortality.

ARE MATERNAL DEATHS PREVENTABLE?

Whether a death could have been prevented is one of the key questions of mortality reviews, because the answer can be used to prioritize changes in clinical policy and health system improvements. Whereas less than optimal medical care can be identified in the majority of maternal deaths, only 30–40% are considered potentially preventable [4▪▪,20▪▪,46▪]. The highest rates of preventability are noted among ethnic minorities, and among deaths attributed to hemorrhage, hypertensive disorders of pregnancy, and sepsis or infection.

NINE LESSONS FROM MATERNAL MORTALITY REVIEWS

The final section outlines a sample of recommendations for care from recent maternal mortality reviews.

Venous thromboembolism prophylaxis

Following the publication of national guidelines for peripartum thromboprophylaxis, the rate of death from venous thromboembolism in the UK declined almost 60% from 1.94 per 100 000 maternities in 2003–2005 to 0.79 in 2006–2008 [4▪▪]. The Hospital Corporation of America introduced universal perioperative pneumatic compression devices for all women undergoing cesarean delivery in 2007, and the risk of death due to postcesarean venous thromboembolism declined from 1.5 per 100 000 cesareans in 2001–2006 to 0.5 in 2008–2010 [47].

The American College of Gynecologists now recommends mechanical thromboembolism prophylaxis for all women undergoing cesarean delivery who are not already receiving pharmacologic prophylaxis [48]. Pneumatic compression devices should be used postoperatively until the patient is mobile and any anticoagulation therapy is resumed. This practice bulletin also provides risk-stratified dosing recommendations for pharmacologic prophylaxis with unfractionated heparin or low-molecular-weight heparin for women with additional risk factors for thromboembolism, most importantly, prior thrombosis or known thrombophilia [48]. Obese women need weight-adjusted dosing to ensure effective pharmacologic thromboprophylaxis [4▪▪].

Hypertensive crisis

Systolic blood pressure above 160 mmHg or diastolic blood pressure above 110 mmHg constitutes a hypertensive crisis in a pregnant woman, and requires urgent treatment to minimize risk for cerebral hemorrhage [2▪,4▪▪,49▪▪]. Intravenous labetalol, intravenous hydralazine, and oral nifedipine can each be effective, and protocols are available to guide initial therapy while awaiting physician arrival at the bedside [49▪▪]. The combination of magnesium sulfate and antihypertensive therapy can lead to abrupt onset of hypotension and cardiovascular arrest [4▪▪].

Shortness of breath, orthopnea, tachypnea, or wheezing

Although shortness of breath with exercise is a normal pregnancy symptom, feeling short of breath at rest is not. Critical diagnoses to identify include infection, pulmonary edema, pulmonary embolism, and aortic dissection. Wheezing can be the primary sign of pulmonary edema or pulmonary embolism. Ignoring tachypnea and misattributing respiratory symptoms to asthma, anemia, panic attacks, or chest infection were common mistakes in maternal cardiac deaths in the UK [4▪▪].

Chest or intrascapular pain

In a clinically stable pregnant patient reporting acute chest or intrascapular pain, three conditions must be excluded as soon as possible: pulmonary

embolism, myocardial infarction, and vascular catastrophe [4▪▪,50]. An expeditious work-up includes serial 12-lead electrocardiogram and cardiac enzymes, chest X-ray, and computed tomography (CT) angiography with or without additional diagnostic tests to rule out pulmonary embolism and aortic dissection [49▪▪,50]. Nondiagnostic testing can delay definitive diagnosis and appropriate therapy.

Cardiovascular disease

Given the potential for cardiovascular decompensation associated with the normal physiologic changes of pregnancy, women with known cardiovascular disease or a history of peripartum cardiomyopathy need periodic consultation with a cardiologist with expertise in the care of women with heart disease in pregnancy, even when care is otherwise conducted in the community [4▪▪,49▪▪]. These visits should establish baseline cardiovascular function, periodically evaluate response to the physiologic demands of pregnancy, and educate the woman about the signs and symptoms that could indicate deterioration. Antepartum anesthesiology consultations can provide the opportunity to verify whether a recent echocardiogram is available or indicated, and to coordinate with the patient, obstetrician, and cardiologist to develop a detailed delivery plan. Specific factors that predict cardiovascular decompensation in pregnancy or the peripartum period include prior cardiac events or arrhythmia, poor functional class, cyanosis, left heart obstruction, left-ventricular systolic dysfunction, decreased subpulmonary ejection fraction, pulmonary hypertension, and pulmonary regurgitation [38▪,51]. Serum B-type natriuretic protein level greater than 100 pg/ml may suggest early heart failure in pregnant women [52,53].

Sepsis

Given a number of cases in which the early signs of sepsis were missed, the Saving Mothers' Lives report from the UK suggested the following criteria to detect impending sepsis in pregnancy and the peripartum period: temperature above 38°C, sustained tachycardia greater than 100 beats per minute, or tachypnea greater than 20 breaths per minute, particularly in the setting of abdominal or chest pain, diarrhea, vomiting, reduced or absent fetal movements, absent fetal heart tones, significant vaginal discharge, postpartum uterine tenderness, costovertebral angle tenderness, or a general appearance of unwellness [4▪▪]. Drawing from the Surviving Sepsis Guidelines, this report recommends early broad-spectrum antibiotics (within the first hour of recognizing severe sepsis), source control within 6 h of presentation, fluid resuscitation to target a central venous pressure of at least 8 mmHg (≥12 mmHg in ventilated patients), and vasopressors (starting with norepinephrine 0.1 mcg/kg/min) to maintain mean arterial pressure of at least 65 mmHg [4▪▪,54].

Postpartum hemorrhage

Postpartum hemorrhage is repeatedly considered the category of death that is most likely to be preventable [21▪,46▪]. The state of California produced an obstetric hemorrhage toolkit to guide system improvements to prevent and respond to major obstetric hemorrhage [55▪▪]. The recommendations center on a set of structured routine assessments, and early intervention to reduce the risk of denial and delay. At least one California hospital has reported improvements in its rates of major hemorrhage, disseminated intravascular coagulopathy, and unit-wide blood product consumption, as a result of implementing these system improvements [56▪].

Multiple reviews now recommend that women with abnormal placentation and those who decline blood products deliver in a tertiary setting [4▪▪,46▪,49▪▪]. Whereas interventional radiology techniques can be an effective prophylactic procedure to limit hemorrhage for the patient with known abnormal placentation, radiology consultation is not an appropriate treatment to rescue women with uncontrolled postpartum bleeding. These women need aggressive hemostatic and volume resuscitation while the obstetrician deploys surgical interventions to control the source of bleeding [49▪▪].

Structured monitoring protocols

Delays in diagnosis and treatment have been repeatedly identified, particularly following deaths from exsanguination and sepsis. Early warning scoring systems based on vital sign triggers have been proposed to improve recognition of women with impending critical illness [4▪▪,6]. A recent prospective evaluation in a delivery center in the UK suggests that the Modified Early Obstetric Warning Score (MEOWS) is 89% sensitive, with a positive predictive value of 39%, and a negative predictive value of 98% to predict severe obstetric morbidity [57▪]. Studies that use nonobstetric MEWS, or that attempt to predict only the most severe outcomes, identify a lower positive predictive value [58▪]. But even a positive predictive value as low as 5% may be useful to direct physician attention and to guide nurses to increase intensity of monitoring.

Improving care for women with high-risk conditions

Increasing numbers of women with pre-existing medical conditions are becoming pregnant, such that the majority of near-miss morbidity and mortality events are concentrated in less than 12% of the delivering population [41▪]. Prepregnancy counseling and expert multidisciplinary care during the antenatal, intrapartum, and postpartum periods have been proposed to improve outcomes for women with pre-existing medical illness [59]. Whether an individual woman would benefit from triage to a tertiary facility depends on the difference in resources and the risk of serious physiologic decompensation.

CONCLUSION

A maternal death can be one of the most devastating outcomes in all of medicine. Individual cases often follow complex trajectories that reflect the interaction of pre-existing medical conditions and other risk factors, unexpected complications, and lost opportunities to alter the fatal course of events. Even though the cases can be widely disparate, systematic reviews afford the opportunity to identify current event rates and trends and derive lessons to improve future care.

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Conflicts of interest

There are no conflicts of interest to report.
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REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

- ▪ of special interest
- ▪▪ of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (pp. 389–391).

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This report contains the official WHO estimates for the maternal mortality ratio for 181 countries around the world, and tracks progress towards Millenium Development Goal 5, to reduce global maternal mortality by 75% between 1990 and 2015.

2. Schutte JM, Steegers EA, Schuitemaker NW, *et al.* Rise in maternal mortality ▪ in the Netherlands. BJOG 2010; 117:399–406.

The confidential enquiry into maternal death in the Netherlands found that pre-eclampsia was the leading cause of maternal death among Dutch women between 1993 and 2005, with the majority of these cases due to cerebral hemorrhage or encephalopathy in the setting of severe hypertension.

3. Hogan MC, Foreman KJ, Naghavi M, *et al.* Maternal mortality for 181 ▪ countries, 1980–2008: a systematic analysis of progress towards Millennium Development Goal 5. Lancet 2010; 375:1609–1623.

This study analyzes all available data sources from both low and high-income countries, and uses sophisticated analytic methods to generate updated estimates for the maternal mortality ratio for 181 countries each year between 1980 and 2008. Further analysis estimated the specific impact of HIV on the number of global maternal deaths.

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The Confidential Enquiry in the UK is the gold standard for maternal mortality review. In this triennial report, chapters on sepsis, anesthesia, cardiovascular disease, and critical care are particularly helpful for the anesthesiologist.

5. Berg CJ, Callaghan WM, Syverson C, Henderson Z. Pregnancy-related ▪▪ mortality in the United States, 1998 to 2005. Obstet Gynecol 2010; 116:1302–1309.

This publication from the Pregnancy Mortality Surveillance System provides the most comprehensive and current national review of maternal deaths in the USA. Currently seven categories each contribute between 10 and 13% of all pregnancy-related deaths: hemorrhage, venous thromboembolism, hypertensive disorders of pregnancy, infection, cardiomyopathy, other cardiovascular disorders, and other medical disorders.

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This report from the National Center for Health Statistics describes the interactions between advanced maternal age, assisted reproductive technology and multiple gestation.

31. Bateman BT, Bansil P, Hernandez-Diaz S, *et al.* Prevalence, trends, and ■ outcomes of chronic hypertension: a nationwide sample of delivery admissions. Am J Obstet Gynecol 2012; 206:134 e131–e138.

This study analyzes the impact of chronic hypertension on a wide range of maternal morbidities and maternal death, and explores interactions between chronic hypertension, systemic lupus erythematosus and chronic renal failure on adverse maternal outcomes. Future analyses are needed to explore similar interactions to understand the combinations of conditions that are particularly detrimental to maternal health.

32. Martin J, Hamilton B, Ventura S, *et al.* Births: final data for 2009. Natl Vital Stat Rep 2011; 60:1–104.
33. Kim SY, Dietz PM, England L, *et al.* Trends in prepregnancy obesity in nine states, 1993–2003. Obesity (Silver Spring) 2007; 15:986–993.
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This population-based cohort analysis of postpartum hemorrhage in Sweden found that maternal obesity increases risk for hemorrhage attributed to postpatum uterine atony, but does not increase risk for hemorrhage due to retained placenta.

35. Kayem G, Kurinczuk J, Lewis G, *et al.* Risk factors for progression from severe ■ maternal morbidity to death: a national cohort study. PLoS One 2011; 6:e29077.

This analysis combined data from the UK Obstetric Surveillance System (UKOSS) and the UK Confidential Enquiry of maternal deaths to identify the demographic and clinical characteristics that increase risk of death as opposed to severe obstetric morbidity.

36. Kuklina E, Callaghan W. Chronic heart disease and severe obstetric morbidity ■ among hospitalisations for pregnancy in the USA: 1995–2006. BJOG 2011; 118:345–352.

This population-based cross-sectional analysis of the Nationwide Inpatient Sample in the USA estimates the incidence and trends of chronic heart disease among women admitted for childbirth, and the impact of each condition on severe obstetric morbidity.

37. Kuklina EV, Callaghan WM. Cardiomyopathy and other myocardial disorders ■ among hospitalizations for pregnancy in the United States: 2004–2006. Obstet Gynecol 2010; 115:93–100.

A new ICD-9 code for peripartum cardiomyopathy was introduced in 2003, and this population-based cross-sectional analysis of the Nationwide Inpatient Sample in the USA focused on severe obstetric complications associated with peripartum cardiomyopathy and other myocardial disorders during delivery and postparutm hospitalizations.

38. Karamlou T, Diggs BS, McCrindle BW, Welke KF. A growing problem: ■ maternal death and peripartum complications are higher in women with grown-up congenital heart disease. Ann Thorac Surg 2011; 92:2193–2198; discussion 2198–2199..

This population-based cross-sectional analysis of the Nationwide Inpatient Sample in the USA focused on diagnoses of congenital heart disease among women admitted for delivery. A diagnosis of ventricular septal defect (VSD) was associated with the highest risk of maternal death and complications.

39. Deneux-Tharaux C, Carmona E, Bouvier-Colle MH, Breart G. Postpartum maternal mortality and cesarean delivery. Obstet Gynecol 2006; 108:541–548.
40. Clark SL, Belfort MA, Dildy GA, *et al.* Maternal death in the 21st century: causes, prevention, and relationship to cesarean delivery. Am J Obstet Gynecol 2008; 199:36 e31–e35.
41. Mhyre JM, Bateman BT, Leffert LR. Influence of patient comorbidities on the ■ risk of near-miss maternal morbidity or mortality. Anesthesiology 2011; 115:963–972.

This population-based cross-sectional analysis of the Nationwide Inpatient Sample in the USA found that risk for near-miss morbidity or maternal death is concentrated in less than 12% of the delivering population. Future clinical efforts to reduce maternal mortality must focus on optimizing care for these high-risk women.

42. Walker LO, Chesnut LW. Identifying health disparities and social inequities affecting childbearing women and infants. J Obstet Gynecol Neonatal Nurs 2010; 39:328–338.
43. Saucedo M, Deneux-Tharaux C, Bouvier-Colle MH. Understanding regional ■ differences in maternal mortality: a national case-control study in France. BJOG 2011 [Epub ahead of print].

This case-control study compared the quality and region of care for 328 French women who died postpartum, with a representative sample of control patients. Outcomes differed between regions, leading the authors to conclude that the organization and quality of care may play a role in the differential risk of maternal mortality between regions in France.

44. Bryant AS, Worjoloh A, Caughey AB, Washington AE. Racial/ethnic dispa- ■■ rities in obstetric outcomes and care: prevalence and determinants. Am J Obstet Gynecol 2010; 202:335–343.

This review explores a wide range of racial and ethnic disparities in obstetric outcomes, and provides a useful theoretical framework to explain them; this framework includes five factors: genetic predisposition, behavior, social circumstances, environmental exposures, and differences in quality of care.

45. Tucker MJ, 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; 97:247–251.
46. The California Pregnancy-Associated Mortality Review. Report from 2002 ■ and 2003 Maternal Death Reviews. Sacramento: California Department of Public Health, Maternal Child and Adolescent Health Division; 2011. Available at http://www.cdph.ca.gov/data/statistics/Documents/MO-CA-PAMR-MaternalDeathReview-2002-03.pdf, accessed February 25, 2012.

Numerous states in the USA have maternal mortality review committees that ascertain and review all maternal deaths in the state in order to generate priorities and recommendations to improve future outcomes. Unfortunately, legal barriers limit the ability of individual states to share this data. The State of California has produced the most comprehensive report of any state.

47. Clark SL, Meyers JA, Frye DK, Perlin JA. Patient safety in obstetrics: the Hospital Corporation of America experience. Am J Obstet Gynecol 2011; 204:283–287.
48. James A. Practice bulletin no. 123: thromboembolism in pregnancy. Obstet Gynecol 2011; 118:718–729.
49. Clark SL, Hankins GD. Preventing maternal death: 10 clinical diamonds. ■■ Obstet Gynecol 2012; 119:360–364.

The Hospital Corporation of America is a private operator of healthcare facilities that oversees 17% of delivery centers in the USA, and undertakes regular centralized quality improvement-related reviews of maternal deaths. This review summarizes 10 recurrent errors that account for a disproportionate share of maternal deaths in this system, and suggests the development of local clinical protocols to reduce the effect of medical error on maternal mortality.

50. la Chapelle CF, Schutte JM, Schuitemaker NW, *et al.* Maternal mortality attributable to vascular dissection and rupture in the Netherlands: a nationwide confidential enquiry. BJOG 2012; 119:86–93.
51. Siu SC, Sermer M, Colman JM, *et al.* Prospective multicenter study of pregnancy outcomes in women with heart disease. Circulation 2001; 104:515–521.
52. Tanous D, Siu SC, Mason J, *et al.* B-type natriuretic peptide in pregnant women with heart disease. J Am Coll Cardiol 2010; 56:1247–1253.
53. Kamiya CA, Iwamiya T, Neki R, *et al.* Outcome of Pregnancy and Effects on the Right Heart in Women With Repaired Tetralogy of Fallot. Circ J 2012. [Epub ahead of print]
54. Dellinger RP, Levy MM, Carlet JM, *et al.* Surviving Sepsis Campaign: international guidelines for management of severe sepsis and septic shock: 2008. Crit Care Med 2008; 36:296–327.
55. OB Hemorrhage Protocol. OB Hemorrhage Care Guidelines: Checklist ■■ Format V.1.4. CMQCC Hemorrhage Task Force 2010. http://www.cmqcc.org/ob_hemorrhage, accessed January 4, 2012.

This website-based toolkit produced by the California Maternal Quality Care Collaborative includes a wealth of protocols, best practices, and tools to guide system-based improvements to improve readiness, recognition, response, and reporting of obstetric hemorrhage.

56. Shields LE, Smalarz K, Reffigee L, *et al.* Comprehensive maternal hemorrhage ■ protocols improve patient safety and reduce utilization of blood products. Am J Obstet Gynecol 2011; 205:368 e361–e368.

This community hospital in California implemented a full panel of system improvements recommended by the California Maternal Quality Care Collaborative and demonstrated improvements in both patient and institutional outcomes related to obstetric hemorrhage.

57. Singh S, McGlennan A, England A, Simons R. A validation study of the ■ CEMACH recommended modified early obstetric warning system (MEOWS). Anaesthesia 2012; 67:12–18.
These authors prospectively enrolled 676 consecutive obstetric admissions, and compared completed MEOWS charts for triggers and the medical record for evidence of morbidity. Singh *et al.* provide a blank MEOWS chart and an algorithm to escalate care in article appendices.

58. Lappen JR, Keene M, Lore M, *et al.* Existing models fail to predict sepsis in an ■ obstetric population with intrauterine infection. Am J Obstet Gynecol 2010; 203:573 e571–e575.
These authors analyzed nonobstetric MEWS criteria for 913 pregnant women with chorioamnionitis, and found that only 5% of women with a MEWS at least 5 developed severe sepsis, required ICU transfer or died ($n = 5/92$).

59. Nelson-Piercy C, Mackillop L, Williams DJ, *et al.* Maternal mortality in the UK and the need for obstetric physicians. Br Med J 2011; 343:d4993.