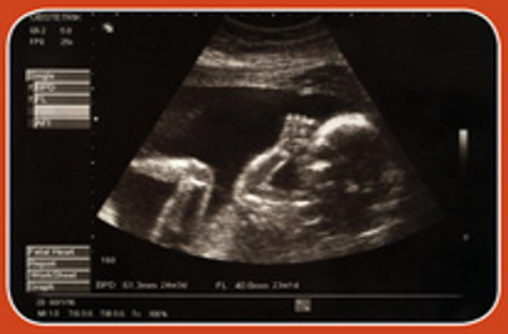

Critical Care Obstetrics

Editor-in-Chief Jeffrey P. Phelan

Editors Luis D. Pacheco, Michael R. Foley, George R. Saade, Gary A. Dildy, Michael A. Belfort

Sixth Edition

WILEY Blackwell

Critical Care Obstetrics

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Foreword to the Sixth Edition

This is a story about a book, this book – *Critical Care Obstetrics*. Strange as it may seem, this book has a bicoastal beginning and arose almost simultaneously on both coasts without the future editors having any idea that they were going to start a book – let alone be editors of a book that would continue to be published over 30 years and is now in its sixth edition. The bicoastal beginnings were triggered by the introduction of two articles on invasive hemodynamic monitoring in preeclampsia: Benedetti and Cotton [1] at the Los Angeles County/University of Southern California (LAC/USC) Medical Center on the west coast, and Phelan and Yurth [2] at the Naval Regional Medical Center in the old building on the east coast. In retrospect, the pulmonary artery catheter became the Aladdin's lamp of *Critical Care Obstetrics*. Once the Genie appeared, terms such as left ventricular stroke work index, pulmonary artery pressure, hyperdynamic ventricular function, and pulmonary capillary wedge pressure became commonplace in the obstetrical community.

Interestingly enough, the origins of *Critical Care Obstetrics* had its genesis at the then-epicenter of fetal assessment: LAC/USC Medical Center. There, the schools of fetal monitoring, obstetrical ultrasonography, and fetal echocardiography were united under one umbrella. But something was missing. There, a void needed to be filled: maternal critical care. But that was about to change.

As the story goes, it was a quiet Sunday afternoon in the year 1981. I was working as an OB/GYN hospitalist, as it is known today, at Hollywood Presbyterian Hospital in Hollywood, California, with a then-resident, Steven L. Clark, MD, whom I was about to meet. A code blue was called in another unit of the hospital. As I ran to that area to attempt CPR on a nonpregnant stranger, an OB resident named Steve Clark was also running to the same code. By the time we had arrived at the code, the gentleman had already been resuscitated by the code blue team.

Several months later, Dr. Clark and I had a discussion, similar to other conversations that faculty and fellows had, on what he should consider doing as his fellowship project. As my recollection best serves me, the newly published Phelan–Yurth article (published in 1982) served as an impetus to explore the new frontier of critical care obstetrics. Soon thereafter, Dr. Clark took the bull by the horns and catapulted us into the new dimension of critical care obstetrics.

Sometime later, Dr. Clark, a fellow at the time, came into my office and quickly shut the door. Almost simultaneously, he said,

"Jeff, I am going to make you famous! You and I are going to do a book called *Critical Care Obstetrics*."

While I was admittedly impressed by his bravado, my response was less than enthusiastic and laced with serious doubts. I said simply, "Who would buy a book from us?" After all, Dr. Clark was a first-year fellow and I was just a junior faculty member.

Much to my amazement, a whole lot of folks would buy this book and have kept on buying each new edition.

Never did I imagine in 1987 that, now more than 30 years later, I would be in a rice field in Shijyonawate (just north of Osaka), Japan, watching the annual rice harvest and editing the sixth edition of *Critical Care Obstetrics*. As the sun slowly set in the west, the harvester continued up and down the rows of rice, separating the rice from its stalks and projecting the rice into collection bags. The rice harvesting, much like critical care obstetrics, has changed dramatically over the past 30 years. More than 30 years after that eventful day with Dr. Clark and five editions later, life and this book, *Critical Care Obstetrics*, have taught us how much "time flies when we are alive."

While working on the sixth edition, there were also many stories within the book's five prior editions. One story struck me hard personally. In my first edition, there was an inscription written 30 years ago to my Father. Then, I wrote the following:

"To my Dad, Thanks for being my Father & teaching me that hard work and perseverance pays off, Love always, your Son, Jeff 1987."

Sadly, my Father died a few weeks later.

Edward J. Quilligan, MD, played a major role in the development of *Critical Care Obstetrics*. Dr. Quilligan wrote the forewords for the first two editions and was key to the success of *Critical Care Obstetrics*. Dr. Quilligan, a giant in our specialty, wrote in the first edition that "regardless of the complications encountered during pregnancy, this excellent text will materially help you achieve that goal." Dr. Quilligan went on to say in the second edition that "with this textbook, we, as obstetricians are no longer a 'medically educated night-watchman'." We believe that we have upheld those traditions of excellence in keeping with the bold statements of Dr. Quilligan made so many years ago.

Another story rests with the third edition. The third edition of *Critical Care Obstetrics* was dedicated to a maternal-fetal medicine giant, "under whose guidance the discipline of Maternal-Fetal Medicine was formed, and who directed the training of leaders of the field – Richard H. Paul, MD." It was truly a dedication richly deserved. All of us, and there were many of us who were trained under his leadership, greatly appreciate what Dr. Paul did for all of us and our patients over our lifetimes.

Dedications were also not a stranger to other editions of the book. Over these 30 years, there have been dedications to parents twice, wives and/or children three times, and once to the trench physicians.

During these 30 years, there have been a total of nine editors. In the first edition, there were three editors for the book: Steven L. Clark, MD, Jeffrey P. Phelan, MD, and David Cotton, MD. For the second edition, Gary D.V. Hankins, MD, another giant in our field, became an editor. With the fourth edition, Gary A. Dildy, MD, Michael A. Belfort, MBBCH, MD, PhD, and George Saade, MD, were added as editors. In 2010, Michael R. Foley, MD, joined us for the fifth edition. For the sixth edition of the book, Luis D. Pacheco, MD, brought his special expertise. With the publishing of the sixth edition of *Critical Care Obstetrics*, Jeffrey P. Phelan, MD, will have been the only editor for all six editions.

The following table illustrates changes to the book, *Critical Care Obstetrics*, over the past 30 years.

Edition	Year	Editors	Authors	Chapters	Pages	Index pages	Weight (lbs.)	Volume (cm^3)
1	1987	3	28	28	508	11	2.7	1419
2	1991	4	39	32	733	14	3.6	1996
Handbook	1994	4	*	34	487	10	1.5	919
3	1997	4	37	37	763	24	4.1	1996
4	2004	6	59	46	691	10	4.1	2521
5	2010	5	77	52	750	11	5.2	2986
6	2018	6	109	61	1136	29	≈7.2	≈2898

During these 30 years, there have been six editions and one *Handbook*. The number of authors has increased 275% from the first edition to the sixth. Between the first and fifth editions, the weight of the book increased 91%. There is no telling how much the sixth edition will weigh in paper form. Clearly, the digital version will be considerably lighter. With the sixth edition, 12 new or restructured chapters have been created, including but not limited to the following: "Interventional Radiology in Pregnancy," "Maternal-Fetal Oxygenation," "Critical Care Drills," "Maternal-Fetal Transport in the High-Risk Pregnancy," "The Placenta as a Critical Care Issue," "Mass Casualties and the Obstetrical Patient," and, of course, "Medical-Legal Considerations in Critical Care Obstetrics."

As many of us are aware, providing care to a critically ill pregnant woman is like a storm. We will bask in the sunlight one moment and be shattered on the rocks in the next. What makes us who we are is what we do when that storm comes: we must look at that critically ill patient as we have done before and do our best [3]. We, the editors of the sixth edition, hope that this new edition helps you to achieve your best.

While we – Jeffrey P. Phelan, MD, Steven L. Clark, MD, David Cotton, MD, Gary D.V. Hankins, MD, Michael A. Belfort, MD, PhD, Gary A. Dildy, MD, George Saade, MD, Luis D. Pacheco, MD, and Michael R. Foley, MD, the editors at various times over these 30 years – have lived this *Critical Care Obstetrics* book fairy tale, we would like to thank you, the Readers, for sharing this journey with us.

Editor-in-Chief
Jeffrey P. Phelan, MD, JD

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Part One

Basic Critical Care Clinical and Surgical Principles

1

Epidemiology of Critical Illness in Pregnancy

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Introduction

The successful epidemiologic evaluation of any disease or condition has several prerequisites. Two of the most important prerequisites are that the condition should be accurately defined and that there should be measurable outcomes of interest. Another requirement is that there must be some systematic way of data collection or surveillance that will allow the measurement of the outcomes of interest and associated risk factors. The epidemiologic evaluation of critical illness associated with pregnancy has met with mixed success on all of these counts.

Historically, surveillance of pregnancy-related critical illness has focused on the well-defined outcome of maternal mortality in order to identify illnesses or conditions that might have led to maternal death. Identification of various conditions associated with maternal mortality initially came from observations by astute clinicians. One of the best examples is the link described by Semmelweiss between handwashing habits and puerperal fever. In most industrial and many developing countries, there are now population-based surveillance mechanisms in place to track maternal mortality. These often are mandated by law. In fact, the World Health Organization uses maternal mortality as one of the measures of the health of a population [1].

Fortunately, in most industrialized nations, the maternal mortality rates have fallen to very low levels. Unfortunately, recent statistics for the United States suggest that overall maternal mortality has been increasing, but it remains unclear whether this is just due to improvements in surveillance [2]. Although maternal mortality is an important maternal health measure, tracking maternal deaths may not be the best way to assess pregnancy-related critical illnesses since the majority of such illnesses do not result in maternal death. As stated by Harmer [3], "death represents the tip of the morbidity iceberg, the size of which is unknown." Unlike mortality, which is an unequivocal endpoint, critical illness in pregnancy as a morbidity outcome is difficult to define and, therefore, difficult to measure and study precisely.

There are many common conditions in pregnancy – such as hypertensive diseases, intrapartum and postpartum hemorrhage, venous thromboembolism, diabetes, thyroid disease, asthma, seizure disorders, and infection and sepsis – that occur frequently and require special medical care, but do not actually become critical illnesses. Most women with these complications have relatively uneventful pregnancies that result in good outcomes for both mother and infant, but each of these conditions can be associated with significant complications that have the potential for serious morbidity, disability, or death. The stage at which any condition becomes severe enough to be classified as a critical illness has not been clearly defined. However, it may be helpful to consider critical illness as impending, developing, or established significant organ dysfunction, which may lead to long-term morbidity or death. This allows some flexibility in the characterization of disease severity, since it recognizes conditions that can deteriorate rather quickly in pregnancy.

Maternal mortality data collection is reasonably well established in many places, but specific structured surveillance systems that track severe complications of pregnancy (without maternal mortality) are rare. It has been suggested that most women suffering a critical illness in pregnancy are likely to spend some time in an intensive care unit (ICU) [3–5]. These cases have been described by some as "near-miss" mortality cases [6,7]. Therefore, examination of cases admitted to ICUs can

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provide insight into the nature of pregnancy-related critical illnesses and can complement maternal mortality surveillance. However, it should be noted that nearly two-thirds of maternal deaths might occur in women who never reach an ICU [5].

The remainder of this chapter reviews much of what is currently known about the epidemiology of critical illness in pregnancy. Some of the information is based on published studies; however, much of the data are derived from publicly available data that are collected as part of nationwide surveillance systems in the United States.

Pregnancy-related hospitalizations

Pregnancy complications contribute significantly to maternal, fetal, and infant morbidity, as well as mortality [8]. Many women with complicating conditions are hospitalized without being delivered. Although maternal complications of pregnancy are the fifth leading cause of infant mortality in the United States, little is known about the epidemiology of maternal complications associated with hospitalizations. Examination of complicating conditions associated with maternal hospitalizations can provide information on the types of conditions requiring hospitalized care. In the United States between 1991 and 1992, it was estimated that 18.0% of pregnancies were associated with non-delivery hospitalization, with disproportionate rates between black (28.1%) and white (17.2%) women [9]. This 18.0% hospitalization rate comprised 12.3% for obstetric conditions (18.3% among black women and 11.9% among white women), 4.4% for pregnancy losses (8.1% among black women and 3.9% among white women), and 1.3% for non-obstetric (medical or surgical) conditions (1.5% among black women and 1.3% among white women). The likelihood of pregnancy-associated hospitalizations in the United States declined between 1986–1987 and 1991–1992 [9,10].

More recent data about pregnancy-related hospitalization diagnoses can be found in the aggregated National Hospital Discharge Summary (NHDS) data for 2005–2009. These data are assembled by the National Center for Health Statistics (NCHS) of the US Centers for Disease Control and Prevention. The NHDS data are a survey of medical records from short-stay, non-federal hospitals in the United States, conducted annually since 1965. A detailed description of the survey and the database can be found in Ref. [11]. Briefly, for each hospital admission, the NHDS data include a primary and up to six secondary diagnoses, as well as up to four procedures performed for each hospitalization. These diagnoses and procedures are all coded based on the International Classification of Diseases (9th rev., clinical modification). We examined the rates (per 100 hospitalizations) of hospitalizations by indications (discharge diagnoses) during 2005–2009 in the United States, separately for delivery ($n = 20{,}862{,}592$) and non-delivery ($n = 2{,}225{,}243$) hospitalizations. We also examined the mean hospital length of stay (LOS; with a 95% confidence interval [CI]). Antepartum and postpartum hospitalizations were grouped as non-delivery hospitalizations.

During 2005–2009, nearly 8.8% of all hospitalizations were for hypertensive diseases associated with a delivery, and 9.1% were for hypertensive diseases not delivered (Table 1.1). Mean hospital LOS, an indirect measure of acuity for some illnesses, was higher for delivery-related than for non-delivery-related hospitalizations for hypertensive diseases. Hemorrhage, as the underlying reason for hospitalization (as either a primary or secondary diagnosis), occurred with similar frequencies for delivery- and non-delivery-related hospitalizations. Non-delivery hospitalizations for genitourinary infections occurred over nine times more frequently (12.3%) than delivery-related ones (1.3%), although the average LOS was shorter for non-delivery hospitalizations.

Hospitalizations for preterm labor occurred over twice as frequently for non-delivery hospitalizations (18.0%) than for delivery-related hospitalizations (8.0%). This is expected since many preterm labor patients are successfully treated for arrest of labor and some of these hospitalizations are for "false labor." Liver disorders were uncommonly associated with hospitalization. However, the mean hospital LOS for liver disorders that occurred with non-delivery hospitalizations was 6.6 days, compared with a mean LOS of 3.7 days if the liver condition was delivery related. Coagulation-related defects required 4.6 days of hospitalization if not related to delivery compared with a mean LOS of 3.7 days if the condition was delivery related. Hospitalizations for embolism-related complications were infrequent, but generally required extended hospital stays during delivery-related hospitalizations.

The top 10 conditions associated with hospital admissions, separately for delivery- and non-delivery-related events, are presented in Figure 1.1. The chief cause for hospitalization (either delivery or non-delivery related) was preterm labor. The second most frequent condition was hypertensive disease (8.8% for delivery related and 9.1% for non-delivery related), followed by anemia (6.8% vs. 8.5%). Hospitalizations for infection-related conditions occurred over twice more frequently for non-delivery episodes (14.0%) than delivery episodes (4.4%). In contrast, the proportion hospitalized for hemorrhage was similar for deliveries (4.3%) and non-deliveries (4.2%). These data provide important insights into the most common complications and conditions associated

Table 1.1 Rate (per 100 hospitalizations) of delivery- and non-delivery-related hospitalizations, and associated hospital length of stay by diagnosis: United States, 2005–2009.

	Delivery hospitalization (*n* = 20,862,592)		**Non-delivery hospitalization (*n* = 2,225,243)**	
Hospital admission diagnosis[a]	**Rate (%)**	**Mean LOS (95% CI)**	**Rate (%)**	**Mean LOS (95% CI)**
Hypertensive diseases				
Chronic hypertension	4.6	3.0 (3.0, 3.1)	4.6	2.6 (2.4, 2.9)
Preeclampsia/eclampsia	3.8	4.0 (3.8, 4.1)	3.9	3.0 (2.7, 3.4)
Chronic hypertension + preeclampsia	0.4	5.7 (5.0, 6.3)	0.7	3.9 (2.1, 5.8)
Hemorrhage-related				
Placental abruption	1.0	4.0 (3.5, 4.4)	0.7	4.3 (3.3, 5.3)
Placenta previa	0.6	4.5 (3.7, 5.3))	0.1	4.4 (2.9, 6.0)
Hemorrhage (undetermined etiology)	0.3	3.3 (2.9, 3.7)	1.4	2.0 (1.6, 2.4)
Vasa previa	<0.01	4.8 (2.6, 7.1)	–	–
Postpartum hemorrhage	2.5	2.8 (2.7, 3.0)	1.0	2.4 (1.9, 3.0)
Infection-related				
Viral infections (not malaria/rubella)	1.8	2.9 (2.7, 3.1)	1.5	4.2 (3.0, 5.4)
Genitourinary infections	1.3	3.8 (3.5, 4.1)	12.3	3.1 (2.7, 3.6)
Infection of the amniotic cavity	1.5	4.0 (3.7, 4.2)	0.5	4.1 (1.4, 6.9)
Anesthesia-related complications	<0.01	4.0 (3.0, 5.0)	–	–
Diabetes				
Preexisting diabetes	0.9	3.5 (3.3, 3.7)	3.2	3.6 (3.2, 4.0)
Gestational diabetes	5.0	3.0 (2.9, 3.1)	3.2	4.6 (3.5, 5.8)
Preterm labor	8.0	4.1 (3.9, 4.3)	18.0	3.3 (3.0, 3.7)
Maternal anemia	8.5	3.1 (3.0, 3.2)	6.8	3.6 (3.2, 4.0)
Drug dependency	<0.01	3.4 (2.9, 3.9)	0.8	4.9 (3.2, 6.7)
Renal disorders	0.2	3.2 (2.5, 4.0)	1.8	2.9 (2.2, 3.6)
Liver disorders	<0.01	3.7 (2.9, 4.6)	0.2	6.6 (2.8, 10.4)
Congenital cardiovascular disease	0.9	3.3 (3.1, 3.6)	1.6	3.7 (3.0, 4.5)
Thyroid disorders	0.4	2.5 (2.3, 2.7)	0.7	3.2 (2.1, 4.2)
Uterine tumors	0.9	3.4 (3.2, 3.7)	0.5	2.4 (1.8, 3.0)
Uterine rupture	0.1	3.6 (3.1, 4.1)	–	–
Postpartum coagulation defects	0.2	4.0 (3.1, 4.9)	<0.1	3.5 (2.6, 4.4)
Shock/hypotension	0.1	3.7 (2.8, 4.7)	0.3	4.6 (1.4, 7.9)
Acute renal failure	0.02	7.0 (3.0, 11.0)	0.02	3.4 (0.1, 6.7)
Embolism-related				
Amniotic fluid embolism	–		–	–
Blood clot embolism	0.01	6.0 (4.9, 7.2)	0.2	3.3 (2.3, 4.3)
Other pulmonary embolism	–	–	–	–

CI, Confidence interval; LOS; length of stay.

[a]The diagnoses associated with hospital admissions include both primary and secondary reasons for hospitalizations. Each admission may have had up to six associated diagnoses.

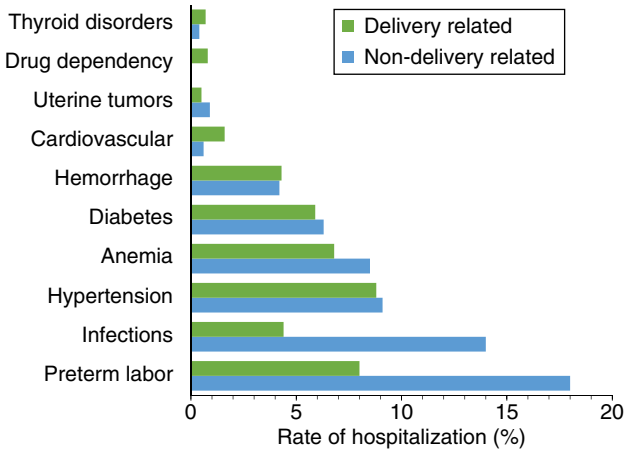

Figure 1.1 Ten leading causes of delivery-related and non-delivery-related maternal hospitalizations in the United States, 2005–2009.

with pregnancy hospitalization. The LOS data also give some indication of resource allocation needs. While this is important for understanding the epidemiology of illness in pregnancy, it does not allow a detailed examination of illness severity.

Maternal mortality

The national health promotion and disease prevention objectives of the Healthy People 2010 indicators specified a goal of no more than 3.3 maternal deaths per 100,000 live births in the United States [12]. The goal for maternal deaths among black women was set at no more than 5.0 per 100,000 live births. As of 2012 (the latest available statistics on maternal deaths in the United States), this objective remains elusive. The pregnancy-related maternal mortality ratio (PRMR) per 100,000 live births for the United States peaked at 17.8 in 2009 and 2011, with a modest decrease to 15.9 for 2012 [2], and with the ratio over threefold greater among black compared with white women [13]. Therefore, the Healthy People 2020 target of 11.4 maternal deaths per 100,000 live births also seems overly optimistic given the most recent trends. Several studies that have examined trends in maternal mortality statistics have concluded that a majority of pregnancy-related deaths (including those resulting from ectopic pregnancies, and some cases of infection and hemorrhage) are preventable [1,13–15]. However, maternal deaths due to other complications, such as pregnancy-induced hypertension, placenta previa, retained placenta, and thromboembolism, are considered by some as difficult to prevent [16,17]. Nevertheless, some mortality prevention should be possible, even in these situations.

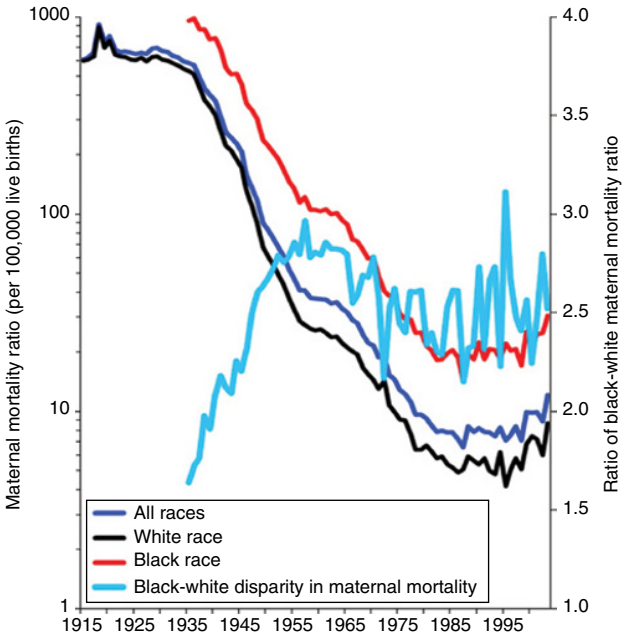

Figure 1.2 Trends in the maternal mortality ratio (number of maternal deaths per 100,000 live births) in the United States, 1915–2003, and the black-white disparity in the maternal mortality ratio. The term *ratio* is used instead of *rate* because the numerator includes some maternal deaths that were not related to live births and thus were not included in the denominator. *Source*: Figure reproduced from Ananth and D'Alton (2016) [2], with permission of the publisher.

The maternal mortality ratio (MMR) has undergone dramatic shifts over the past century (Figure 1.2). The MMR dropped precipitously from the turn of the 20th century from 600 per 100,000 live births in 1915 to approximately 40 per 100,000 live births in the mid-1960s to about 7 per 100,000 live births in the mid-1980s. Subsequently, the mortality ratio increased between 1987 (7.2 per 100,000 live births) and 1990 (10.0 per 100,000 live births). During the period 1991–1997, the mortality ratio further increased to 11.5 per 100,000 live births. The mortality ratio continued to increase to 17.8 in 2009 and 2011, which is a relative increase of nearly 250% over the nadir in the 1980s [2]. The reasons for the most recent increases are not clear, but they may be related to a combination of true increases and improved surveillance using better case-tracking methods. Of note, the high pregnancy mortality ratios in 2009 and 2011 may have been attributable, at least in part, to infection-related deaths during the influenza A H1N1 pandemic from 2009 to 2010 [13].

Several maternal risk factors have been examined in relation to maternal deaths. Women aged 35–39 years carry a 2.6-fold (95% CI, 2.2, 3.1) increased risk of maternal death, and those over 40 years are at a 5.9-fold (95% CI, 4.6, 7.7) increased risk. Black maternal race confers a relative risk of 3.7 (95% CI, 3.3, 4.1) for maternal death

Table 1.2 Pregnancy-related maternal deaths ($n = 3358$) by underlying cause: United Staets, 2006–2010.

	All outcomes		Pregnancy outcome					
Cause of death	**%**	**PRMR[a]**	**Live birth**	**Stillbirth**	**Ectopic**	**Abortion[b]**	**Undelivered**	**Unknown**
Embolism	14.9	2.4	16.4	10.8	0	12.2	16.1	10.9
Cardiovascular conditions	14.6	2.3	14.4	11.4	0	7.8	20.2	12.7
Infection	13.6	2.2	12.5	22.2	1.0	46.7	12.1	13.8
Non-cardiovascular conditions	12.8	2.0	10.4	18.4	0	5.6	22.4	10.9.
Cardiomyopathy	11.8	1.9	14.6	1.3	0	0	5.0	20.6
Hemorrhage	11.4	1.8	8.8	17.7	97.1	17.8	4.5	9.4
Hypertension	9.4	1.5	11.3	12.0	0	0	6.3	8.5
Cerebrovascular accidents	6.2	1.0	6.1	1.9	0	0	8.0	8.5
Anesthesia	0.7	0.1	0.7	0	1.0	7.8	0	0.3
Unknown	4.7	0.8	4.8	4.4	1.0	2.2	5.4	4.4
Total		16.0						

PRMR, Pregnancy-related mortality ratio.
[a]PRMR (condition-specific) per 100,000 live births for 20,959,533 live births from 2006 to 2010.
[b]Includes both spontaneous and induced abortions.
Source: Adapted from Creanga *et al.* [13].

compared with white women. Similarly, women without any prenatal care during pregnancy have an almost two-fold increased risk of death relative to those who received prenatal care [18]. Although these risks have been recognized for over 25 years, there has been little progress in reducing these risks.

The chief cause for a pregnancy-related maternal death depends on whether the pregnancy results in a live birth, stillbirth, ectopic pregnancy, abortion, or molar gestation (Table 1.2). For the period 2006–2010, embolism was the most common cause of overall pregnancy-related mortality (14.9%), leading to an overall PRMR for embolism of 2.4 per 100,000 live births. This is a significant change from the 1987–1990 data, when the most common cause (28.8%) of pregnancy-related mortality was the family of hypertensive diseases (PRMR 2.6). For the 2006–2010 period, the next most common etiologies were cardiovascular diseases (PRMR 2.3) and infection-related deaths (PRMR 2.2). Among ectopic pregnancies, the chief cause of death was hemorrhage (97.1%). Infections were the leading cause of stillbirth-related (22.2%) and abortion-related (46.7%) maternal deaths [13].

Understanding the epidemiology of pregnancy-related deaths is essential to targeting specific interventions. Improved population-based surveillance through targeted reviews of all pregnancy-related deaths, as well as additional research to understand the causes of maternal deaths by indication, will help in achieving the Healthy People 2020 targets for reduction in maternal mortality.

Perinatal mortality

Perinatal mortality, defined by the World Health Organization as fetal deaths plus deaths of live-born infants within the first 28 days, is an important indicator of population health. Examination of the maternal conditions related to perinatal mortality can provide further information on the association and impact of these conditions on pregnancy outcomes. Table 1.3 shows the results of our examination of perinatal mortality rates among singleton and multiple births (twins, triplets, and quadruplets) by gestational age and high-risk conditions. The study population comprises all births in the United States that occurred in 1995–1998. Data were derived from the national linked birth/infant death files, assembled by the National Center for Health Statistics of the Centers for Disease Control and Prevention [19]. Gestational age was predominantly based on the date of the last menstrual period [20], and it was grouped as 20–27, 28–32, 33–36, and ≥37 weeks. Perinatal mortality rates were assessed for hypertension (chronic hypertension, pregnancy-induced hypertension, and eclampsia), hemorrhage (placental abruption, placenta previa, and uterine bleeding of undetermined etiology), diabetes (preexisting and gestational diabetes), and small-for-gestational-age (SGA) births (defined as birth weight below the 10th centile for gestational age). We derived norms for the 10th centile birth weight for singleton and multiple births from the

Table 1.3 Perinatal mortality rates among singleton and multiple gestations by gestational age and high-risk conditions: United States, 1995–1998.

	20–27 weeks		28–32 weeks		33–36 weeks		≥37 weeks	
High-risk conditions	**PMR**	**Relative risk[a] (95% CI)**	**PMR**	**Relative risk[a] (95% CI)**	**PMR**	**Relative risk[a] (95% CI)**	**PMR**	**Relative risk[a] `(95% CI)**
Singletons								
Number of births	*n* = 103,755		*n* = 352,291		*n* = 1,072,784		*n* = 13,440,671	
Hypertension[b]	200.4	0.6 (0.5, 0.7)	53.1	0.6 (0.5, 0.6)	13.5	0.6 (0.5, 0.7)	3.6	1.3 (0.5, 0.7)
Hemorrhage[c]	308.9	1.1 (1.0, 1.2)	73.1	1.4 (1.3, 1.5)	19.9	1.6 (1.5, 1.7)	3.6	1.6 (1.5, 1.7)
Diabetes	287.0	1.0 (0.9, 1.1)	60.8	1.2 (1.1, 1.3)	19.5	1.8 (1.7, 1.9)	5.0	2.3 (2.1, 2.4)
SGA	467.4	2.3 (2.1, 2.5)	196.3	6.2 (6.0, 6.4)	56.3	7.8 (7.5, 8.1)	9.1	5.5 (5.4, 5.7)
No complications[d]	297.6	1.0 (Referent)	38.8	1.0 (Referent)	7.0	1.0 (Referent)	1.5	1.0 (Referent)
Multiples								
Number of births	*n* = 23,055		*n* = 76,329		*n* = 147,627		*n* = 187,109	
Hypertension[b]	183.5	0.7 (0.6, 0.8)	21.4	0.5 (0.4, 0.6)	5.3	0.6 (0.5, 0.7)	4.9	0.8 (0.6, 1.1)
Hemorrhage[c]	251.6	1.0 (0.9, 1.1)	36.6	1.1 (1.0, 1.3)	9.6	1.2 (1.0, 1.4)	6.7	1.3 (1.1, 1.5)
Diabetes	214.9	0.8 (0.7, 1.1)	28.7	0.9 (0.7, 1.2)	9.7	1.3 (1.0, 1.7)	5.9	1.2 (0.9, 1.7)
SGA	394.5	2.0 (1.6, 2.4)	133.4	6.8 (6.3, 7.4)	36.8	7.5 (6.6, 8.4)	24.9	8.6 (7.6, 9.7)
No complications[d]	251.1	1.0 (Referent)	23.4	1.0 (Referent)	5.2	1.0 (Referent)	2.8	1.0 (Referent)

CI, Confidence interval; PMR, perinatal mortality rate per 1000 births; SGA, small-for-gestational-age births.
[a]Relative risk for each high-risk condition was adjusted for all other high-risk conditions shown in the table.
[b]Hypertension includes chronic hypertension, pregnancy-induced hypertension, and eclampsia.
[c]Hemorrhage includes placental abruption, placenta previa, and uterine bleeding of undermined etiology.
[d]No complications include those who did not have any complications listed in the table.

corresponding singleton and multiple births that occurred in 1995–1998 in the United States. Finally, relative risks (with 95% CIs) for perinatal death by each high-risk condition were derived from multivariable logistic regression models after adjusting for all other high-risk conditions.

Perinatal mortality rates progressively decline, among both singleton and multiple births, for each high-risk condition with increasing gestational age (Table 1.3). Among singleton and multiple gestations, with the exception of SGA births, mortality rates were generally higher for each high-risk condition, relative to the no complications group. Infants delivered small for their gestational age carried the highest risk of dying during the perinatal period compared with those born to mothers without complications. Among singleton births, the relative risks for perinatal death for SGA infants were 2.3, 6.2, 7.8, and 5.5 for those delivered at 20–27 weeks, 28–32 weeks, 33–36 weeks, and term, respectively. Among multiple births, these relative risks were similar at 2.0, 6.8, 7.5, and 8.6, respectively, for each of the four gestational age categories.

Pregnancy-related ICU admissions

Evaluation of obstetric admissions to ICUs may be one of the better ways to approach surveillance of critical illnesses in pregnancy. Unfortunately, there are no publicly available population-based databases for obstetric admissions to an ICU that provide sufficiently detailed information to allow in-depth study of these conditions. Therefore, it is reasonable to examine descriptive case series for information on these conditions. We reviewed 66 studies published between 1990 and 2016 involving approximately 7,616,710 deliveries and found an overall obstetric-related admission rate to an ICU of 0.49% (range, 0.07–1.69%) (Table 1.4).

Some of the variation in the rates among studies may be explained by the nature of the populations studied. Hospitals that are tertiary referral centers for large catchment areas typically receive a more concentrated high-risk population. These facilities would be expected to have higher rates of obstetric admissions to an ICU. However, most of these studies provided sufficient data to allow the exclusion of patients transported from