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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 Semmelweis 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 are often 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.

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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 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-related 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 nonobstetric (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, nonfederal hospitals in the United States, conducted annually since 1965 [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-related (n = 20,862,592) and non-delivery-related (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-related 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-related 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-related hospitalizations.

Hospitalizations for preterm labor occurred over twice as frequently for non-delivery-related 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-related 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

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-related hospitalization (n = 20,862,592)		Non-delivery-related 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)
Superimposed 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.

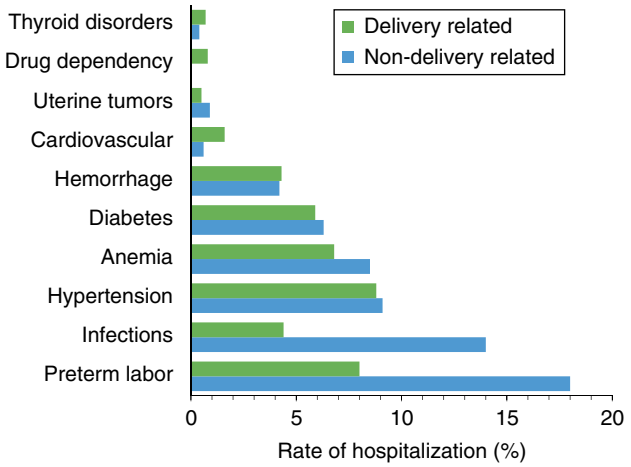

Figure 1.1 Ten leading causes of delivery- and non-delivery-related maternal hospitalizations in the United States, 2005–2009.

non-delivery related), followed by anemia (6.8% vs. 8.5%). Hospitalizations for infection-related conditions occurred over twice more frequently for non-delivery-related episodes (14.0%) than delivery episodes (4.4%). In contrast, the proportion hospitalized for hemorrhage was similar for deliveries (4.3%) and nondeliveries (4.2%). These data provide important insights into the most common complications and conditions associated 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 2020, 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].

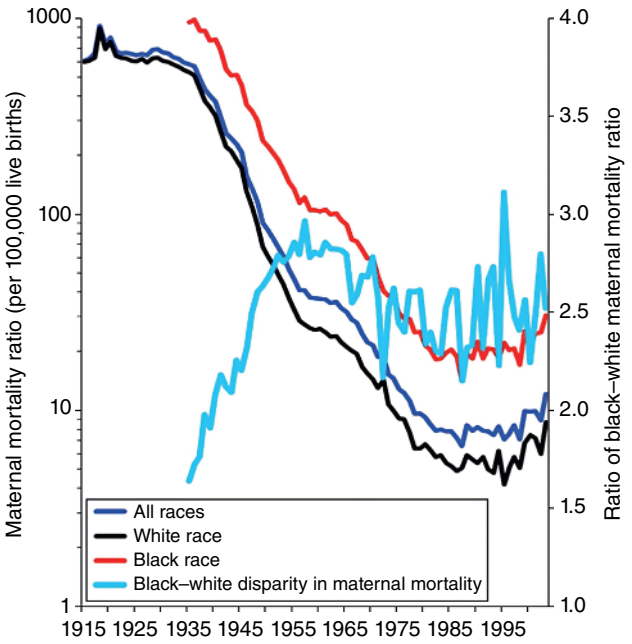

Figure 1.2 Trends in the maternal mortality ratio (number of maternal deaths per 100,000 live births) in the United States, 1915–2003, and the black–white disparity in the maternal mortality ratio. The term ratio is used instead of rate because the numerator includes some maternal deaths that were not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

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.

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 MMR 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, to more recent statistic of 23.8 per 100,000 live births in 2020. 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].

Table 1.2 Pregnancy-related maternal deaths (n = 3358) by underlying cause: United States, 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
Noncardiovascular 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].

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 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 NCHS 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

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.

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 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 76 studies published between 1990 and 2021 involving approximately 15,233,420 deliveries and found an overall obstetric-related admission rate to an ICU of 1.40% (range, 0.07–3.97%) (Table 1.4). We excluded studies that reported ICU admissions during the recent severe acute respiratory syndrome coronavirus 2 (COVID-19) pandemic due to the disproportionate impact of the virus on maternal critical illness.

Table 1.4 Obstetric admission rates to an ICU and corresponding maternal mortality rates from 76 studies from 1990 to 2021.

Reference	Years	Location	Total deliveries	Maternal ICU admissions	Maternal deaths per ICU admissions	Fetal/neonatal deaths per ICU admission
Mabie and Sibai (1990) [24]	1986–1989	USA	22,651	200 (0.88%)	7 (3.5%)	–
Kilpatrick and Matthay (1992) [25]	1985–1990	USA	8000[a]	32 (0.4%)	4 (12.0%)	6 (18.8%)
Collop and Sahn (1993) [26]	1988–1991	USA	–	20 (–)	4 (20.0%)	7 (35.0%)
El-Solh and Grant (1996) [27]	1989–1995	USA	–	96 (–)	10/93 (10.8%)	10 (10.4%)
Monoco *et al.* (1993) [28]	1983–1990	USA	15,323	38 (0.25%)	7 (18.4%)	4 (10.5%)
Panchal *et al.* (2000) [23]	1984–1997	USA	822,591	1023 (0.12%)	34 (3.3%)	–
Afessa *et al.* (2001) [29]	1991–1998	USA	–	78 (–)	2 (2.7%)	13 (16.7%)
Gilbert *et al.* (2000) [30]	1991–1998	USA	49,349	233 (0.47%)	8 (3.4%)	–
Hogg *et al.* (2000) [31]	1989–1997	USA	30,405	172 (0.57%)	23 (13.4%)	2 (1.2%)
Munnur *et al.* (2005) [32]	1992–2001	USA	58,000	174 (0.3%)	4 (2.3%)	23 (13.2%)
Muench *et al.* (2008) [33]	24 months	USA	2565	34 (1.33%)	–	–
Maan *et al.* (2009) [34]	1997–2005	USA	1,004,116	15,447 (1.54%)	–	–
Small *et al.* (2012) [35]	2005–2011	USA	19,575	94 (0.48%)	5 (5.3%)	–
Orsini *et al.* (2012) [36]	2009–2012	USA	4715	19 (0.40%)	–	–
Wanderer *et al.* (2013) [37]	1999–2008	USA	698,379	2927 (0.42%)	53 (1.8%)	–
Thakur *et al.* (2016) [38]	2006–2010	USA	27,295	69 (0.25%)	3 (4.3%)	–
Oud *et al.* (2017) [21]	2001–2010	USA	4,060,659	158,410 (3.90%)	414 (0.3%)	3009 (1.9%)
Mahutte *et al.* (1999) [4]	1991–1997	Canada	44,340	131 (0.30%)	3 (2.3%)	–
Lapinsky *et al.* (1997) [39]	1997	Canada	25,000[a]	65 (0.26%)	0	7 (10.8%)
Baskett and Sternadel (1998) [6]	1980–1993	Canada	76,119	55 (0.07%)	2 (3.6%)	–
Rios *et al.* (2012) [40]	2008–2010	Argentina	30,053	242 (0.81%)	5 (2.1%)	23 (9.5%)
Vasquez *et al.* (2007) [41]	1998–2005	Argentina	23,044	161 (0.70%)	11 (6.8%)	18 (11.2%)
Bandeira *et al.* (2014) [42]	2007–2009	Brazil	–	299 (-)	14 (4.7%)	–
Paternina-Caicedo *et al.* (2015) [43]	2006–2011	Columbia	50,897	724 (1.42%)	31 (4.3%)	–
Hazelgrove *et al.* (2001) [5]	1994–1996	England	122,850	210 (0.17%)	7 (3.3%)	40/200 (20.0%)
DeMello and Restall (1990) [44]	1985–1989	England	9425	13 (0.14%)	0	–
Selo-Ojeme *et al.* (2005) [45]	1993–2003	England	31,097	22 (0.11%)	1 (4.5%)	1 (4.5%)
Ryan *et al.* (2000) [46]	1996–1998	Ireland	26,164	17 (0.07%)	0	–
Bouvier-Colle *et al.* (1996) [47]	1991	France	140,000[a]	435 (0.31%)	22 (5.1%)	58 (13.3%)
Koeberle *et al.* (2000) [48]	1986–1996	France	27,059[a]	46 (0.17%)	2 (4.3%)	–
Lelong *et al.* (2013) [49]	1997–2006	France	–	96 (–)	2 (2.1%)	20 (20.8%)
Chantry *et al.* (2015) [50]	2006–2009	France	3,262,526	11,824 (0.36%)	154 (1.3 %)	–
Barry *et al.* (2019) [22]	2010–2014	France	4,030,409	16,011 (3.97%)	208 (1.3%)	–

(*Continued*)

Table 1.4 (Continued)

Reference	Years	Location	Total deliveries	Maternal ICU admissions	Maternal deaths per ICU admissions	Fetal/neonatal deaths per ICU admission
Farr *et al.* (2017) [51]	1996–2003, 2011–2014	Austria	37,236	238 (0.64%)	12 (5.0%)	–
De Greve *et al.* (2016) [52]	2012	Belgium	–	190 (-)	-	–
Loverro *et al.* (2001) [53]	1987–1998	Italy	23,694	41 (0.17%)	2 (4.9%)	5 (12.2%)
Keizer *et al.* (2006) [54]	1990–2001	Netherlands	18,581	142 (0.76%)	7 (4.9%)	35 (24.6%)
Zwart *et al.* (2010) [55]	2004–2006	Netherlands	371,021	847 (0.23%)	29 (3.4%)	–
Heinonen *et al.* (2002) [56]	1993–2000	Finland	23,404	22 (0.14%)	1 (4.5%)	–
Seppänen *et al.* (2016) [57]	2007–2011	Finland	–	291 (-)	1 (0.3%)	–
Krawczyk *et al.* (2021) [58]	2007–2014	Poland	21,180[a]	266 (1.3%)	4 (1.5%)	–
Demirkiran *et al.* (2003) [59]	1995–2000	Turkey	14,045[a]	125 (0.89%)	13 (9.6%)	–
Yuvaci *et al.* (2018) [60]	2014–2015	Turkey	16,728	68 (0.41%)	2 (2.9%)	–
Munnur *et al.* (2005) [32]	1992–2001	India	157,694	754 (0.48%)	189 (25%)	368 (48.81%)
Gupta *et al.* (2011) [61]	2009–2010	India	16,756	24 (0.14%)	10 (41.7%)	–
Ramachandra *et al.* (2013) [62]	2005–2011	India	16,804	65 (0.39%)	22 (33.8%)	–
Chawla *et al.* (2013) [63]	2007–2010	India	6592	35 (0.53%)	10 (28.6%)	–
Ashraf *et al.* (2014) [64]	2012–2013	India	14,474	55 (0.38%)	7 (12.7%)	–
Gombar *et al.* (2014) [65]	2007–2012	India	21,943	144 (0.66%)	42 (29.2%)	32 (22.2%)
Jain *et al.* (2016) [66]	2010–2011	India	15,775	90 (0.57%)	30 (33.3%)	–
Murki *et al.* (2016) [67]	–	India	1127	19 (1.69%)	–	–
Rathod *et al.* (2016) [68]	2010–2013	India	61,615	765 (1.24%)	119 (15.6%)	–
Bibi *et al.* (2008) [69]	2006	Pakistan	2224	30 (1.35%)	10 (33.3%)	13 (43.3%)
Thakur *et al.* (2015) [70]	2012	Nepal	–	192 (–)	24 (12.5%)	–
Shrestha *et al.* (2018) [71]	2012–2017	Nepal	9524	80 (0.84%)	4 (5.0%)	–
Okafor and Aniebue (2004) [72]	1997–2002	Nigeria	6544	18 (0.28%)	6 (33%)	–
Adeniran *et al.* (2015) [73]	2010–2013	Nigeria	–	90 (%)	41 (45.6%)	–
Platteau *et al.* (1997) [74]	1992	South Africa	–	80 (-)	17 (21.3%)	39 (48.6%)
Cohen *et al.* (2000) [75]	1994–1998	Israel	19,474	46 (0.24%)	1 (2.3%)	10 (21.7%)
Lewinsohn *et al.* (1994) [76]	8 years	Israel	–	58 (-)	4 (6.9%)	–
Lataifeh *et al.* (2010) [77]	2002–2008	Jordan	11,665	43 (0.37%)	3 (7.0%)	8 (18.6%)
Richa *et al.* (2008) [78]	1998–2005	Lebanon	–	15 (-)	5 (33.3%)	–
Al-Suleiman *et al.* (2006) [79]	1992–2004	Saudi Arabia	29,432	64 (0.22%)	6 (9.4%)	8/55 (14.5%)
Aldawood *et al.* (2011) [80]	1999–2009	Saudi Arabia	–	75 (0.15%)	6 (8.0%)	–
Mirghani *et al.* (2004) [81]	1997–2002	UAE	23,383	60 (0.26%)	2 (3.3%)	–

Table 1.4 (Continued)

Reference	Years	Location	Total deliveries	Maternal ICU admissions	Maternal deaths per ICU admissions	Fetal/neonatal deaths per ICU admission
Tang *et al.* (1997) [82]	1988–1995	China	39,350	49 (0.12%)	2 (4.1%)	4 (8.2%)
Ng *et al.* (1992) [83]	1985–1990	China	16,264	37 (0.22%)	2 (5.4%)	–
Leung *et al.* (2010) [84]	1998–2007	China	37,505	50 (0.13%)	3 (6.0%)	4 (8.0%)
Yuqi *et al.* (2017) [85]	2009–2016	China	304,375[a]	487	9 (1.8%)	49 (10.1%)
Zhao *et al.* (2018) [86]	2008–2016	China	87,850	491 (0.56%)	10 (2.0%)	45 (9.2%)
Cheng and Raman (2003) [87]	1994–1999	Singapore	13,438	39 (0.28%)	2 (5.1%)	–
Ng *et al.* (2014) [88]	2006–2010	Hong Kong	28,976	67 (0.23%)	2 (3.0 %)	3 (4.5%)
Stephens (1991) [89]	1979–1989	Australia	61,435	126 (0.21%)	1 (0.8%)	–
Crozier *et al.* (2011) [90]	2006–2008	Australia	8151	31 (0.38%)	1 (3.2%)	–
Paxton *et al.* (2014) [91]	2007–2009	Australia	21,101	249 (1.18%)	–	19 (7.6%)
Sadler *et al.* (2013) [92]	2010–2011	New Zealand	15,217	42 (0.28%)	0	–
Summary (pooled data)	–	–	15,233,420	214,537 (1.40%)	1701/200,156 (0.9%)	3883/162,969 (2.4%)

ICU, Intensive care unit; PP, postpartum; UAE, United Arab Emirates; USA, United States; – indicates data not provided or unable to be calculated (these values are excluded from summaries of columns).
[a] Estimate calculated based on data in paper.

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. The highest rates of ICU admissions were found in two population-based studies from Texas (3.9%) and France (3.97%), which also had the largest number of subjects included. Since these included hospitals at all levels, these studies may be more representative of an unbiased ICU admission rate [21,22]. Community-oriented facilities are probably less likely to care for critically ill obstetric patients unless the illnesses develop so acutely that they would preclude transport to a higher-level facility. One of the largest studies of pregnancy-related ICU admissions involved 37 maternity hospitals in Maryland and included hospitals at all care levels [23]. This study found a nearly 30% lower admission rate to ICUs for obstetric patients from community hospitals compared with major teaching hospitals. Another source of variation was the different criteria for admission to the ICU used at different institutions. Finally, there were major differences in the inclusion criteria used for these studies that contribute significantly to the variability in reported ICU utilization rates.

Reported maternal mortality for critically ill obstetric patients admitted to an ICU is approximately 0.9% (Table 1.4). This reflects the true seriousness of the illnesses of these women. The wide range of mortality of 0–46% is due to many factors. Most of the studies were small, and just a few deaths may affect rates significantly. Conversely, the three largest studies that represented approximately 75% of the overall deliveries of the 76 studies had lower maternal mortality of 0.3–1.3%, which lowers the overall pooled mortality from all of the published studies [50,21,22]. The populations studied also differ in underlying health status. Reports from less developed countries had much higher mortality. The time period of the study can also have an impact. In general, earlier studies had higher maternal mortality. These earlier studies represent the early stages of development of care mechanisms for critically ill obstetric patients. They probably reflect part of the "learning curve" of critical care obstetrics, as well as differences in available technology [93]. Regardless of this, the mortality from these ICU admissions is several orders of magnitude higher than the general US population MMR of 16 per 100,000 live births [13]. Therefore, these cases are a good representation of an obstetric population with critical illnesses.

Illnesses responsible for obstetric ICU admissions

Examination of the conditions leading to obstetric ICU admissions provides some insight into the nature of illnesses requiring critical care related to pregnancy. Data were pooled from 59 published studies with 198,940

Table 1.5 Complications primarily responsible for admission to the intensive care unit for obstetric patients.

Category	Category examples	n	%
Hypertensive diseases	Eclampsia, preeclampsia, HELLP syndrome, hypertensive crisis	47,572	23.9
Hemorrhage	Shock, abruption, previa, postpartum hemorrhage, accreta, uterine rupture	24,066	12.1
Cardiac	Valvular disease, arrhythmia, cardiomyopathy, infarction	16,015	8.1
Sepsis/infection	Chorioamnionitis, pyelonephritis, malaria, hepatitis, meningitis, miscellaneous	5153	2.3
Pulmonary	Pulmonary edema, pneumonia, adult respiratory distress syndrome, asthma, thromboembolic diseases, amniotic fluid embolus, tuberculosis	4428	2.2
Central nervous system	Intracranial hemorrhage, noneclamptic seizure, arteriovenous malformation	2662	1.3
Gastrointestinal	Pancreatitis, acute fatty liver of pregnancy, inflammatory bowel disease, gallbladder disease	2405	1.2
Anesthesia complication	Allergic reaction, failed intubation, high spinal	501	0.3
Renal	Renal failure	194	0.1
Endocrine	Diabetic ketoacidosis, thyroid storm	70	0.04
Hematologic	Thrombotic thrombocytopenic purpura, sickle cell disease, disseminated intravascular coagulation, aspiration	53	0.03
Malignancy	Various	44	0.02
Other	Insufficient information to assign to specific organ system, but included anaphylaxis, trauma, neurologic disorders, drug, and overdose/poisoning	7804	3.9

Source: Data summarized from 59 published studies of 198,940 cases [4–6,21,22,24–28,29,32,35–43,46,48–50,52–56,58–64,68–72,74–79,81–86,88–92].

subjects that provided sufficient details about the primary indication for the ICU admission (Table 1.5). It is no surprise that obstetric hypertensive diseases and hemorrhage were responsible for 40% of the primary admitting diagnoses. Specific body system dysfunction was responsible for the majority of the remaining admissions. Of those, cardiac, infectious, and pulmonary complications had the greatest frequency. A subset was examined of 33 studies with information on 3838 ICU patients regarding whether the primary admitting diagnosis was related to an obstetric complication or a medical complication [4,24,25,27,28,38,40–42,46,48,52–54,57,59,61–64,70,79,81–84,87,88,91,92,94]. The pooled data indicate that approximately 75.3% (n = 1889) were classified as obstetric related and 24.7% (n = 949) were due to medical complications, a 3:1 ratio. These data clearly highlight the complex nature of obstetric critical care illnesses and provide support for a multidisciplinary approach to management since these women are quite ill with a variety of diseases.

Causes of mortality in obstetric ICU admissions

When specific causes of mortality for the obstetric ICU admissions were reviewed, 47 studies gave sufficient data to assign a primary etiology for maternal death (Table 1.6). Of a total of 707 maternal deaths, over 56% were related to complications of hemorrhage, hypertensive diseases, and infection. Other deaths were most related to complications of the pulmonary, cardiac, and central nervous systems; malignancy; and gastrointestinal complications. More importantly, despite an identified primary etiology for the maternal deaths, most cases were associated with multiorgan dysfunction, which again emphasizes the complex condition of these critically ill women. Over 40% of all maternal deaths in the ICU were directly related to obstetric conditions (mainly hypertensive diseases and hemorrhage, with additional minor contributions from amniotic fluid embolism and acute fatty liver of pregnancy). The remaining deaths were due to a variety of other conditions (Table 1.6).

Perinatal loss with obstetric ICU admissions

When considering the implications of critical illness for obstetric patients, the focus is usually on the mother. However, it is important to reemphasize that many of these conditions may also have a significant impact on fetal and neonatal outcomes. There is surprisingly little detailed information available on these perinatal outcomes in pregnancies complicated by critical illnesses. However, there are data on perinatal outcomes based on specific disease conditions. Maternal high-risk conditions associated with perinatal mortality in the United States are presented in Table 1.3. However, these data do not separate outcomes by severity of maternal illness. We were able to identify 30 studies that provided information

Table 1.6 Distribution of specified primary causes of mortality in 536 obstetric admissions to intensive care units reported in 47 studies.

Specified etiology	Number	%
Hemorrhage	154	21.8
Hypertensive diseases	135	19.1
Infection	110	15.6
Pulmonary	91	12.9
Cardiac	81	11.5
Central nervous system	58	8.2
Malignancy	11	2.1
Gastrointestinal	13	1.8
Anesthesia complication	5	0.9
Hematologic	3	0.6
Poisoning/overdose	2	0.4
Trauma	1	0.2
Unspecified/Other	46	6.5

Source: Data from [4–6,24–28,29,32,35–42,46,48–50,53–56,59,61,62,64,72–77,79–83,89,43,68,85,86].

on fetal or neonatal mortality rates for obstetric admissions to the ICU (Table 1.4). Fetal and/or neonatal deaths were identified in 3883 of the pooled 162,969 cases, resulting in an overall mortality of 2.4%. Reported rates ranged from 1.2% to 48.8%. Removing the largest study from Texas that accounted for 3009 of the fetal deaths from 158,410 of the ICU admissions [85] would give a reported rate of 19.2%. These proportions do not reflect a true perinatal mortality rate since some of the losses may have occurred before 20 weeks of gestation. In addition, the denominator includes a number of previable and postpartum admissions for conditions not expected to affect fetal or neonatal mortality. Nevertheless, the high loss rate highlights the importance of considering the fetus when managing critical illnesses in pregnancy.

Summary

In summary, understanding the nature of critical illness in pregnancy is an important and evolving process. Assessment of pregnancy-related critical illness requires more than mortality reviews. Our currently available tools and databases for examining these patients need improvement. Reports of critically ill women admitted to the ICU have further refined our understanding of these diseases. Targeted surveillance of obstetric ICU admissions is needed to identify variations in care and disease that may affect management. As our understanding of these conditions continues to mature, we will hopefully gain greater insight into the specific nature of these conditions that will lead to improved prevention strategies and better therapies for the diseases when they occur. In our view, these data will improve our ability to plan and allocate the necessary resources to adequately care for these often complex and severe illnesses.

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References

1 Khan KS, Wojdyla D, Say L, *et al*. WHO analysis of causes of maternal death: A systematic review. Lancet. 2006;367:1066–1074.
2 Ananth CV, D'Alton ME. Maternal mortality and serious morbidity in New York: Recognizing the burden of the problem. Semin Perinatol. 2016;40:79–80.
3 Harmer M. Maternal mortality: Is it still relevant? Anaesthesia. 1997;52:99–100.
4 Mahutte NG, Murphy-Kaulbeck L, Le Q, *et al*. Obstetrics admissions to the intensive care unit. Obstet Gynecol. 1999;94:263–266.
5 Hazelgrove JF, Price C, Pappachan GD. Multicenter study of obstetric admissions to 14 intensive care units in southern England. Crit Care Med. 2001;29:770–775.
6 Baskett TF, Sternadel J. Maternal intensive care and near-miss mortality in obstetrics. Br J Obstet Gynaecol. 1998;105:981–984.
7 Mantel GD, Buchmann E, Rees H, Pattinson RC. Severe acute maternal morbidity: A pilot study of a definition for a near-miss. Br J Obstet Gynaecol. 1998;105:985–990.
8 Scott CL, Chavez GF, Atrash HK, *et al*. Hospitalizations for severe complications of pregnancy, 1987–1992. Obstet Gynecol. 1997;90:225–229.
9 Bennett TA, Kotelchuck M, Cox CE, *et al*. Pregnancy-associated hospitalizations in the United States in 1991 and 1992: A comprehensive review of maternal morbidity. Am J Obstet Gynecol. 1998;178:346–354.

10 Franks AL, Kendrick JS, Olson DR, *et al*. Hospitalization for pregnancy complications, United States, 1986 and 1987. Am J Obstet Gynecol. 1992;166:1339–1344.

11 National Center for Health Statistics. Design and operation of the National Hospital Discharge Survey: 1988 redesign. Series I. Programs and collection procedures. DHHS Publication 2001-1315, no. 39. Washington, DC: US Department of Health and Human Services, CDC; 2000.

12 National Center for Health Statistics. Healthy people 2010 final review. Hyattsville, MD: US Department of Health and Human Services, Public Health Service, CDC; 2010. Hospital, Mineola, NY.

13 Creanga AA, Berg CJ, Syverson C, *et al*. Pregnancy-related mortality in the United States, 2006–2010. Obstet Gynecol. 2015;125:5–12.

14 Sachs BP, Brown DA, Driscoll SG, *et al*. Maternal mortality in Massachusetts: Trends and prevention. N Engl J Med. 1987;316:667–672.

15 Syverson CJ, Chavkin W, Atrash HK, *et al*. Pregnancy-related mortality in New York City, 1980 to 1984: Causes of death and associated factors. Am J Obstet Gynecol. 1991;164:603–608.

16 Mertz KJ, Parker AL, Halpin GJ. Pregnancy-related mortality in New Jersey, 1975–1989. Am J Public Health. 1992;82:1085–1088.

17 Berg CJ, Atrash HK, Koonin LM, Tucker M. Pregnancy-related mortality in the United States, 1987–1990. Obstet Gynecol. 1996;88:161–167.

18 Atrash HK, Rowley D, Hogue CJ. Maternal and perinatal mortality. Curr Opin Obstet Gynecol. 1992;4:61–71.

19 MacDorman MF, Atkinson JO. Infant mortality statistics from the linked birth/infant death data set – 1995 period data. Mon Vital Stat Rep. 1998 Feb 26;46(6 Suppl. 2):1–22.

20 Taffel S, Johnson D, Heuser R. A method of imputing length of gestation on birth certificates. Vital Health Stat 2. 1982 May;93:1–11.

21 Oud L. Epidemiology of pregnancy-associated ICU utilization in Texas: 2001–2010. J Clin Med Res. 2017;9:143–153.

22 Barry Y, Deneux-Tharaux C, Saucedo M, *et al*. Maternal admissions to intensive care units in France: Trends in rates, causes and severity from 2010 to 2014. Anaesth Crit Care Pain Med. 2019;38:363–369.

23 Panchal S, Arria AM, Harris AP. Intensive care utilization during hospital admission for delivery: Prevalence, risk factors, and outcomes in a statewide population. Anesthesiology. 2000;92:1537–1544.

24 Mabie WC, Sibai BM. Treatment in an obstetric intensive care unit. Am J Obstet Gynecol. 1990;162:1–4.

25 Kilpatrick SJ, Matthay MA. Obstetric patients requiring critical care: A five-year review. Chest. 1992;101: 1407–1412.

26 Collop NA, Sahn SA. Critical illness in pregnancy: An analysis of 20 patients admitted to a medical intensive care unit. Chest. 1993;103:1548–1552.

27 El-Solh AA, Grant BJ. A comparison of severity of illness scoring systems for critically ill obstetrics patients. Chest. 1996;110:1299–1304.

28 Monoco TJ, Spielman FJ, Katz VL. Pregnant patients in the intensive care unit: A descriptive analysis. South Med J. 1993;86:414–417.

29 Afessa B, Green B, Delke I, Koch K. Systemic inflammatory response syndrome, organ failure, and outcome in critically ill obstetric patients treated in an ICU. Chest. 2001;120:1271–1277.

30 Gilbert TT, Hardie R, Martin A, *et al*. (Abstract). Obstetric admissions to the intensive care unit: Demographic and severity of illness analysis. Am J Respir Crit Care Med. 2000;161:A236.

31 Hogg B, Hauth JC, Kimberlin D, *et al*. Intensive care unit utilization during pregnancy. Obstet Gynecol. 2000;95(Suppl.):62S.

32 Munnur U, Karnad DR, Bandi VDP, *et al*. Critically ill obstetric patients in an American and an Indian public hospital: Comparison of case-mix, organ dysfunction, intensive care requirements, and outcomes. Intensive Care Med. 2005;31:1087–1094.

33 Muench MV, Baschat AA, Malinow AM, Mighty HE. Analysis of disease in the obstetric intensive care unit at a university referral center: A 24-month review of prospective data. J Reprod Med. 2008;53:914–920.

34 Maan I, Puri I, Jain NJ, *et al*. Characteristics of obstetric intensive care unit admissions in New Jersey. J Matern Fetal Neonatal Med. 2009;22:785–790.

35 Small MJ, James AH, Kershaw T, *et al*. Near-miss maternal mortality: Cardiac dysfunction as the principal cause of obstetric intensive care unit admissions. Obstet Gynecol. 2012;119:250–255.

36 Orsini J, Butala A, Diaz L, *et al*. Clinical profile of obstetric patients admitted to the medical-surgical intensive care unit (MSICU) of an inner-city hospital in New York. J Clin Med Res. 2012;4:314–317.

37 Wanderer JP, Leffert LR, Mhyre JM, *et al*. Epidemiology of obstetric-related ICU admissions in Maryland: 1999–2008. Crit Care Med. 2013;41:1844–1852.

38 Thakur M, Gonik B, Gill N, *et al*. Intensive care admissions in pregnancy: Analysis of a level of support scoring system. Matern Child Health J. 2016;20:106–113.

39 Lapinsky SE, Kruczynski K, Seaward GR, *et al*. Critical care management of the obstetric patient. Can J Anaesth. 1997;44:325–329.

40 Rios FG, Risso-Vázquez A, Alvarez J, *et al*. Clinical characteristics and outcomes of obstetric patients admitted to the intensive care unit. Int J Gynaecol Obstet. 2012;119:136–140.

41 Vasquez DN, Estenssoro E, Canales HS, *et al*. Clinical characteristics and outcomes of obstetric patients requiring ICU admission. Chest. 2007;131:718–724.

42 Bandeira AR, Rezende CA, Reis ZS, *et al*. Epidemiologic profile, survival, and maternal prognosis factors among women at an obstetric intensive care unit. Int J Gynaecol Obstet. 2014;124:63–66.

43 Paternina-Caicedo AJ, Rojas-Suarez JA, Dueñas-Castel C, *et al*. Mortality risk prediction with an updated Acute Physiology and Chronic Health Evaluation II score in critically ill obstetric patients: A cohort study. J Intensive Care Med. 2015;30:97–102.

44 DeMello WF, Restall J. The requirement of intensive care support for the pregnant population. Anesthesia. 1990;45:888.

45 Selo-Ojeme DO, Omosaiye M, Battacherjee P, Kadir RA. Risk factors for obstetric admissions to the intensive care unit in a tertiary hospital: A case control study. Arch Gynecol Obstet. 2005;272:207.

46 Ryan M, Hamilton V, Bowen M, McKenna P. The role of a high-dependency unit in a regional obstetric hospital. Anaesthesia. 2000;55:1155–1158.

47 Bouvier-Colle MH, Salanave B, Ancel PY, *et al*. Obstetric patients treated in intensive care units and maternal mortality. Regional teams for the survey. Eur J Obstet Gynecol. Reprod Biol. 1996;65:121–125.

48 Koeberle P, Levy A, Surcin S, *et al*. Complications obstétricales graves nécessitant une hospitalization en reanimation: Etude retrospective sur 10 ans au CHU de Basançon. Ann Fr Anesth Réanim. 2000;19:445–451.

49 Lelong E, Pourrat O, Pinsard M, *et al*. Admission of women to an intensive care unit during pregnancy or the postpartum period: Circumstances and prognosis. A retrospective series of 96 cases. Rev Med Interne. 2013;34:141–147.

50 Chantry AA, Deneux-Tharaux C, Bonnet MP, Bouvier-Colle MH. Pregnancy-related ICU admissions in France: Trends in rate and severity, 2006–2009. Crit Care Med. 2015;43:78–86.

51 Farr A, Lenz-Gebhart A, Einig S, *et al*. Outcomes and trends of peripartum maternal admission to the intensive care unit. Wien Klin Wochenschr. 2017;129:605–611.

52 De Greve M, Van Mieghem T, Van Den Berghe G, Hanssens M. Obstetric admissions to the intensive care unit in a tertiary hospital. Gynecol Obstet Invest. 2016;81315–81320.

53 Loverro G, Pansini V, Greco P, *et al*. Indications and outcome for intensive care unit admission during puerperium. Arch Gynecol Obstet. 2001;265:195–198.

54 Keizer JL, Zwart JJ, Meerman RH, *et al*. Obstetric intensive care admissions: A 12-year review in a tertiary care centre. Eur J Obstet Gynecol. Reprod Biol. 2006;128:152–156.

55 Zwart JJ, Dupuis JR, Richters A, *et al*. Obstetric intensive care unit admission: A 2-year nationwide population-based cohort study. Intensive Care Med. 2010;36:256–263.

56 Heinonen S, Tyrväinen E, Saarikoski S, Ruokonen E. Need for maternal critical care in obstetrics: A population-based analysis. Int J Obstet Anesthesia. 2002;11:260–264.

57 Seppänen P, Sund R, Roos M, *et al*. Obstetric admissions to ICUs in Finland: A multicentre study. Intensive Crit Care Nurs. 2016;35:38–44.

58 Krawczyk P, Jastrzebska A, Lipka D, Huras H. Pregnancy related and postpartum admissions to intensive care unit in the obstetric tertiary care center – an 8-year retrospective study. Ginekol Pol. 2021;92:575–578.

59 Demirkiran O, Dikmen Y, Utku T, Urkmez S. Critically ill obstetric patients in the intensive care unit. Int J Obstet Anesthesia. 2003;12:266–270.

60 Yuvaci HU, Duzcan T, Akdemir N, *et al*. Treatment results of patients followed in intensive care unit in severe maternal morbidity cases. Gynecol Obstet Reprod Med. 2018;24:129–130.

61 Gupta S, Naithani U, Doshi V, *et al*. Obstetric critical care: A prospective analysis of clinical characteristics, predictability, and fetomaternal outcome in a new dedicated obstetric intensive care unit. Indian J Anaesth. 2011;55:146–153.

62 Ramachandra Bhat PB, Navada MH, Rao SV, Nagarathna G. Evaluation of obstetric admissions to intensive care unit of a tertiary referral center in coastal India. Indian J Crit Care Med. 2013;17:34–37.

63 Chawla S, Nakra M, Mohan S, *et al*. Why do obstetric patients go to the ICU? A 3-year study. Med J Armed Forces India. 2013;69:134–137.

64 Ashraf N, Mishra SK, Kundra P, *et al*. Obstetric patients requiring intensive care: A one year retrospective study in a tertiary care institute in India. Anesthesiol Res Pract. 2014;2014:789450.

65 Gombar S, Ahuja V, Jafra A. A retrospective analysis of obstetric patient's outcome in intensive care unit of a tertiary care center. J Anaesthesiol Clin Pharmacol. 2014;30:502–507.

66 Jain S, Guleria K, Vaid NB, *et al*. Predictors and outcome of obstetric admissions to intensive care unit: A comparative study. Indian J Public Health. 2016;60:159–163.

67 Murki A, Dhope S, Kamineni V. Feto-maternal outcomes in obstetric patients with near miss morbidity: An audit of obstetric high dependency unit. J Matern Fetal Neonatal Med. 2016 May 10:1–3. [Epub ahead of print]

68 Rathod AT, Malini KV. Study of obstetric admissions to the Intensive Care Unit of a Tertiary Care Hospital. J Obstet Gynaecol India. 2016;66(Suppl. 1):12–17.

69 Bibi S, Ghaffar S, Memon S, Memon S. Severe acute maternal morbidity (SAMM) in postpartum period

requiring tertiary hospital care. Iran J Reprod Med. 2012;10:87–92.
70 Thakur A, Basnet P, Agrawal A, Uprety DK. Profile of patients admitted in maternal intensive care unit at BPKIHS, a tertiary hospital in eastern Nepal. J Nepal Health Res Counc. 2015;13:90–94.
71 Shrestha D, Aryal S, Baniya S. Evaluation of clinical characteristics and outcomes of obstetric patients admitted to intensive care unit. J Lumbini Med Coll. 2018;6:11–16.
72 Okafor UV, Aniebue U. Admission pattern and outcome in critical care obstetric patients. Int J Obstet Anesthesia. 2004;13:164–166.
73 Adeniran AS, Bolaji BO, Fawole AA, Oyedepo OO. Predictors of maternal mortality among critically ill obstetric patients. Malawi Med J. 2015;27:16–19.
74 Platteau P, Engelhardt T, Moodley J, Muckart DJ. Obstetric and gynaecological patients in an intensive care unit: A 1 year review. Trop Doctor. 1997;27:202–206.
75 Cohen J, Singer P, Kogan A, *et al*. Course and outcome of obstetric patients in a general intensive care unit. Acta Obstet Gynecol. Scand. 2000;79:846–850.
76 Lewinsohn G, Herman A, Lenov Y, Klinowski E. Critically ill obstetrical patients: Outcome and predictability. Crit Care Med. 1994;22:1412–1414.
77 Lataifeh I, Amarin Z, Zayed F, *et al*. Indications and outcome for obstetric patients' admission to intensive care unit: A 7-year review. J Obstet Gynaecol. 2010;30:378–382.
78 Richa F, Karim N, Yazbeck P. Obstetric admissions to the intensive care unit: An eight-year review. J Med Liban. 2008;56:215–219.
79 Al-Suleiman SA, Qutub HO, Rahman J, Rahman MS. Obstetric admissions to the intensive care unit: A 12-year review. Arch Gynecol Obstet. 2006;274:4–8.
80 Aldawood A. Clinical characteristics and outcomes of critically ill obstetric patients: A ten-year review. Ann Saudi Med. 2011;31:518–522.
81 Mirghani HM, Hamed M, Ezimokhai M, Weerasinghe DSL. Pregnancy-related admissions to the intensive care unit. Int J Obstet Anesthesia. 2004;13:82–85.
81 Paxton JL, Presneill J, Aitken L. Characteristics of obstetric patients referred to intensive care in an Australian tertiary hospital. Aust NZ J Obstet Gynaecol. 2014;54:445–449.
82 Tang LC, Kwok AC, Wong AY, *et al*. Critical care in obstetrical patients: An eight-year review. Chinese Med J (English). 1997;110:936–941.
83 Ng Tl, Lim E, Tweed WA, Arulkumaran S. Obstetric admissions to the intensive care unit: A retrospective review. Ann Acad Med Singapore. 1992;21:804–806.
84 Leung NY, Lau AC, Chan KK, Yan WW. Clinical characteristics and outcomes of obstetric patients admitted to the Intensive Care Unit: A 10-year retrospective review. Hong Kong Med J. 2010;16:18–25.
85 Yuqi L, Tan G, Chengming S, Xuri S. The ICU Is becoming a main battlefield for severe maternal rescue in China: An 8-year single-center clinical experience. Crit Care Med. 2017;45:e1106–e1110.
86 Zhao Z, Han S, Yao G, *et al*. Pregnancy-related ICU admissions from 2008 to 2016 in China: A first multicenter report. Crit Care Med. 2018;46:e1002–e1009.
87 Cheng C, Raman S. Intensive care use by critically ill obstetric patients: A five-year review. Int J Obstet Anesthesia. 2003;12:89–92.
88 Ng VK, Lo TK, Tsang HH, *et al*. Intensive care unit admission of obstetric cases: A single centre experience with contemporary update. Hong Kong Med J. 2014;20:24–31.
89 Stephens ID. ICU admissions from an obstetrical hospital. Can J Anaesth. 1991;38:677–681.
90 Crozier TM, Wallace EM. Obstetric admissions to an integrated general intensive care unit in a quaternary maternity facility. Aust NZ J Obstet Gynaecol. 2011;51:233–238.
92 Sadler LC, Austin DM, Masson VL, *et al*. Review of contributory factors in maternity admissions to intensive care at a New Zealand tertiary hospital. Am J Obstet Gynecol. 2013;209:549.e1–549.e7.
93 Knaus WA, Draper EA, Wagner DP, Zimmerman JE. An evaluation of outcome from intensive care in major medical centers. Ann Intern Med. 1986;104:410–418.
94 Stevens TA, Carroll MA, Promecene PA, *et al*. Utility of Acute Physiology, Age, and Chronic Health Evaluation (APACHE III) score in maternal admissions to the intensive care unit. Am J Obstet Gynecol. 2006;194:13–15.