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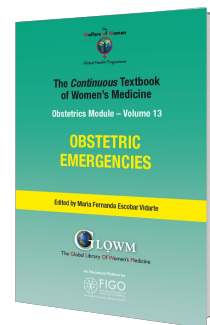
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Chapter

Obstetric Intensive Care Unit: Impact in Maternal Mortality

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AUTHORS

Gamunu Ratnayake, MBBS, MSc, MRCP, DRCOG, FRCA, EDIC

Department of Anaesthesia, King's College Hospital, London, UK

Galina Fastovets, MBBS, Dip OG Ultrasound, Dip Hum Reprod Fam Plann

Family Health & Human Reproduction, Regional Center, Bryansk, Russian Federation

Vinod Patil, FRCA

Department of Anaesthesia, Queen's Hospital Romford, London, UK

INTRODUCTION

Maternal critical care in the obstetric population is a burgeoning area of medicine.¹ Worldwide it is still primarily provided by adult intensivists who may or may not have specialist knowledge of unique peripartum maternal critical illness. Over the past decade, there has been an increasing interest in developing this field of intensive care, with obstetricians and obstetric anesthetists helping to develop these services.

In the United Kingdom, there has been a systematic, national enquiry into the death of any pregnant woman since the 1950s, through an initiative called the Confidential Enquiry into Maternal Mortality.² The UK also has a robust intensive care national database of clinical cases admitted to critical care, which identifies peripartum admissions. Therefore, data from the UK provide a useful insight into the evolving treatment and outcomes of women admitted to critical care in the peripartum period.

Unfortunately, critical care is not widely available outside the more economically developed countries. This is largely related to the exponentially higher costs associated with intensive care or high dependency units. This is owing to greater nurse to patient ratios (1 : 1 for intensive care, and 1 : 2 or 3 for high dependency units), more doctors with specialist training and more intensive organ support and monitoring equipment.

Data for the critical care management of patients from poorer or less economically developed countries are lacking. This is owing to a combination of a lack of availability of critical care services, and less formalized databases for the analysis (or even collection) of these epidemiological data. As such, the majority of this chapter will refer to the validated and robust data provided from more economically developed countries such as the UK and USA supported by data in the published literature from other countries.

Interestingly the remit of delivering critical care is moving outside the intensive and high dependency units, onto the wards with the aid of critical care outreach teams. This is also true of the labor units. In many western countries, there has been the development of high dependency areas within the labor suite. This allows for higher intensity monitoring and nursing without compromising the 'mother and baby centric' care required (such as support for breastfeeding, encouraging bonding of mother, father and baby, and dealing with labor specific issues which general intensive care units may not fully appreciate).

Given the unique situation and challenges faced by patients in the peripartum period, the approach to these patients necessitates a multidisciplinary team approach with input from midwives, obstetricians, obstetric anaesthetists and intensivists. This underlies the complexity of these patients, with multiple healthcare needs.

As more comorbid women are becoming pregnant and effectively supported through their pregnancies, there is an increasing need to provide critical care medicine in the obstetric recovery/high dependency unit.

HISTORY OF MATERNAL CRITICAL CARE

Although maternal access to critical care has always been available in modern healthcare systems of economically developed countries, its recognition as a separate specialty with unique challenges and nuances is relatively recent. It was less than 20 years ago that the Confidential Enquiry into Maternal Deaths in the UK included a chapter on 'near miss and severe maternal morbidity'.³ This was arguably a turning point in the way maternal health was considered, as there was more emphasis on the potential long-term morbidity associated with severe maternal illnesses. As maternal mortality continued to fall at the start of the 21st century through a combination of better public health and education, alongside earlier diagnosis and treatment of potential problems, morbidity remained significant. Modern day critical care no doubt plays a vital role in reducing mortality; however, on a day to day basis its greatest effect is likely to be related to mitigating serious morbidity.

In terms of mortality, developed countries continue to have a low rate, which varies between 0.05 and 1.7%.^{4,5} In developing countries, this can increase up to 8.2%.⁶ Interestingly the rates of maternal mortality have dropped dramatically since the late 20th century. The last two MBRRACE studies have shown a plateau in maternal mortality.² Maternal admission to critical care also remains relatively low (at around 0.3% in the UK).²

Despite a small proportion of women being admitted to critical care for management of potentially life-threatening complications in the peripartum period, there is little training for either intensivists or obstetricians in the management of these complex patients. The UK has long pioneered the development of evidence-based guidelines and protocols for reducing obstetric morbidity and mortality through a number of review and retrospective analysis initiatives. Most recently, the Maternal Critical Care Working Group was created in 2011 to help review and create standards for the management of these patients.⁷ One of the main catalysts for the development of this multidisciplinary task force into maternal critical care was the fact that 'for every *one* mother who dies in childbirth, *nine* mothers have suffered significant morbidity'.⁸

The most recent Confidential Enquiry into Maternal Death reported 261 maternal deaths between 2006 and 2008 from causes directly related to pregnancy.² Looking at the Intensive Care National Audit and Research Centre (ICNARC) data for 2007, there were 523 admissions (260/100,000) to critical care units of patients who were either pregnant or recently pregnant.⁹ Of these 71% (418) were admitted for a primarily obstetric complication or diagnosis.

The main reasons for admission of obstetric patients to the critical care were as follows:

1. Massive obstetric hemorrhage (>2.5 L)
2. Eclampsia
3. Sepsis
4. Thromboembolism
5. Acute organ dysfunction (renal, hepatic, cardiac, respiratory or neurological)
6. Anaesthesia-related morbidity (aspiration, anaphylaxis, muscle relaxant related problems)

The most recent comprehensive incidence data have been collated by the Scottish Confidential Audit of Severe Maternal

Morbidity and are summarized in the Table 1.¹⁰

Table 1 A summary of the categories of severe maternal mortality admitted to ICU between 2007 and 2012 reported to the 10th annual report Scottish Confidential Audit of Severe Maternal Mortality: Reducing Avoidable Harm.¹¹ There were 62,000 births in that time period.

Reason for ICU admission	Number of cases 2007–2012
Major obstetric hemorrhage	305
Not categorized	148
Acute respiratory dysfunction	21
Septic shock	19
Cardiac arrest	10
Eclampsia	10
Pulmonary edema	19
Renal/liver dysfunction	30
Anaphylactic shock	4
Anesthetic problem	5
Coma	1
Cerebrovascular embolism	3
Massive pulmonary embolus	6
Total	581 (of 549 women)

There are robust data in the UK with regards to maternal mortality (14/100,000) and intensive care utilization (260/100,000).⁷ Unfortunately, these data do not include utilization of higher-level care provided on the labor units by anesthetists and critical care outreach teams. The combined Royal College paper on maternal critical care utilization estimates this may be as high as 1200/100,000 (which is 20 times what the ICNARC data would suggest).^{7,12}

FORMS OF MATERNAL CRITICAL CARE

The Department of Health in the UK produced a document in 2000 called 'Comprehensive Critical Care'.¹³ This paper suggested that the terms high dependency and intensive care should be replaced with 'critical care'. The paper also emphasized the concept of critical care without walls. This refers to expanding organ support and specialist management modalities outside of critical care units. The emphasis was on outreach and providing necessary treatments at the point of need. The type of critical care management and treatment that the patient required could then be defined using the Intensive Care Society 'Levels of Care' definition.¹⁴ The levels of care as relating to the pregnant woman are summarized in Table 2.

Table 2 An adaptation of the examples of levels of critical care outlined in the Royal College document on maternal critical care (adapted from the RCOG Maternal Critical Care Guidelines).⁷

Level of care	Maternal example
LEVEL 0: Normal ward care	Care of low risk mother

Level of care	Maternal example
LEVEL 1: Additional monitoring or intervention, or step down from higher level of care	Risk of hemorrhage Oxytocin infusion Mild pre-eclampsia with oral antihypertensive and fluid restriction Medical conditions such as diabetes on insulin infusion, congenital heart disease
LEVEL 2: Single organ support	Basic respiratory support: 50% oxygen or more via face mask Non-invasive ventilation or continuous positive pressure ventilation Basic cardiovascular: Intravenous hypotensives to manage pre-eclampsia Arterial line (for pressure monitoring or blood gas sampling) Central line for fluid management or specialist drug administration Advanced cardiovascular: Use of 2 or more antihypertensives, antiarrhythmics or vasoactive drugs Measuring cardiac output Neurological support: Magnesium for controlling seizures Intracranial pressure monitoring Liver support Treatment of fulminant liver failure (e.g. from HELLP, acute fatty liver, working up for liver transplant)
LEVEL 3: Advanced respiratory support alone or support of 2 or more organ systems	Advanced respiratory support Invasive mechanical ventilation Support of 2 or more organ systems: Renal support (basic or advanced) Cardiac support (basic or advanced)

The joint Royal College document outlines the importance of early warning physiological scoring systems. In the UK the National Health Service Early Warning Score (NEWS) was introduced; however, it was never validated for pregnant women. The Maternal Early Obstetric Warning Score (MEOWS) is widely used on obstetric units and does provide a useful trigger for senior review of patients. However, it has not been validated as a trigger for admission to critical care. The joint guidelines suggest the following protocol for escalation of care in obstetric patients:⁷

1. LOW SCORE: early warning score (EWS) = 3
 - a. Midwife in charge notified
2. MEDIUM SCORE: EWS = 4–5
 - a. Obstetrician review
 - b. Escalation for review by general medical doctor, anesthetist or critical care outreach team
3. HIGH SCORE = EWS >6
 - a. Obstetrician and critical care doctors review the patient simultaneously

This model enables critical care to be flexible. It can start outside of the critical care units with the use of anesthetists, outreach teams and maternal HDUs.¹⁵ The dedicated maternal HDU on the labor ward is becoming more prevalent in the UK. This involves the provision of level 2 care within the labor ward, thus allowing the specialist maternal services provided by midwives to continue. These would otherwise be interrupted by transferring mothers to adult critical care

environments.

The provision of these higher-level services can range from intravenous infusions to invasive arterial blood pressure monitoring. This does require either dedicated critical care nurses being recruited or advanced training of specialist midwives to manage the high dependency unit. An outline of all the required competencies can be found in Appendix 6 of the Joint Royal College guidelines.⁷

EFFECT ON MORTALITY

Maternal mortality is the metric most commonly used to monitor maternal health and healthcare provision worldwide. It is often used as an international development goal.¹⁶ Globally there has been a 44% reduction in the maternal mortality ratio, from 385 maternal deaths per 100,000 live births in 1990, to only 216 in 2015.¹⁷ Of note, this is significantly higher than the maternal mortality ratio in more economically developed countries, which ranges from 3 to 12 per 100,000. A notable exception to the reduction in maternal mortality is the US where there has been a 16.7% increase in maternal mortality ratio from 1990 to 2015 (up to 14 per 100,000 live births).¹⁸

When assessing the global maternal death rates, the majority of deaths occur in less economically developed countries, predominantly subSaharan Africa.¹⁷ More than half of maternal deaths between 2003 and 2009 were due to hemorrhage, sepsis or hypertensive disorders.¹⁹

When causes of maternal death are divided into regions, it becomes apparent that certain geographic areas have a propensity for different causes of death. In Northern Africa for example, 36.9% of deaths were caused by hemorrhage (compared to only 16.3% in more economically developed countries).¹⁹ It should be noted that the vast majority of deaths in poorer countries were due to sepsis.¹⁹ This is interesting in the context of critical care provision, as sepsis is eminently treatable with a combination of early antibiotics and then vasopressor support in more severe forms of sepsis. Unfortunately, often the problem in poorer countries is a lack of access to early appropriate antibiotics. One may argue that, in these countries, money would be better invested in access to early antibiotics and review by healthcare professionals.

There are no data to reliably reflect the effect of maternal critical care services on maternal mortality. Although it is true that less economically developed countries do not generally have access to critical care services, the majority of their deaths are likely to be mitigated by access to simple medical treatments. The Surviving Sepsis Campaign made it clear that early access to appropriate antibiotics was the greatest determinant of survival.²⁰ Similarly survival from major hemorrhage often comes from giving appropriate blood and blood products early. Once a patient becomes under-resuscitated they can develop a vicious cycle of disseminated intravascular coagulation and death. Again, rather than massive investments in maternal critical care in the less economically developed countries, it may be more cost effective to invest in simple interventions such as access to blood and blood products.

It is difficult to accurately ascertain what the effect of maternal critical care is on maternal mortality. It is certainly true that maternal mortality has reduced over the past 25 years globally. However, the trend in America cannot be ignored. America has a large proportion of critical care beds compared to its population; however, mortality seems to be increasing. Although there is ongoing work looking into why this is, it is generally accepted that the American population has developed more comorbidities over time. These range from increase in body mass index to advancing maternal age. Additionally there is a higher proportion of expecting mothers with serious medical problems who may not have been able to get pregnant many years ago, who are now surviving to give birth. These patients range from previous cardiac surgery to patients with transplants.

Although it will never be easy to link the presence of maternal critical care with maternal mortality for all the confounding variables, it is clear that as the maternal population is becoming more comorbid there is an increasing need for more intensive support of these patients during the peripartum period.

EFFECT ON MORBIDITY

For many years, maternal mortality has been used as the primary metric for maternal outcome. Recently there is

increasing interest in severe morbidity, as this reflects a far greater proportion of women undergoing pregnancy.²¹ Although worldwide maternal mortality appears to be falling, morbidity seems to be rising rapidly. The severe morbidity rate in the US has doubled from 1999 to 2011 (from 74 per 100,000 to 163 per 100,000).²² Unfortunately less economically developed countries have an even higher rate of severe morbidity, with some estimates as high as 8% of all deliveries.²³

Geller *et al.* propose an interesting conceptual framework for considering near-miss maternal morbidity.²⁴ They describe a continuum from normal pregnancy to morbidity to severe morbidity to death.

Severe morbidity refers to women who experience severe pregnancy, delivery or postpartum complications. These include conditions such as massive hemorrhage, cardiac arrest, organ system failure, stroke and other conditions that lead to extended hospital stays, massive transfusion, minor surgery or other major medical interventions.²⁵

There are no direct studies linking the emergence of maternal critical care with a reduction in maternal mortality. However, there is an increase in comorbid mothers, and therefore it is logical that it may play some part in the reduction in mortality. One can argue that women who previously were too unwell to survive pregnancy can now reach motherhood with the help of maternal critical care services. It should, however, be noted that antenatal services in general have also significantly improved, which may account for the majority of the improvement in maternal mortality. One of the major challenges has been defining significant maternal morbidity. There have been a number of attempts at having a clear definition. The International Network of Obstetric Surveillance Systems (INOSS) developed a consensus amongst 13 countries.²⁶ They outlined eight conditions:

1. Eclampsia
2. Amniotic fluid embolism
3. Pregnancy related hysterectomy
4. Severe primary postpartum hemorrhage
5. Uterine rupture
6. Abnormally invasive placenta
7. Spontaneous hemoperitoneum
8. Cardiac arrest in pregnancy

The incidence of various types of morbidity are difficult to ascertain in general as it varies from country to country based on a variety of variables including economic development, healthcare systems and reporting of adverse events. Nair *et al.* published a comprehensive list of incidence of maternal morbidity in England (which has a robust and well-established reporting system).²⁷ The prevalence of severe maternal morbidity conditions from this study is summarized below.

Table 3 Summary of the prevalence data published in 2016 in England per 1,000 live births²⁷

Morbidity condition	Prevalence (per 1,000 live births)
Acute abdomen	0.01
Acute renal failure	0.08
Acute psychosis	0.05
Cardiac arrest/failure/infarction	0.05
Cerebral edema or coma	0.01
Disseminated intravascular coagulation	0.01
Cerebrovascular accident	0.04
Major complications of anesthesia	0.06
Obstetric embolism (include amniotic fluid)	0.27

Shock Morbidity condition	Prevalence (per 1,000 live births)
Sickle cell crisis	0.05
Status asthmaticus	0.02
Status epilepticus	0.03
Uterine rupture	0.48
Eclampsia	0.71
Sepsis	0.44
Cerebral venous thrombosis	0.003

There is increasing evidence that more women are presenting with severe comorbidities.²⁸ This change in demographics may be explained by an increasing maternal age at the time of their first pregnancy.²⁹

There are sparse data on the admission demographics of mothers brought to critical care. Obviously, the demographics and rates will vary depending on the country and healthcare system. Farr *et al.* published a relatively recent retrospective analysis of mothers admitted to critical care at the Vienna University Hospital between 2011 and 2014. They compared the demographics to those patients admitted between 1996 and 2003 as a historical comparison.³⁰ This hospital has around 3000 deliveries per year.

Farr *et al.* showed that less general anesthetics were performed for mothers more recently, and consequently more mothers had neuroaxial blocks. There were more patients who survived intensive care, but the same number of near misses and deaths. This seems to indicate that the threshold to admit to critical care has reduced, however, in this series there does not seem to be a mortality benefit. Although the mortality rate did not change, the mothers who were admitted had more comorbidities. It is possible that the plateau in maternal mortality may be owing to better critical care, compensating for the sicker parturients. This is very difficult to prove with the data available to date.

COST-EFFECTIVENESS OF MATERNAL CRITICAL CARE

There are no studies or cost analyses looking at the cost-effectiveness of maternal critical care. It would be a difficult calculation to perform as the death of a mother will have serious and lifelong repercussions on both the baby and the rest of the family unit. There is no doubt that as patients become more complex, and women with significant comorbidities choose to get pregnant, they will require the support of maternal critical care.

Given the very high maternal mortality that still exists globally, with a finite resource allocation, the role of maternal critical care needs to be reviewed in less economically developed countries. One could argue that rather than spending a significant amount of money setting up maternal critical care services in countries with high maternal mortalities, investment in simple interventions such as access to trained healthcare professionals, early antibiotics and blood and blood products may well be more useful.

Maternal critical care in more economically developed countries certainly has a place in reducing the already low maternal mortality. However, it is difficult to quantify the exact reduction in mortality from the more widespread use of maternal critical care. It is reasonable to conclude that maternal critical care has had a large impact in reducing maternal morbidity. After a serious complication such as massive obstetric hemorrhage or sepsis, providing diligent high dependency care may significantly improve this morbidity. As further studies are performed, whilst maternal critical care fully evolves as a separate entity to adult critical care, we will see a clearer picture of the impact of maternal critical care on morbidity and mortality.

CONCLUSION

Maternal critical care is a rapidly developing field of maternal medicine. The evidence for the development of these

services is still being developed, but intrinsically there seems to be more demand for maternal critical care as the population of women becomes more comorbid. In the UK, there have been joint guidelines from a variety of Royal Colleges to help develop these services.

As mothers become more medically complicated the utilization of these services is undoubtedly going to increase. Many of these mothers will lack the physiological reserve to cope with delivery and potential complications of childbirth.

Maternal critical care is very different to adult critical care as the mothers have unique conditions and physiologies that require specialist management (such as having a hypercoagulable state and blood pressure control being vital to prevent complications). Maternal critical care is fast developing as a separate speciality and will likely require specialist training of both midwives and doctors (obstetricians and obstetric anaesthetists).

Although it is undoubted that maternal critical care will continue to flourish in more economically developed countries, it is arguable whether the same investment is cost-effective in less economically developed countries. In poorer countries, the maternal mortality appears to be higher, and deaths seem to be related to lack of basic treatments such as early antibiotics, access to healthcare teams and blood or blood products. The initial economic investments and ongoing financial commitment to providing maternal critical care, which would benefit a fraction of mothers, compared to more comprehensive maternal services for all mothers, would arguably detract from an economic case for developing these services in poorer countries.

In more economically developed countries where maternal mortality rates have already plateaued; however, maternal critical care services may well aid with the greater challenge of mitigating the effects of severe maternal morbidity.

Overall maternal critical care will continue to develop as a speciality, and form an important part of post-delivery care of mothers. As the service matures, and training improves it will be interesting to see how this faculty helps to manage the increasing epidemic of comorbid mothers. It is almost certainly going to be a vital tool in maintaining the low maternal mortality rates in the more economically developed countries.

PRACTICE RECOMMENDATIONS

- **Any critically ill patient in the peripartum period must have a multidisciplinary team approach to their care. Opinions and expertise must be obtained from critical care doctors, obstetricians, obstetric anaesthetists, senior midwives and critical care outreach nurses.**
- **Consider critical care involvement in any mother with massive obstetric hemorrhage (>2.5L), eclampsia, sepsis, thromboembolism or acute organ dysfunction (liver, kidneys, heart, lungs or neurological).**
- **Early warning physiological scores (such as MEOWS or EWS) maybe useful to trigger early senior reviews of potentially critically unwell mothers.**
- **Development of maternal critical care units in labor wards may help continuity of care and earlier intensive treatment of unwell mothers.**
- **The Surviving sepsis campaign has shown that early critical care involvement in non-obstetric patients is important in improving survival. It stands to reason that the same is true in the obstetric population.**

CONFLICTS OF INTEREST

The authors of this chapter declare that they have no interests that conflict with the contents of the chapter.

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