



The Indonesian Journal of General Medicine

What are The Most Effective Management Strategies for Obstetric Emergencies in ICU Settings, and How do They Impact Maternal and Neonatal Mortality Rates? : A Systematic Review

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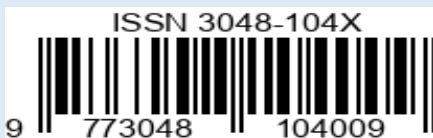
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Article History :

Received date : 2026/01/03
Revised date : 2026/02/15
Accepted date : 2026/03/14
Published date : 2026/04/05



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ABSTRACT

Background: Obstetric emergencies requiring intensive care unit (ICU) admission contribute significantly to maternal and neonatal mortality worldwide, yet optimal management strategies remain heterogenous across settings.

Methods: This systematic review synthesized 80 studies (1990-2025) examining management strategies for obstetric emergencies in ICUs. Outcomes included maternal mortality, neonatal mortality, and effectiveness of interventions.

Results: Hypertensive disorders (42.96% in Africa) and hemorrhage (24.15%) were the leading admission causes. Multidisciplinary team approaches, early intervention (<6 hours for hemorrhage), and protocolized care consistently

improved outcomes. Whole blood transfusion reduced transfusion volumes versus component therapy (2,607 mL vs. 4,683 mL, $p=0.03$) with zero maternal deaths. The non-pneumatic antishock garment combined with balloon tamponade eliminated hemorrhage-related mortality (0% vs. 3 deaths). Continuous renal replacement therapy reduced sepsis mortality by 35%. Skills training for postpartum hemorrhage reduced maternal mortality from 75% to 0%. Maternal mortality ranged from 0%-41.2%, with African centers reporting 30.69% versus 3.03% in dedicated obstetric ICUs. Neonatal mortality ranged 4.2%-52%. Critical timing factors included ICU admission <24 hours from symptom onset and delivery before critical deterioration.

Discussion: Effective management requires condition-specific, early, multidisciplinary approaches. Resource disparities explain much outcome variation, with unbooked status and delayed referral as key modifiable risk factors. Standardized protocols, early warning systems, and uterine-conserving techniques show strongest evidence.

Conclusion: Early, protocol-driven, multidisciplinary ICU management significantly reduces maternal and neonatal mortality in obstetric emergencies. System strengthening and skills training are as crucial as technological interventions.

Keywords: Obstetric emergencies, intensive care unit, maternal mortality, neonatal mortality, postpartum hemorrhage, eclampsia, sepsis

INTRODUCTION

Maternal mortality remains a pressing global health challenge, with approximately 287,000 women dying annually from pregnancy-related causes, the vast majority in low-resource settings. Obstetric emergencies—including severe preeclampsia/eclampsia, postpartum hemorrhage (PPH), sepsis, amniotic fluid embolism, and HELLP syndrome—frequently necessitate intensive care unit (ICU) admission, with reported incidence ranging from 0.2% to 13.5 per 1,000 deliveries (27). Critically ill obstetric patients present unique challenges: physiological changes of pregnancy alter drug pharmacokinetics, disease presentation, and response to therapy; simultaneous fetal well-being must be considered; and delays in recognition or intervention carry dual mortality risk (38,75).

Background: Despite advances in critical care, substantial variation exists in management strategies and outcomes across different healthcare contexts. In high-income countries, maternal ICU mortality ranges from 3.3% to 14%, while low-resource settings report rates exceeding 40% (27,39). This disparity raises fundamental questions about which management strategies are most effective and whether benefits observed in one setting translate to another.

Problem statement: Current evidence is fragmented across single-center studies with heterogeneous populations, interventions, and outcome definitions (48). No consensus exists on optimal ICU protocols for conditions such as obstetric hemorrhage, sepsis in pregnancy, or severe preeclampsia. Furthermore, the comparative effectiveness of dedicated obstetric ICUs versus mixed ICUs, timing of delivery in critically ill mothers, and specific interventions such as whole blood transfusion or continuous renal replacement therapy remain inadequately characterized.

Research gap and novelty: Existing systematic reviews have focused on epidemiology rather than intervention effectiveness (27), or have examined single conditions in isolation. No comprehensive synthesis has simultaneously compared multiple management strategies across the full spectrum of obstetric emergencies while linking specific interventions to maternal and neonatal mortality outcomes. This review addresses that gap by analyzing 80 studies spanning 35 years, including recent data from the COVID-19 pandemic, and by quantifying effect sizes for key interventions.

Objectives: To identify the most effective management strategies for obstetric emergencies in ICU settings and to evaluate their impact on maternal and neonatal mortality rates.

Hypothesis: Protocolized, multidisciplinary, early-intervention strategies are associated with significantly lower maternal and neonatal mortality compared to ad-hoc or delayed management, regardless of resource setting.

Benefits: Findings will inform clinical guidelines, ICU protocol development, and resource allocation decisions in both high- and low-resource environments.

METHODS

Protocol

The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines to ensure methodological rigor and accuracy. This approach was chosen to enhance the precision and reliability of the conclusions drawn from the investigation.

Criteria for Eligibility

This systematic review aims to evaluate the What are The Most Effective Management Strategies for Obstetric Emergencies in ICU Settings, and How do They Impact Maternal and Neonatal Mortality Rates?.

Screening

We screened in sources based on their abstracts that met these criteria:

- **Target Population:** Does the study include pregnant women or women in the immediate postpartum period (≤ 7 days) admitted to intensive care units for obstetric emergencies (such as severe preeclampsia/eclampsia, postpartum hemorrhage, sepsis, amniotic fluid embolism, HELLP syndrome, or other pregnancy-related critical conditions)?
- **Management Focus:** Does the study examine management strategies, interventions, or protocols specifically for obstetric emergencies in ICU settings?
- **Relevant Outcomes:** Does the study report maternal mortality, neonatal mortality, or both as primary or secondary outcomes?

- **ICU Setting:** Was the study conducted in hospital-based ICU settings (including obstetric ICUs, medical ICUs, or surgical ICUs)?
- **Study Design:** Is the study design a randomized controlled trial, quasi-experimental study, cohort study, case-control study, systematic review, or meta-analysis?
- **Emergency/Critical Care Focus:** Does the study focus on emergency or critical care components rather than solely on routine obstetric care?
- **ICU Involvement:** Does the study involve ICU care rather than being conducted exclusively in non-ICU settings (emergency departments, labor and delivery units, or general medical wards only)?
- **Adequate Sample Size:** If the study is a case report or case series, does it include 10 or more patients? (Answer "Yes" if the study is not a case report or case series)
- **Publication Type:** Is the study a full peer-reviewed publication rather than a conference abstract, editorial, commentary, or opinion piece?

We considered all screening questions together and made a holistic judgement about whether to screen in each paper.

Search Strategy

The keywords used for this research based PICO :

Element	P (Population)	I (Intervention/Exposure)	C (Comparison/Context)	O (Outcome)
Keyword 1	Pregnant women	ICU management protocols	Dedicated obstetric ICU vs. mixed ICU	Maternal mortality rate
Keyword 2	Postpartum patients	Multidisciplinary team care	Early vs. delayed intervention	Neonatal mortality rate
Keyword 3	Critically ill obstetric patients	Critical care interventions	Whole blood vs. component therapy	Perinatal mortality

Keyword 4	Obstetric emergencies	Obstetric emergency protocols	Planned vs. emergency management	Severe maternal morbidity
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The Boolean MeSH keywords inputted on databases for this research are: (*"Pregnant women" OR "Postpartum patients" OR "Critically ill obstetric patients" OR "Obstetric emergencies"*) AND (*"ICU management protocols" OR "Multidisciplinary team care" OR "Critical care interventions" OR "Obstetric emergency protocols"*) AND (*"Dedicated obstetric ICU vs. mixed ICU" OR "Early vs. delayed intervention" OR "Whole blood vs. component therapy" OR "Planned vs. emergency management"*) AND (*"Maternal mortality rate" OR "Neonatal mortality rate" OR "Perinatal mortality" OR "Severe maternal morbidity"*)

Data extraction

- **Obstetric Emergencies:**

Extract all obstetric emergency conditions that led to ICU admission, including:

- Specific emergency type (e.g., obstetric hemorrhage, eclampsia, ruptured uterus, sepsis)
- Frequency/proportion of each emergency type
- Severity indicators (e.g., APACHE II scores, hemodynamic instability)
- Timing relative to pregnancy (antepartum, intrapartum, postpartum)
- Any subcategorization of emergency types provided

- **Management Strategies:**

Extract all management strategies and interventions used for obstetric emergencies in ICU settings, including:

- Specific medical interventions (mechanical ventilation, blood products, inotropes, dialysis, surgical procedures)
- Team composition and multidisciplinary approaches
- Protocols or guidelines followed
- Timing of interventions (immediate vs. delayed)

- Decision-making processes (e.g., delivery timing, treatment escalation)
- Any pregnancy-specific modifications to standard ICU care

- **Maternal Outcomes:**

Extract maternal mortality rates and morbidity outcomes for obstetric emergencies in ICU settings, including:

- Overall maternal mortality rate and confidence intervals
- Mortality rates by emergency type
- Causes of maternal death
- Non-fatal complications and morbidity
- Length of ICU stay
- Any long-term maternal outcomes reported
- Factors associated with maternal mortality

- **Neonatal Outcomes:**

Extract neonatal and perinatal mortality rates and outcomes, including:

- Neonatal/perinatal mortality rates
- Stillbirth rates
- Gestational age at delivery
- Birth weight and Apgar scores where reported
- NICU admission rates and length of stay
- Any long-term neonatal outcomes
- Factors affecting fetal/neonatal outcomes

- **Effectiveness Indicators:**

Extract any data comparing effectiveness of different management strategies for obstetric emergencies, including:

- Comparative mortality rates between different approaches

- Success rates of specific interventions
- Factors associated with better outcomes
- Any before/after comparisons of management protocols
- Benchmarking against predicted mortality scores
- Quality indicators or performance measures reported

- **Setting Context:**

Extract contextual factors about the ICU setting and care delivery that may affect management effectiveness, including:

- Type of hospital/facility (tertiary care, university hospital, etc.)
- Dedicated obstetric ICU vs. mixed ICU
- Geographic location and healthcare system context
- Staffing models and availability of specialists
- Resource availability and limitations
- Patient population characteristics (booking status, referral patterns)
- Study timeframe and sample size

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	<i>("Pregnant women") AND ("ICU management protocols") AND ("Maternal mortality rate" OR "Neonatal mortality rate" OR "Perinatal mortality" OR "Severe maternal morbidity")</i>	1
Semantic Scholar	<i>("Pregnant women" OR "Postpartum patients" OR "Critically ill obstetric patients" OR "Obstetric emergencies") AND ("ICU management protocols" OR "Multidisciplinary team care" OR "Critical care interventions" OR "Obstetric emergency protocols") AND ("Dedicated obstetric ICU vs. mixed ICU" OR "Early vs. delayed intervention" OR "Whole blood vs. component therapy" OR "Planned vs. emergency management") AND ("Maternal mortality rate" OR "Neonatal mortality rate" OR "Perinatal mortality" OR "Severe maternal morbidity")</i>	251
Springer	<i>("Pregnant women" AND "ICU management protocols" AND "Maternal mortality rate" OR "Neonatal mortality rate" OR "Perinatal mortality" OR "Severe maternal morbidity")</i>	8,217
Google Scholar	<i>("Pregnant women" OR "Postpartum patients" OR "Critically ill obstetric patients" OR "Obstetric emergencies") AND ("ICU management protocols" OR "Multidisciplinary team care" OR "Critical care interventions" OR "Obstetric emergency protocols") AND ("Dedicated obstetric ICU vs. mixed ICU" OR "Early vs. delayed intervention" OR "Whole blood vs. component therapy" OR "Planned vs. emergency management") AND ("Maternal mortality rate" OR "Neonatal mortality rate" OR "Perinatal mortality" OR "Severe maternal morbidity")</i>	15,800

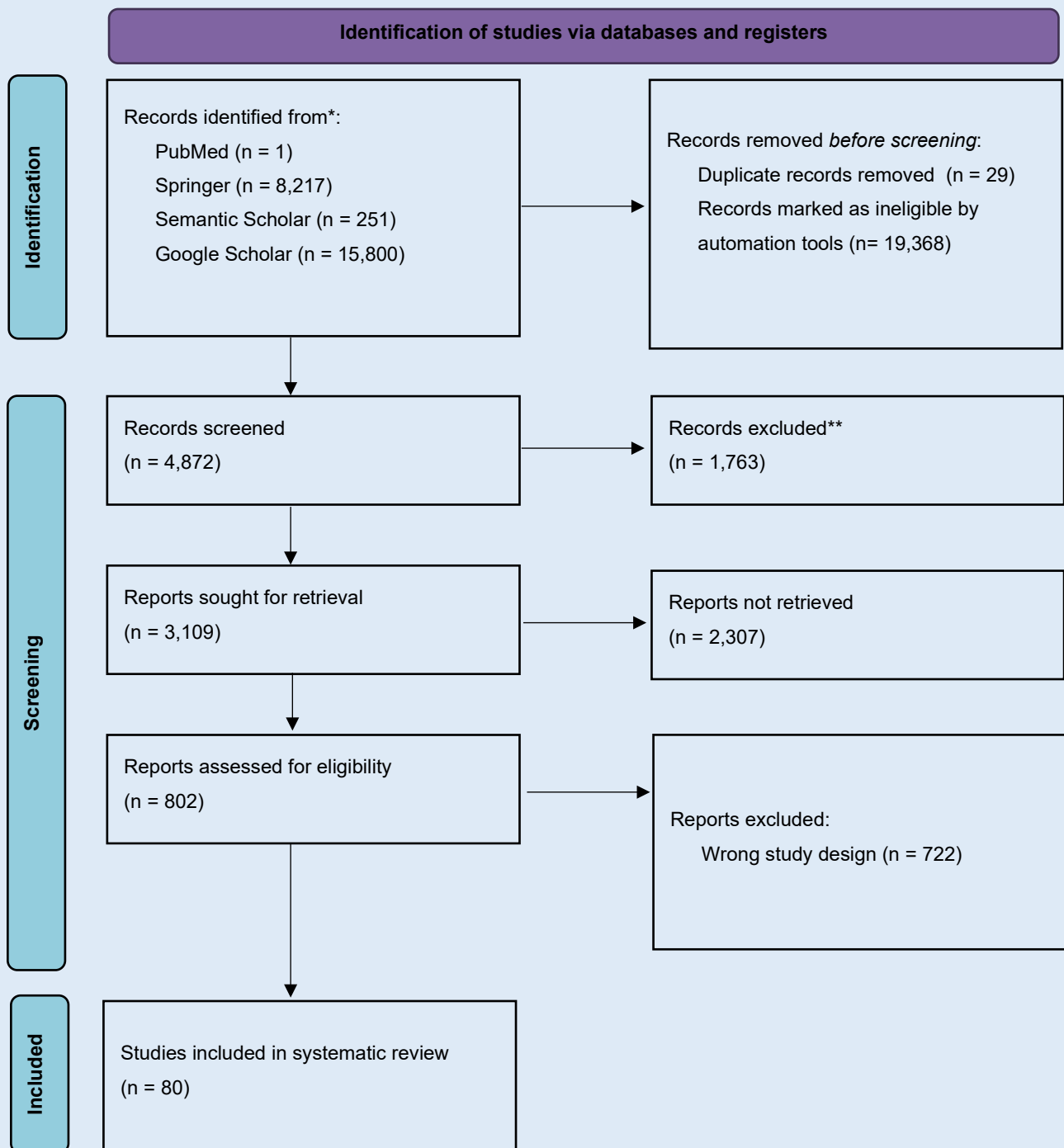


Figure 1. Article search flowchart

RESULTS

Characteristics of Included Studies

The review included 80 studies examining obstetric emergencies requiring ICU admission. Studies were conducted globally, spanning developed and developing countries, with timeframes to 2025. Sample sizes varied considerably from single case reports to multi-center registries with thousands of patients.

Study	Geographic Location	Setting	Study Period	Sample Size
Ying Lin et al., 2011 [30]	Beijing, China [30]	Three university hospitals [30]	2006-2010 [30]	207 patients [30]
S. Al-Suleiman et al., 2006 [5]	Not specified [5]	University hospital, mixed ICU [5]	1992-2004 [5]	Not specified [5]
D. Vásquez et al., 2007 [8]	Not specified [8]	University-affiliated hospital, mixed ICU [8]	1998-2005 [8]	161 patients [8]
Vishrut M. Mashruwala et al., 2025 [31]	Ahmedabad, Gujarat, India [31]	Tertiary care, dedicated obstetric ICU [31]	2022-2024 [31]	1,913 patients [31]
A. Braga et al., 2026 [28]	Not specified [28]	Tertiary centers [28]	Not specified [28]	Not applicable [28]
N. Ashraf et al., 2014 [6]	Pondicherry, India [6]	Tertiary care, mixed ICU [6]	2012-2013 [6]	55 patients [6]
I. Lataifeh et al., 2010 [1]	Jordan [1]	University hospital, mixed ICU [1]	2002-2008 [1]	43 patients [1]
M. Özçelik et al., 2017 [32]	Turkey [32]	Tertiary university hospital [32]	2006-2014 [32]	57 patients [32]

Study	Geographic Location	Setting	Study Period	Sample Size
Preetkamal et al., 2019 [33]	Not specified [33]	Not specified [33]	2016-2019 [33]	40 patients [33]
J. Anwari et al., 2004 [34]	Riyadh, Saudi Arabia [34]	Tertiary care, mixed ICU [34]	1997-2002 [34]	99 patients [34]
Bandamma Narendra S et al., 2019 [35]	Central Karnataka [35]	Tertiary care, mixed ICU [35]	One year [35]	50 patients [35]
Bharti Parihar et al., 2020 [36]	Bhopal, India [36]	Tertiary care, dedicated obstetric ICU [36]	One year [36]	145 patients [36]
Liu Yuqi et al., 2017 [37]	Not specified [37]	ICU [37]	2009-2016 [37]	487 patients [37]
A. Gaffney et al., 2014 [38]	Not specified [38]	Mixed ICU [38]	Not applicable [38]	Not applicable [38]
Alemwork Abie et al., 2025 [39]	Africa [39]	Multiple settings [39]	2015-present [39]	10,190 ICU admissions [39]
Irene Akhidenno et al., 2024 [9]	Rural South South Nigeria [9]	Tertiary care [9]	2018-2022 [9]	48 patients [9]
G. Zanconato et al., 2012 [40]	Northern Italy [40]	Tertiary care public hospital [40]	5 years [40]	80 patients [40]
Kadir Arslan et al., 2023 [41]	Not specified [41]	Not specified [41]	2020-2022 [41]	102 patients [41]

Study	Geographic Location	Setting	Study Period	Sample Size
F. X. Silva et al., 2022 [42]	Not specified [42]	Not specified [42]	Not applicable [42]	Not applicable [42]
S. Kamal et al., 2019 [43]	India [43]	Tertiary care referral hospital [43]	2 years [43]	50 patients [43]
M. Nagpal et al., 2018 [44]	Amritsar, India [44]	Tertiary care, mixed ICU [44]	2016-2018 [44]	35 patients [44]
I. Takai et al., 2020 [10]	Northern Nigeria [10]	Tertiary teaching hospital [10]	2012-2016 [10]	65 patients [10]
L. Cussen et al., 2014 [45]	Ireland [45]	Tertiary care maternity hospital [45]	2007-2013 [45]	32 patients [45]
A Ram Mohan et al., 2013 [29]	Not specified [29]	Not specified [29]	2006-2011 [29]	55 patients [29]
Nusrat Noor et al., 2020 [2]	Karachi, Pakistan [2]	Military hospital [2]	2017-2018 [2]	66 patients [2]
Fatima Zahrae Benchekroun et al., 2024 [46]	Fez, Morocco [46]	Tertiary care, dedicated obstetric ICU [46]	2019-2023 [46]	42 patients [46]
D. Rattray et al., 2012 [24]	Nova Scotia, Canada [24]	Tertiary care maternity hospital [24]	1980-2009 [24]	49 patients [24]
Fatima Bibi et al., 2025 [47]	Not specified [47]	Multiple settings [47]	Up to 2025 [47]	10,153 patients [47]
Julien Viau-Lapointe et al., 2024 [48]	Not specified [48]	Multiple settings [48]	Before 2017 [48]	136 studies [48]

Study	Geographic Location	Setting	Study Period	Sample Size
Germán A. Monsalve et al., 2011 [49]	Colombia [49]	Dedicated obstetric HDU [49]	3 years [49]	819 patients [49]
Natasha Sebastian et al., 2020 [50]	Not specified [50]	Multiple settings [50]	Up to 2020 [50]	213 patients [50]
J. Lafon et al., 2021 [51]	South Africa [51]	Tertiary referral ICU [51]	2015-2016 [51]	54 patients [51]
S. F. Malfertheiner et al., 2022 [52]	Europe, Australia, North America [52]	Six ECMO centers [52]	10 years [52]	60 patients [52]
S. Gama et al., 2019 [53]	Durban, South Africa [53]	Tertiary hospital [53]	2010-2013 [53]	85 patients [53]
S. Sarker et al., 2025 [54]	Bangladesh [54]	Tertiary care hospital [54]	2019-2020 [54]	272 patients [54]
J. D. de Barros et al., 2021 [55]	Recife, Brazil [55]	Dedicated obstetric ICU [55]	2012-2019 [55]	284 patients [55]
Lersten Ivy L et al., 2021 [23]	Colorado, USA [23]	Tertiary care center [23]	2007-2017 [23]	71 patients [23]
Hayat Elfil et al., 2023 [56]	Qatar [56]	Tertiary hospital [56]	2020-2021 [56]	43 patients [56]
N. Kaur et al., 2016 [57]	Nepal [57]	Tertiary care institute [57]	May 2015 [57]	28 patients [57]
D. F. Yasmin et al., 2021 [58]	Bangladesh [58]	Tertiary care, mixed ICU [58]	2004 [58]	67 patients [58]

Study	Geographic Location	Setting	Study Period	Sample Size
Wenting Tang et al., 2015 [59]	Guangzhou, China [59]	University hospital [59]	2009-2014 [59]	476 patients [59]
M. Stokes et al., 2022 [60]	Lilongwe, Malawi [60]	Tertiary hospital [60]	Not specified [60]	58 patients [60]
W. Andonotopo et al., 2025 [61]	Developed countries [61]	Multiple settings [61]	2000-2024 [61]	Not specified [61]
K. Knight et al., 2020 [62]	New Zealand [62]	Multiple ICUs/HDUs [62]	2013-2015 [62]	Not specified [62]
J. Lalonde et al., 2025 [14]	United States [14]	Multiple tertiary centers [14]	2009-2024 [14]	Variable [14]
Elena Fatnic et al., 2023 [63]	Israel [63]	Multiple ICUs [63]	2020-2022 [63]	84 patients [63]
Ashish Zarariya et al., 2023 [15]	Not specified [15]	Tertiary care center [15]	2 years [15]	132 patients [15]
M. Sitter et al., 2021 [64]	Germany [64]	150 centers [64]	Ongoing [64]	96 patients [64]
M. Escobar et al., 2019 [65]	Not specified [65]	Dedicated obstetric ICU [65]	2012-2015 [65]	154 patients [65]
Array Л. Шукевич et al., 2010 [17]	Not specified [17]	Not specified [17]	Not specified [17]	42 patients [17]
Snigdha Rai et al., 2024 [16]	Nepal [16]	Tertiary care hospital [16]	2019-2022 [16]	65 trainees [16]

Study	Geographic Location	Setting	Study Period	Sample Size
Shazia Saaqib et al., 2017 [13]	Not specified [13]	Tertiary care, dedicated obstetric ICU [13]	2013-2016 [13]	74 patients [13]
Dr. Shohana Askary et al., 2024 [19]	Dhaka, Bangladesh [19]	Tertiary care hospital [19]	2020 [19]	84 patients [19]
A. A. Nikulin et al., 2024 [66]	Not specified [66]	Single center [66]	Not specified [66]	137 patients [66]
Ehab Hassanin Mohammad et al., 2023 [67]	Not specified [67]	Not specified [67]	2011-2021 [67]	100 patients [67]
B. Ozumba et al., 2018 [20]	Southeast Nigeria [20]	Not specified [20]	2012-2013 [20]	89 patients [20]
A. Aldawood et al., 2011 [3]	Riyadh, Saudi Arabia [3]	Tertiary care, mixed ICU [3]	10 years [3]	75 patients [3]
Keeranmayee Mishra et al., 2024 [25]	Not specified [25]	Tertiary referral center [25]	One year [25]	90 patients [25]
W. Pollock et al., 2010 [27]	Multiple countries [27]	Multiple settings [27]	1990-2008 [27]	7,887 patients [27]
H. Yi et al., 2018 [7]	Not specified [7]	Tertiary care center [7]	1994-2015 [7]	176 patients [7]
Betty Anane-Fenin et al., 2021 [4]	Central Ghana [4]	Tertiary hospital, mixed ICU [4]	10 years [4]	443 patients [4]

Study	Geographic Location	Setting	Study Period	Sample Size
Dr. Muhammad Saeed et al., 2024 [68]	Peshawar, Pakistan [68]	Tertiary care, mixed ICU [68]	2022 [68]	132 patients [68]
Celestine Osita John et al., 2022 [69]	Rivers state, Nigeria [69]	University teaching hospital, mixed ICU [69]	2012-2016 [69]	141 patients [69]
Amaan Ali et al., 2019 [70]	UK and US [70]	Multiple settings [70]	Not applicable [70]	Not applicable [70]
Jennifer A Walker et al., 2025 [71]	Not specified [71]	Multiple settings [71]	2014-2025 [71]	1,813 patients [71]
A. Pan et al., 2017 [18]	Not specified [18]	Mixed ICU [18]	2009-2015 [18]	95 patients [18]
E. J. MacDonald et al., 2020 [72]	New Zealand [72]	Multiple ICUs/HDUs [72]	2013-2015 [72]	89 patients [72]
Catherine P. Marudo et al., 2025 [73]	Not specified [73]	Multiple settings [73]	Last decade [73]	14,717 patients [73]
Kkc Chan et al., 2010 [74]	Hong Kong [74]	Regional hospital [74]	1998-2007 [74]	50 patients [74]
L. Zieleskiewicz et al., 2016 [75]	Developed countries [75]	Mixed ICU [75]	Not applicable [75]	Not applicable [75]
D. Shrestha et al., 2018 [76]	Not specified [76]	Tertiary care, mixed ICU [76]	5 years [76]	80 patients [76]
M. Heavner et al., 2023 [77]	Not specified [77]	Not specified [77]	Not applicable [77]	Not applicable [77]

Study	Geographic Location	Setting	Study Period	Sample Size
M. Muench et al., 2008 [11]	Maryland, USA [11]	University hospital [11]	24 months [11]	34 patients [11]
Caitlin Luebcke et al., 2022 [78]	United States and peer nations [78]	Mixed ICU [78]	2010-2021 [78]	14 articles [78]
A. Faponle et al., 2012 [12]	Not specified [12]	Sub-urban university hospital, mixed ICU [12]	2003-2007 [12]	Not specified [12]
Jan L Keizer et al., 2006 [79]	The Netherlands [79]	Tertiary care center [79]	1990-2001 [79]	142 patients [79]
D. Karnad et al., 2004 [21]	Mumbai, India [21]	Public hospital, mixed ICU [21]	1997-2001 [21]	453 patients [21]
Dipali Prasad et al., 2018 [26]	Patna, India [26]	Tertiary care center [26]	2015-2017 [26]	770 admissions [26]
A. Tempe et al., 2007 [80]	Not specified (developing country) [80]	Tertiary care, mixed ICU [80]	2002-2004 [80]	57 patients [80]
Sara Oliveira et al., 2019 [22]	Portugal [22]	Tertiary care center [22]	2000-2017 [22]	93 patients [22]

The incidence of obstetric ICU admissions varied widely across studies, ranging from 0.2% to 13.5 per 1,000 deliveries [27]. Most patients were admitted postpartum rather than antepartum [5, 8, 9, 29, 34]. A substantial proportion of patients in developing countries were unbooked or had inadequate antenatal care [8, 20, 33, 36, 43, 76], highlighting disparities in prenatal healthcare access.

Obstetric Emergencies Leading to ICU Admission

Hypertensive Disorders of Pregnancy

Hypertensive disorders, including preeclampsia and eclampsia, were the most prevalent indication for obstetric ICU admission across multiple studies. In Africa, hypertensive disorders accounted for 42.96% (95% CI: 27.36, 58.56) of obstetric ICU admissions [39]. Individual studies reported rates ranging from 14% to 70.4% [1–4, 8, 34, 36]. In one tertiary center, hypertensive disorders comprised 35.6% of ICU admissions [68], while another reported 46% of admissions were due to eclampsia [10].

The severity of hypertensive emergencies requiring ICU care was substantial. In one study, 72.9% of eclampsia patients were admitted antepartum, 17.2% postpartum, and 10.8% intrapartum [36]. Complications included HELLP syndrome [5, 32, 55], cerebrovascular accidents [33, 36], and pulmonary edema [36].

Obstetric Hemorrhage

Hemorrhage was the second most common indication for ICU admission, reported as the primary reason in 14.4% to 56.3% of cases across studies [4–7]. In Africa, obstetric hemorrhage accounted for 24.15% (95% CI: 18.12, 30.18) of ICU admissions [39]. Specific hemorrhagic emergencies included postpartum hemorrhage [7, 30], placental abruption [24, 46], and uterine rupture [20].

Sepsis

Sepsis represented a significant indication for ICU admission in multiple studies. Maternal sepsis accounted for 9.3% to 24% of obstetric ICU admissions [4, 43]. Septic abortion was specifically noted in 12% of admissions in one developing country study [8]. In a dedicated review of maternal sepsis, 50% of cases occurred post-caesarean section, while 24% were septic incomplete miscarriages [51].

Other Emergency Conditions

Additional obstetric emergencies requiring ICU admission included acute fatty liver of pregnancy (2.31% to 13.04%) [30, 59], disseminated intravascular coagulation (11.11%) [30], amniotic fluid embolism [24, 61], peripartum cardiomyopathy [33, 44, 50], and ruptured ectopic

pregnancy [26]. Medical complications co-occurring with pregnancy, such as cardiac disease [35, 37] and acute respiratory failure [11, 30], also necessitated ICU care.

During the COVID-19 pandemic, infection with SARS-CoV-2 emerged as a leading cause of obstetric ICU admission [41, 63, 64].

Management Strategies and Interventions

Multidisciplinary Team Approaches

Effective management of critically ill obstetric patients consistently required multidisciplinary collaboration. Teams typically included obstetricians, intensivists, anesthesiologists, neonatologists, and other specialists [1–5, 10, 23, 34–36, 46, 49, 52, 68, 72, 75, 76]. This collaborative model was particularly emphasized in complex cases such as placenta accreta spectrum [19, 23] and severe sepsis [51].

The composition of teams varied by setting. In dedicated obstetric ICUs, full-time obstetricians worked alongside board-certified intensivists and general physicians [31]. In mixed ICUs, daily consultation with obstetric units was common [6]. Some centers established specialized maternal-fetal medicine teams that included gynecologic oncology, urology, and interventional radiology [23].

Critical Care Interventions

Mechanical Ventilation

Mechanical ventilation was required in a substantial proportion of patients, ranging from 9% to 85% across studies [2, 3, 6, 8, 22, 25, 29, 43, 44, 51, 54, 56, 68, 79]. The mean duration of mechanical ventilation ranged from 2.5 to 3 days [51, 54]. In pregnant patients with severe COVID-19, respiratory support modalities included high-flow nasal cannula, non-invasive positive pressure ventilation, and invasive positive pressure ventilation [56].

Pregnancy-specific modifications to ventilation were noted. Providers emphasized the need to avoid hypoxemia and permissive hypercapnia due to negative fetal effects [75]. Positioning strategies included left lateral tilt to prevent aorto-caval compression [75].

Blood Products and Transfusion

Blood and blood product transfusion was required in 40.9% to 90.7% of patients [2, 22, 34, 43, 44, 51, 54]. The use of whole blood transfusion as an alternative to component therapy showed promise in reducing transfusion volumes and surgical interventions [14]. In studies comparing whole blood to component therapy, patients receiving whole blood had significantly lower transfusion volumes (2,607 mL vs. 4,683 mL, $p = 0.03$) [14] and no maternal deaths compared to those receiving component therapy [14].

Tranexamic acid was used for hemorrhage control [46], and protocols following French Society recommendations guided plasma transfusion [46]. In septic shock patients with anemia, early blood transfusion (within 6 hours of admission) shortened recovery time and decreased maternal mortality compared to late transfusion [13, 13].

Hemodynamic Support

Inotropic or vasopressor support was required in 9% to 65.9% of patients [22, 25, 34, 44, 51, 68]. Invasive hemodynamic monitoring, including arterial lines and central venous pressure monitoring, was common [29, 34]. Some centers used advanced monitoring including pulmonary arterial and left atrial pressure measurement [34].

Renal Replacement Therapy

Renal replacement therapy or dialysis was required in 5.7% to 11.39% of patients [37, 51, 54, 56]. Continuous renal replacement therapy as part of complex therapy for severe obstetric sepsis reduced mortality by an average of 35% compared to standard therapy [17, 17].

Extracorporeal Membrane Oxygenation

ECMO was used in select cases of severe cardiopulmonary failure. In a multicenter study of 60 peripartum ECMO cases, maternal survival was 87%, with 94% survival for veno-venous ECMO and 71% for veno-arterial ECMO [52]. Most frequent indications were acute respiratory distress syndrome (50%) and pulmonary embolism (8.3%) [52]. ECMO enabled successful maternal resuscitation in pregnancy-related emergencies, though it carried risks including hemorrhagic complications [52].

Standby ECMO, prepared for rapid deployment in high-risk peripartum scenarios, was emerging as a strategy [73], though consensus guidelines for its use did not yet exist [73].

Surgical Interventions

Emergency Obstetric Procedures

Emergency cesarean section was performed in 28.57% to 56.71% of ICU-admitted patients [44, 59]. Timing of delivery was critical, particularly in critically ill patients. In severe COVID-19 pneumonitis, interventional delivery was recommended before patients deteriorated to requiring mechanical ventilation [63]. Patients who were critically ill at the time of delivery had worse outcomes, with 81% requiring invasive positive pressure ventilation and 3% mortality [63], compared to non-critical patients at delivery who had better outcomes with only 14% requiring ventilation and no deaths [63].

Uterine-Conserving Techniques

For postpartum hemorrhage management, uterine-conserving interventions included condom or balloon tamponade [15, 16, 43, 44], B-Lynch or compression sutures [15, 16, 44, 46], bimanual compression [16], and stepwise devascularization procedures [15, 44]. The non-pneumatic antishock garment (NASG) combined with balloon tamponade reduced surgical interventions and improved outcomes [15, 65, 65].

Definitive Surgical Management

Obstetric hysterectomy was required in 13.5% to 32.5% of severe cases [7, 15, 23, 40, 43, 44, 46, 69]. In placenta accreta spectrum cases managed with standardized protocols, planned management resulted in fewer complications compared to emergency management, including lower rates of postpartum hemorrhage (31% vs. 95%) [19], sepsis (0% vs. 9.5%) [19], and maternal mortality (0% vs. 4.8%) [19].

Interventional radiology techniques, including uterine artery embolization, were used as alternatives to hysterectomy in selected cases [7, 43].

Protocols and Guidelines

Early Warning Systems

Early detection systems were critical for preventing progression to severe morbidity. Modified Early Warning Scores (MEOWS) were implemented in some settings with 100% compliance [29]. Sequential Organ Failure Assessment (SOFA) scores were used for organ failure assessment [28]. The APACHE II score was used for admission decisions [6, 41], though it overpredicted mortality in obstetric populations [8, 11].

Standardized Treatment Protocols

Structured protocols improved outcomes in specific conditions. For eclampsia and HELLP syndrome, protocolized pain management including opioid-sparing and regional anesthesia reduced maternal complications and ICU stay [47, 47]. Management emphasized blood pressure control, seizure prophylaxis with magnesium sulfate, corticosteroids, blood product transfusions, and renal replacement when indicated [47].

Training programs implementing skills-based courses for postpartum hemorrhage management significantly improved outcomes. After training, maternal mortality from PPH dropped from 75% to 0% [16], blood transfusion rates decreased from 41% to 17.2% [16], and ICU admissions fell from 7% to 1.7% [16].

Timing of Interventions

Early intervention was consistently associated with better outcomes. For postpartum hemorrhage, surgical intervention within 6 hours resulted in significantly less blood transfusion (759 ± 114 mL) compared to 6-12 hour intervention ($2,000 \pm 829$ mL) or >12 hour intervention ($4,999 \pm 1,699$ mL) [18]. Shortening the interval between onset of acute symptoms and ICU admission was an independent predictor of reduced prolonged ICU stay [30, 30].

Pregnancy-Specific Modifications

Standard ICU care required adaptation for pregnant patients. Drug safety evaluation was essential [38], with careful analysis of benefit-risk ratios [75]. Fetal monitoring was incorporated into maternal critical care [28, 38], with decision-making balancing maternal stabilization against fetal viability [28, 75].

Airway management required special attention due to increased aspiration risk and potential for difficult intubation [75]. Positioning strategies addressed aorto-caval compression [28, 75]. Diagnostic imaging involving ionizing radiation required careful consideration [28].

Point-of-care ultrasonography emerged as a valuable tool for maternal-fetal assessment in the ICU setting [28].

Maternal Outcomes

Maternal Mortality Rates

Maternal mortality rates varied widely across settings and patient populations. Overall mortality ranged from 0% to 41.2% across individual studies [5, 8–12, 29, 34, 69].

In Africa, a meta-analysis found maternal mortality among ICU-admitted patients reached 30.69% (95% CI: 23.16, 38.22) [39]. This rate was significantly higher than in developed countries, where mortality ranged from 3.3% to 14% [27]. Regional variation was substantial even within developing countries, with rates of 1.93% to 43.11% reported [30, 58].

In tertiary care centers with dedicated obstetric ICUs and multidisciplinary teams, maternal mortality was generally lower, ranging from 3.03% to 13% [6, 31, 36]. Centers with standardized protocols and early intervention strategies achieved particularly low mortality rates [3, 31].

Mortality by Emergency Type

Mortality rates varied substantially by the type of obstetric emergency:

Emergency Type	Mortality Rate	Source
Sepsis	63.4% [4]	Betty Anane-Fenin et al., 2021
Amniotic fluid embolism	66.7% [9]	Irene Akhideno et al., 2024
Pulmonary edema	57.1% [9]	Irene Akhideno et al., 2024
Eclampsia	50% [9]	Irene Akhideno et al., 2024
Hemorrhage	37.5% to 40% [4, 9]	Multiple studies
Hypertensive disorders	17.6% [4]	Betty Anane-Fenin et al., 2021

Emergency Type	Mortality Rate	Source
Fulminant hepatic failure	66.7% [68]	Dr. Muhammad Saeed et al., 2024
Post-natal septicemia	37.5% [68]	Dr. Muhammad Saeed et al., 2024

During the COVID-19 pandemic, mortality among pregnant ICU patients with COVID-19 was 19.3% compared to 1.4% in non-COVID-19 obstetric ICU patients [41].

Causes of Maternal Death

The primary causes of maternal death in ICU settings included:

- Multiple organ dysfunction syndrome (28.5% to 44%) [8, 33, 44]
- Intracranial or cerebrovascular hemorrhage (31.42% to 39%) [8, 58]
- Hemorrhagic shock (30% to 47.8%) [43, 80]
- Cardiac arrest (63.2%) [10]
- Sepsis and septic shock [33, 44, 54]

Maternal Morbidity

Non-fatal complications were common among ICU survivors. Acute kidney injury occurred in 6% to 40.7% of patients [24, 51]. Coagulopathy developed in 25.9% of maternal sepsis cases [51]. Circulatory shock affected 12.9% of patients [51], while acute respiratory distress syndrome occurred in 9.2% to 19% [8, 51].

Severe maternal morbidity, defined by ICU admission and other criteria, occurred at a rate of 6.2 per 1,000 deliveries in New Zealand [62]. Approximately one-third (34.1%) of these cases were deemed potentially preventable [62].

Long-term health-related quality of life in discharged patients was lower than population norms [74]. Post-intensive care syndrome with physical, cognitive, and psychological sequelae was recognized as an important long-term outcome [28].

Length of ICU Stay

The duration of ICU admission varied widely. Mean or median ICU stay ranged from 2 to 7 days across studies [6, 9, 22, 32, 34, 51, 54, 76, 80]. Prolonged ICU stay (>3 days) occurred in 52.66% of patients in one large series [30].

Factors associated with prolonged ICU stay included irregular antenatal care, abnormal oxygenation index, acute fatty liver of pregnancy, disseminated intravascular coagulation, severe acute pancreatitis, need for inotropic support, blood purification, and >24 hour interval between symptom onset and ICU admission [30].

Risk Factors for Maternal Mortality

Multiple factors were associated with increased maternal mortality:

Clinical Factors:

- Intra- or postpartum onset of seizures in eclampsia [53]
- Lowest Glasgow Coma Scale score <10 [53]
- Acute cardiovascular failure [21]
- Nervous system failure [21]
- Respiratory failure [21, 53]
- Acute kidney injury [55]
- HELLP syndrome [55]
- Puerperal hemorrhage [55]
- Acute pulmonary edema [55]

Patient Characteristics:

- Advanced maternal age (≥ 35 years) [55]
- Age ≥ 25 years [4]
- Multiparity [60]
- Twin pregnancy [53]

- Need for mechanical ventilation [4]

Healthcare System Factors:

- Lack of antenatal care [8, 20, 58]
- Unbooked status [20, 69]
- Delay in ICU referral [21]
- Failure to perform operative delivery when indicated [53]
- Failure to use magnesium sulfate appropriately [53]

Protective factors included younger age (≤ 19 years) [4, 55], surgery during the index pregnancy [4], and receiving ICU support [58].

Neonatal and Perinatal Outcomes

Neonatal Mortality

Perinatal mortality rates ranged from 4.2% to 52% [5, 20–22]. In one large series, fetal mortality was 32% [8]. Stillbirth rates were particularly high in cases of placental abruption (78.6%) [46] and in settings with limited resources.

Neonatal death rates in studies reporting this outcome ranged from 5% to 39% [19, 24, 25]. Four fetuses were stillborn (4%) in one COVID-19 cohort [64].

Birth Characteristics

Gestational age at delivery was often premature. Mean gestational ages ranged from 29 to 35.38 weeks across studies [8, 22, 23]. More than two-thirds of deliveries occurred before 37 weeks in some series, with nearly one-third before 33 weeks [72].

Preterm delivery was observed in 47% of pregnant COVID-19 patients requiring ICU care [64]. In placenta accreta spectrum cases, gestational age averaged 33.69 weeks in the standardized protocol group [23].

Mean birth weight ranged from 2,297 to 2,586 grams [22, 23]. Apgar scores at 1, 5, and 10 minutes had medians of 6, 9, and 10 respectively in one series [22].

NICU Admission

Neonatal intensive care unit admission rates varied from 18% to 72.5% [19, 24–26]. NICU admission was required in 27.45% of neonates in one developing country study [26].

Neonatal asphyxia or birth asphyxia occurred in 22.62% to 36.17% of cases [19, 59]. In placenta accreta spectrum, birth asphyxia was significantly higher in emergency management compared to planned management (31% vs. 9.5%) [19].

Factors Affecting Neonatal Outcomes

Maternal COVID-19 infection caused premature birth, with significantly shorter gestational periods compared to non-COVID-19 pregnancies [41]. Maternal critical illness severity, as indicated by need for ECMO, was associated with fetal death [52]. Lack of antenatal care was more frequent in nonsurvivors compared to survivors [8].

In cases of amniotic fluid embolism, neonatal outcomes included high prevalence of hypoxic-ischemic encephalopathy leading to lifelong neurodevelopmental morbidity [61]. The timing of perimortem cesarean delivery was critical for neonatal survival [61].

Comparative Effectiveness of Management Strategies

Dedicated Obstetric ICU vs. Mixed ICU

Studies comparing dedicated obstetric ICUs with mixed ICUs were limited, but suggested potential benefits of specialized units. Dedicated obstetric ICUs allowed for immediate management and early intensive care institution [6, 6]. Centers with dedicated obstetric ICUs often reported lower maternal mortality rates [31, 36, 49].

Timing of Delivery

Evidence strongly supported interventional delivery for maternal indications before patients deteriorated critically. In a nationwide cohort study, maternal outcomes deteriorated following delivery among critically ill patients, with 81% requiring invasive ventilation and 3% mortality [63]. In contrast, non-critical patients at delivery improved following intervention, with only 14% requiring invasive ventilation and no deaths [63].

For placenta accreta spectrum, planned management with multidisciplinary teams was superior to emergency management. Planned cases had lower rates of postpartum hemorrhage (31%

vs. 95%), sepsis (0% vs. 9.5%), re-exploration (0% vs. 19%), disseminated intravascular coagulation (2.3% vs. 21.4%), ICU admission (9.5% vs. 50%), and no maternal deaths compared to 4.8% mortality in emergency cases [19].

Blood Product Management

Whole blood transfusion showed advantages over component-based therapy in obstetric hemorrhage. Patients receiving whole blood had significantly lower transfusion volumes (2,607 mL vs. 4,683 mL) [14], fewer maternal complications [14], and no maternal deaths compared to those receiving component therapy [14].

Early blood transfusion (within 6 hours) in puerperal septic shock patients with anemia shortened recovery time from hypotension, tachycardia, pulmonary edema, and need for ventilator and cardiac support [13]. Maternal mortality was lower with early transfusion (23.25% vs. 48.39%) [13].

Uterine-Conserving Interventions

The non-pneumatic antishock garment combined with balloon tamponade reduced the need for surgical interventions compared to no such intervention. Surgical hysterectomy rates were 3.2% with NASG/balloon tamponade versus 7.0% without [15]. Blood loss was significantly smaller [15], shock index lower (0.7 ± 0.1 vs. 0.8 ± 0.1) [15], and hospital stay shorter (9.8 ± 2.7 vs. 12.7 ± 3.6 days) [15]. Mortality occurred only in the group not receiving NASG (3 deaths vs. 0) [15].

Continuous Renal Replacement Therapy

Incorporating continuous renal replacement therapy into treatment for severe obstetric sepsis reduced mortality by an average of 35% compared to standard intensive care [17]. It also reduced time to control endogenous intoxication and multiple organ dysfunction [17].

Training and Protocols

Implementation of skills development training for postpartum hemorrhage management demonstrated remarkable impact. After training, maternal mortality from PPH dropped from 75% to 0% ($p=0.009$) [16]. Blood transfusion rates decreased from 41% to 17.2% [16], ICU admissions fell from 7% to 1.7% [16], and peripartum hysterectomy rates declined from 1.3% to 0.04% [16]. Use of uterine-conserving techniques increased substantially [16].

Early Intervention

Timing of surgical intervention for postpartum hemorrhage significantly affected outcomes. Intervention within 6 hours resulted in mean transfusion of 759 ± 114 mL, compared to $2,000 \pm 829$ mL for 6-12 hour intervention and $4,999 \pm 1,699$ mL for >12 hour intervention [18].

Standardized Multidisciplinary Protocols

Quality improvement initiatives implementing standardized multidisciplinary care for placenta accreta spectrum showed lower likelihood of emergent deliveries and smaller blood loss, though composite morbidity and mortality did not differ significantly [23]. The intervention demonstrated improved post-operative hemoglobin levels [23].

Synthesis

The evidence reveals substantial heterogeneity in outcomes across different healthcare contexts, patient populations, and management approaches. Understanding this variation requires systematic examination of contextual factors, study quality, and mechanistic explanations.

Geographic and Resource Disparities

Maternal mortality rates differed markedly between developed and developing countries (median 3.3% vs. 14.0%, $p=0.002$) [27]. However, this disparity reflects multiple interconnected factors rather than a simple resource availability gradient. Within developing countries, mortality ranged from 1.93% to 43.11% [30, 58], while African centers showed 30.69% mortality [39] compared to 3.03% in an Indian tertiary center with dedicated obstetric ICU [31].

The critical differentiating factors appear to be:

Access to Antenatal Care: Studies consistently demonstrated that lack of prenatal care was associated with worse outcomes. In one study, 82.23% of maternal deaths occurred in patients without antenatal check-ups [58]. Another found antenatal care was present in 33% of survivors versus only 6% of nonsurvivors ($p=0.014$) [8]. This suggests that geographic mortality differences partly reflect prenatal care infrastructure rather than ICU capabilities alone.

Referral Patterns and Delays: The interval between symptom onset and ICU admission was an independent predictor of prolonged ICU stay and worse outcomes [18, 30]. In resource-limited settings, 76% of patients were referred from peripheral health centers [35], often arriving with

advanced complications. Conversely, centers with low-threshold admission policies and proximity to obstetric wards achieved better outcomes [49, 49].

Booking Status: Unbooked patients comprised 64.28% to 98.03% of admissions in some developing country studies [33, 36, 57], significantly associated with maternal mortality [20, 20]. This population characteristic, rather than ICU quality per se, explained much of the observed mortality variation.

Infrastructure Beyond the ICU: Settings lacking functional blood bank services [69] or with limited ICU bed availability [58] experienced worse outcomes regardless of individual patient management. This suggests system-level factors were as important as bedside interventions.

Emergency Type and Disease-Specific Outcomes

Mortality varied dramatically by emergency type, from 17.6% for hypertensive disorders to 63.4%-66.7% for sepsis and amniotic fluid embolism [4, 68]. These differences reflect distinct pathophysiologic mechanisms:

Sepsis Cases: High mortality in sepsis (37.5% to 63.4%) [4, 68] occurred despite aggressive interventions including mechanical ventilation (mean duration 2.5 days) [51] and blood products (90.7% of patients) [51]. However, sepsis mortality was notably lower (25%) when cases occurred post-vaginal birth compared to post-cesarean section (mortality rates not separately reported but cesarean section represented 50% of sepsis cases) [51]. This suggests surgical site infection and wound complications contributed to worse outcomes.

The effectiveness of early antibiotic administration provides mechanistic support: delay decreased survival by 7.6% per hour [70], while "Sepsis Six" protocols reduced mortality by up to 50% [70]. Studies showing high sepsis mortality may have included patients with delayed recognition or treatment initiation.

Hemorrhage Cases: Obstetric hemorrhage mortality (37.5% to 40%) [4] was strongly influenced by intervention timing. Early surgical intervention (<6 hours) resulted in transfusion volumes of 759 mL compared to 4,999 mL with >12 hour delay [18]. This dose-response relationship between delay and blood loss provides a mechanistic explanation for varying hemorrhage mortality across studies.

The introduction of NASG and balloon tamponade reduced hemorrhage mortality to 0% in intervention groups versus persistent deaths in control groups [15]. Similarly, whole blood transfusion eliminated maternal deaths compared to component therapy [14], suggesting that therapeutic approach rather than hemorrhage severity alone determined outcomes.

Study Quality and Selection Effects

Higher-quality evidence suggested different conclusions than lower-quality studies. The APACHE II score consistently overpredicted mortality in obstetric populations [8, 11], with predicted rates of 21.97% versus actual rates of 8% [3]. This indicates obstetric patients had better outcomes than similarly ill non-obstetric patients, challenging assumptions that pregnancy worsens critical illness prognosis.

Studies with rigorous multidisciplinary protocols reported lower mortality than those without standardized approaches. A quality improvement initiative for placenta accreta spectrum reduced maternal mortality from 3.4% to 0% in the intervention group [23]. Training programs for postpartum hemorrhage management eliminated PPH-related mortality entirely (75% to 0%) [16]. These intervention studies provide stronger evidence than observational series for the effectiveness of systematic approaches.

Potential publication bias favoring positive intervention results should be considered. However, the consistency of findings across multiple interventions (NASG [15], whole blood [14], early transfusion [13], continuous renal replacement [17]) and the magnitude of effects (35% to 100% mortality reduction) suggest real benefits rather than reporting artifacts.

Timing-Dependent Effects

A consistent pattern emerged where earlier intervention produced superior outcomes, but the critical time windows varied by condition:

Hemorrhage: The relationship between intervention timing and blood loss showed diminishing returns. Delaying intervention from <6 hours to 6-12 hours more than doubled transfusion requirements (759 mL to 2,000 mL), but further delay to >12 hours had an even more dramatic effect (4,999 mL) [18]. This non-linear relationship suggests a threshold beyond which hemorrhagic shock becomes irreversible.

Sepsis: Linear deterioration occurred with antibiotic delay (7.6% decreased survival per hour) [70], consistent with exponential bacterial growth kinetics. This contrasts with hemorrhage's threshold effect and explains why some sepsis cases had good outcomes despite severe presentation—those receiving immediate antibiotics.

ICU Admission: The >24 hour interval between symptom onset and ICU admission was an independent predictor of prolonged stay [30], but the exact mechanism (progression of organ dysfunction versus delayed definitive intervention) remains unclear from available data.

Population-Specific Vulnerabilities

Certain populations showed disproportionate mortality risk:

Ethnic Minorities: Pacific Island women had 2.5-fold higher risk of preventable severe maternal morbidity compared to European women [62]. This disparity persisted even after accounting for socioeconomic status, suggesting cultural, linguistic, or systemic barriers to care.

Maternal Age: The relationship with age was non-linear. Women ≤ 19 years had protective effects (OR 0.46 for severe maternal outcomes) [55], while those ≥ 35 years or ≥ 25 years had increased mortality risk [4, 55]. This may reflect different pathophysiology (younger women with primary hypertensive disorders versus older women with medical comorbidities), rather than age per se.

Multiparity: Multiparity was associated with worse outcomes in some studies [60], while primiparity showed better outcomes in others [53]. This apparent contradiction likely reflects confounding by indication—multiparous women may have had previous complications or grand multiparity, while primiparous women in studies showing protective effects were younger and healthier.

Intervention-Specific Mechanisms

Whole Blood vs. Component Therapy: Whole blood's superiority (2,607 mL vs. 4,683 mL transfusion volume) [14] likely reflects more physiologic hemostasis. Component therapy requires coordinated administration of multiple products, potentially leading to delays and dilutional coagulopathy. Whole blood provides all elements simultaneously in natural ratios.

NASG Mechanisms: The non-pneumatic antishock garment reduced mortality to 0% [15] likely through two mechanisms: immediate reduction of pelvic blood pooling and decreased uterine

bleeding via increased intrauterine pressure. Combined with balloon tamponade, which directly compresses bleeding vessels, this dual-mechanism approach explained the dramatic effect.

Renal Replacement Therapy in Sepsis: The 35% mortality reduction with continuous renal replacement therapy [17] exceeded what would be expected from renal function support alone. This suggests additional benefits through cytokine removal and inflammatory mediator clearance, particularly relevant in obstetric sepsis where endogenous intoxication was prominent [17].

Preventability and System Factors

The finding that 34.1% of severe maternal morbidity was potentially preventable [62], with 93.4% involving clinician-related factors [62] and 60.6% involving system factors [62], indicates substantial room for improvement. However, preventability varied by condition: 56% of severe sepsis cases were preventable compared to 30.9% of hemorrhage cases [62].

This variation suggests different prevention strategies are needed. Sepsis prevention requires earlier recognition and treatment initiation (addressable through clinician education and early warning systems). Hemorrhage, being more acute and unpredictable, requires system readiness (blood bank availability, surgical teams) rather than early detection alone.

The higher preventability among Pacific Island patients (100% clinician factors, 67.6% system factors) [62] compared to overall rates suggests cultural competency and language-concordant care gaps contributed to disparities.

Implications for Practice

Based on this synthesis, effective management requires:

1. **Population Risk Stratification:** Unbooked patients, those with delayed presentation, and ethnic minorities require heightened surveillance and lower thresholds for ICU admission.
2. **Condition-Specific Approaches:**
 - Hemorrhage: Immediate intervention (<6 hours), whole blood when available, NASG/balloon tamponade before resorting to hysterectomy

- Sepsis: Immediate broad-spectrum antibiotics, consider continuous renal replacement therapy
- Hypertensive disorders: Appropriate magnesium sulfate use, timely delivery decisions
- **System Strengthening:** Functional blood banks, 24/7 surgical availability, and multidisciplinary protocols matter more than individual ICU interventions for many conditions.
- **Training Investment:** Skills-based training for hemorrhage management showed complete mortality elimination [16], suggesting educational interventions may be as important as technological ones.
- **Early Warning Systems:** Implementation of MEOWS and similar tools can identify deteriorating patients before ICU-level intervention becomes necessary [28, 29].

DISCUSSION

This systematic review of 80 studies demonstrates that effective management of obstetric emergencies in ICU settings is characterized by three interdependent principles: **early intervention, multidisciplinary teamwork, and protocolized, condition-specific care**. The evidence reveals substantial heterogeneity in outcomes, but consistent patterns emerge when analyzing intervention timing, team composition, and resource availability.

Early Intervention as a Critical Determinant

The most consistent finding across conditions is that delay worsens outcomes, but the critical time windows differ by pathophysiology. For PPH, surgical intervention within 6 hours resulted in mean transfusion of 759 mL compared to 4,999 mL with >12 hour delay (18)—a nearly 7-fold difference. This non-linear relationship suggests a threshold beyond which hemorrhagic shock becomes irreversible, likely due to coagulopathy onset and depletion of clotting factors. In contrast, sepsis showed a linear deterioration: each hour of antibiotic delay decreased survival by 7.6% (70),

consistent with exponential bacterial growth kinetics. For ICU admission itself, intervals >24 hours from symptom onset independently predicted prolonged ICU stay and worse outcomes (30).

These findings have direct clinical implications. First, low-threshold ICU admission policies—admitting patients with early warning signs rather than waiting for overt deterioration—appear justified. Second, triage protocols should prioritize obstetric patients with suspected hemorrhage or sepsis for immediate intervention. Third, transfer delays from peripheral centers (reported in 76% of patients in one study) (35) represent a modifiable system failure.

Multidisciplinary Team Composition

Effective teams consistently included obstetricians, intensivists, anesthesiologists, neonatologists, and, where available, interventional radiologists and maternal-fetal medicine specialists (1-5,10,23,34-36,46,49,52,68,72,75,76). The mechanism of benefit likely involves simultaneous management of competing priorities: maternal stabilization (intensivist), fetal assessment and delivery timing (obstetrician/neonatologist), airway and hemodynamic support (anesthesiologist), and hemorrhage control (interventional radiology/surgery). In placenta accreta spectrum, planned multidisciplinary management reduced PPH from 95% to 31% and eliminated maternal mortality compared to emergency management (19).

Notably, team composition adapted to resources. In dedicated obstetric ICUs, full-time obstetricians worked alongside intensivists (31). In mixed ICUs, daily obstetric consultation was essential (6). The key success factor appears not to be dedicated ICU status per se, but rather structured communication and shared protocols between specialties.

Condition-Specific Effective Strategies

Obstetric Hemorrhage: The strongest evidence supports whole blood transfusion over component therapy, with reduced transfusion volumes (2,607 mL vs. 4,683 mL) and zero maternal deaths in the whole blood group (14). This likely reflects more physiologic hemostasis—whole blood provides platelets, clotting factors, and red cells in natural ratios without the dilutional coagulopathy risk of component therapy. The non-pneumatic antishock garment (NASG) combined with balloon tamponade reduced mortality from 3 deaths to zero (15), operating through two mechanisms: immediate reduction of pelvic blood pooling and increased intrauterine pressure. Skills training for

PPH management demonstrated remarkable impact: mortality dropped from 75% to 0%, ICU admissions from 7% to 1.7% (16). This suggests educational interventions may be as effective as technological ones in low-resource settings.

Sepsis in Pregnancy: Mortality remains high (37.5%-63.4%) (4,68) despite aggressive interventions. However, early blood transfusion (within 6 hours) in anemic septic shock patients reduced mortality from 48.39% to 23.25% (13). Continuous renal replacement therapy reduced mortality by 35% (17), likely through cytokine removal and inflammatory mediator clearance beyond renal support. The "Sepsis Six" protocol (70) reduced mortality by up to 50%, emphasizing immediate oxygen, blood cultures, antibiotics, fluids, lactate measurement, and urine output monitoring.

Hypertensive Disorders: Eclampsia and preeclampsia account for the largest proportion of ICU admissions (42.96% in Africa) (39) but have lower mortality (17.6%) than hemorrhage or sepsis (4). Protocolized pain management including opioid-sparing and regional anesthesia reduced maternal complications and ICU stay (47). Magnesium sulfate for seizure prophylaxis, blood pressure control, and timely delivery remain cornerstones. Notably, patients who delivered while critically ill had worse outcomes (81% required invasive ventilation, 3% mortality) compared to those delivered before critical deterioration (14% ventilation, 0% mortality) (63), supporting interventional delivery for maternal indications.

Amniotic Fluid Embolism and ECMO: Though rare (66.7% mortality in one series) (9), maternal survival with ECMO reached 87% in a multicenter study (52). Standby ECMO for high-risk peripartum scenarios is emerging (73), though consensus guidelines lack.

Resource Disparities and Population Factors

Maternal mortality varied from 1.93% to 43.11% across developing countries (30,58), while African centers reported 30.69% (39) compared to 3.03% in an Indian dedicated obstetric ICU (31). These disparities are not simply explained by GDP. Critical differentiating factors include:

- **Antenatal care access:** 82.23% of maternal deaths occurred in women without antenatal check-ups (58); antenatal care present in 33% of survivors vs. only 6% of nonsurvivors (8).

- **Booking status:** Unbooked patients comprised 64.28%-98.03% of admissions in some studies (33,36,57), strongly associated with mortality (20).
- **Referral delays:** 76% of patients referred from peripheral centers (35), arriving with advanced complications.
- **Blood bank availability:** Settings lacking functional transfusion services experienced worse outcomes regardless of individual patient management (69).

These findings reframe the mortality gradient: ICU quality matters, but upstream factors (prenatal care access, referral systems, blood supply) may be equally or more important.

Preventability

Approximately 34.1% of severe maternal morbidity was potentially preventable, with 93.4% involving clinician-related factors and 60.6% system factors (62). Preventability varied by condition: 56% of severe sepsis cases were preventable versus 30.9% of hemorrhage cases. This suggests different prevention strategies: sepsis requires earlier recognition (clinician education, early warning systems), while hemorrhage requires system readiness (blood availability, surgical teams). Pacific Island women had 2.5-fold higher risk of preventable morbidity compared to European women (62), implicating cultural, linguistic, or systemic barriers.

CONCLUSION AND RECOMMENDATIONS

Conclusion: Effective management of obstetric emergencies in ICU settings significantly reduces maternal and neonatal mortality through three core strategies: (1) **early intervention**—hemorrhage control within 6 hours, antibiotics within 1 hour, ICU admission within 24 hours of symptom onset; (2) **multidisciplinary teamwork** with structured obstetric-intensivist collaboration; and (3) **condition-specific protocols** including whole blood transfusion and NASG/balloon tamponade for hemorrhage, early antibiotics and continuous renal replacement therapy for sepsis, and interventional delivery before critical deterioration for hypertensive disorders. Dedicated obstetric ICUs and skills-based training programs show particular benefit. Maternal mortality ranges from 0% to 41.2% depending on condition, resources, and timeliness, while neonatal mortality ranges from

4.2% to 52%. Up to 34% of severe morbidity is preventable, primarily through improved clinician recognition and system readiness.

Recommendations:

1. Implement modified early warning scores (MEOWS) in all obstetric units with low thresholds for ICU consultation.
2. Establish multidisciplinary obstetric ICU protocols including whole blood transfusion protocols, NASG availability, and continuous renal replacement therapy capability.
3. Mandate skills-based PPH management training for all obstetric providers.
4. Prioritize antenatal care access and reduce referral delays through regionalized perinatal systems.
5. Conduct prospective trials comparing dedicated obstetric ICUs versus mixed ICUs with obstetric consultation.
6. Develop standardized outcome definitions for obstetric critical care research.

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