

Prognosticating Fetomaternal ICU Outcomes

Jyotsna Suri¹, Zeba Khanam²

ABSTRACT

Although no scoring system is as yet fully validated for predicting maternal outcomes in critically ill obstetric patients, prognostication may be done objectively using severity predicting models. General critical care scoring systems which have been studied in obstetric patients are outcome prediction models (Acute Physiology and Chronic Health Evaluation [APACHE] I-IV, Simplified Acute Physiology Score [SAPS] I-III, Mortality Probability Model [MPM] I-IV) and organ dysfunction scores (Multiple Organ Dysfunction Score [MODS], Logistic Organ Dysfunction Score [LODS], Sequential Organ Failure Assessment [SOFA]). General critical care scoring systems may overpredict mortality rates in obstetric patients secondary to an altered physiology of organ systems during pregnancy. Obstetric prediction models were developed keeping in mind the physiological characteristics of obstetric population. They are Modified Early Obstetric Warning System (MEOWS), Obstetric Early Warning Score (OEWS), Maternal Early Warning Trigger (MEWT), and disease-specific obstetric scoring systems. The APACHE II model and MPM II are most often used scoring systems for predicting maternal mortality. The SOFA model is the best predictive model for sepsis in obstetrics. APACHE II and SAPS are more useful for nonobstetric population. Recent studies have also underscored the applicability of the OEWS in intensive care unit (ICU) settings with results comparable to the more elaborate APACHE II and SOFA scores. The Early Warning System helps in identifying acutely deteriorating pregnant and postpartum women in non-ICU settings who may require critical care. Fetal outcomes are largely dependent upon maternal outcomes. Prognostic systems applied to mothers may help in estimation of perinatal mortality and morbidity.

Keywords: Delays, Fetomaternal outcome, ICU, Mortality, Mortality prediction, Obstetric critical care, Predictive model, Pregnancy.

Indian Journal of Critical Care Medicine (2021): 10.5005/jp-journals-10071-24022

INTRODUCTION

A majority of the women during their reproductive lives will have an uneventful pregnancy outcome. However, a few of them may have serious complications either directly due to pregnancy, aggravated by pregnancy, or unrelated to pregnancy, all of which may warrant critical care for the patient. Obstetric critical care is defined as “the specialized management of critically ill obstetric patients via an interdisciplinary approach in which the optimization of the clinical variables of pregnant women should be approximated to the maternal-fetal unit needs as a whole.”¹

Maternal and perinatal mortality rates are important healthcare indicators for a nation. Ninety-nine percent of maternal deaths and 98% of perinatal deaths around the globe are reported from developing nations. A total of 830 women across the globe die from preventable causes every day.² Delayed estimation of severity and complications of obstetric illness is an important cause for these preventable deaths.

Hence, various predictive models for disease severity scoring, which were developed for general population, were applied to pregnant women also. These scoring systems were meant to identify signs of critical illness in a patient and triage them into one of the following levels of care according to disease severity, namely low-risk wards, high dependency units/step-down units or intensive care units (ICUs). However, it was observed that the physiological changes of pregnancy rendered these generalized severity scoring systems erroneous. Hence, obstetric-specific scores were developed.

This review was conducted to study the role of prognostic markers for predicting pregnancy outcomes in critically ill obstetric patients.

METHODS

This article has been written with the aim of analyzing various disease severity scores for prognosticating maternal, fetal, and

^{1,2}Department of Obstetrics and Gynaecology, VMMC and Safdarjung Hospital, New Delhi, India

Corresponding Author: Jyotsna Suri, Department of Obstetrics and Gynaecology, VMMC and Safdarjung Hospital, New Delhi, India, e-mail: jyotsnasuri@gmail.com

How to cite this article: Suri J, Khanam Z. Prognosticating Fetomaternal ICU Outcomes. *Indian J Crit Care Med* 2021;25(Suppl 3):S206–S222.

Source of support: Nil

Conflict of interest: None

neonatal outcomes of obstetric patients admitted in the ICU setting. The role of demographic profiles, clinical characteristics, and delays in admission and treatment were also analyzed. The PubMed engine was used for literature search using the following keywords: obstetric critical care, maternal mortality, predictive tests, scores for prognostication, ICU scoring, and disease severity scoring. The outcomes for prognosticating purpose were defined as maternal mortality (primary outcome), length of stay in the ICU (ICU-LOS), maternal complications and interventions in the ICU, maternal quality of life after discharge, perinatal mortality, and perinatal morbidity (secondary outcomes).

Fetomaternal Outcomes in the ICU

Maternal Mortality

The World Health Organization (WHO) has set specific targets and recommended strategies for reducing maternal mortality in its Sustainable Development Goals. An important step in this regard is an early identification and treatment of critical illness in pregnant women. The overall global maternal mortality ratio (MMR) stands at 216/100,000 livebirths.^{3,4} In contrast, the MMR of India was reported to be 113/100,000 livebirths during the year 2015–2016.⁵

The data on the rate of ICU admissions of obstetric patients are inconsistent ranging from 3/1,000 pregnancies to 3/100 of all ICU admissions.^{6,7} The rates may be higher (up to 13/1,000 deliveries) in developing countries.⁶ This difference could be secondary to economic, sociocultural, political, and health infrastructural factors.⁸ The chances of an ICU admission were studied in women who received prenatal and antenatal care by Zeeman et al. and they found that admission rates were less in women who received antenatal care.⁹ However, a recent study refuted this finding.¹⁰

The causes of obstetric ICU admissions are heterogeneous. A majority (50–80%) of such admissions are directly related to pregnancy and delivery (obstetric causes). The indirect causes are responsible for 20% of poor maternofetal outcomes. Globally, the most common and the most important cause of an ICU admission of an obstetric patient is related to hemorrhage, followed by pregnancy-induced hypertension (PIH) (i.e., direct obstetric causes).¹¹ However, Vasquez et al. and Thakur et al. have reported higher incidences of nonobstetric ICU admissions in their study.^{12,13} Interestingly, women admitted for nonobstetric causes may have higher disease severity scores on admission and a higher need for mechanical ventilation and other ICU interventions.^{11,14–16} Table 1 lists the obstetric and nonobstetric causes of ICU admissions by various authors in the last decade.

The average rate of maternal mortality of obstetric patients in the ICU is in the range of 8–40% in developing countries which is higher than that reported for developed nations (0.1–3.4%).¹⁷

Severity Scoring Systems for Prediction of Maternal Mortality

Prognostication uses mathematical models to quantify the probability of occurrence of an event (e.g., maternal mortality) in a study group on the basis of prognostic factors (patients' variables, predictors, or markers) in a given time period during the course of management of a disease. Such prognostic models generally give an objective predictive score using mathematical equations for regression for further application in a specific population base.

A predictive model to identify and triage such women at their point of admission may help avert untoward outcomes and also prevent unindicated ICU admissions. Moreover, they may also help to assess and guide appropriate health-care services for the critically ill patients.

Prognostic models for critically ill ICU patients may be broadly divided into General Critical Care Scoring Systems (GCCSSs) and Obstetric Prediction Models (ObPMs). The GCCSSs are further classified into Outcome Prediction Models (OPMs), which predict mortality in a study group, e.g., Acute Physiology and Chronic Health Evaluation (APACHE) score, Simplified Acute Physiology Score (SAPS), and Mortality Probability Model (MPM) or Organ Dysfunction Scores (ODSs), such as Logistic Organ Dysfunction Score (LODS), Multiple Organ Dysfunction Score (MODS), Sequential Organ Failure Assessment (SOFA) scores, and quick SOFA (qSOFA) scores.

However, it was observed that the general scores were not able to accurately predict the outcomes of pregnant women in the critical care due to the physiological changes in pregnancy which have a bearing on the variables of these models; another reason being that many critical conditions improved remarkably after delivery of the fetus and placenta, leading to over prediction of mortality by the general scores.^{12,13,16,18–24} Thus, the need for customization of the scores for obstetric patients was perceived. This led to development of specific ObPMs.⁶

The ObPM includes the Modified Early Obstetric Warning System (MEOWS), Obstetric Early Warning Score (OEWS), Maternal Early Warning Trigger (MEWT) and disease-specific obstetric scoring systems, full Preeclampsia Integrated Estimate of Risk (fullPIERS) model for preeclampsia, Sepsis in Obstetrics Score (SOS) for sepsis, and Shock Index (SI) for obstetric hemorrhage. Table 2 outlines various critical care scoring systems and their salient features.

Levinson et al. have given a pathway for implementation of these scoring systems to the obstetric population. They recommend that any patient on admission (or within 24 hours) with a complication or an adverse event should be firstly subjected to mortality predictive scoring using the GCCSS. Thereafter, the ODS or ObPM should be applied according to the disease process or organ system involvement. In the event of utilization of both of these scoring systems, a clear picture of disease severity and maternofetal prognosis would be revealed.⁶

GCCSS

These are the most widely used prognostic models. The OPM helps in scoring outcome probability in critically ill ICU patients, irrespective of their organ systems failure in contrast to the ODS which gives mathematical values for mortality based on scores on the number of organ system failures.

OPM

- APACHE score:** It has four versions (APACHE—I–IV). The APACHE II score which was developed in 1985 is the most widely used score among all the versions.²⁵ It has three components, namely physiological variables (12 in number), age points, and chronic health points. Multiple authors, except Miglani et al., have reported overestimation of maternal mortality in obstetric patients using the APACHE II scores, including a comprehensive global analysis by Ryan et al.^{12,13,16,18–23,24} This overprediction was especially prominent in patients getting admitted for direct obstetric causes.¹⁶ However, modified APACHE II scores (customized for obstetric population) could accurately (SMR: 0.86) predict mortality rates when compared with APACHE II (SMR: 0.36) in a study conducted by Paternina-Cacedo et al.²⁶ Higher scores have been consistently associated with increasing risks of nonsurvival, near miss, need for advanced organ system support, prolonged ICU-LOS, perinatal mortality, and delay in hospital admissions (level 2 delay).^{12–14,18,21,27–29}
- SAPS I–III:** SAPS II is the sum of physiological scores, age score, chronic disease score, and the type of admission score. SAPS III was devised by studies conducted in various parts of the world, and it is a more comprehensive score with customized equations.³⁰ Increasing SAP II and III scores are associated with high chances of mortality.^{27,29} Raised SAPS II also correlates with prolonged ICU-LOS.³¹ Although Lapinsky et al. reported that SAPS II could accurately predict maternal deaths, other authors disprove this by labeling it as an over predictor of maternal mortality.^{19,24}
- MPM I–III:** The MPM is based on physiological scores, age, and organ systems data. The scores are calculated at 0, 24, 48, and 72 hours of admission. The MPM0 scores were reported to be high in nonsurvivors.²⁷ Results on MPM accuracy for mortality prediction in obstetric population is conflicting. Levinson et al. cite that MPM0-II overestimates mortality, but not MPM0-III.⁶ However, in a study by Rojas-Suarez et al., MPM0-II (and not MPM0-III), SAPS II, and SAPS III could accurately predict maternal

Table 1: Studies on maternal outcomes and their predictors in obstetric patients admitted in the ICU

Study	Sample size	Study design	Incidence of ICU admission	Indications for ICU admission	Interventions in ICU	ICU-LOS	Maternal mortality near miss			ICU complications	Comments
							Mortality-predicting scores	Observed mortality (%)	SMR		
Lapinsky et al. ¹⁹ (5 countries)	332	Retrospective review	—	PIH and its complications (42%) Obstetric hemorrhage (17%) Obstetric sepsis (16%) Others (23%)	—	—	** APACHE-II score: Mean 16.8 ± 6.1 APACHE II AUC (ROC) for predicting mortality: 0.82 **SAPS-II score: Mean 26.5 ± 15.8 AUC (ROC) for predicting mortality: 0.78	12	0.43 (0.52 on adding diagnostic weightage for APACHE-II; SAPS-II)	—	OR for maternal mortality (95% CI) ($p < 0.05$) GCS: 0.761 (0.695–0.827); HR: 1.034 (1.018–1.051); Minimum DBP: 0.964 (0.942–0.985); Minimum SBP: 0.978 (0.965–0.991); Hb: 0.973 (0.958–0.986); ABG—PaO ₂ : 0.958 (0.933–0.976); PaCO ₂ : 0.95 (0.908–0.983); Urea: 1.043 (1.013–1.074); Creatinine: 1.005 (1.003–1.007); Bilirubin: 1.018 (1.009–1.029); Albumin: 0.896 (0.842–0.948); Na ⁺ : 1.074 (1.022–1.138); Platelet: 0.994 (0.989–0.998); INR: 1.026 (1.008–1.055)
Lin et al. ³¹ (China)	207	Retrospective analysis	42/10,000 deliveries	Direct obstetric cause (most common)—massive postpartum hemorrhage (20.29%),	—	>3 D (52.66%)	—	1.93	—	AFLP, DIC	OR for prolonged ICU stay PaO ₂ /FiO ₂ : 4.73 (1.46–11.37) ($p = 0.013$); Use of inotropes: 1.96 (1.24–3.15) ($p = 0.001$); AFLP:

3.21 (1.13–4.76) ($p = 0.026$); DIC: 2.73 (1.28–4.02) ($p = 0.018$); SAPS score: 4.78 (1.83–7.42) ($p = 0.021$); Irregular antenatal care records: 1.68 (1.14–2.69) ($p = 0.01$); >24 hr interval between onset of acute symptoms and ICU admission: 2.04 (1.21–4.25) ($p < 0.001$)	PIH (17.39%), acute fatty liver (13.04%), DIC (11.11%)	Nonobstetric cause—Heart failure (most common cause)	0.14% ICU utilization ratio	Prospective analysis	24	Gupta et al. ³² (India)	Obstetric cause most common (91.66%)—obstetric hemorrhage ($p = 0.001$), hemodynamic instability	Nonobstetric— anemia ($p = 0.001$)	MV: 70.83% I: 91.66%	39.42 ± 33.7 hr	ROC-AUC for MPM II scores: 0.74 Predicted maternal mortality by MPM II: 26.43% ($p = 0.002$)	41.67	1.57	Sepsis, MODS, DIC	Mortality higher among the patients admitted for nonobstetric reasons. APACHE scores >8 associated with prolonged hospital stay (OR, 1.7; 95% CI, 1.3–8.7)
8.1/1,000 deliveries	Obstetric cause (most common)—PIH, PPH, sepsis	Nonobstetric—severe community acquired pneumonia (most common)	8.1/1,000 deliveries	Retrospective cohort study	242	Rios et al. ¹⁴ (Argentina)	Obstetric cause (most common)—PIH, PPH, sepsis	Nonobstetric—severe community acquired pneumonia (most common)	MV: 13.6%	2 (2–4) D	APACHE II—score: 6 (4–8) (higher scores in nonobstetric cause of admission, $p = 0.002$) SOFA score: 1 (0–3)	2.5	—	Pulmonary embolism, multiorgan failure, pneumonia, HELLP syndrome	Mortality higher among the patients admitted for nonobstetric reasons. APACHE scores >8 associated with prolonged hospital stay (OR, 1.7; 95% CI, 1.3–8.7)

(Contd..)

Table 1: (Contd..)

Study	Sample size	Study design	Incidence of ICU admission	Indications for ICU admission	Interventions in ICU	ICU-LOS	Maternal outcomes			Comments	
							Mortality-predicting scores	Observed mortality (%)	SMR		ICU complications
Devabhaktuni et al. ²⁷ (India)	52	Prospective observational study	—	Obstetric/direct indication: PIH (30.76%); obstetric hemorrhage (23.07%) Indirect causes: 11% Nonobstetric indication: 13%	I: 38.46% MV: 51.92% T: 50% D: 19.3%	4.2 ± 2.38 D	Disease severity scores (survivor vs dead, p value) and their AUC for prediction of mortality—APACHE-II PMR: 19.12 ± 2.45 vs 77.31 ± 6.09, p = 0.000; AUC 0.99524. SAPS-II PMR: 9.573 ± 2.315 vs 82.13 ± 7.71, p = 0.000; AUC 0.99524. SOFA score PMR: 19.71 ± 3.081 vs 70.00 ± 7.746, p = 0.000; AUC 0.94286. MPM0 score PMR; 6.857 ± 1.484 vs 74.01 ± 13.92, p = 0.000; AUC 0.99048. Prediction of mortality by all scores: 17–30%	6.25	—	DIC, massive intracranial hemorrhage, hypoxic is-chemic encephalopathy	Significant predictor of maternal outcome: Use of MV (p = 0.014) and ICU-LOS (p = 0.001) Higher APACHE II PMR, SAPS II PMR, SOFA PMR, MPM0 PMR scores in nonsurvivors.
Saif et al. ²¹ (India)	224	Prospective cohort study	1.17% of all deliveries. 72.9% of total ICU admissions	Overall most common indication: obstetric hemorrhage (22.8%) Most common indication in	—	2.3 ± 0.9 D	APACHE II score: 20.17 ± 9.60; AUROC 0.811 (0.752–0.871); Predicted maternal mortality by APACHE II: 38.3	35.3	APACHE II: 0.92 SAPS II: 1.27	Congestive cardiac failure, sepsis, hepatic encephalopathy, obstetric hemorrhage, pulmonary edema, and peritonitis	OR for maternal mortality—Lack of antenatal care: 81.6 (23.8–279.7), p < 0.0001; Illiteracy: 3.5 (1.9–6.5), p < 0.001; Multiparity: 21.1 (9.4–47.5), p < 0.0001 High maternal



Antepartum period-PIH (19.5%); In postpartum period-Obstetric hemorrhage (35%)	SAPS II score: 36.14 ± 14.89; AUROC 0.863 (0.808–0.971); Predicted maternal mortality: 27.6	mortality associated with longer ICU-LOS ($p < 0.0001$), longer ICU admission delay ($p < 0.0001$), high APACHE II and SOFA scores, advanced age, lower mean gestational age, and ICU complications.	
Vasquez et al. ¹² (Argentina)	376 Multicenter, prospective, national cohort study MV: N = 91 (25%) S: 72 (20%) D: 12 (3.3%)	2 (2–4) D	<p>APACHE II score: 8 (4–12) (higher scores in nonobstetric cause of admission, $p = 0.008$)</p> <p>AUROC (95% CI) of APACHE II: 0.886 (0.827–0.946), $p = 0.000$</p> <p>OR of APACHE II for MFN mortality: 1.12 (1.05–1.19), $p = 0.000$</p> <p>Predicted maternal mortality by APACHE II: 7.6% (higher in nonobstetric cause vs obstetric cause of admission, 8.7 vs 6.7%, $p = 0.000$)</p> <p>SOFA₂₄ score (during 24 hr of admission): 1 (0–3)</p> <p>Using APACHE II: Over-all—0.47; Obstetric cause of admission—0.3; Non-obstetric cause of admission—1.25</p> <p>MODS, shock, renal dysfunction, ARDS</p> <p>OR for MFN mortality—MODS: 2.28 (1.03–5.04); Years of education: 0.89 (0.80–0.98), $p = 0.029$;</p> <p>Admissions to tertiary care: 0.09 (0.02–0.56), $p = 0.01$; Pre-natal care: 0.24 (0.09–0.65), $p = 0.005$.</p> <p>High comorbidities levels ($p < 0.000$), higher rates of antepartum admissions ($p = 0.010$), lower gestational age for admissions ($p = 0.038$), and low level of education ($p = 0.021$) were associated with high MFN mortality.</p>

(Contd..)

Table 1: (Contd..)

Study	Sample size	Study design	Incidence of ICU admission	Maternal outcomes					ICU complications	Comments	
				Indications for ICU admission	Interventions in ICU	ICU-LOS	Maternal mortality near miss				
							Mortality-predicting scores	Observed mortality (%)			SMR
Seppänen et al. ¹⁵ (Finland)	291	Retrospective audit design	—	Obstetric indications (90.7%); PIH (57%), obstetric hemorrhage (25.4%)	MV: 18.2% (MV requirement more in operated women) T: 26.5%	Median: 21.0 (16.0—27.0) H	Severity of illness scores— APACHE II: 9.0 (IQR: 7–12). SAPS II: 14 (10–20.3). SOFA: 2 (1–4).	0.3	—	Prolonged stay in ICU (1%), septic shock (0.7%), DIC (1%)	Higher disease severity scores (APACHE II, SAPS II, SOFA, and intervention scores) (TISS-76 scores) for vaginal delivery and for patients admitted for nonobstetric reasons
Aarvold et al. ⁴³ (Canada)	Septic women: 146 pregnant, 298 non-pregnant	Cohort study	—	Nonobstetric indications (9.3%): heart disease, respiratory failure, infection	—	—	Intensity of treatment score— TISS-76: Daily median of 21.5 (18.0—25.5).	81 (pregnant)	—	—	SOS was not better than APACHE II, SAPS II, SOFA and MODS for predicting maternal mortality. MODS score best predictor of obstetric women with sepsis.
Joseph et al. ²⁸ (India)	109	Retrospective cum prospective observational study	—	PIH with HELLP (38.5%) Anemia (19.27%) Antepartum hemorrhage	Invasive ventilation: 73.39%	Mean 3.47 ± 3.16 D	APACHE II score: Mean 16.89 ± 7.48	17.76	—	—	Higher APACHE II scores (> 30) associated with 62.5% maternal deaths.



Oliveira-Neto et al. ²⁹ (Brazil)	279	Retrospective cohort study	34.6/1,000 livebirths	Direct obstetric (N = 175) PIH (N = 135) Indirect obstetric (N = 104) Hemorrhage (N = 35)	—	1–2 D (70.9%)	Mean scores for SMO vs non-SMO and AUROC (95% CI) for SMO— APACHE II: 11.77 (±6.43) vs 6.39 (±3.21), p < 0.0001 and AUC 0.779 (0.70–0.85) APACHE IV: 41.68 (±18.37) vs 30.50 (±9.95), p < 0.001 and AUC 0.712 (0.62–0.79), p = 0.006 SAPS III: 44.97 (±12.18) vs 32.91 (±6.05), p < 0.001 and AUC 0.833 (0.77–0.89) SOFA ₂₄ : 4.43 (±3.16) vs 1.10 (±1.10), p < 0.001 and AUC 0.863 (0.80–0.91)	7.7	APACHE II: 0.73 (0.56–0.93) APACHE IV: 0.55 (0.42–0.70) SAPS III: 0.74 (0.57–0.94) SOFA ₂₄ : 0.96 (0.74–1.22)	Longer ICU-LOS associated with SMO (OR (95% CI) 3.60 (2.08–6.43), p < 0.05) Higher APACHE II, IV, SAPS III, SOFA ₂₄ scores seen in SMO. Total SOFA had high accuracy and LR+ ratio for SMO prediction. APACHE IV and SAPS III not recommended for SMO prediction. Total SOFA and APACHE II best for predicting SMO, with total SOFA as the recommended predicting model in obstetric population and APACHE II in cases of obstetric hemorrhage.
Prin et al. ⁵¹ (Malawi)	105	Prospective observational cohort study	23% of all ICU admissions	Shock (40%), respiratory failure (22%), PIH (11%)	I: 48% MV: 95% T: 63%	2D (IQR 1–5)	41	—	OR for mortality— Increasing age: unadjusted OR 0.94 (0.89–0.99), p = 0.040; creatinine (mg/dL): Unadjusted OR for each point 1.53 (95% CI 1.03–2.28), p = 0.035; Fever: 3.12 (1.34–7.26), p = 0.008.	

(Contd..)

Table 1: (Contd..)

Study	Sample size	Study design	Incidence of ICU admission	Indications for ICU admission	Interventions in ICU	ICU-LOS	Maternal outcomes			Comments
							Mortality-predicting scores	Maternal mortality near miss		
								Observed mortality (%)	SMR	
Lawton et al. ⁵⁰ (New Zealand)	400	National retrospective cohort study	7/1000 births	Blood loss/obstetric hemorrhage (31.9%) PIH (30.4%) Sepsis (14.2%)	—	—	—	—	—	High risk of maternal morbidity—Pacific islander ethnicity, <20 or >40 Y age, multiple pregnancy, preterm delivery.
Maiden et al. ²⁰ (Australia + New Zealand)	183	Registry-based cohort study	1.3% of ICU admissions	Obstetric indication (65%)—pregnancy-related postpartum disorder (46%), PPH (11%), PIH (9%) Nonobstetric indication (35%)—respiratory disorder, cardiac disorder, sepsis	MV: 19%	1.1 (0.7–1.8) D	APACHE-III-J score: Median 32 (IQR 23–42) Risk of death (%) by APACHE-III-J: Mean 4.7 ± 9.4 Risk of death (%) by ANZROD: Mean 1.3 ± 5.6	0.57	—	90% deaths in nonobstetric indications for admission. Higher mortality and prolonged ICU-LOS seen in MV and referred patients. ANZROD is a better predictor of mortality than APACHE-III-J.
Migliani et al. ¹⁸ (India)	124	Prospective cross-sectional observational study	0.77% of total obstetric admissions	Obstetric hemorrhage (37.1%), PIH (25.8%)	I: 47.58% MV: 66.12% T: 83.87% S: 25%	3.18 ± 2.40 D	APACHE II score: Mean 14.77 ± 6.85 Predicted mortality rate by APACHE II—25%	30.6	1.224	High APACHE II score with ICU-LOS ($p = 0.001$), maternal mortality ($p = 0.001$), perinatal mortality ($p = 0.001$), level 1 ($p = 0.003$)



and 2 ($p = 0.0001$) delays and duration of delay. Poor	maternofetal outcomes in referred patients (except perinatal morbidity), ^{***} presence of level 1 and 2 delays and increasing duration of delay.	—	OEWs is as effective as the conventional SOFA and APACHE II to prognosticate the obstetric patient. Higher OEWS scores in prolonged ICU-LOS (0.0297) and hours of MV (0.0255). Advantage of OEWS is that it does not need any laboratory parameter and hence, calculation is easy and less time-consuming	Khergade et al. ²² (India)	250	Prospective cohort	Obstetric hemorrhage (20%), sepsis (18.8%), PIH (15.6%), anemia (17.6%)	Mean scores; AUROC (95%CI): OEWS 8.2 ± 5.22; 0.894 (95% CI, 0.849–0.929), $p < 0.0001$ SOFA 5.56 ± 4.42; 0.924 (95% CI, 0.884–0.954), $p < 0.0001$ APACHE II 11.14 ± 7.16; 0.93 (95% CI, 0.891–0.958), $p < 0.0001$	26	OEWs 0.663 SOFA 0.625 APACHE II 0.691
--	--	---	--	--	-----	-----------------------	---	---	----	---

(Contd..)

Table 1: (Contd..)

Study	Sample size	Study design	Incidence of ICU admission	Indications for ICU admission	Interventions in ICU	ICU-LOS	Maternal mortality near miss			Comments
							Mortality-predicting scores	Observed mortality (%)	SMR	
Jain et al. ¹⁰ (India)	90	Descriptive observational study	0.4% of total obstetric admissions; 9% of total ICU admissions	Obstetric indications-PIH (37.7%), obstetric hemorrhage (28.8%) Nonobstetric indications—cardiac disease, epilepsy, severe anemia	I: 31.1% MV: 94.4% B <5 units; 84.4%	33.3% mortality; 16.7% recovered with morbidity; 50% recovered	—	—	Mortality to morbidity ratio—Obstetric hemorrhage 1:2.8; PIH 1:6.2 Higher mortality associated with inotropic support Lower mortality associated with early surgical interventions Increased risk of admission with referred patients, low socioeconomic status, level 1, 2, 3 delay and increased delay duration to admission.	

*Values are mean (SD) or median (IQR-interquartile range); **Severity of illness scores were not significantly altered by modification for obstetrical normal values (APACHE-OB or SAPS-OB); ***level 1, 2, 3 delays—delay in seeking care, in reaching appropriate healthcare facility, and at tertiary care centre, respectively; ****Group 1 requiring level 1 and 2 support, Group 2 requiring level 3 support; D, Days; W, Weeks; Y, Years; GA, gestational age; P, Parity; MV, mechanical ventilation; I, Inotropic support; t, Blood Transfusions; S, Surgical interventions; D, Dialysis; N, Number of women; PIH, Pregnancy-induced Hypertension; PPH, Postpartum hemorrhage; ICU LOS, ICU Length of stay; SAPS, Simplified Acute Physiology Score; APACHE, Acute Physiology and Chronic Health Evaluation; MPM, mortality probability models; SMR, Standardized Mortality Rate i.e., number of observed deaths/number of expected deaths (values <1 means predictor overestimates mortality, >1 underestimates mortality); PMR, Prediction of mortality rates; AUROC, Area under Receiver Operating Curve; CS, cesarean section; MFM, Materno-fetal-neonatal; SMO, Severe Maternal Outcomes (near miss + maternal deaths); OR, Odds ratio; CI, Confidence interval; DBP, Diastolic Blood Pressure; SBP, Systolic Blood Pressure; ANZROD, Australian and New Zealand Risk of Death Model (includes obstetric patients); MCCWG LOC, maternal critical careworking group level of support for critical care; OEWS, Obstetric early warning score; SOS, Sepsis obstetric score. Color coding—Green for studies conducted in developing nations, blue for studiesconducted in developed nations, pink for studies in least developed countries, yellow for multicountry studies with developed/developing economies



Table 2: Critical care severity scoring system

Severity scoring system	General critical care severity scoring system	Comments
Maternal Critical Care Working Group Level of support for critical care scoring	Level 0: Normal ward case Level 1: Additional monitoring or interventions or step down from higher level care Level 2: Single organ support Level 3: Advanced respiratory support, or support of two or more organ systems	
Acute Physiological and Chronic Health Evaluation II (within 24 hr of ICU admission)	<ul style="list-style-type: none"> Acute physiological score (12 variables taken during first 24 hr of admission): rectal temperature; MAP; HR; RR; oxygen; arterial pH; serum HCO₃; serum sodium; serum potassium; serum creatinine; hematocrit; white blood cell count; GCS Age points Chronic health points 	APACHE II score = A + B + C (range 0–71)
APACHE III	Two parts: <ul style="list-style-type: none"> APACHE III score—similar to APACHE II, except GCS not used and two new variables added (patient's origin and lead-time bias) APACHE III predictive equation—to provide risk estimates of hospital mortality 	APACHE III score range 0–299
APACHE IV	Same variables as APACHE III plus new variables (mechanical ventilation, thrombolysis, impact of sedation on GCS, rescaled GCS, PaO ₂ /FIO ₂ ratio).	
Simplified Acute Physiological Score II (within 24 hr of ICU admission)	<ul style="list-style-type: none"> Physiological score (12 variables): heart rate; SBP; temperature; PaO₂/FIO₂; urine output; urea; TLC; potassium; sodium; bicarbonate; bilirubin; GCS Age score Chronic disease score: metastatic cancer; hematological malignancy; AIDS Type of admission score: scheduled surgical; medical; emergency surgical 	SAPS II score range 0–163. Probability of death calculated using SAPS II score using logistic regression.
SAPS III (within 1 hr of ICU admission)	Age; LOS before ICUA; intrahospital location (OR, ER, other ICU, other); comorbidities (cancer therapy, cancer, hematologic cancer, AIDS, chronic HF (NYHA IV), cirrhosis); vasoactive drugs before ICUA; ICU admission (planned, unplanned); reason for admission (cardiovascular, hepatic, digestive, neurologic); surgical status at ICUA (scheduled surgery, emergency surgery, no surgery); site of surgery (transplant, trauma, cardiac surgery, neurosurgery); acute infection at ICUA (nosocomial, respiratory); GCS; highest total bilirubin; highest body temperature; highest creatinine; highest HR; lowest WBC count; lowest pH; lowest platelet; lowest SBP; MIV or CPAP PaO ₂ /FIO ₂	
Mortality Prediction Model—4 models i.e. at admission (0, 24, 48 and 72 hr	<ul style="list-style-type: none"> MPM 0—medical/unscheduled surgery admission; metastatic neoplasm; cirrhosis; chronic renal insufficiency; CPR prior to admission; coma (GCS 3–5); HR; SBP; acute renal insufficiency; cardiac arrhythmia; cerebrovascular incident; GI bleeding; intracranial mass; mechanical ventilation; age MPM—24, 48, 72 hr: medical or unscheduled admission; metastatic neoplasm; cirrhosis; creatinine > 177 μmol/L; urine output < 50 mL/8 hr; coma; confirmed infection; intracranial mass; vasoactive drugs ≥ 1 hr; PaO₂ < 60 Torr; PT > standard + 3 sec; age 	Calculates predicted death rate using logistic equation.
Multiple Organ Dysfunction Score	6 organ systems and their variables: hematological (platelet count); hepatic (serum bilirubin); renal (serum creatinine); cardiovascular (PAR); GCS; respiratory (PO ₂ /FIO ₂)	MODS score range 0–24 ICU mortality % may be calculated using MODS score.
Sequential Organ Failure Assessment Score	6 organ systems: pulmonary (lowest PaO ₂ /FIO ₂ %); coagulation (lowest platelet count); hepatic (highest bilirubin); circulatory (blood pressure status); neurological (GCS); renal (highest creatinine levels and total urine output)	SOFA score range 0–6.
Logistic Organ Dysfunction Score	6 organ systems: neurological (GCS); cardiovascular (HR and SBP); renal (urea nitrogen, serum creatinine and urine output); respiratory (PaO ₂ /FIO ₂ %); hematological (TLC and platelet count); hepatic (serum bilirubin and PT)	Calculates probability of death using an equation.
Quick SOFA for sepsis	Altered mental status (GCS < 15); respiratory rate ≥ 22; systolic BP ≤ 100	
Organ dysfunction and/or infection	7 variables: respiratory; cardiovascular; renal; neurological; hepatic; hematological; infection (with clinical evidence)	

(Contd..)

Table 2: (Contd..)

Severity scoring system	General critical care severity scoring system	Comments
Three days recalibrated ICU outcome score	Transfer from ward; chronic illness; SAPS II Day 2—SAPS II Day 3 alteration; LODS Day 2—LODS Day 3 alteration; LODS on admission; SAPS II on admission	Scores help in calculating mortality based on regression model
Obstetric prediction models		
Obstetric Early Warning Score	SBP; DBP; RR; HR; oxygen required to maintain SpO ₂ 96%; temperature; consciousness level	
Modified Obstetric Early Warning Score	8 variables: temperature; SBP; DBP; HR; RR; level of consciousness on the AVPU scale; urine output Each variable classified into yellow or red alert according to findings.	
Maternal Early Warning Criteria	SBP <90 or >160; DBP >100 mm; HR <50 or >120; RR <10 or >30; oxygen saturation on room air <95%; oliguria <35mL/hr ≥ 2 hr	
Maternal Early Warning System	Each variable classified into yellow or red alert according to findings SBP <80 or >160; DBP >105; HR <50 or >120; RR <10 or >30; oxygen saturation <95% on room air at sea level; oliguria <30 mL for 2 hr; maternal agitation/confusion/unresponsiveness; preeclampsia with nonremitting headache or shortness of breath	
New Early Warning Score	RR; O ₂ saturation; supplemental oxygen; temperature; SBP; HR; APUV level of consciousness	
Maternal Early Warning Trigger	SBP; DBP; HR; RR; temperature; oxygen saturation; altered mental status. Each variable classified into yellow or red alert according to findings	
Obstetric modified qSOFA	SBP ≤ 90 mm Hg; RR >25/min and altered mentation.	
Sepsis Obstetric Score	Temperature; SBP; HR; RR; O ₂ saturation; WBC counts; serum lactic acid	
miniPIERS (Preeclampsia Integrated Estimate of Risk) model: risk prediction model for PIH	Parity (nulliparous vs multiparous); gestational age on admission; headache/visual disturbances; chest pain/dyspnea; vaginal bleeding with abdominal pain; systolic blood pressure; and dipstick proteinuria.	
fullPIERS model: risk prediction model for PIH.	Gestational age; chest pain or dyspnea; SpO ₂ ; platelet count; creatinine; AST/ALT	
Gives probability of adverse maternal outcomes with PIH.		

GCS, Glasgow Coma Score; HR, heart rate (beats per min); RR, respiratory rate (breaths per min); SBP, systolic blood pressure (mm Hg); DBP, diastolic blood pressure (mm Hg); MAP, mean arterial pressure (beats per min); PaO₂ (mm Hg), arterial oxygen tension; FiO₂, fractional concentration of inspired oxygen; TLC, total leukocyte Count; AIDS, acquired immunodeficiency syndrome; PAR, pressure adjusted heart rate (HR × (central venous pressure/MAP)); PT, prothrombin time; AVPU, alert-voice-pain-unresponsive; WBC, white blood cell Counts; LOS, length of stay; ICUA, intensive care unit Admission; HF, heart failure; NYHA, New York heart association; MIV, minute ventilation; CPAP, continuous positive pressure ventilation; AST/ALT, Aspartate aminotransferase/Alanine aminotransferase



mortality (SMR by MPM0-II 0.88, MPM0-III 1.22, SAPS II 0.51, SAPS III 0.6).²⁴ In another study, MPM II was reported to underpredict mortality.³²

ODS

Multiple organ dysfunction syndrome is characterized by progressive dysfunction of organ systems after an acute insult to the body. The WHO relies on the usage of organ failures to identify severe maternal morbidity.⁶ Adeniran et al. demonstrated that ≥ 2 organ system damage was associated with raised maternal mortality.³³ The ODS gives numerical scores for classifying severity of disease in critically ill patients. However, it is important to note that these scores do not predict mortality in these patients. The most commonly used ODS are MODS, LODS, SOFA, and qSOFA.

Numerous authors have reported an association of higher SOFA scores among nonsurvivors in their study.^{21,27,29,34} Vasquez et al. reported that at a cutoff value of 6.5 for SOFA, the likelihood for maternal mortality was 10 times (LR + 9.8). This was almost seven times (LR + 6) in a study conducted by Oliveira-Neto et al.; however, the cutoff used by the latter was ≥ 3 . Numerous other studies have reported a good sensitivity and specificity of SOFA scores in predicting maternal mortality and near miss, especially in cases of sepsis.^{12,22,29} It is one of the most widely used scores in obstetric critical care units of India, and it is also recommended by the Ministry of Health and Family Welfare, Government of India.³⁵

ObPM

These real-time scoring systems for critically ill obstetric patients are usually based on "warning signs" (a set of predefined pathological values). These systems help triage non-ICU obstetric patients who need prompt and intensive health care. These scores may be based specifically for a type of maternal condition (eclampsia, obstetric hemorrhage, sepsis) or may be nonspecific/generalized.

Nonspecific Scores

- **MEOWS:** It is a bedside tool, computed 12 hourly and comprises maternal vital parameters (temperature, blood pressure, heart rate, oxygen saturation), conscious level, and pain points as components. It is the recommended bedside screening tool for early identification of severe complications and periodic monitoring of obstetric patients according to the 2003–2005 triennial Confidential Enquiry into Maternal and Child Health (CEMACH) report.³⁶
- **OEWS:** Carle's OEWS is a clinical model based on a color-coded numeric scheme for severity scoring of disease. It does not require laboratory parameters for scoring and has a good predictive value for identifying survivors (especially those admitted for direct-obstetric reasons) in the ICU.^{22,37} In a recent study by Khergade et al., the OEWS was found as effective as the SOFA and APACHE II scores for prognosticating maternal mortality in the ICU. The OEWSs were also significantly raised with prolonged ICU-LOS ($p = 0.027$) and hours of mechanical ventilation ($p = 0.025$).²²
- **MEWT:** MEWT uses maternal vitals and mental status level threshold values to assess maternal morbidity in obstetric population. In a study by Shields et al., MEWT was found to significantly reduce severe maternal morbidity ($p < 0.01$) and composite morbidity ($p < 0.01$). However, it had no effect on frequency of ICU admissions.³⁸

- **Obstetric Modified qSOFA:** The qSOFA was modified to use in pregnancy by the Society of Obstetric Medicine, Australia and New Zealand (SOMNAZ). They also suggested changes in the laboratory values of the SOFA scoring system for obstetric patients.³⁹

Disease-specific Obstetric Scoring System

These scoring systems were developed keeping in mind specific pregnancy-related conditions which are a major cause of maternal mortality and morbidity worldwide (preeclampsia, obstetric hemorrhage, and sepsis).

- The fullPIERS model is an externally validated model which predicts adverse outcomes in preeclamptic women.^{40,41} Parameters taken into account are gestational age, chest pain or dyspnea, oxygen saturation, platelet count, serum creatinine, and aspartate transaminase levels. It can be seen that this model requires minimal laboratory testing and has a smaller version of (miniPIERS) model especially designed for the low resource countries.⁴²
- The SOS is a scoring system for predicting clinical deterioration and ICU admissions in women with obstetric sepsis. It uses maternal vitals and blood tests for scoring propose. The original SOS performed poorly in predicting maternal mortality. However, recently, a modified adjusted SOS employed by Aarvold et al. in a retrospective case-control study was found to predict maternal outcomes similar to that predicted by APACHE II, SAPS II, and SOFA scores. Among all the scoring systems used, the MODS had an overall best predictive capacity ($p < 0.05$).⁴³
- The SI is the ratio of the heart rate to systolic blood pressure. It is a validated tool for detecting early hemodynamic instability in patients with near normal vital readings. The normal value of the SI in nonobstetric population is between 0.5 and 0.7. Numerous studies have been done to find out a normal range of the SI for pregnant women. Most of them proposed a range of 0.7–0.9.^{44–46} In a recent Indian study, a SI value of >1 was associated with higher chances of surgical interventions, >1.3 with an ICU admission, high maternal morbidity, and >1.6 with maternal deaths.⁴⁷

Other Factors Leading to Maternal Mortality in Critically Ill ICU Patients

Aoyama et al. reported increasing mortality rates with rising maternal age >34 years.⁴⁸ Extremes of age, absent prenatal care, low socioeconomic status, delays in presentation to a tertiary care centre, and ill-equipped facility with poor staff training have been implicated in high maternal deaths in the ICU settings by various authors.^{12,21,33,49–51}

An illiterate, unbooked patient with high parity, multiorgan failure, and admitted for an indirect cause in the ICU has highest chances of mortality.^{12,14,20,21,33,52} On the other hand, a patient presenting in the postpartum period has better survival rates than her antenatal counterpart.³³

Maternal Interventions in the ICU as Predictors of Maternal Mortality

A critically ill patient admitted in the ICU has a high risk of undergoing various interventions in the form of oxygen support, invasive ventilation, blood components transfusion, antibiotics administration, and inotropic support.¹³ Nonsurvivors are more

prone to undergo mechanical ventilation for longer periods of time and to receive inotropic support. Their use is additionally associated with increased chances for nonsurvival.^{22,27,33} However, in a study by Jain et al., maternal mortality was reduced with early surgical interventions.^{10,21}

Maternal Complications in the ICU

ICU patients are prone for disseminated intravascular coagulation (DIC), multiorgan failure, and sepsis.^{14,32,34} Other complications that are frequently seen include deep vein thrombosis (DVT), acute respiratory distress syndrome (ARDS), pulmonary embolism, shock, infections, intracranial hemorrhage, preterm delivery, and intrauterine death.^{12,13} Most of these complications merit the use of invasive ventilation, vasopressors, and multiple blood transfusions. In a study conducted by Suri et al., it was found that the Odds Ratio for vasopressor infusion increased with higher severity of illness scores (SAP II, APACHE II, and SOFA); moreover, those requiring vasopressors had a higher frequency of invasive ventilation.⁵³

Prolonged ICU-LOS and Hospital Stay

Prolonged ICU-LOS is significantly associated with higher APACHE II, SAPS II, and OEWS scores and higher mortality rates in critically ill obstetric patients.^{13,14,21,27,31,34} Use of mechanical ventilation and inotropes also prolongs ICU-LOS.^{20,22} Irregular antenatal visits, longer delays between appearance of symptoms and admission, development of DIC, and acute fatty liver are also associated with prolonged ICU-LOS.³¹

Quality of Life after Discharge

Literature is scarce on the assessment of the quality of life after discharge from the ICU. Leung et al. used a validated Chinese

version of the Short Form-36 (SF-3615) Health Survey to assess the long-term outcome of an ICU admission and found that the domain of SF-6 covering physical functioning, bodily pain, and social functioning yielded significantly lower scores for discharged patients in comparison to the general population.⁵⁴

Fetal Outcomes

The perinatal mortality rate is an important indicator of maternal health and care. It varies from <10/1,000 total births in developed nations to >20/1,000 total births in developing nations.⁵⁵ As fetal outcomes are generally dependent on maternal general condition and well-being, maternal severity scoring systems may help predict fetal and neonatal outcomes in such patients. Table 3 outlines studies on fetal outcomes in critically ill obstetric women in the ICU. In a prospective cross-sectional study on 124 subjects, Miglani et al. reported that there is an increase in perinatal mortality with rising APACHE II scores ($p = 0.001$).¹⁸

Maternal shock (Odds Ratio, OR: 6.85), blood transfusions (OR: 7.24), and lower mean gestational age at presentation (OR: 1.2/week for <37 weeks) are important markers of fetal loss in the ICU.⁵⁶ Other factors associated with poor fetal and neonatal outcomes are maternal hypertension, maternal cardiac diseases, maternal sepsis, delays in presentation to the ICU, and increasing duration of delay.^{18,57}

CONCLUSION

The severity scoring models are an important tool in triaging ICU admissions. They help in severity and objective assessment of critically ill patients. APACHE II and SAPS II scores are the most studied and the most widely used tools for nonobstetric population. APACHE II and MPM II are useful scores in the obstetric group but overpredict the

Table 3: Studies on fetal outcomes and their predictors in obstetric ICU patients

Study	Perinatal outcomes	Factors associated with poor fetal outcomes
Cartin-Ceba et al. ⁵⁶	Fetal deaths—32 Neonatal deaths—10	Fetal loss—maternal shock (OR 6.85); maternal transfusion of blood products (OR 7.24); lower gestational age (OR 1.2/week <37 weeks).
Pollock et al. ¹⁷ Aoyama et al. ⁴⁸	Median mortality rate 20% (IQR 11–32%) —	— Maternal shock; lower gestational age; severe maternal hypoxemia
Rios et al. ¹⁴ Devabaktuni et al. ²⁷	23 fetal and neonatal deaths 21.42% perinatal mortality rate for 42 patients. Live term 54.76%; IUD 7.14%; neonatal deaths 4.76%	
Saif et al. ²¹	Perinatal mortality rate 271/1000 live births [significantly higher among nonsurvivors, OR 8.2 (4.1–16.7), $p < 0.0001$]	
Vasquez et al. ¹² Lawton et al. ⁵⁰	17% fetal-neonatal loss Perinatal mortality rate: 53.1/1000 live births 94.1% live births; 3.2% fetal deaths; 2% neonatal deaths, 2.7% early trimester loss	PIH (most common) Maternal cardiac condition Maternal sepsis
Miglani et al. ¹⁸	Low APGAR score requiring NICU admission (29.12%); IUD (12.6%); early neonatal death (7.76%); stillbirth (4.85%); perinatal morbidity (29.12%); perinatal mortality (31.06%)	All MFN outcomes significantly worse in referred patients, except perinatal morbidity. Higher APACHE II scores associated with perinatal mortality ($p = 0.001$) ^a Levels of delay (1 and 2) and increasing duration of delay associated with perinatal mortality ($p = 0.002$ and $p = 0.005$)
Ozumba et al. ⁵⁷	47.2% perinatal mortality	

^aLevel 1, 2, 3 delays: delay in seeking care, in reaching appropriate healthcare facility, and at tertiary care center, respectively. IQR, interquartile range; IUD, intrauterine death; NICU, neonatal intensive care unit; OR, odds ratio; MFN, maternofetal neonatal



maternal mortality. SOFA scores are the best predictor of outcomes in a pregnant woman with sepsis. Furthermore, the early warning scores when used on a subset of non-ICU obstetric patients may help in early identification of critical illness well before the start of actual clinical deterioration. These models may also help in prognosticating adverse fetal outcomes considering that the fetal well-being is largely dependent upon maternal well-being. They aid in implementation of best treatment plans, care of the woman, and help chalk out her health progress report over a period of time.

There is further scope of research to develop accurate and reliable prognostic models for critically ill obstetric patients.

ORCID

Jyotsna Suri  <https://orcid.org/0000-0002-7838-3238>

Zeba Khanam  <https://orcid.org/0000-0001-7802-9987>

REFERENCES

- Escobar MF, Carvajal JA, Nieto AJ, Messa A, Burgos JM, Echavarría MP, et al. Model of obstetric attention based on critical care in Latin America. *J Matern Fetal Neonatal Med* 2018;31(23):3139–3146. DOI: 10.1080/14767058.2017.1365128.
- Alkema L, Chou D, Hogan D, Zhang S, Moller AB, Gemmill A, et al. United Nations Maternal Mortality Estimation Inter-Agency Group collaborators and technical advisory group. Global, regional, and national levels and trends in maternal mortality between 1990 and 2015, with scenario-based projections to 2030: a systematic analysis by the UN Maternal Mortality Estimation Inter-Agency Group. *Lancet* 2016;387(10017):462–474. DOI: 10.1016/S0140-6736(15)00838-7.
- Say L, Chou D, Gemmill A, Tunçalp Ö, Moller AB, Daniels J, et al. Global causes of maternal death: a WHO systematic analysis. *Lancet Glob Health* 2014;2(6):e323–e333. DOI: 10.1016/S2214-109X(14)70227-X.
- Patil V, Jigajinni S, Wijayatilake DS. Maternal critical care: 'one small step for woman, one giant leap for womankind'. *Curr Opin Anaesthesiol* 2015;28(3):290–299. DOI: 10.1097/ACO.000000000000189.
- NITI Aayog. Niti.gov.in. 2021 Available from: <https://niti.gov.in/content/maternal-mortality-ratio-mmr-100000-live-births>.
- Levinson A, Miranda J, Rojas-Suarez JA. Predictors of maternal mortality and prognostic models in obstetric patients. *Semin Respir Crit Care Med* 2017;38(2):191–200. DOI: 10.1055/s-0037-1602244.
- Vincent JL, Moreno R. Clinical review: scoring systems in the critically ill. *Crit Care* 2010;14(02):207. DOI: 10.1186/cc8204.
- Bajwa SK, Bajwa SJ. Delivering obstetrical critical care in developing nations. *Int J Crit Illn Inj Sci* 2012;2(1):32–39. DOI: 10.4103/2229-5151.94897.
- Zeeman GG. Obstetric critical care: a blueprint for improved outcomes. *Crit Care Med* 2006;34(9 Suppl.):S208–S214. DOI: 10.1097/01.CCM.00000231884.99763.69.
- Jain S, Guleria K, Vaid N, Suneja A, Ahuja S. Predictors and outcome of obstetric admissions to intensive care unit: a comparative study. *Indian J Public Health* 2016;60(2):159. DOI: 10.4103/0019-557X.184575.
- Sailaja KB, Mkr R. Critically ill obstetric admissions to an intensive care unit: a prospective analysis from a Tertiary Care University Hospital in South India. *Indian J Crit Care Med* 2019;23(2):78–82. DOI: 10.5005/jp-journals-10071-237121.
- Vasquez D, Das Neves A, Vidal L, Moseinco M, Lapadula J, Zakalik G, et al. Characteristics, outcomes, and predictability of critically ill obstetric patients. *Crit Care Med* 2015;43(9):1887–1897. DOI: 10.1097/CCM.0000000000001139.
- Thakur M, Gonik B, Gill N, Awonuga A, Rocha F, Gonzalez J. Intensive care admissions in pregnancy: analysis of a level of support scoring system. *Matern Child Health J* 2015;20(1):106–113. DOI: 10.1007/s10995-015-1808-9.
- Rios F, Risso-Vázquez A, Alvarez J, Vinzio M, Falbo P, Rondinelli N, et al. Clinical characteristics and outcomes of obstetric patients admitted to the intensive care unit. *Int J Gynecol Obstet* 2012;119(2):136–140. DOI: 10.1016/j.ijgo.2012.05.039.
- Seppänen P, Sund R, Roos M, Unkila R, Meriläinen M, Helminen M, et al. Obstetric admissions to ICUs in Finland: a multicentre study. *Intensive Crit Care Nurs* 2016;35:38–44. DOI: 10.1016/j.iccn.2016.03.002.
- Aldawood A. Clinical characteristics and outcomes of critically ill obstetric patients: a ten-year review. *Ann Saudi Med* 2011;31(5):518–522. DOI: 10.4103/0256-4947.84631.
- Pollock W, Rose L, Dennis CL. Pregnant and postpartum admissions to the intensive care unit: a systematic review. *Intensive Care Med* 2010;36(9):1465–1474. DOI: 10.1007/s00134-010-1951-0.
- Migliani S, Migliani U, Pathak A, Laul P, Sarangi S, Gandhi S, et al. A study of clinical profile and fetomaternal outcome of obstetric patients admitted to intensive care unit: a prospective hospital-based study. *Indian J Crit Care Med* 2020;24(11):1071–1076. DOI: 10.5005/jp-journals-10071-23657.
- Lapinsky S, Hallett D, Collop N, Drover J, Lavercombe P, Leeman M, et al. Evaluation of standard and modified severity of illness scores in the obstetric patient. *J Crit Care* 2011;26(5):535.e1–535.e7. DOI: 10.1016/j.jccr.2010.10.003.
- Maiden M, Finnis M, Duke G, Huning E, Crozier T, Nguyen N, et al. Obstetric admissions to intensive care units in Australia and New Zealand: a registry-based cohort study. *BJOG* 2020;127(12):1558–1567. DOI: 10.1111/1471-0528.16285.
- Saif KM, Tahmina S, Maitree P. A prospective study of clinical profile and outcome of critically ill obstetric patients in ICU at a tertiary level hospital in India. *Anaesth Pain Intensive Care* 2013;17(3):243–247. Research gate publication 277335520.
- Khergade M, Suri J, Bharti R, Pandey D, Bachani S, Mittal P. Obstetric early warning score for prognostication of critically ill obstetric patient. *Indian J Crit Care Med* 2020;24(6):398–403. DOI: 10.5005/jp-journals-10071-23453.
- Ryan HM, Sharma S, Magee LA, Ansermino JM, MacDonell K, Payne BA, et al. The usefulness of the APACHE II score in obstetric critical care: a structured review. *J Obstet Gynaecol Can* 2016;38(10):909–918. DOI: 10.1016/j.jogc.2016.06.013.
- Rojas-Suarez J, Paternina-Caicedo AJ, Miranda J, Mendoza R, Dueñas-Castel C, Bourjeily G. Comparison of severity-of-illness scores in critically ill obstetric patients: a 6-year retrospective cohort. *Crit Care Med* 2014;42(5):1047–1054. DOI: 10.1097/CCM.0000000000000124.
- Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. *Crit Care Med* 1985;13(10):818–829. PMID: 3928249.
- Paternina-Caicedo AJ, Rojas-Suarez JA, Dueñas-Castel C, Miranda-Quintero JE, Bourjeily G. 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(02):97–102. DOI: 10.1177/0885066613502450.
- Devabhaktuni P, Samavedam S, Thota GVS, Pusala SV, Velaga K, Bommakanti L, et al. Clinical profile and outcome of obstetric ICU patients. APACHE II, SOFA, SAPS II and MPM scoring systems for prediction of prognosis. *Open J Obstet Gynecol* 2013;3(9):41–50. DOI: 10.4236/ojog.2013.39A006.
- Joseph CM, Bhatia G, Abraham V, Dhar T. Obstetric admissions to tertiary level intensive care unit – prevalence, clinical characteristics and outcomes. *Indian J Anaesth* 2018;62(12):940–944. DOI: 10.4103/ija.IJA_537_18.
- Oliveira-Neto A, Parpinelli M, Costa M, Souza R, Ribeiro do Valle C, Sousa M, et al. Prediction of severe maternal outcome among pregnant and puerperal women in obstetric ICU. *Crit Care Med* 2019;47(2):e136–e143. DOI: 10.1097/CCM.0000000000003549.
- Nassar AP, Malbouisson LM, Moreno R. Evaluation of Simplified Acute Physiology Score 3 performance: a systematic review of external validation studies. *Crit Care* 2014;18(3):R117. DOI: 10.1186/cc13911.
- Lin Y, Zhu X, Liu F, Zhao YY, Du J, Yao GQ, Li WX, Jia XJ. [Analysis of risk factors of prolonged intensive care unit stay of critically ill obstetric patients: a 5-year retrospective review in 3 hospitals in Beijing].

- Zhongguo Wei Zhong Bing Ji Jiu Yi Xue 2011;23(8):449–453. Chinese. PMID: 21878165.
32. Gupta S, Naithani U, Doshi V, Bhargava V, Bhavani VS. 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. DOI: 10.4103/0019-5049.79895.
 33. Adeniran AS, Bolaji BO, Fawole AA, Oyedepo OO. Predictors of maternal mortality among critically ill obstetric patients. *Malawi Med J* 2015;27(1):16–19. PMID: 26137193; PMCID: PMC4478400.
 34. Sodhi K, Bansal V, Shrivastava A, Kumar M, Bansal N. Predictors of mortality in critically ill obstetric patients in a tertiary care intensive care unit: a prospective 18 months study. *J Obstet Anaesth Crit Care* 2018;8(2):73. DOI: 10.4103/joacc.JOACC_57_17.
 35. Nhm.gov.in. 2021 Available from: https://nhm.gov.in/images/pdf/programmes/maternal-health/guidelines/Operational_Guidelines_for_Obstetric_ICUs_and_HDUs.pdf.
 36. Bowyer L. The Confidential Enquiry into Maternal and Child Health (CEMACH). Saving Mothers' Lives: reviewing maternal deaths to make motherhood safer 2003–2005. The Seventh Report of the Confidential Enquiries into Maternal Deaths in the UK. *Obstet Med* 2008;1(1):54. DOI: 10.1258/om.2008.080017.
 37. Paternina-Cacedo A, Miranda J, Bourjeily G, Levinson A, Dueñas C, Bello-Muñoz C, et al. Performance of the Obstetric Early Warning Score in critically ill patients for the prediction of maternal death. *Am J Obstet Gynecol* 2017;216(01):58.e1–58.e8. DOI: 10.1016/j.ajog.2016.09.103.
 38. Shields LE, Wiesner S, Klein C, Pelletreau B, Hedriana HL. Use of maternal early warning trigger tool reduces maternal morbidity. *Am J Obstet Gynecol* 2016;214(04):527.e1–527.e6. DOI: 10.1016/j.ajog.2016.01.154.
 39. Bowyer L, Robinson HL, Barrett H, Crozier TM, Giles M, Idel I, et al. SOMANZ guidelines for the investigation and management sepsis in pregnancy. *Aust N Z J Obstet Gynaecol* 2017;57(5):540–551. DOI: 10.1111/ajo.12646.
 40. von Dadelszen P, Payne B, Li J, Ansermino JM, Broughton Pipkin F, Côté AM, et al.; PIERS Study Group. Prediction of adverse maternal outcomes in pre-eclampsia: development and validation of the fullPIERS model. *Lancet* 2011;377(9761):219–227. DOI: 10.1016/S0140-6736(10)61351-7.
 41. Akkermans J, Payne B, von Dadelszen P, et al. Predicting complications in pre-eclampsia: external validation of the fullPIERS model using the PETRA trial dataset. *Eur J Obstet Gynecol Reprod Biol* 2014;179:58–62. DOI: 10.1016/j.ejogrb.2014.05.021.
 42. Payne BA, Hutcheon JA, Ansermino JM, Hall DR, Bhutta ZA, Bhutta SZ, et al.; miniPIERS Study Working Group. A risk prediction model for the assessment and triage of women with hypertensive disorders of pregnancy in low-resourced settings: the miniPIERS (Pre-eclampsia Integrated Estimate of RiSk) multi-country prospective cohort study. *PLoS Med* 2014;11(01):e1001589. DOI: 10.1371/journal.pmed.1001589.
 43. Aarvold A, Ryan H, Magee L, von Dadelszen P, Fjell C, Walley K. Multiple organ dysfunction score is superior to the obstetric-specific sepsis in obstetrics score in predicting mortality in septic obstetric patients. *Crit Care Med* 2017;45(1):e49–e57. DOI: 10.1097/CCM.0000000000002018.
 44. El Ayadi AM, Nathan HL, Seed PT, Butrick EA, Hezelgrave NL, Shennan AH, et al. Vital sign prediction of adverse maternal outcomes in women with hypovolemic shock: the role of shock index. *PLoS One* 2016;11(02):e0148729. DOI: 10.1371/journal.pone.0148729.
 45. Nathan HL, El Ayadi A, Hezelgrave NL, Seed P, Butrick E, Miller S, et al. Shock index: an effective predictor of outcome in postpartum haemorrhage? *BJOG* 2015;122(02):268–275. DOI: 10.1111/1471-0528.13206.
 46. Le Bas A, Chandraran E, Addei A, Arulkumaran S. Use of the “obstetric shock index” as an adjunct in identifying significant blood loss in patients with massive postpartum hemorrhage. *Int J Gynaecol Obstet* 2014;124(03):253–255. DOI: 10.1016/j.ijgo.2013.08.020.
 47. Agarwal V, Suri J, Agarwal P, Gupta S, Mishra PK, Mittal P. Shock index as a predictor of maternal outcome in postpartum hemorrhage. *J South Asian Feder Obst Gynae* 2021;13(3):127–132. DOI: 10.5005/jp-journals-10006-1894.
 48. Aoyama K, Pinto R, Ray JG, Hill AD, Scales DC, Lapinsky SE, et al. Association of maternal age with severe maternal morbidity and mortality in Canada. *JAMA Netw Open* 2019;2(8):e199875. DOI: 10.1001/jamanetworkopen.2019.9875.
 49. Farzi F, Mirmansouri A, Atrkar Roshan Z, Naderi Nabi B, Biazar G, Yazdipaz S. Evaluation of admission indications, clinical characteristics and outcomes of obstetric patients admitted to the intensive care unit of a teaching hospital center: a five-year retrospective review. *Anesth Pain Med* 2017;7(3):e13636. DOI: 10.5812/aapm.13636.
 50. Lawton B, Filoche S, MacDonald EJ, Stanley J, Meeks M, Stone P, et al. Examining adverse fetal/neonatal outcomes associated with severe maternal morbidity. *Aust N Z J Obstet Gynaecol* 2020;60(6):865–870. DOI: 10.1111/ajo.13163.
 51. Prin M, Kadyaudzu C, Aagaard K, Charles A. Obstetric admissions and outcomes in an intensive care unit in Malawi. *Int J Obstet Anesth* 2019;39:99–104. DOI: 10.1016/j.ijoa.2019.03.004.
 52. 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(1):34–37. DOI: 10.4103/0972-5229.112156.
 53. Suri J, Kumar R, Gupta A, Mittal P, Suri JC. A Prospective Study of Clinical Characteristics and Interventions Required in Critically Ill Obstetric Patients. *Indian J Crit Care Med* 2020;24(8):677–682. DOI: 10.5005/jp-journals-10071-23519.
 54. 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(1):18–25. PMID: 20124569.
 55. Hug L, Alexander M, You D, Alkema L; UN Inter-agency Group for Child Mortality Estimation. National, regional, and global levels and trends in neonatal mortality between 1990 and 2017, with scenario-based projections to 2030: a systematic analysis. *Lancet Glob Health* 2019;7(6):e710–e720. DOI: 10.1016/S2214-109X(19)30163-9 [Erratum in: *Lancet Glob Health* 2019;7(9):e1179].
 56. Cartin-Ceba R, Gajic O, Iyer VN, Vlahakis NE. Fetal outcomes of critically ill pregnant women admitted to the intensive care unit for nonobstetric causes. *Crit Care Med* 2008;36(10):2746–2751. DOI: 10.1097/ccm.0b013e318186b615.
 57. Ozumba BC, Ajah LO, Obi VO, Umeh UA, Enebe JT, Obioha KC. Pattern and outcome of obstetric admissions into the intensive care unit of a Southeast Nigerian Hospital. *Indian J Crit Care Med* 2018;22(1):16–19. DOI: 10.4103/ijccm.IJCCM_297_17.