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Sequential Organ Failure Assessment Score (Sofa Score) for Evaluating Outcome of Severe Maternal Morbidity in Obstetric Intensive Care

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Abstract: ***Introduction**: Severe Maternal Morbidity (SMM) is a progressive process and life - threatening condition for a pregnant woman and if not managed in - time eventually may lead to maternal death. Therefore, an early identification of patients at risk of increasing organ damage could have an impact in terms of outcome improvement. **Objectives**: To determine the prognostic accuracy of Sequential Organ Failure Assessment Score (SOFA) for evaluating organ failure and outcome of severe maternal morbidity in obstetrics intensive care. To correlate the SOFA, qSOFA (quick SOFA) Score and duration of ICU Stay with maternal mortality. **Methods**: A prospective observational cohort study was conducted on 164 women admitted in ten bedded multidisciplinary ICU. Patients were followed up daily and total and maximum SOFA scores were calculated. qSOFA score was calculated at the time of admission. ROC curve was made to determine optimum cut off and the prognostic accuracy of SOFA and qSOFA score. Mean SOFA, qSOFA score and duration of ICU stay were compared between survivors and non survivors. **Results**: Mean age of the study population was 25.78 ± 3.97 years. Eclampsia (36.58%) followed by haemorrhage (20.73%) were the most common causes of ICU admission. Mortality rate was 28.7%. Total maximum SOFA scores were significantly higher in non - survivors than in survivors (14.1 ± 2.7 vs 6.9 ± 1.9). At cut off of 10, AUC was 0.988 (95%CI, SE 0.006, 0.977 - 1.000; p<0.001) which demonstrated that the SOFA score was a reliable predictor of mortality. Also, qSOFA scores were higher in non - survivors than in survivors (2.8 ± 0.4 vs 1.6 ± 0.6). A significant association of increasing duration of ICU stay and mortality was found. **Conclusion**: Sequential Organ Failure Score showed good predictive and diagnostic abilities for maternal mortality in patients with SMM admitted to ICU.*

Keywords: SOFA Score; Severe Maternal Morbidity; Maternal Mortality

1. Introduction

Pregnancy is regarded as one of the most draining period for a woman both mentally and physically, ironically it is also one of the most emotionally engaging period of her life[1]. Severe Maternal Morbidity (SMM) is understood as a progressive process and if not managed in - time it eventually leads to maternal death [2]. Organ dysfunction is a continuous, dynamic process of alterations in organ function and is a part of the pathophysiologic process of SMM[3]. Various patient's demographics exhibit distinct patterns of organ dysfunction [4]. Research conducted in intensive care units (ICUs) has indicated that higher maternal mortality is directly correlated with the severity of organ dysfunction, the quantity of failing organs, and the duration of the condition[3, 4, 5].

Critically ill patients are characterized by a progressive and time - dependent organ dysfunction, which can vary from a mild degree to completely irreversible organ failure. This clinical deterioration has been shown to be an independent predictor of mortality, and an early identification of patients at risk of increasing organ damage could have an impact in terms of outcome improvement[6, 7]. Since the advent of modern medicine and surgical approaches having taken over traditional midwifery practices, there has been a significant improvement in the maternal and neonatal outcomes [8, 9, 10], yet almost 15% of all pregnancies globally, are potent to severe complications and cause almost five hundred thousand maternal deaths annually worldwide[11]. The Indian context however is a little different, in a nation - wide study, conducted in year 2020 across India, maternal mortality was reported to be 99/100000[12], which had dropped by almost 70% from its peak during 1997 - 1999. Maternal deaths are not only affected by increased risk attributable to pregnancy but also from the poor - quality maternal care from health services[13].

There have been attempts by various studies to evaluate the role of already in - use tools such as the Mortality Probability Models (MPMs), Simplified Acute Physiology Score II (SAPS II) and Acute Physiology and Chronic Health Evaluation II (APACHE II), which are currently used in ICUs for stratifying severity, evaluating therapeutic response, and estimating prognoses in SMM cases [14, 15, 16], however, these tests do not take into consideration various physiological changes that play key role during pregnancy and hence often overestimate the severity of illness and maternal mortality[17, 18, 19], such that, it is proposed that a method evaluating organ dysfunction appears to offer greater sensitivity and specificity.

One of the most useful tool that can be used is the Sequential Organ Failure Assessment (SOFA) score, which was developed and later validated as a tool for quantifying the degree of organ dysfunction and the prognosis of severely ill patients[20, 21]. Total maximum SOFA score, a measurement

resulting from and complementing the SOFA score, takes into consideration the maximum degree of alteration in organ function resulting from the insult suffered during the period the patient remained in the ICU[19]. The objective of this study was to evaluate organ dysfunction and prognostic accuracy of SOFA score in cases of SMM admitted to an obstetric ICU. While the overall aim of the study was to evaluate the utility of SOFA score to predict the outcome (survival or non - survival) of women with severe maternal illness admitted to intensive care unit so that prompt and effective management can be done at earlier stages of organ dysfunction so as to decrease the maternal mortality.

Aims and Objectives

- To study the prognostic accuracy of Sequential Organ Failure Assessment Score for evaluating organ failure and outcome of severe maternal morbidity in obstetrics intensive care.
- To correlate the SOFA and qSOFA (QuickSOFA) Score with maternal mortality.
- To correlate the duration of ICU stay and outcome.
- To calculate mortality among obstetric patients requiring Intensive Care Unit.

2. Materials and Methods

A Prospective Observational Cohort study was conducted in a ten bedded multidisciplinary ICU in SRN Hospital attached to M. L. N Medical College Prayagraj over a duration of 1 year.

Inclusion Criteria:
All obstetric patients admitted in a multidisciplinary ICU during pregnancy or within 6 weeks of delivery at SRN Hospital, MLN Medical College Prayagraj. All patients or their representative (if they are too sick to do so) giving written informed consent.

Exclusion criteria:
Age <18 years and >40 years**,** all gynaecological patients**,** Patients transferred to wards within 24 hours of admission to the ICU**,** Patients not giving consent

Sample size:
The sample size was calculated based on a previous study that reported that maternal mortality in the age group of 21–30 years was 19% (Bhadade et al., 2012), 95% level of confidence and error rate, usually set at 0.06 level. Total 164 patients were included in this study.

$$n=Z^2 P (1 - P) /d^2$$

Where n = sample size, Z = Z for a level of confidence of 95%, which is conventional is 1.96
P= expected prevalence or proportion (in proportion of one; if 19%, P = 0.19) d= precision (d = 0.06)
$n=1.96x1.96x0.19x0.81/0.06^2$ n=164.2

Methodology

Ethical clearance was obtained from the university and informed consent was obtained from all the participants willing to participate in the study.

The SOFA score was calculated on day 1 (at the time of admission), and subsequently on days 2, 3, 5, 7, 14, 21, and 28, as far as possible.

Highest/worst SOFA score for each organ system was calculated. The total and maximum (cumulative and individual) SOFA scores were determined.

Patients were followed up daily, with critical events during their ICU stay recorded.

Follow - up continued until 28 - days or discharge or mortality, whichever occurred earlier.

The maximum SOFA score, indicating the highest daily SOFA score over the study period, was determined.

The qSOFA Score was calculated at the time of admission.

It ranges from 0 to 24. A score of 13 or more was considered high risk.

Table 1: Sequential Organ Failure Assessment Score (SOFA)

Score	0	1	2	3	4
PaO_2/Fio_2	≥400	<400	<300	<200 with respiratory support	<100 with Respiratory support
Bilirubin (mg/dl)	<1.2	1.2 - 1.9	2.0 - 5.9	6.0 - 11.9	>12.0
Mean Arterial Pressure	MAP >70mmhg	MAP <70mmhg	Dopamine <5 OR Dobutamine (any dose)	Dopamine 5.1 - 15 or norepinephrine<=0. a[1]	Dopamine >15 or norepinephrine >0.1[a]
Glasgow Coma Scale	15	13 - 14	10-12	6-9	6
Platelets, $x10^3$/microL	≥150	<150	<100	<50	<20
Creatinine (mg/dl)	<1.2	1.2 - 1.9	2.0 - 3.4	3.5 - 4.9	>5.0

[a]Catecholamine doses are given as µg/kg/min for at least 1 h

Table 1 (a): qSOFA (quick SOFA) Score:
A score of 2 or more is considered high risk

Score	0	1
Systolic blood pressure	>100 mmHg	≤100 mmHg
Respiratory rate	<22 breaths/min	≥22 breath/min
Altered mental status	No	Yes

Mean total SOFA score	This is the sum of follow up day SOFA scores divided by the number of days of ICU stay.
Maximum SOFA score	This is the highest daily SOFA score over the course of the study period.

Glasgow Coma Scale

BEHAVIOR	RESPONSE	SCORE
Eye opening response	Spontaneously	4
	To speech	3
	To pain	2
	No response	1
Best verbal response	Oriented to time, place, and person	5
	Confused	4
	Inappropriate words	3
	Incomprehensible sounds	2
	No response	1
Best motor response	Obeys commands	6
	Moves to localized pain	5
	Flexion withdrawal from pain	4
	Abnormal flexion (decorticate)	3
	Abnormal extension (decerebrate)	2
	No response	1
Total score:	*Best response*	15
	Comatose client	8 or less
	Totally unresponsive	3

Figure 1: Glasgow Coma Score

3. Observation and Results

The present study was conducted in the Department of Obstetrics & Gynaecology, MLN Medical College, Prayagraj to study the prognostic accuracy of Sequential Organ Failure Assessment Score for evaluating organ failure and outcome of severe maternal morbidity in obstetrics intensive care.

Table 2: Study population based on their age

Age Group (years)	No.	%
≤ 20 years	16	9.80%
21 - 25years	64	39.00%
26 - 30years	68	41.40%
≥31 years	16	9.80%
Total	**164**	**100%**
Mean Age in years ± SD (Range)	25.78 ± 3.97 (19 - 39) years	

Inference: It was observed that most of the study participants 41.4% were aged between 26 to 30 years.

Table 3: Study population based on their Parity

Type of admission	Gravida/Parity	Number	Percentage (%)
Antenatal	Primigravida	37	22.50%
	Multigravida	79	48.20%
Postnatal		42	25.70%
Post - abortal		6	3.60%
Total		**164**	**100%**

Inference: It was observed that the majority of the patients were admitted in the antenatal period (70.7%), out of them most were multigravida (48.2%).

Table 4: Study population based on their cause of ICU admission and their outcome

Cause	Total (n)	Percentage (%)	Survivor (%)	Non - Survivor (%)
Pre - eclampsia with severe features	13	7.93%	9 (69.2%)	4 (30.8%)
Eclampsia	60	36.58%	44 (73.3%)	16 (26.7%)
Hemorrhage	34	20.73%	20 (58.8%)	14 (41.2%)
Acute Respiratory Distress	15	9.15%	13 (86.7%)	2 (13.3%)
Ruptured Ectopic Pregnancy	7	4.27%	6 (85.7%)	1 (14.3%)
Ruptured Uterus	10	6.1%	8 (80.0%)	2 (20.0%)
Others*	25	15.24%	17 (68.0%)	8 (32.0%)
Total	164	100%	117	47

* Sepsis, Gastroenteritis, Poisoning, AKI with MODS, TRALI, HELLP Syndrome, Heart Disease in Pregnancy, Uterine Perforation, Abnormal labour like Obstructed Labour, IUD with Non progression of labour, Previous LSCS with impending Rupture.

Inference - Maximum patients were admitted to ICU due to Eclampsia (36.58%) followed by Hemorrhage (20.73%).

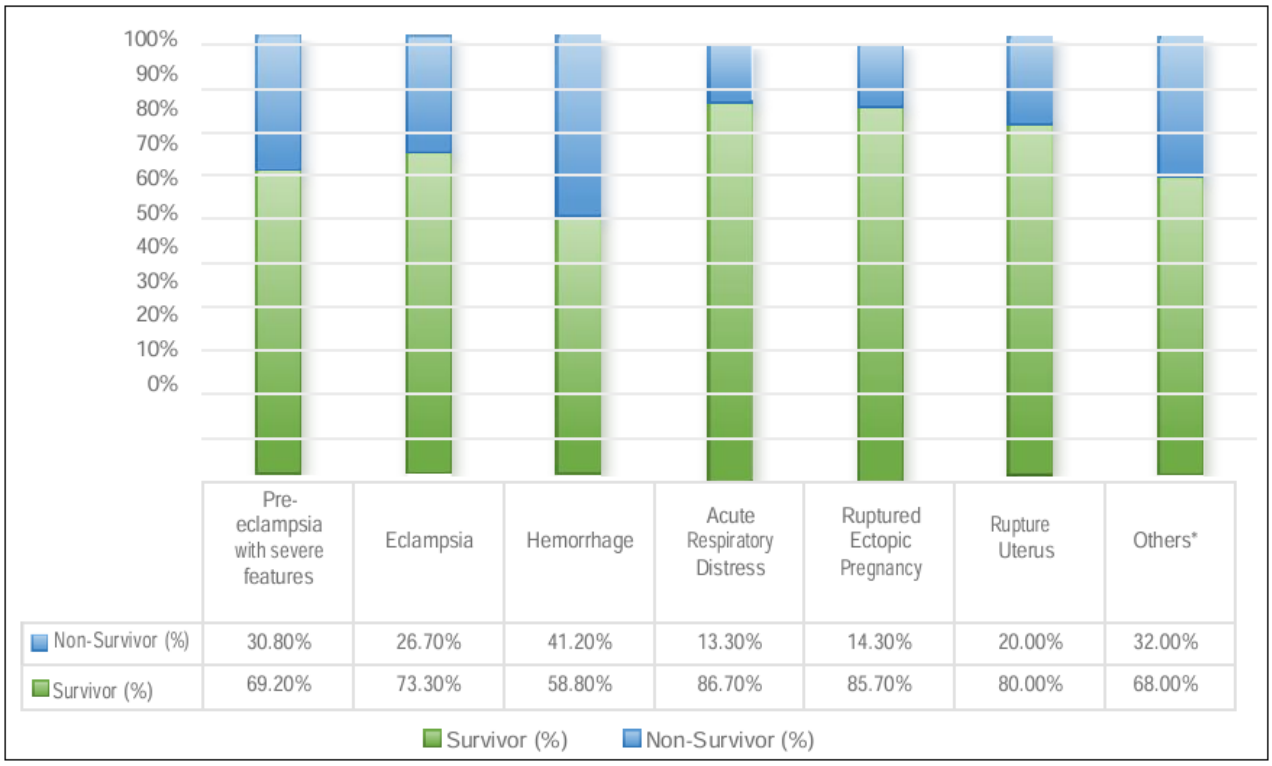

Figure 2: Bar diagram depicting the study population"s cause of ICU Admission according to their outcome

Table 5: Study population based on their management

Management		(n, %)
Surgical Management	LSCS	78 (47.6%)
	Peripartum Hysterectomy + Hysterectomy	23 (14.0%)
	Exploratory Laparotomy (Ruptured uterus Repair/ Ruptured ectopic pregnancy)	12 (7.3%)
Vaginal Delivery		7 (4.3%)
Medical Management		44 (26.8%)
Total		164 (100%)

Inference - Out of 164 women enrolled in the study Majority of the patients admitted to ICU had undergone surgical management (68.9%) of which LSCS (47.6%) being the most commonly performed one, followed by peripartum hysterectomy (13.4%). Only 4.3% of the patients delivered vaginally.26.8 % of the patients were managed medically.

Table 6: Association between SOFA score and mortality

SOFA score	Mortality		Total	Chi - square value	p - value
	Yes (%) / Non Survivor	No (%) / Survivor			
<10	1 (0.95%)	104 (99.05%)	105 (64.03%)	21.505	<0.001 (significant)
≥10	46 (77.97%)	13 (33.03%)	59 (35.97%)		
Total (%)	**47 (28.66%)**	**117 (71.34%)**	**164 (100%)**		
Mean	14.1 ± 2.7	6.9 ± 1.9	8.97 ± 3.95		

Inference: It was observed that the majority of the patients who did not survive had a SOFA score of ≥10. Out of total patients having a SOFA score of ≥10, 77.97% (46/59) of them did not survive. Mean SOFA score for the survivors was 6.9 ± 1.9 while for non survivors it was significantly higher i. e 14.1 ± 2.7. The association between the incidence of mortality and the SOFA score was found to be statistically significant (p - value <0.001).

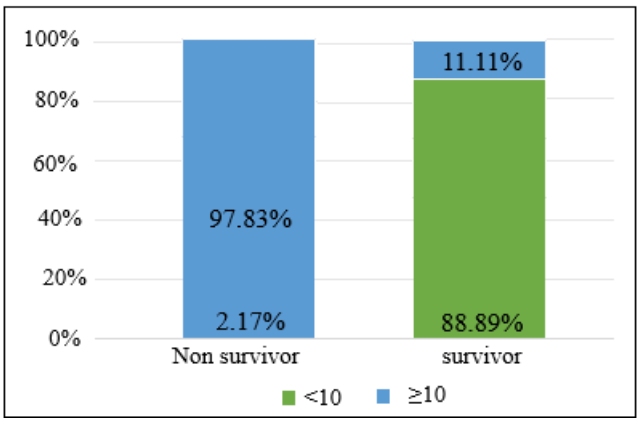

Figure 3: Bar diagram depicting association of SOFA score and mortality

Table 7: Association between qSOFA score and mortality

qSOFA score	Mortality		Total (%)	Chi - square value	p - value
	Yes (%) / Non Survivor	No (%) / Survivor			
<2	0 (0.0%)	54 (100.0%)	54 (32.9%)	29.914	<0.001
≥2	47 (42.7%)	63 (57.3%)	110 (67.1%)		
Total (%)	47 (28.7%)	117 (71.3%)	164 (100%)		
Mean	2.8 ± 0.4	1.6 ± 0.6	1.95 ± 0.78		

Inference: It was observed that none of the patients having qSOFA score of <2 expired. Meanwhile, among the patients who had a qSOFA score at admission ≥ 2, 42.7% expired and 57.3% survived. Mean qSOFA Score for the survivors was 1.6 ± 0.6 while for non survivors it was higher i. e 2.8 ± 0.4. The association between the incidence of death and the qSOFA score was found to be statistically significant.

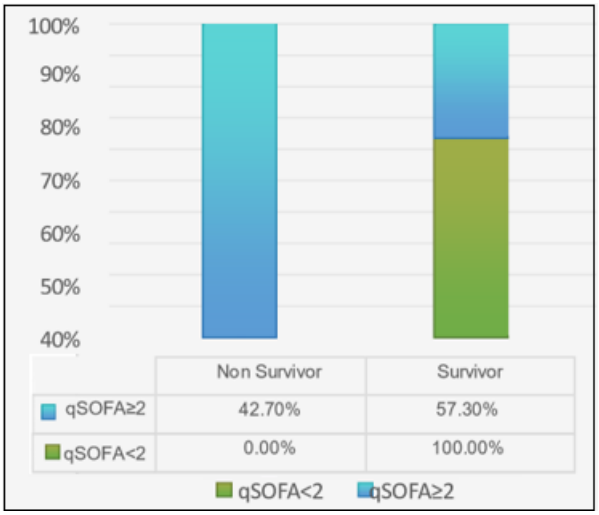

Figure 4: Bar diagram depicting association between qSOFA Score and mortality

Table 8: Distribution of the study population according to their outcome and its association with SOFA score, qSOFA score and duration of ICU stay

SN	Parameter	Survivor (n=117)		Non Survivor (n=47)		Student's t - test	
		Mean	SD	Mean	SD	t	p
1	SOFA	6.90	1.98	14.13	2.68	19.007	<0.001
2	qSOFA	1.62	0.63	2.79	0.41	11.801	<0.001
3	ICU Stay	3.85	1.64	4.85	3.55	2.728	0.007

Inference – Survived cases had a significantly lesser duration of ICU Stay 3.85±1.64 days vs. 4.85±3.55 days in non-survived cases. SOFA score was 6.90±1.98 of survived cases vs.14.13 ± 2.68 of non survived cases and qSOFA score was 1.62±0.63 of survived cases vs.2.79±0.41 in non survived cases.

Table 9: Study population according to their duration of ICU stay and outcome

Duration of ICU Stay	Total (n)	Survivor (n, %)	Non-Survivor (n, %)	P value (Chi square test)
2 to 5 days	133	104 (78.2%)	29 (21.8%)	^{2}= 20.117, <0.001
6 to 10days	27	13 (48.1%)	14 (51.9%)	
>10days	4	0 (0%)	4 (100%)	
Total	**164**	**117**	**47**	

P value <0.001 is significant.

Inference –Rate of mortality increases with duration of ICU stay i. e.2 - 5 days (21.8%), 6 - 10 days (51.9%), >10 days (100.0%). This difference was found to be statistically significant.

4. Discussion

The Sequential Organ Failure Assessment (SOFA) score is a clinical tool designed to quantify the extent of organ dysfunction in critically ill patients, particularly those in intensive care units (ICUs). One of the critical strengths of the SOFA score in this population is its ability to provide a dynamic assessment of a patient's condition. In the present study, the average age of women was 25.78 ± 3.97 years, majority were from rural areas (59.8%) and from lower socioeconomic class (51.2%), it emphasises the vulnerability of rural populations.70.7% patients were antenatal, most of them were multigravida (48.2%) and out of them 54.27% of the women were unbooked /unregistered cases. This finding is particularly concerning as it highlights the potential for preventable complications in unbooked pregnancies.

In this study, Pregnancy induced Hypertension emerged as the most common cause of ICU admission (44.51%) of which are pre - eclampsia with severe features (7.93%) and eclampsia (36.58%), followed by hemorrhage (20.73%). These findings align closely with those reported by Tiwari and Diwar et al (2022) [23] where eclampsia (35.7%) and pre - eclampsia (13.62%) were the leading causes of ICU admission, Srivastva et al. (2021) [20] also found that most were admitted due to mainly hypertensive disorders (46%). Divya and Dasari et al. (2023) [24] also observed hypertensive disorder as 22.4% being the most common medical disorder in obstetric patients presenting to emergency obstetric care. This consistency across studies emphasises the significant burden of hypertensive disorders of pregnancy, particularly eclampsia, in contributing to severe maternal morbidity. Hemorrhage, another leading cause of ICU admission in the present study, is also a well - documented cause of severe maternal morbidity.

In the present study, eclampsia was the main cause of ICU admission but the main cause of mortality was hemorrhage.41.2% of all the patients admitted to ICU due to hemorrhage could not survive compared to about 26.7% of all due to eclampsia could not survive.

In our study, most of the patients were managed by surgical management (68.9%), lower segment caesarean section (LSCS) (47.6%) being the most commonly performed. This pattern of treatment is consistent with the findings of previous studies, such as those by Kallur et al. (2014) and Dasgupta et al. (2017) [25] where LSCS (78.82% and 69.27% respectively) was the most common surgical intervention done among the ICU admitted obstetric patients.

It was observed that overall mortality of the patients in the present study was 28.7% (47/164). In other studies, like Dasgupta et al. (2017) [25] reported a mortality rate of 33.6%. Tiwari and Diwar et al (2022) [23] had a mortality rate of 27.52% in their study similar to our findings.

In the present study, majority of all the survivors had a SOFA score below 10 (88.89%), while a majority of all the non - survivors had a SOFA score of 10 or higher (97.83%). Maximum SOFA scores were significantly higher in non - survivors than in survivors (14.1 ± 2.7 vs 6.9 ± 1.9). This finding is consistent with the results of previous studies such Srivastva et al. (2021) [20] who observed that total maximum SOFA scores were significantly higher in non - survivors than in survivors (14.09 ± 5.53 vs 7.47 ± 4.58, p< 0.001). Tiwari and Diwar et al. (2022) [23] also observed the survival of patients was significantly associated with low SOFA scores with mean SOFA score of 6.48 ± 2.804 among survivors and 10.42 ± 3.579 among non survivors (p - value=0.001).

In our study the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of the SOFA score at a cutoff of ≥10 were 97.9%, 88.9%, 78.0%, and 99.0%, respectively, with an overall diagnostic accuracy of 91.5%. The prognostic efficacy of the SOFA score in the present study is further supported by the ROC analysis, at a cut off of 10, AUC was 0.988 (95%CI, SE 0.006, 0.977 - 1.000; p<0.001) which demonstrated that the SOFA score was a reliable predictor of mortality. Srivastva et al. (2021) [20] evaluated the ability of total maximum SOFA score to predict ICU mortality using ROC curve. AUC of 0.859, SE 0.035 (p<0.001), sensitivity of 96.6% and specificity of 90.0% with a cut off value of 10 was observed showing good discriminatory power for predicting the mortality. This strong association between higher SOFA scores and mortality highlights the prognostic efficacy of the SOFA score in predicting outcomes in severe maternal morbidity.

The present study found that all patients with a qSOFA score below 2 survived, while those with a score of 2 or higher had a mortality rate of 42.7%. qSOFA scores in this study were higher in non - survivors than in survivors (2.8 ± 0.4 vs 1.6 ± 0.6). Despite its simplicity the qSOFA score showed a sensitivity of 100.0%, but a lower specificity (46.2%) compared to the SOFA score. The prognostic efficacy of the SOFA score in the present study was further calculated by the ROC analysis, at a cut off of 2, AUC was 0.904 (95%CI, SE 0.025, 0.856 - 0.953; p<0.001) which demonstrated that the qSOFA score could be used as a reliable predictor of mortality. But this lower specificity suggests that while the qSOFA score is useful for identifying patients at high risk of mortality, it may not be as effective as the SOFA score in distinguishing between survivors and non - survivors. Our finding aligns with another study which was done in obstetric population by Agarwal et al. (2021) [26], which also found that the SOFA score was more predictive of mortality compared to SOS, PAS and qSOFA score in cases of pregnancy - associated sepsis. However, the qSOFA score's high sensitivity (100.0%) is consistent with its intended use as a quick bedside assessment tool and can be easily used at peripheral centers.

The present study observed that survived cases had significantly lower ICU Stay of 3.85±1.64 days vs.4.85±3.55 days in non - survived cases, SOFA score was 6.90 ±1.98 of survived cases vs.14.13 ± 2.68 of non - survived cases and qSOFA score was 1.62±0.63 of survived cases vs.2.79±0.41 in non - survived cases. Similar findings were observed by Srivastva et al. (2021) [20] and Tiwari and Diwar et al. (2022) [23] where higher scores were associated with more risk of mortality. Rate of mortality increases with duration of ICU stay i. e.2 - 5 days (21.8%), 6 - 10 days (51.9%), >10 days (100.0%). It implies that with longer duration of ICU stay the probability of survival decreases might be due to greater organ dysfunction over time.

The study's findings highlight the need for ongoing efforts to improve the management of hypertensive disorders of pregnancy, particularly eclampsia, which remains a leading cause of ICU admission and severe maternal morbidity. Additionally, the high proportion of unbooked cases and the association between lower socioeconomic status and ICU admission highlight the importance of enhancing antenatal care services, especially in rural and economically poorer populations.

5. Conclusions

The SOFA Score performs fairly well in estimating the degree of Organ Dysfunction and prognosticating the outcome. It is a simple tool to be used in critical care obstetrics setting. Various studies have shown Eclampsia and Preeclampsia being the primary reasons for ICU admissions. Elevated SOFA scores and qSOFA scores were linked to increased mortality rates among obstetric patients in the ICU. Prompt recognition of obstetric complications and timely intervention can help obstetricians minimize ICU admissions and reduce maternal mortality, which can be adequately assessed by the use of SOFA score.

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