Original Article

Retrospective analysis of patients with severe maternal morbidity receiving anaesthesia services using 'WHO near miss approach' and the applicability of maternal severity score as a predictor of maternal outcome

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ABSTRACT

Background and Aims: Risk stratification of severely morbid obstetric patients receiving anaesthesia services can be helpful in improving maternal outcomes. This study was undertaken to analyse these patients using the WHO near-miss (NM) approach and to assess the applicability of maternal severity score (MSS) to predict maternal mortality. **Methodology:** This is a one-year retrospective cohort analysis at a tertiary care centre. Of all the obstetric patients receiving anaesthesia, those with 'potentially life-threatening conditions' (PLTC) were identified. Amongst women with PLTC, those fulfilling the WHO NM criteria were grouped into either maternal near miss (MNM) or maternal death (MD) depending on final survival outcome. The MSS was assessed upon admission to post-anaesthesia ICU. The cases of "near miss" were compared to maternal death to determine the factors and WHO NM criteria significantly associated with mortality. Area under ROC curve (AUROC) was used to assess the accuracy of MSS to predict maternal mortality. **Results:** Of the 4351 anaesthetised obstetric patients, 301 were PLTC, 59 MNM and 11 MD. Obstetric haemorrhage was the commonest PLTC with the highest risk for MNM and MD. Preoperative organ dysfunction, referral from other centres, intra-uterine fetal death (IUFD) and WHO cardiovascular and respiratory NM criteria were significantly associated with mortality. MSS had excellent accuracy for the prediction of mortality (AUROC was 0.986 and 95% CI 0.966–0.996). **Conclusion:** Haemorrhage is the leading cause of MNM and MD. MSS is reliable in stratifying the severity of maternal morbidity and in predicting maternal mortality. Thus it can be used as an effective prognostic tool.

Key words: Anaesthesia, maternal near miss, maternal severity score, post-anaesthesia critical care

INTRODUCTION

Women can have potentially life-threatening conditions (PLTC) during pregnancy, labour and after termination of pregnancy.[1] Some of these women die (maternal death), while a proportion of them narrowly escape death thereby becoming near miss (MNM). MNM and maternal death (MD) together form the severe maternal outcome (SMO).[2] WHO defines MNM as 'a woman who nearly died but survived a complication that occurred during pregnancy, childbirth or within 42 days of termination of pregnancy'. Since the MNM

cases share characteristics with MD, in order to avoid MD, the MNM cases must be identified early,

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consistently and uniformly. WHO has published 25 clinical, laboratory and management-based markers for organ dysfunction called the WHO near miss criteria (WHO NM criteria) to identify MNM.[1] The total number of criteria present in a woman is the "maternal severity score" (MSS).[3] The use of MSS that is unique to pregnant patients allows the early identification and risk stratification of MNM.[4]

This study was conducted in women with severe maternal complications receiving anaesthesia and postoperative critical care. The objective was to study the association of PLTC, patient factors and WHO NM criteria with severe maternal outcome. It also aimed to study MSS upon admission to the Post Anaesthesia Care Unit (PACU) as the predictor of maternal mortality.

METHODOLOGY

This is a single-center retrospective cohort study. The tertiary care center is a 1900-bed public teaching hospital. It is a referral center for many public and private hospitals. There is a post-anaesthesia intensive care unit (PACU) managed by anaesthesiologists, where postoperative patients requiring intensive care from all surgical specialties including obstetrics are admitted.

After obtaining the institutional ethics committee approval, a retrospective record analysis of all the obstetric patients receiving anaesthesia and those admitted to PACU, during the period January 2016 to December 2016 was done. A standard data record form was used to abstract the data. Waiver for patient's consent was obtained, as there was no direct patient involvement or revelation of patient's identity.

An operational definition by WHO was used for identifying women with PLTC amongst all cases given anaesthesia. This included cases of obstetric haemorrhage, severe pre-eclampsia, eclampsia, sepsis or severe systemic infection and non-obstetrical causes contributing to morbidity. From PLTC, women who fulfilled at least one of WHO NM criteria [Table 1] were included for detailed analysis and grouped into MNM and MD depending on whether they survived or not. Severe maternal outcome (SMO) included both MNM and MD. Amongst the investigation-based criteria, serum lactate was not used due its non-availability.

Patient characteristics including age, gestational age, obstetric history, history of previous caesarean section (CS), referral from other centers were noted. Preoperative medical records were analysed for the presence of associated or contributory causes of morbidity. The mode of delivery, neonatal outcome indication for anaesthesia and surgical intervention were recorded.

As per institutional protocol, all patients with severe maternal complications were admitted to PACU. MSS was recorded at the time of admission to PACU. Based on WHO NM criteria, organ system dysfunction (cardiovascular, respiratory, renal, hepatic, neurological, coagulation/hematological, uterine) was identified. The timing of the presence of first NM marker (preoperative/intraoperative/postoperative) and thus organ dysfunction timing was recorded.

Cases of MNM and maternal death were compared for morbidity conditions, patient characteristics and each WHO NM criterion to find the significant association with mortality. Mortality index (Number of Maternal deaths due to a cause divided by number of total SMO due to that cause, expressed as percentage) for each factor was assessed. The association of mortality with organ system dysfunction was assessed.

Based on previous year's data, with the ratio of near miss to mortality as 5:1 in the present set up, a power of 80% at 95% significance level and considering the area under ROC curve (AUROC) for MSS as 0.5 for null hypothesis, in order to have AUROC of 0.9, the minimum sample size was calculated to be 48 with 40 negative cases (MNM) and 8 positive (MD). Detailed analysis of 70 cases (59 MNM and 11 Maternal death) occurring in one year was done for this study. WHO considered the prevalence of 7.5 cases of SMO per 1000 deliveries as adequate to produce significant results.[2] In the present study, there were 16.08 cases of SMO per 1000 operated cases. Hence, the sample size was considered to be adequate.

Data was analysed using SPSS Inc. Released 2009. PASW Statistics for Windows, Version 18.0. Chicago: SPSS Inc. For normally distributed data, the results were given as mean and standard deviation (SD) and as a median and interquartile range [IQR] for data not normally distributed. The numerical data were analysed by unpaired *t*-test for normally distributed data and by Mann–Whitney U test if it was not distributed normally. Number and percentage were used for the comparison of various factors, morbidity condition and WHO NM criteria between

Table 1: WHO 'Near miss' criteria[3]	
Organ system dysfunction	**Marker for organ dysfunction**
Cardiovascular dysfunction	1. shock
	2. cardiac arrest (absence of pulse/heart beat and loss of consciousness),
	3. use of continuous vasoactive drugs,
	4. cardiopulmonary resuscitation,
	5. severe hypoperfusion (lactate >5 mmol/l or >45 mg/dl),
	6. severe acidosis (pH <7.1)
Respiratory dysfunction	1. acute cyanosis,
	2. gasping,
	3. severe tachypnea (respiratory rate >40 breaths per minute),
	4. severe bradypnea (respiratory rate <6 breaths per minute),
	5. intubation and ventilation not related to anaesthesia,
	6. severe hypoxemia (O_2 saturation <90% for ≥60 min or PAO_2/FiO_2 <200)
Renal dysfunction	1. oliguria non-responsive to fluids or diuretics,
	2. dialysis for acute renal failure
	3. severe acute azotemia (creatinine ≥300 μmol/ml or ≥3.5 mg/dl)
Coagulation/	1. failure to form clots
haematological dysfunction	2. massive transfusion of blood or red cells (≥5 units)
	3. severe acute thrombocytopenia (<50 000 platelets/ml)
Hepatic dysfunction	1. Jaundice in the presence of pre-eclampsia
	2. severe acute hyperbilirubinemia (bilirubin >100 μmol/l or >6.0 mg/dl)
Neurological dysfunction	1. prolonged unconsciousness (lasting ≥12 h)/coma (including metabolic coma),
	2. stroke
	3. uncontrollable fits/status epilepticus
	4. total paralysis
Uterine dysfunction	1. uterine haemorrhage or infection leading to hysterectomy

MNM and MD. Chi square test or Fisher exact test as applicable were used for categorical data analysis. A *P* value <0.05 was considered significant. Relative risk (95% confidence interval) of SMO was calculated for morbidity conditions amongst cases with PLTC. The diagnostic accuracy of WHO NM criteria was assessed for the prediction of mortality among cases of PLTC. A receiver operating characteristic curve (ROC curve) for different MSS points was generated and the cut off points for MSS score were obtained with specificity and sensitivity for the predicted mortality. The accuracy of MSS in predicting mortality was measured by the area under the ROC curve. An AUC >0.7 was considered a good fit.

RESULTS

During the one-year study period, there were a total of 10166 hospital deliveries. A total of 4351 obstetric patients were given anaesthesia. Of these, 301 women were with PTLC, 59 were MNM cases and 11 MDs [Figure 1].

Table 2 shows the analysis of morbidity conditions amongst all patients with PTLC. Obstetric haemorrhage was commonest followed by hypertensive disorders amongst PTLC and SMO. The relative risk of
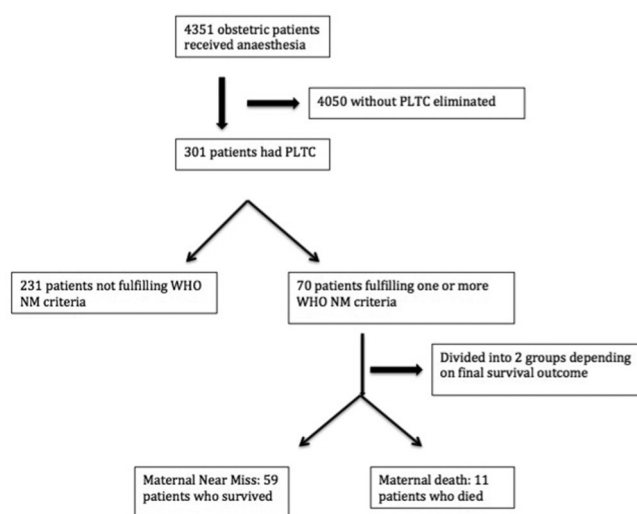
Figure 1: Flowchart showing stratification of cases

developing SMO (MNM and maternal death) was also highest with haemorrhage. Though the associated comorbid conditions like gestational diabetes, cardiac disease and severe anaemia were frequent, the risk of SMO was significant with anaemia.

Both groups were comparable with respect to age (MNM 27.5 ± 4.79, MD 27.36 ± 4.95, *P* = 0.92), mean gestational age at the time of anaesthesia (MNM 31.38 ± 10.02, MD 32.94 ± 9.05, *P* 0.63) and for

Primary determinants of morbidity	PTLC (*n*=301) No.(%)	MNM (*n*=59) No.(%)	MD (*n*=11) No.(%)	SMO (70) No.(%)	Relative risk (95%CI)
Haemorrhagic Complications	130 (43.1)	40 (67.7)	7 (63.6)	47 (67.1)	2.68 (1.72-4.18) $P<0.0001$
Hypertensive Disorders	105 (34.8)	17 (28.8)	4 (36.3)	21 (30)	0.80 (0.508-1.25) $P=0.3342$
Severe Sepsis and Systemic Infection	10 (3.32)	1 (1.69)	3 (27.27)	4 (5.71)	1.76 (0.8019-3.879) $P=0.1583$
Associated/Contributory Conditions (Total)	94 (31.2)	29 (49.14)	8 (72.72)	37 (50.85)	2.47 (1.65-3.68) $P<0.0001$
Cardiac	27 (8.97)	5 (8.47)	1 (9.09)	6 (8.57)	0.9201 (0.44-1.92) $P=0.824$
Respiratory	8 (2.65)	4 (6.77)	1 (9.09)	5 (7.14)	2.8173 (1.58-5.021) $P=0.0004$
Anaemia	29 (9.63)	18 (30.50)	6 (54.54)	24 (34.2)	4.89 (3.58-6.68) $P<0.0001$
GDM	34 (11.29)	2 (3.3)	0 (0)	2 (2.8)	0.2310 (0.059-0.90) $P=0.0347$

Table 2: Analysis of severe morbidity condition as per WHO near miss approach

parity (primigravida 33.9% in MNM vs. 45.4% in MD, *P* 0.46 and multigravida 66.1% in MNM vs. 54.5% in MD, P 0.46).

Table 3 shows the comparison between MNM and maternal mortality (MM). Previous caesarean sections had significantly lower mortality. Caesarean section was frequent mode of delivery in both MNM and MM. Higher percentage of patients in mortality group received anaesthesia for the exploration for haemorrhage (54% in MM versus 20% in MNM). This included the rupture of uterus, exploration after normal delivery and CS. IUFD/still birth and referral from another hospital had significantly high risk of mortality. Out of 11 maternal deaths, eight patients were referred and 10 patients had at least one near-miss marker present preoperatively.

Amongst all haemorrhagic complications, haemorrhage due to abnormal placentation was the most frequent in MNM, while the post-partum haemorrhage (PPH) with other causes mainly uterine atony were the most frequent in mortality. PPH and rupture uterus had high mortality index. Severe PIH with HELLP syndrome and sepsis had higher mortality with high mortality index. Severe anaemia any time in perioperative period, had higher mortality index.

Table 4 compares the presence of WHO NM criteria and the organ system involved between MNM and MD. Cardiovascular dysfunction and uterine dysfunction (hysterectomy) were mostly frequent but the cardiovascular and respiratory NM marker had significant associations with mortality. The mortality index increased as the number of organ systems

involved increased. All patients in the MD group and 93.22% patients in the MNM group required mechanical ventilation. In most, extended mechanical ventilation after general anaesthesia was required for haemodynamic instability, coagulation disorder or neurological dysfunction.

The diagnostic accuracy of the WHO NM criteria to predict mortality was 100.00% sensitive (CI 71.5–100), 79.66% specific (CI 74.56–84.1). Median (IQR) MSS for MD was 3 (3–7). This was significantly higher when compared to Median (IQR), 1 (1-2) for MNM, *P* < 0.0001. When ROC curve was plotted for different MSS points and outcomes [Figure 2], the AUROC was 0.986 (95% CI- 0.966–0.996) suggesting an excellent fit of MSS for predicting mortality. The best cut off value was MSS >1 with the sensitivity of 100% and specificity of 91.7%. The probability of death in MD group (56.04%) was significantly higher compared to MNM (7.58%), *P* < 0.0001. The predicted mortality was 10.5 and the calculated standard mortality ratio (observed death/predicted death) was 1.04.

DISCUSSION

The determination of the risk of a woman becoming critically ill or dying is helpful to better anticipate and prevent serious illness and to guide therapeutic decision-making. To define this risk, organ system-based criteria have been suggested to be the most specific and least susceptible to bias.[1,5] Due to the altered physiology in pregnancy and dramatic improvements seen after delivery, most of the available scoring systems used in critically ill non-obstetric patients for severity of illness and prediction of mortality are not

Table 3: Comparison of factors & morbidity conditions between near miss and mortality				
Parameters	MNM (*n*=59)	MD (*n*=11)	*P*	Mortality index (%)
Age (Years)				
Mean±SD	27.5±4.79	27.36±4.95	0.92	
≥35 years (no.)	2	1		
Gestational Age				
Mean (weeks)	31.38±10.02	32.94±9.05	0.632	
<34 weeks: no.(%)	20 (33.8)	2 (18.2)	0.306	
≥34 weeks: no.(%)	39 (66.1)	9 (81.8)	0.306	
Gravida no.(%)				
Primi	20 (33.9)	5 (45.4)	0.465	
Multi	39 (66.1)	6 (54.5)	0.465	
Mode of delivery no. (%)				
Vaginal	7 (11.8)	2 (18.18)	0.608	22.2
CS	43 (72.9)	7 (63.63)	0.717	14.0
MTP/Ectopic pregnancy	9 (15.2)	1 (9.1)	1.00	10.0
Pregnancy outcome no. (%)				
Alive	41 (69.5)	5 (45.4)	0.168	10.8
IUFD/Stillbirth	9 (15.2)	5 (45.4)	0.035	35.7
Previous CS no.(%)	27 (45.7)	1 (9.1)	0.040	3.5
Referred no.(%)	14 (23.7)	8 (72.7)	0.002	36.3
Anaesthesia indication no. (%)				
CS	41 (69.5)	5 (45.4)	0.168	10.8
Exploration for haemorrhage	12 (20.33)	6 (54.5)	0.026	33.3
Exploration for ruptured ectopic	5 (8.4)	0 (0.0)	1.000	NA
MTP	1 (1.7)	0 (0.0)	1.000	NA
Timing of organ dysfunction no.(%)				
Preoperative	33 (55.9)	10 (90.9)	0.041	23.25%
Intraoperative	26 (44.06)	0 (0%)	0.005	NA
Postoperative	0 (0.00)	1 (9.09%)	0.601	100%
Haemorrhage No. (%)				
Total	40 (67.8)	7 (63.6)	0.742	14.9
Antepartum Haemorrhage	6 (10.1)	1 (9.1)	1.000	14.2
Abnormal placentation	18 (30.5)	1 (9.1)	0.267	5.2
PPH (other than abnormal placentation)	9 (15.2)	4 (36.3)	0.084	30.7
Ruptured Uterus	2 (3.3)	1 (9.1)	0.406	33.3
Ruptured Ectopic	5 (8.4)	0 (0)	0.583	NA
Sepsis/no. (%)				
severe systemic infection	1 (1.7)	3 (27.2)	0.010	75
Hypertensive disorders				
Total	17 (28.8)	4 (36.3)	0.722	19.04
Severe PIH	6 (10.1)	1 (9.1)	1.000	14.28
Severe PIH + HELLP	4 (6.7)	3 (27.2)	0.072	42.85
ECLAMPSIA	7 (11.8)	0 (0)	0.586	NA
Associated/Contributory conditions				
Total	29 (49.1%)	8 (72.72%)	0.196	21.62%
CVS	5 (8.4)	1 (9.1)	1.000	16.66%
Respiratory	4 (6.7)	1 (9.1)	1.000	20%
Anaemia	18 (30.5)	6 (54.5)	0.168	25%
GDM	2 (3.3)	0 (0)	1.000	NA

applicable in obstetrics.[6] APACHE II and SOFA scores have been previously reported to overpredict mortality among pregnant women.[7-9] This study is unique to have used the WHO NM criteria and MSS, specific to obstetric population amongst women receiving anaesthesia and those requiring post-operative critical care. The standardised approach recommended by the WHO also allows for uniform comparison across regions.

In accordance with previous studies in developing countries, obstetric haemorrhage was the leading cause of MNM and mortality.[6,10,11] In a systematic review by the WHO, haemorrhage was the leading

Table 4: Comparison of WHO near miss criteria present between maternal near miss (MNM) & maternal death (MD)					
Total SMO (70) no (%)	MNM (59) no. (%)	MD (11) no.(%)	P	Mortality index (%)	RR (95%CI)
Cardiovascular System					
Total 35 (50%)	25 (42%)	10 (90%)	0.006	28	10.0 (1.35-74.00)
Shock	14 (23.7)	6 (54.5)	0.064	30	3.00 (1.03-8.72)
PH <7.1	1 (1.69)	2 (18.18)	0.062	66	4.96 (1.81-13.55)
Arrest	0 (0)	2 (18.18)	0.022	100	7.55 (4.11-13.88)
CPR	1 (1.69)	2 (18.18)	0.062	66	4.96 (1.81-13.55)
Continuous inotropes	15 (25.4)	9 (81.8)	0.006	37.5	8.62 (2.02-36.78)
Respiratory System					
Total 11 (15.15%)	6 (10.16%)	5 (45%)	0.010	45	4.46 (1.64-12.11)
Acute cyanosis	0 (0)	1 (9.1)	0.157	100	6.90 (3.89-12.23)
Gasping	0 (0)	2 (18.2)	0.022	100	7.55 (4.11-13.88)
RR >40	1 (1.7)	2 (18.2)	0.062	66	4.96 (1.81-13.55)
Intubation not related to anaesthesia	0 (0)	3 (27.2)	0.003	100	8.37 (4.37-16.04)
SaO_2 <90	6 (10.16)	4 (36.3)	0.0438	40	3.42 (1.22-9.60)
PaO_2/FiO_2 <200	6 (10.16)	4 (36.3)	0.0438	40	3.42 (1.22-9.60)
Renal System					
Total 1 (1.4%)	0 (0%)	1 (9.09%)	0.157	100	6.90 (3.89-12.23)
Oliguria	0 (0)	1 (9.1)	0.157	100	6.90 (3.89-12.23)
Creatinine >3.5	0 (0)	1 (9.1)	0.157	100	6.90 (3.89-12.23)
Coagulation/Haematological System					
Total 14 (20%)	10 (16.9)	4 (36.3)	0.1422		2.28 (0.77-6.73)
Failure to form clots	5 (8.47)	2 (18.2)	0.301	28	2.00 (0.53-7.47)
PRC >5	1 (1.7)	0 (0)	1.00	NS	1.64 (13.98-19.31)
Platelet count <50,000	6 (10.16)	4 (36.3)	0.043	40	3.42 (1.22-9.60)
Hepatic system					
Total 4 (5.71%)	3 (5.08)	1 (9.1)	0.503		1.65 (0.27-9.89)
Jaundice with PIH	3 (5.1)	1 (9.1)	0.503	25	1.65 (0.27-9.89)
S Bilirubin >6	0 (0)	1 (9.1)	0.157	100	6.90 (3.89-12.23)
Neurological System					
Total 7 (10%)	7 (11.86)	0 (0)	0.586		0.34 (0.02-5.35)
Unconsciousness	2 (3.38)	0 (0)	1.00	NA	1.00 (0.07-13.26)
Uncontrolled fits	5 (8.47)	0 (0)	0.584	NA	0.47 (0.03-7.15)
Hysterectomy					
Total 30 (42%)	23 (38.98)	7 (63.63)	0.186		2.33 (0.75-7.24)
Uterine Hysterectomy	23 (38.9)	7 (63.63)	0.186	23.3	
Number of organ system involved					
1	45 (76)	4 (36.36)	0.0132	8.16	
2	13 (22.03)	2 (18.2)	1.000	13.33	
3	1 (1.7)	2 (18.2)	0.0622	66.66	
4	0 (0)	3 (27.3)	0.003	100	

cause of maternal deaths in Africa and in Asia.[12] Though having a significantly high risk for developing SMO, the risk of mortality was not significant with haemorrhage in the present study. Amongst the causes of haemorrhage that require surgery, abnormal placentation (placenta previa, accreta and percreta,) had low mortality. Previous researchers had a similar observation.[13,14] The use of interventional radiology for the preoperative balloon catheterisation of uterine artery in cases of morbidly adherent placenta (performed in one patient in present study) is known to improve outcome.[15] As reported previously, PPH due to uterine atony and ruptured uterus had

high mortality index in our set up.[3,16,17] Despite having a protocol for the management of massive obstetric haemorrhage, the use of intraoperative uterotonics and availability of blood products, delayed referral of these patients could have led to mortality. Previous researchers have highlighted similar observations.[6]

Hypertension was the second leading cause of near miss and mortality. No death was observed amongst eclamptic patients who were given anaesthesia. Strict vigilance, protocol-based administration of magnesium sulphate, timely delivery and ICU care for such patients practised at our center could be the reason for this. In accordance with previous literature,
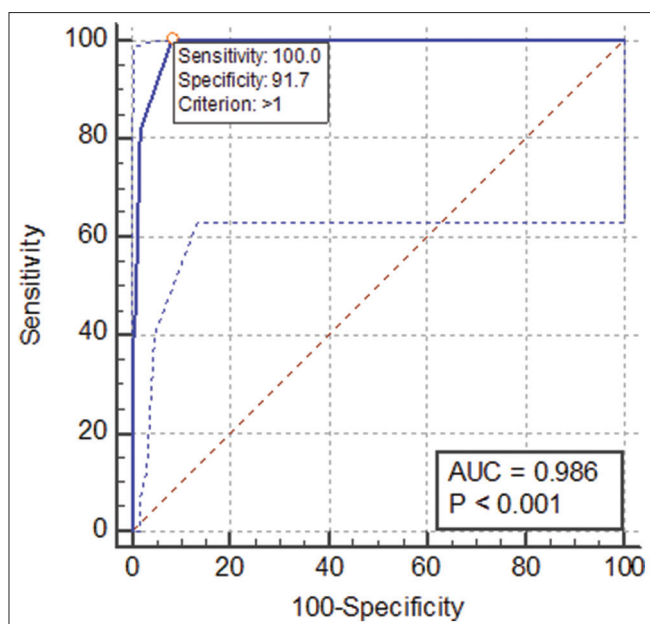
Figure 2: Receiver operated characteristic curve plotted using Maternal severity score at the time of admission to postoperative critical care unit in a tertiary care hospital over 1-year-period

preeclampsia with HELLP syndrome was associated with the significant risk of mortality.[18]

Sepsis is a major preventable cause of maternal mortality and morbidity worldwide. Though less prevalent in the current study, sepsis was significantly associated with mortality. Previous studies also report similar observations.[19] There is an urgent need of measures for the early detection and effective protocol-based management of sepsis.

In this study, age was not found to be an important factor toward contributing to mortality; the mean age was around 27 years in both MNM and mortality and it is noteworthy that most Indian studies for maternal near miss have a mean age of <30 years.[6,20,21] Socioeconomic factors and early age of marriage in our country might have contributed to this.

The high incidence of CS in both groups may represent a selection bias. CS is often used as a modality to terminate a high-risk pregnancy. Mortality index of delivery by CS was not high. A study that applied near miss concept in ICU observed that delivery by caesarean is associated with significantly lower occurrence of SMO in women with PTLC.[9] Nonetheless, it is prudent to remember that in some patients, CS could be a solution to critical illness while in others, complications of CS could be a determining factor for critical illness.

Previous CS is identified as independent risk factor for severe maternal outcome as it increases the risk of placental invasion, uterine rupture and obstetric hysterectomy.[16] This study did not find any significant association of previous CS with mortality.

In this study, a significantly higher number of patients in the mortality group resulted in adverse pregnancy outcomes in the form of fetal death. An insult severe enough to cause fetal death needs timely intervention and vigilance especially in the peri-operative period. Preventing a woman's progression along the continuum of severity may also improve delivery outcomes and newborn health.[22]

Ten out of 11 patients who died had at least one NM marker present preoperatively. This stresses the importance of identifying NM at the earliest and defining the degree of organ dysfunction so that the available resources can be directed to improve the outcome. High mortality with postoperative organ dysfunction also stresses the need of a dedicated obstetric ICU and high dependency unit (HDU) where high-risk obstetric cases not requiring critical care, can be monitored.[17,23]

Anaemia has been identified as an important indirect cause of mortality.[24] Although antenatal anemia was not recorded in this study, severe anaemia in the peri-operative period was associated with a high mortality index. In contrast to other studies, mortality in obstetric patients with cardiac disease was low in our study.[21] Medical co-existing conditions in pregnancy, not individually but along with obstetric complications can pose a significant threat to the survival of the mother and require a multidisciplinary approach for peri-operative optimisation.

Delays in seeking, reaching and receiving quality care are the important causes of maternal death.[17] In developing countries, 75% women with obstetric complications are in a critical state upon arrival.[25] Of 11 maternal deaths, eight were referred in a moribund state where irreversible organ dysfunction had already set in before anaesthetic intervention.

In the present study, the WHO NM criteria identified MNM and predicted mortality with 100.00% sensitivity and 79.66% specificity. This was comparable to previous studies.[3,4] In a WHO multicenter survey, the NM criteria considered on a whole were found to be reliable and highly associated with maternal

mortality.[26] Very few studies have assessed the association of each WHO NM criterion with the final outcome. In a study from Uganda, shock, prolonged coma (for up to 12 h), intubation unrelated to anaesthesia and cardiopulmonary resuscitation were predictive of a maternal death.[27] The need for haemodynamic support with a vasoactive drug was directly associated with a worse prognosis and higher maternal mortality in another study.[4] As reported previously, the present study also observed that most criteria in the cardiovascular and respiratory systems, if present at admission to PACU, were significantly associated with mortality.[28] Renal dysfunction secondary to preeclampsia is reported to improve after the termination of pregnancy.[28] Acute kidney injury secondary to sepsis was the cause of death in one of our patients with renal dysfunction.

Despite the high prevalence of uterine dysfunction in the form of obstetric hysterectomy, both groups were associated with significantly low risk of death. Hysterectomy for bleeding or uterine sepsis is performed as a critical intervention and early hysterectomy for such complications is reported to decrease mortality.[28,29] Multiorgan failure is a major predictor of mortality[20,30] Similar to a previous study, the present study observed that mortality increased with the involvement of more than two organ systems.[19]

The AUC for MSS upon admission to PACU (0.986) suggested an excellent fit. The median MSS of patients who died (3; 3–7) was significantly higher than the MSS of those who were MNM (1; 1–2). MSS was significantly associated with the outcome in a previous study and was reported to be a good prognostic tool to assess the severity of maternal complications and estimate the probability of death in MNM. In the present study, MSS predicted the mortality well (predicted 10.5, observed 11 and SMR 1.04)

The limitations of this study are that it is retrospective and performed at a single center. However, it is innovative to have used WHO NM criteria and MSS to stratify risk in patients receiving anaesthesia and those admitted to PACU.

To conclude, haemorrhage is the leading cause of severe maternal outcome. Reduction in pre-hospital referral barriers in case of haemorrhage or severe preeclampsia can have an immense impact. Pre-operative organ dysfunction and the WHO NM criteria for cardiovascular and respiratory system dysfunction are significantly associated with mortality. MSS at admission to PACU can reliably predict mortality and can be used as an effective guide for management of a near miss to prevent progress to death. Its extended applicability can also be as a preoperative risk assessment tool in obstetric anaesthesia for early identification of 'near miss' so that the available resources can be channelised to improve maternal outcome.

Conflicts of interest

There are no conflicts of interest.

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