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Shock Index and Modified Shock Index as Predictors of Adverse Maternal Outcomes in Primary Postpartum Hemorrhage

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ABSTRACT

Background: Postpartum hemorrhage is a leading cause of maternal morbidity and mortality, particularly in developing countries like Nepal. Early identification of women at risk is vital but traditional methods are sometimes subjective. Simple objective tools are of high importance in times of need. This study aimed to evaluate and compare the predictive performance of the Shock Index and Modified Shock Index for adverse maternal outcomes after primary postpartum hemorrhage.

Methods: A hospital based cross sectional study was conducted at a tertiary maternity hospital in Nepal. The study included 281 women diagnosed with primary postpartum hemorrhage. Heart rate, systolic blood pressure and mean arterial pressure were recorded at 1 and 2 hours postpartum. Shock Index and MSI were calculated. The adverse maternal outcomes such as including blood transfusion, surgical interventions or intensive care unit admissions were analyzed. The predictive ability of Shock Index and Modified Shock Index was analyzed using Receiver Operating Characteristic curve analysis.

Results: Both Shock Index and Modified Shock Index were significant predictors of adverse maternal outcomes. The single best predictor was identified as Shock Index as measured at 1 hour in women who underwent cesarean delivery, with an Area Under the Curve of 0.811 (95% CI: 0.754–0.868). For vaginal deliveries at 1 hour, Shock Index and Modified Shock Index performed similarly (Area Under Curve 0.777 and 0.776, respectively). Predictive ability decreased at the 2 hour mark, especially for patients post-cesarean delivery. Logistic regression confirmed that cesarean delivery and Shock Index at 1 hour were strong and independent predictors of the adverse outcomes.

Conclusions: The Shock Index is a simple and effective tool for the early detection of increased risk of adverse outcomes from postpartum hemorrhage. Modified Shock Index in particular showed greater overall predictability. Its routine implementation in postpartum monitoring, primarily in low-resource settings can significantly aid the triage and facilitate early life saving interventions.

Keywords: maternal mortality; modified shock index; postpartum hemorrhage; shock index.

INTRODUCTION

Postpartum hemorrhage (PPH) is a widely recognized cause of maternal morbidity and mortality globally, attributing estimated 20% of all maternal deaths[1] in 2020, among which most of the maternal deaths out of 287,000 maternal deaths worldwide occurred in low- and middle-income countries.[1] In Nepal, the maternal mortality ratio in 2021 was estimated at 151 per 100,000 live births, highlighting 26% of these deaths caused by obstetric hemorrhage among which 92% were postpartum.[2] This burden of postpartum hemorrhage persists although it is a preventable condition. To aid the management, WHO has also launched initiatives like the "Road Map to Combat Postpartum Hemorrhage 2023-2030."[3]

Traditional PPH assessment depends on visual estimation of blood loss, which is often inaccurate and unreliable, which might even lead to delayed identification of hemodynamic compromise. The Shock Index (SI), calculated as calculated as heart rate

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divided by mean arterial pressure (HR/MAP), have proved to be simple, low-cost tools for determining hemodynamic instability.[4,5] Although guidelines have been incorporating SI as an early warning tool and studies in trauma patients indicate Modified Shock Index (MSI) might have increased predictive accuracy, definite evidence for their comparative effectiveness in primary PPH especially in low resource settings like Nepal, is lacking.[6-8]

The objective of this study was to evaluate and compare the ability of SI and MSI, taken at 1 and 2 hours postpartum after diagnosis of PPH, with respect to predicting the adverse maternal outcomes among those women at a tertiary care centre of Nepal.

METHODS

This study was a hospital-based cross-sectional observational study done at Paropakar Maternity and Women's Hospital in Kathmandu, Nepal. The study duration was from October 2024 to March 2025. Institutional Review Board approval was obtained prior to starting of the study. A non-probability consecutive sampling method was used. The study population included all women who delivered at the hospital plus who were diagnosed with primary PPH during the study period. The inclusion criteria were confirmed diagnosis of primary PPH, successful hemodynamic monitoring with documented heart rate and blood pressure at 1 and 2 hours postpartum after PPH onset. The written informed consent was taken from all the patients before enrolling them into the study. Those patients with pre-existing shock or hemorrhage from any antepartum causes (e.g., placenta previa), hemorrhage due to abortion related causes, ectopic pregnancy, hemorrhage due to secondary PPH and with known pre-existing cardiac disorders altering heart rate or blood pressure were excluded.

Sample size was calculated as follows:

$$n = [DEFF * Np (1-p)] / [d^2 / Z2_{1-a/2} * (N-1) + p * (1-p)]$$

Where,

Population size (for finite population correction factor (fpc) (N): 10000000

Hypothesized % frequency of outcome factor in the population (p): 24% +/-5 [9]

Confidence limits as % of 100 (absolute +/-%) (d): 5%

Design effect (for cluster surveys-DEFF): 1

Confidence interval (%): 95%

Thus, the calculated sample size was 281.

Data were collected using a standard pro forma. Each patient's heart rate (HR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) were recorded at 1 hour and 2 hours postpartum after diagnosis of PPH by using standard automated blood pressure cuffs and pulse oximeters. SI and MSI at 1 and 2 hours were calculated. SI was calculated as HR/SBP.[4] Mean arterial pressure (MAP) was calculated as (2 × DBP + SBP) / 3.[7] Then, MSI was then calculated as HR/MAP.[5]

Adverse maternal outcomes were considered when one or more of the following interventions were present: transfusion of blood (≥1 unit of packed red blood cells), hemostatic sutures application, cervical or perineal repair, condom tamponade application, uterine or internal iliac artery ligation, hysterectomy or Intensive Care Unit (ICU) admission.

Data were collected and entered into Epi Data 3.1 and analyzed using SPSS version 21. The demographic and clinical characteristics were presented as frequencies and percentages. SI and MSI values were assessed for normality using Shapiro-Wilk and Kolmogorov-Smirnov tests. Non-parametric tests were used since data were not normally distributed ($p < 0.05$). To compare SI and MSI values between the 1-hour and 2-hour postpartum, Wilcoxon Signed-Rank test was used. Spearman's rank correlation was used to assess the association between the clinical outcomes and the indices, distinguished by the mode of delivery.

Receiver Operating Characteristic (ROC) curve analysis was done to assess the predictive ability of SI and MSI. To discriminate between patients with or without adverse outcomes, the Area Under the Curve (AUC) with 95% confidence intervals (CI) was calculated for each index at each time point. Logistic regression analysis was done to identify the independent predictors of adverse outcomes at 1 and 2 hours postpartum. The p-value of <0.05 was taken as statistically significant.

RESULTS

This study analyses the data from 281 postpartum women with primary postpartum hemorrhage delivered at Paropakar Maternity and Women's Hospital, Thapathali, Kathmandu. The mean age of the study participants was

observed to be 27.5 years (SD 5.4) and majority of them were in the normal age group 246 (87.5%). The majority of women were Multipara 152 (54.4%). Among 281 of the PPH cases, cesarean section rate 181 (64.4%) found to be much higher than the vaginal delivery 100 (35.6%) (Table 1).

Table 1. Age Group of Mothers.

SN	Age Group	Frequency	Percentage
1	Normal group (20-35 years)	246	87.5
2	High Risk group (<20 & >35 years)	35	12.5
	Total	**281**	**100.0**
	Parity of Mothers	**Frequency**	**Percentage**
1	Primi para	128	45.6
2	Multi para	153	54.4
	Total	**281**	**100.0**
	Modes of Delivery	**Frequency**	**Percentage**
1	Vaginal delivery	100	35.6
2	Caesarian section	181	64.4
	Total	**281**	**100.0**

Mild blood loss was observed most commonly 176 (62.6%) among the women with PPH out of which caesarean delivery had more occurrence. Uterine atony alone accounted for more than half i.e. 162 (58%), which was found 66% in vaginal and 53% in caesarian section, making it the primary cause of postpartum hemorrhage in this study. Abnormal placentation was a more frequent cause among the cesarean group (21.5%) as compared to the vaginal group (1.0%) (Table 2).

Table 2. Causes of Postpartum Hemorrhage by Mode of Delivery.

SN	Cause of PPH	Mode of delivery		Total (%)
		Vaginal delivery (%)	Caesarian Section (%)	
1	Uterine atony	66 (66.0)	96 (53.0)	162 (57.7)
2	Abnormal placentation	1 (1.0)	39 (21.5)	40 (14.2)
3	Uterine atony with engorged vessels	1 (1.0)	22 (12.2)	23 (8.2)
4	Uterine atony with tear	13 (13.0)	6 (3.3)	19 (6.8)
5	Cervical tear	9 (9.0)	1 (0.6)	10 (3.6)
6	Uterine atony with Dense adhesion	0 (0.0)	8 (4.4)	8 (2.8)
7	Retained tissue	6 (6.0)	1 (0.6)	7 (2.5)
8	Scar dehiscence	0 (0.0)	4 (2.2)	4 (1.4)
9	Cervical plus others associated tears	3 (3.0)	1 (0.6)	4 (1.4)
10	Ruptured uterus	0 (0.0)	2 (1.1)	2 (0.7)
11	Thrombocytopenia with extended tear	1 (1.0)	0 (0.0)	1 (0.4)
12	Cesarean Myomectomy	0 (0.0)	1 (0.6)	1 (4.8)
Total		**100 (100.0)**	**181 (100.0)**	**281 (100.0)**

Statistically significant trend was observed towards hemodynamic stabilization between the first and second hour following PPH. A Wilcoxon Signed-Rank test showed that both SI and MSI values decreased significantly while compared from 1 hour to 2 hours ($p < 0.001$ for both) The primary analysis assessed the ability of SI and MSI for the prediction of adverse maternal outcomes using ROC curve analysis. Both SI and MSI demonstrated good predictive

ability for adverse outcomes at 1 hour post-PPH with an AUC for SI of 0.777 (95% CI: 0.694-0.861) whereas for MSI of 0.776 (95% CI: 0.696-0.855).

The Single best predictor identified was SI measured at 1 hour post-cesarean delivery, that achieved a good AUC of 0.811 (95% CI: 0.754-0.868). The MSI at 1 hour also scored well (AUC= 0.768). However, the predictive value of both the indices declined significantly by the 2-hour time in the cesarean group (Table 3 and Figures 1-4).

Table 3. Predictive Performance (AUC) of SI and MSI for Adverse Maternal Outcomes.

Delivery Mode	Time Point	Index	Area Under Curve (AUC)	95% Confidence Interval (CI)	p-value
Vaginal Delivery	1 Hour	SI	0.777	0.694 - 0.861	<0.001
Vaginal Delivery	1 Hour	MSI	0.776	0.696 - 0.855	<0.001
Vaginal Delivery	2 Hour	SI	0.767	0.655 - 0.880	<0.001
Vaginal Delivery	2 Hour	MSI	0.750	0.634 - 0.867	<0.001
Cesarean Delivery	1 Hour	SI	0.811	0.754 - 0.868	<0.001
Cesarean Delivery	1 Hour	MSI	0.768	0.706 - 0.831	<0.001
Cesarean Delivery	2 Hour	SI	0.628	0.542 - 0.714	0.004
Cesarean Delivery	2 Hour	MSI	0.630	0.544 - 0.715	0.004

At the 1 hour time mark, logistic regression confirmed that both the cesarean delivery and an increased SI were strong, independent predictors of need for clinical intervention. This analysis further reinforces the primary findings stating that SI at 1 hour time is an important early predictor of risk (Table 4).

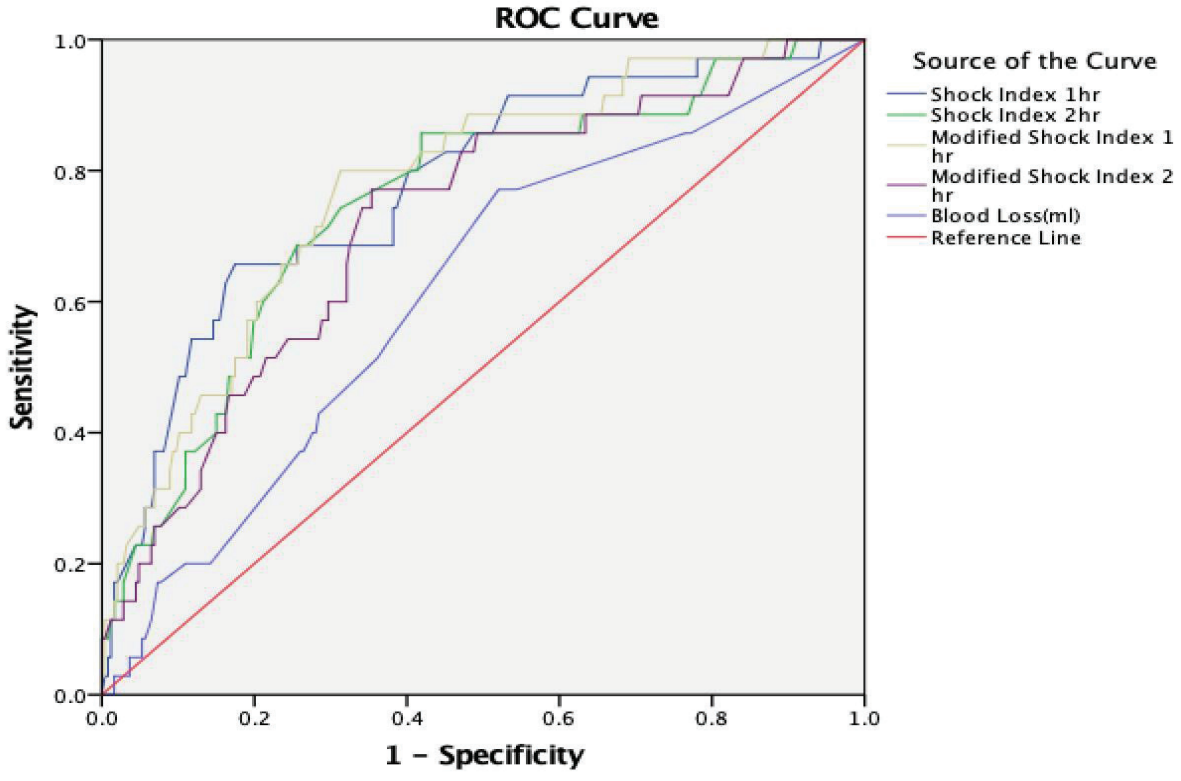

Figure 1. Receiver Operator Characteristic Curve of Clinical Outcome at one hour of Vaginal delivery with PPH.

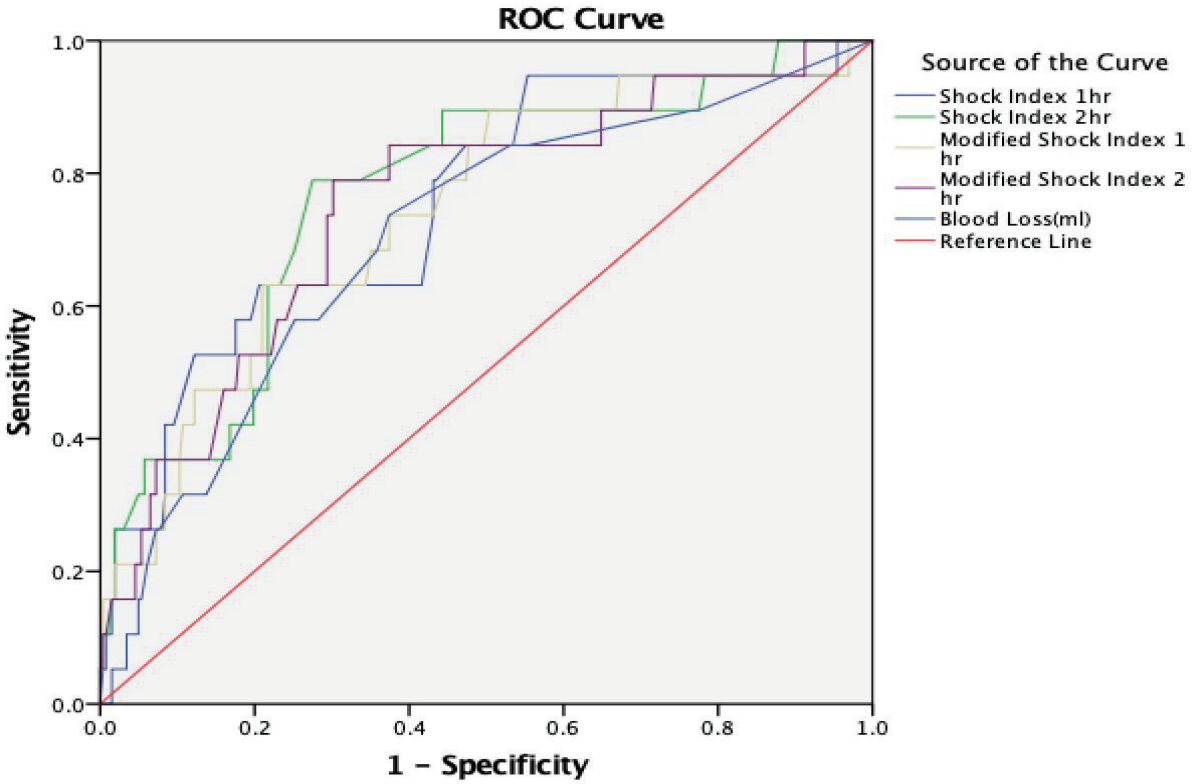

Figure 2. Receiver Operator Characteristic Curve of Clinical Outcome at two hours of Vaginal delivery with PPH.

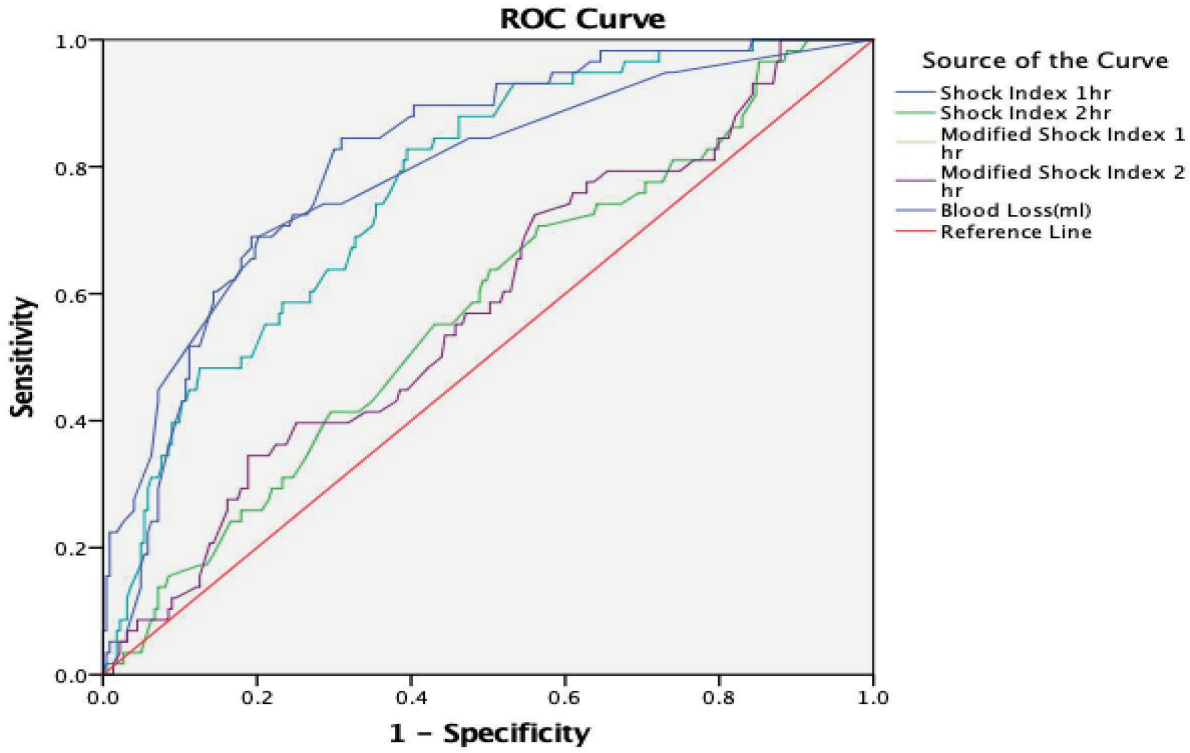

Figure 3. Receiver Operator Characteristic Curve of Clinical Outcome at One hour of Caesarian Section delivery with PPH.

Table 4. Logistic Regression Analysis of Predictors for Adverse Outcomes at 1 Hour

Predictor Variable	B (Coefficient)	Odds Ratio (OR)	95% Confidence Interval for OR	p-value
Mode of Delivery (Cesarean vs. Vaginal)	3.756	42.77	10.31 - 177.5	<0.001
Shock Index (SI) at 1 Hour (per unit)	8.044	3115.0	109.76 - 88398.81	<0.001
Blood Loss (ml)	0.000	1.000	1.000 - 1.000	0.923

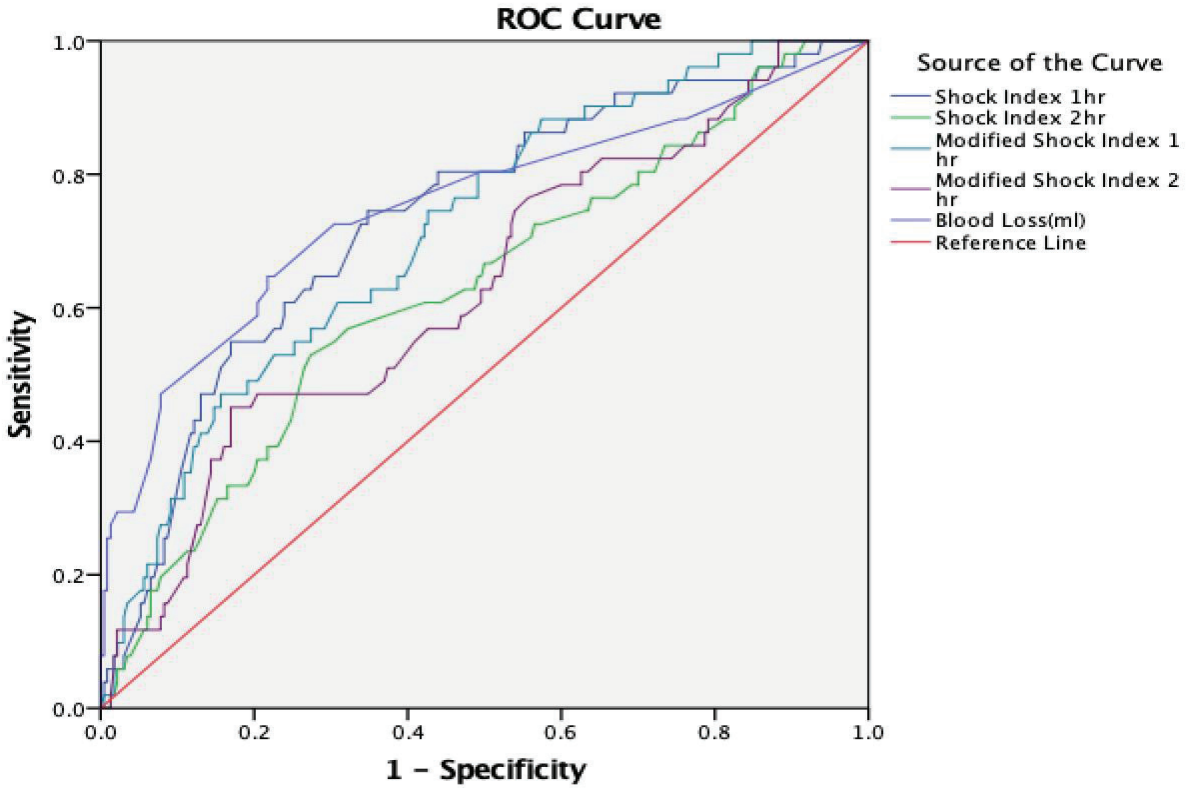

Figure 4. Receiver Operator Characteristic Curve of Clinical Outcome at two hours of Caesarian Section delivery with PPH.

DISCUSSION

In this study, it is demonstrated that both the SI and MSI are valuable predictors of adverse maternal outcomes in women having primary PPH. SI measured at 1 hour after a cesarean delivery was found to be the single most accurate predictor, highlighting superior discrimination and indicating a critical window for intervention in this group.

The results demonstrate that simple hemodynamic indices can effectively identify risk in the important first two hours following PPH. The superior predictability of SI at 1 hour post-cesarean (AUC 0.811) suggests that this measurement is an effective tool as a predictor for identifying patients who need significant intervention. The findings align with previous studies by De Giorgis et al.[10] and Nathan et al.[11], which also reported high predictive value of SI with respect to cesarean delivery. In contrast, the predictive usefulness of SI and MSI remained strong at both 1 and 2 hours for vaginal deliveries, which demonstrated prolonged course of hemorrhage in non-surgical methods of delivery. The observed significant decrease of SI and MSI values from 1 hour to 2 hours across the postpartum hemorrhage patients demonstrated positive impact of timely intervention of initial resuscitation and treatment efforts, which findings are consistent with study by Pacagnella et al.[12]

The findings in this study stated cesarean delivery as the predominant mode of delivery among PPH cases (64.4%) reflecting a growing global trend, especially in tertiary care centres that manage high-risk pregnancies. This is

in line with the study by Betrán et al. where a steady increase of cesarean rates was revealed.[13] The results of this study highlighted cesarean delivery was significantly associated with greater blood loss compared to vaginal delivery, aligning with other evidence. A systematic review by Lumbiganon et al. highlighted that cesarean delivery was associated with greater mean blood loss[14] and study by Knight et al. attributed increasing rates of severe PPH in developed countries to increasing cesarean deliveries.[15] The study by Liu et al. quantified this demonstrating a three- five fold increase in the risk of severe PPH with planned cesarean deliveries.[16]

The primary etiology of PPH in this study was identified as uterine atony (57.7%), which is consistent with the global data demonstrating atony as the cause in 60-80% of PPH cases.[13,17,18] It was observed that uterine atony was often complicated by several factors that differed by delivery mode. In cesarean deliveries, atony was linked with surgical factors like extended uterine tears or bleeding occurring from engorged vessels, whereas in vaginal deliveries, it was associated more with mechanical injuries such as cervical tears or retained placental tissues. This highlights the need for increased monitoring for mixed bleeding sources during surgical deliveries, as indicated by Widmer et al.[18]

The logistics regression analysis revealed that cesarean delivery was a strong risk factor for adverse outcomes at 1 hour following PPH but it became protective by 2 hours highlighting a critical change. This pattern suggests that although patients undergoing cesarean delivery might be at a higher risk, the surgical procedure allows for rapid hemostatic control, reducing the risk of deterioration in later stages compared to potentially increasing risk in PPH after a vaginal delivery. This aligns with the patterns reported by Nathan et al., who found that effective management could potentially improve outcomes even in cesarean deliveries.[11] This also solidifies the concepts discussed by studies like Cannon et al.[19] and Borovac-Pinheiro et al.,[20] that the predictive importance of physiological markers is greater before any definitive interventions can alter the clinical progress.

The implications of our study findings are especially significant for low-resource settings. SI and MSI are less-costly tools that require only the ability to calculate the heart rate and blood pressure parameters that are usually already part of standard postpartum observation. This monitoring provides an opportunity for real-time assessment of hemodynamic status, avoiding the limitations of subjective visual blood loss estimation. The integration of routine calculation of SI into PPH monitoring and management protocols could function as an "obstetric early warning" system,[6] promoting increased surveillance, timely interventions such as blood transfusions or surgical management. This is especially more important in busy delivery units and high demand tertiary care settings where small signs of deterioration can often be missed. The use of these tools can facilitate earlier identification thereby allowing aggressive management of women at high risk. Thus, the monitoring of SI has great potential in reduction of severe maternal morbidity and mortality from PPH in Nepal and similar settings.

The study was conducted in busy delivery settings, which closely reflects the high-demand setting among other tertiary care centers. The prospective mode of data collection and comparison of two indices at two different time points differentiated by mode of delivery provide a critical analysis. However, there were several limitations in the study. First, our findings may not be generalizable to broader healthcare settings since it was a single-centered study. Second, there is a possibility that not all the potential confounding factors that might have influenced the clinical outcomes and decision making were under observation. Finally, the cross-sectional study design establishes associations but cannot establish causality.

The findings from this study support the need for SI integration into clinical practice but also highlight the areas for future research. Multi-centric validation studies are needed to confirm the predictive accuracy of SI and MSI throughout different settings in Nepal. Future research should focus on analyzing population specific SI and MSI threshold values to aid clinical decision making. Furthermore, prospective studies analyzing whether the routine integration of SI-based protocol into PPH identification and management improves maternal outcomes would help provide definitive evidence for its utility.

CONCLUSIONS

Both SI and MSI are simple, non-invasive yet reliable bedside tools for assessing the risk of primary postpartum hemorrhage. Specifically, MSI showed more stable predictive performance over time, showing it as better suitable for routine integration into clinical protocols for early detection of continuous monitoring of hemodynamic instability. The incorporation of these indicators into standard postpartum care and surveillance could help identify the necessity of any earlier interventions for better maternal outcomes,

especially in high-demand and low resource settings.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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