RESEARCH ARTICLE

Shock Index as a Predictor of Maternal Outcome in Postpartum Hemorrhage

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Abstract

Background: Postpartum hemorrhage (PPH) is one of the leading causes of maternal mortality. Shock index (SI) is a hemodynamic parameter for the early identification of hypovolemic shock. This study was conducted to establish the thresholds of SI for predicting the adverse outcomes in PPH and to compare the predictive value of SI with heart rate (HR) and mean arterial pressure (MAP) at the first hour of hemorrhage.

Materials and Methods: This prospective cohort study was conducted at the Department of Obstetrics and Gynecology in a tertiary care hospital at India. The study population consisted of 100 patients who were randomly selected and delivered after 28 weeks with visual blood loss greater than 500 mL in normal vaginal delivery and greater than 1000 mL during lower segment cesarean section (LSCS). HR, MAP, and SI were noted at the first hour of hemorrhage. Area under the receiver operator curve (AUROC) for SI, MAP, and HR for predicting the adverse outcomes such as need for blood transfusion (≥4 blood products), need for intensive care unit (ICU) admission, and need for operative interventions was established and compared. The Threshold value of SI predictive for the above outcomes was established.

Results: SI greater than 1 was associated with the need for operative intervention, SI greater than 1.3 was associated with ICU admission, massive blood transfusion, and increased morbidity, and SI greater than 1.6 was associated with mortality. AUROC of SI [95% confidence interval (CI)] was highest when compared with MAP and HR for almost all outcomes.

Conclusion: Shock index is a simple, noninvasive, and sensitive tool that can be used in PPH triage.

Keywords: Heart rate, Maternal outcome, Mean arterial pressure, Postpartum hemorrhage, Shock index.

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Introduction

Postpartum hemorrhage (PPH) has been conventionally defined as blood loss of 500 mL or more from the genital tract after vaginal delivery and 1000 mL after cesarean section. Recently, it has also been defined as "cumulative blood loss greater than or equal to 1000 mL or blood loss accompanied by signs or symptoms of hypovolemia within 24 hours after the birth process (includes intrapartum blood loss) regardless of route of delivery."[1]

The contribution of PPH in the causation of maternal morbidity and mortality is reflected by the fact that nearly 1,40,000 deaths occur every year globally due to this condition, corresponding to one death every 4 minutes.[2,3] Depending on the rate of blood loss and other factors such as preexisting anemia, untreated PPH can lead to hypovolemic shock, metabolic acidemia, multiorgan dysfunction (MODS), and maternal death within 2–6 hours.[4] Hence, early identification and treatment of women with PPH are the key factors for maternal survival.

Traditional diagnosis and severity of PPH is based on the visual estimation of blood loss (VEBL). However, it has been seen that VEBL is often underestimated.[5] Moreover, in low- and middle-income countries where the prevalence of anemia is seen in 52% of pregnant women, smaller volumes of blood loss can lead to hemodynamic compromise, and hence, VEBL becomes an unreliable tool in these situations.[6] Hemodynamic parameters like systolic blood pressure (SBP) and pulse rate are also very useful tools for the early identification of women having PPH, and their thresholds are conventionally used as clinical trigger in various early warning systems to prompt intervention.[7] However, physiological changes in pregnancy, namely increase in blood volume and cardiac output, may mask conventional hemodynamic parameters till very late.[8]

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Shock index (SI) [heart rate (HR)/SBP] is a hemodynamic stability indicator and has been proposed as an early marker for hemodynamic compromise in nonpregnant women, but recently, it has been seen to correlate well with the hemodynamic compromise in the obstetric population also.[1,3,9–12] In the field of obstetrics and gynecology, the role of SI was first studied in patients of ectopic pregnancy to correlate with the degree of hemoperitoneum.[13] Preliminary studies to define the role of SI in women with PPH as compared to other conventional hemodynamic parameters have shown encouraging results.[8,14]

The scant literature available in the role of SI in PPH has been studied chiefly on a certain subset of the population and is retrospective in nature.[8,14] Therefore, there is a need to establish thresholds for SI in women with PPH in diverse population groups, which are predictive of adverse outcomes.

It was hypothesized that SI would be a useful tool for predicting the adverse outcomes in women with PPH. This

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study was, therefore, conducted with the aim of establishing the thresholds of SI for predicting the adverse outcomes and also comparing the predictive value of SI with heart rate (HR) and mean arterial pressure (MAP) at the first hour after hemorrhage in women with PPH.

Materials and Methods

Study Design

Prospective cohort study

Setting

The study was conducted in the Department of Obstetrics and Gynecology at Vardhaman Mahavir Medical College and Safdarjung Hospital, which is one of the largest tertiary referral teaching hospitals in New Delhi, India, conducting more than 27,000 deliveries annually. The study was conducted from October 2016 to December 2017.

Study Population

Hundred patients who delivered after 28 weeks with visual blood loss greater than 500 mL in normal vaginal delivery and greater than 1000 mL during LSCS were randomly selected. Patients presenting after the first hour of hemorrhage, hypertensive disorders with severe features [BP >160/110, epigastric pain, headache, blurring of vision, and hemolysis, elevated liver enzymes, and a low platelet count (HELLP) syndrome], pre-existing organ dysfunction, heart disease, and severe anemia (Hb <7 g) were excluded from the study.

Subject Evaluation

VEBL was done by counting the number of soaked perineal pads, blood collected in drapes and bucket, spillage of blood on the bed or floor, and suction machine (in case of cesarean section). One fully soaked perineal pad was considered as loss of 100 mL, half soaked pad as 60 mL, and less than half soaked pad as 30 mL, respectively. One fully soaked abdominal mop (45 cm × 45 cm) was considered as 150 mL; 20 × 20 cm incontinence gauze piece as 100 mL; Kelly's pad half soaked as around 300 mL and fully soaked with spill as around 500 mL; and a full kidney tray as around 500 mL and half kidney tray as 250 mL. Patients having PPH with blood on the bed all over constituted a blood loss of 1000 mL and with floor spill around 2000 mL.

Blood pressure (BP) and HR values were recorded at 15-minute intervals at the first hour after PPH in cases. Active management of the third stage was practiced in all patients as per the hospital protocol.[15] After taking BP and HR, SI and MAP were calculated and HR was noted. All the data entries were made in a set proforma, and values of MAP and HR corresponding to the highest SI were selected for the analysis. Cases were followed till discharge from the hospital, and the outcome measures were recorded.

Outcome Measures

The following outcome measures were analyzed: Need for blood or blood product transfusion greater than 4 units; surgical procedures such as balloon tamponade/cervical or vaginal lacerations repair/compression sutures/stepwise devascularization/hysterectomy; intensive care unit (ICU) admission for vasopressor support or ventilator support (invasive and noninvasive); disseminated intravascular coagulation (DIC)[16] or MODS[17]; and maternal mortality.

Statistical Analysis

Data analysis was done by calculating the area under the receiver operating characteristic curve (AUROC) for SI, HR, and MAP with 95% confidence interval (CI) ($p < 0.05$) for each outcome. Threshold values of SI for predicting the outcomes were determined by calculating the sensitivity, specificity, negative predictive value (NPV), and positive predictive value (PPV).

Results

It was seen that most of the cases with PPH were unbooked cases (75%). The mean age was 27.04 + 2.99 years. The most common mode of delivery was vaginal (59%) followed by cesarean section (35%) and instrumental delivery (6%). Risk factors associated with PPH were multiparity (27%), history of the previous section (15%), placenta previa (8%), polyhydramnios (2%), macrosomia (5%), prolonged labor (4%), and instrumental delivery (5%), while 28% patients did not have any risk factor. The most common cause of PPH was atonicity (76%) followed by traumatic PPH (15%) and retained placenta (13%).

The AUROC values for SI were more than that for MAP and HR in predicting the poor outcomes such as ICU admission requiring vasopressors (0.95 vs 0.87 vs 0.83) (Fig. 1), ICU admission requiring ventilator support (0.98 vs 0.94 vs 0.85) (Fig. 2), DIC (0.95 vs 0.94 vs 0.88), MODS (0.95 vs 0.91 vs 0.88) (Fig. 3), mortality (0.99 vs 0.96 vs 0.82) (Fig. 4), need for blood products greater than 10 units (0.91 vs 0.87 vs 0.80), and operative interventions such as hysterectomy (0.91 vs 0.86 vs 0.82), cervical or vaginal tear repairs (0.71 vs 0.70 vs 0.55), and need for manual removal of placenta (0.86 vs 0.72 vs 0.53) (Table 1).

It was seen that the cutoff threshold of SI for ICU admission requiring ventilator support was greater than 1.34 (sensitivity, 95.45% and specificity, 92.2%; PPV, 77.8 and NPV, 98.6) (Table 2). Similar cutoffs were seen for other outcomes such as MODS and requirement of blood products. A cutoff value of 1.4 was associated with outcomes such as DIC, ICU admissions for vasopressor support, and requirements of blood products (>10) with very high sensitivity and NPV. The cutoff value greater than 1.6 was associated with the mortality of the patient with a sensitivity of 100% and specificity of 98.95% (Table 2).

It was found that some operative interventions were required at a SI greater than 1. The cutoff threshold for the manual removal of the placenta was greater than 1.08, while the cutoff threshold for balloon tamponade was greater than 1.1. The need for hysterectomy, cervical and vaginal tear repair, and internal artery ligation was predicted by a SI greater than 1.3 with good sensitivity and specificity (Table 2). So, with the above results, it can be inferred that the cutoff greater than 1 is associated with the need for operative interventions, cutoff greater than 1.3 is associated with ICU admission, massive blood transfusion, and increased morbidity, and cutoff greater than 1.6 is associated with the mortality of the patient.

Discussion

PPH has been seen to be a major contributor of maternal morbidity and mortality. It is known to cause severe maternal outcomes if the treatment is delayed.[9,18–20] Therefore, it has become a challenging task to correctly assess the severity of the PPH, so that timely interventions can be made to prevent severe maternal morbidity and mortality. Previously, many

Table 1: AUROC comparison of SI, MAP, and HR for predicting the outcomes

Outcomes in PPH		*AUROC (SI)*	*AUROC (MAP)*	*AUROC (HR)*	*p value (SI vs MAP)*	*p value (SI vs HR)*
Blood	>4 products	0.888	0.862	0.768	0.694	0.11
	>10 products	0.917	0.871	0.808	0.115	0.035
ICU admission	Ventilator support	0.984	0.942	0.855	0.126	0.013
	Vasopressors	0.955	0.874	0.831	0.039	0.019
	MODS	0.949	0.914	0.888	0.207	0.044
	DIC	0.954	0.948	0.889	0.899	0.295
Maternal mortality		0.998	0.967	0.821	0.258	0.038
Operative	Hysterectomy	0.919	0.875	0.826	0.126	0.031
	Cervical/vaginal tear repair	0.71	0.701	0.553	0.907	0.022
	Internal artery ligation	0.837	0.893	0.641	0.129	0.021
	Balloon tamponade	0.656	0.573	0.695	0.511	0.778
	Manual removal of placenta	0.864	0.725	0.830	0.274	0.605
	Compression sutures	0.677	0.722	0.531	0.704	0.523

PPH, postpartum hemorrhage; HR, heart rate; MAP, mean arterial pressure; SI, shock index; ICU, intensive care unit

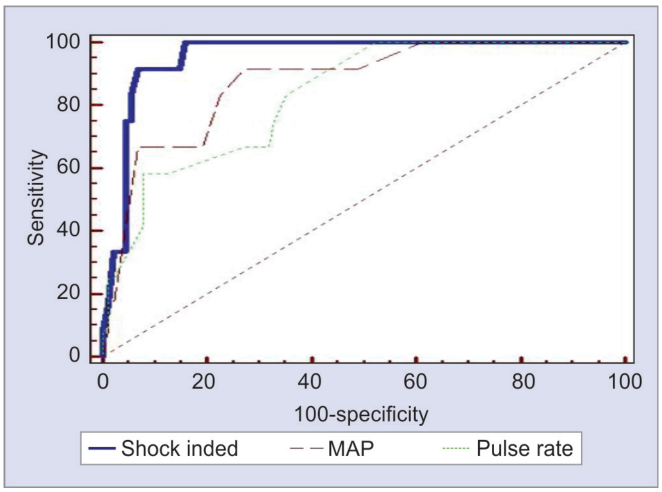

Fig. 1: AUROC comparison of SI, MAP, and HR for the prediction of vasopressor support

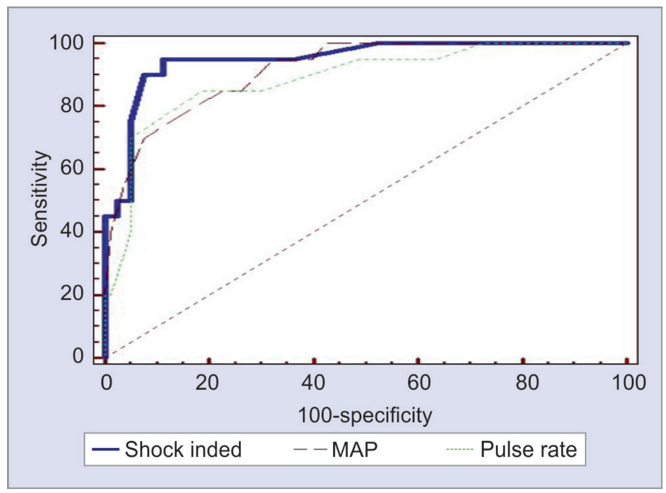

Fig. 3: AUROC comparison of SI, MAP, and HR for the prediction of MODS

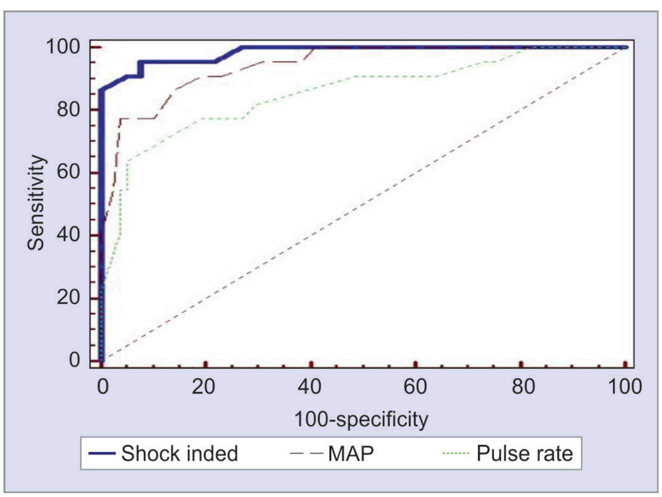

Fig. 2: AUROC comparison of SI, MAP, and HR for the prediction of ventilator support

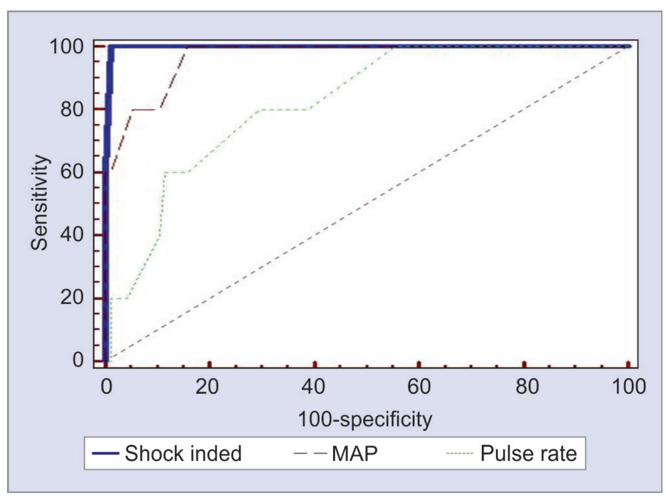

Fig. 4: AUROC comparison of SI, MAP, and HR for the prediction of maternal mortality

Table 2: Cutoff threshold of SI for predicting the outcomes

Outcomes in PPH		*Shock index cutoff*	*Area under the curve (AUROC)*	*95% confidence interval*	*p value*	*Sensitivity (%)*	*Specificity (%)*	*PPV*	*NPV*
Blood	>4 products	>1.32	0.887649	0.808880–0.942076	<0.0001	82.14	93.06	82.1	93.1
	>10 products	>1.4	0.91714	0.844869–0.962904	<0.0001	91.67	90.91	57.9	98.8
ICU admission	Ventilator support	>1.34	0.984266	0.936232–0.998750	<0.0001	95.45	92.31	77.8	98.6
	Vasopressors	>1.446	0.955019	0.893926–0.986360	<0.0001	91.67	93.18	64.7	98.8
	MODS	>1.32	0.949063	0.885913–0.983033	<0.0001	95	88.75	67.9	100
	DIC	>1.4	0.953684	0.892118–0.985630	<0.0001	100	85.26	26.3	100
Maternal mortality		>1.65	0.997895	0.959612–1.000000	<0.0001	100	98.95	83.3	98.6
Operative	Hysterectomy	>1.32	0.918998	0.847188–0.964156	<0.0001	90.91	89.74	71.4	97.2
	Cervical/vaginal tear repair	>1.32	0.709754	0.610474–0.796209	0.0355	75	78.41	32.1	95.8
	Internal Artery ligation	>1.3	0.837222	0.750040–0.903490	<0.0001	90	77.78	31	98.6
	Balloon tamponade	>1.1	0.656288	0.554632–0.748415	0.1331	66.67	71.43	18.8	95.6
	Manual removal of placenta	>1.08	0.864261	0.781238–0.924562	<0.0001	100	79.38	13	100
	Compression sutures	>1.24	0.676976	0.576082–0.767070	0.0103	100	58.76	7	100

PPV, positive predictive value; NPV, negative predictive value; PPH, postpartum hemorrhage; MODS, multiorgan dysfunction; DIC, disseminated intravascular coagulation

studies have been done, which used the amount of blood loss and traditional vital signs (HR and BP) as a means to assess the severity of the PPH. However, most concluded that these conventional parameters do not predict the adverse outcomes till very late.[5,13,21–23]

It was seen in this study that SI is consistently superior to HR for predicting the adverse outcomes in PPH, namely need for vasopressor ($p = 0.019$), ventilator support ($p = 0.013$), massive blood transfusion ($p = 0.035$), need for operative interventions ($p = 0.009$) such as hysterectomy ($p = 0.031$), internal artery ligation ($p = 0.021$), and maternal mortality ($p = 0.038$). Furthermore, SI was significantly superior to MAP for predicting the need for ICU admission requiring vasopressors ($p = 0.039$). It can also be inferred that HR has a poor predictive ability as compared to SI, whereas MAP is statistically comparable to SI in predicting most of the outcomes except the need for vasopressors even though the actual AUROC values for SI are higher for each outcome.

Nathan et al. found that AUROC of SI was highest for predicting the ICU admission as 0.75 (0.63–0.76), as compared to SBP, diastolic blood pressure (DBP), and MAP, but was not significantly higher than HR, which was contrary to our findings. For blood transfusion greater than 4 units, SI had the highest AUROC of 0.67, which was significantly higher than that of HR ($p = 0.032$), but was not significantly higher than MAP ($p = 0.402$). For invasive surgical intervention, SI and HR had the highest AUROC, but did not show any statistically significant results. SI was selected as the most consistently useful of all the predictors, as it performed well across most of the outcomes, which was similar to the results from our study.[14]

In a study by Ayadi and Nathan et al., SI and SBP had the highest AUC value at 0.87 (95% CI, 0.80–0.94) for maternal death, which was significantly higher than HR ($p < 0.05$) and pulse pressure ($p < 0.01$). For severe maternal outcome or critical intervention, the AUC for SI was significantly higher than SBP, DBP, MAP, and pulse pressure ($p < 0.01$).[5]

The cutoff threshold of SI, which was established in our study, was greater than 1 for various operative interventions; greater than 1.3 for ICU admission, multiorgan failure, DIC, and massive blood transfusion; and greater than 1.6 for maternal mortality.

Le Bas et al. found that an SI greater than 1.1 was associated with the increased requirement of blood products, which was also consistent with our findings. They found that it increases the chances of blood transfusion by 89% when the SI is greater than 1.1 at 10 minutes after the delivery.[8]

Nathan et al. proposed thresholds of SI greater than 0.9 for indicating the need for referral to a higher-level facility and SI ≥1.7 for indicating the need for urgent intervention, with the aim of promptly identifying and managing obstetric shock to reduce the maternal adverse events in resource-poor settings.[14] Another study concluded that SI greater than 1.143 and 1.412 were strong initial and "critical" thresholds, respectively.[24]

Ayadi and Nathan found that in low resource settings, a SI threshold of 0.9 indicates the need for referral, 1.4 indicates the urgent need for intervention in tertiary facilities, and 1.7 further improves the specificity (range, 80.7–90.8) without compromising the NPV (range, 88.8–98.5) for the prediction of adverse outcomes.[14] These cutoff ranges were slightly different from what we observed; as the minimum cutoff value predictive of poor outcome in our study was 1.08, which was the requirement for the manual removal of the placenta, Ayadi and Nathan observed poor outcomes in SI of above 0.9.[14] Major morbidities in our study were observed only in SI of above 1.32. The difference in the values could be because the population studied by them belonged to low resource countries of Nigeria, Zambia, and Zimbabwe, where resuscitative measure may not have been as aggressive as in a tertiary referral hospital.

Moreover, their study was retrospective in nature, and the values were derived from the case notes.

One notable feature that should be mentioned is that all the cases of PPH in this study delivered in a tertiary care setup and were provided with immediate fluid or blood resuscitation. The first hour of SI, which was determined in this study, may not hence be representative for a cohort of patients who deliver at the primary care level, where resuscitative measures may be lesser than optimum.

Marcano et al. concluded that the operational stress injury greater than 0.9 was associated with an increased risk of ICU admission and the need for operative interventions. It can be appreciated that the threshold for ICU admission in this study, conducted on the Australian population, was very low, indicating the easy availability of the resources. The authors of the study also noted the fact that most of these patients did not need ICU care.[25]

Strength and Limitations of the Study

The major strength of the present study is that it was performed prospectively on robust sample size, and the patients were followed for outcomes till they were discharged from the hospital. The limitation was that many of the high-risk patients were excluded from the study so as to remove the confounding factors that can alter the SI. Further studies in this subset of patients are also warranted to determine the SI predictive of adverse outcomes.

So, it can be seen that the SI is a good modality in the early identification of PPH and hence aids in the timely management of these patients.

Conclusion

Thus, from the present study, it can be concluded that a cutoff value of SI greater than 1 is associated with the need for operative interventions, cutoff value of SI greater than 1.3 is associated with ICU admission, massive blood transfusion, and increased morbidity, and a cutoff value of SI greater than >1.6 is associated with the mortality of the patient. Thus, we recommend that all patients of PPH with a SI greater than 1 should be immediately transferred to a tertiary care facility where operative interventions and blood transfusion can be carried out safely. When SI is greater than 1.3, the care should be stepped up in the tertiary care center, and all resources such as senior consultants on call, ICU beds, and massive blood transfusion protocols should be mobilized.

Author Contributions

VA conducted the study, analyzed the data, and prepared the manuscript; JS designed the study, planned the study, and prepared the manuscript; PM planned the study and analyzed the data; PA analyzed the data and prepared the manuscript; and SG conducted the study and prepared the manuscript.

Ethical Clearance

Ethical clearance was taken from Institutional Ethics Committee of VMMC and Safdarjung Hospital dated 28/10/16.

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