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ORIGINAL ARTICLE

Shock Index in the Prediction of Adverse Maternal Outcome

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Abstract

Introduction WHO states that obstetric hemorrhage, hypertensive disorders of pregnancy and sepsis account for approximately 50% of maternal deaths worldwide. All these conditions are associated with changes in vital signs including blood pressure (BP) and heart rate (HR). Shock index (SI) is the ratio of HR to systolic BP.

Aims and Objectives To evaluate role of shock index as an early indicator of adverse maternal outcomes and to determine the threshold points of SI for five adverse maternal outcomes**.**

Methodology This was a prospective observational study on 1004 consecutively enrolled subjects presenting in labor. Vital signs and Shock Index were recorded. SI thresholds were analyzed with respect to obstetric complications and adverse outcomes. Parametric tests such as Chi-square, comparison of proportions, comparison of mean and ROC curve analysis were applied on the data.

Results The mean SI value in the vaginal delivery group was 1.02 ± 0.26 and it was 0.95 ± 0.033 in the caesarean delivery group. The values of SI ((Mean and SD) for ICU admission were (1.23 (±0.35)), for (MODS) it was (1.47 (±0.84)), for blood transfusion > 4 units it was (1.15 (±0.41)), for surgical intervention it was (1.58 (±0.51)) and for maternal death (1.39 (±0.85)). SI ≥ 1.4, had sensitivity 26.82% (21.09–33.19); specificity 100%(99.53–100), PPV was 100% and NPV was 82.96%(81.8–84.06)with an AUC of 0.8 (0.78–0.83) on ROC analysis. In subjects with PIH/eclampsia, SI was lower and in patients with severe anemia, SI was higher

Conclusion SI performed well as a screening tool in the prediction of adverse maternal outcomes. SI ≥ 0.9 was significantly associated with maternal adverse outcomes: ICU admission, MODS, surgical intervention, blood transfusion and death. The study proposes an SI cut-off of 0.9 for referral and a cut-off of 1.1 for intervention in a tertiary care hospital. Patients with PIH/eclampsia tend to have lower mean SI values as compared to the rest of the study population, suggesting that SI may not be a reliable indicator in patients with PIH/eclampsia

Keywords Shock index · Adverse · Maternal outcome

Introduction

WHO in a systematic review of causes of maternal mortality, states that obstetric hemorrhage, hypertensive disorders of pregnancy (HTN) and sepsis account for approximately 50% of maternal deaths worldwide [1]. Pregnancy involves significant hemodynamic changes. As the placenta is delivered, auto transfusion results in cardiac output increasing to 80% above pre-pregnancy values. It is during the intrapartum and immediate post-partum period that hemorrhage and sepsis is most prevalent and compensatory mechanisms can mask hypovolemia.

Shock Index (SI) is the ratio of HR to Systolic BP has been proposed as an indicator for early hypovolemia and the need for blood transfusion. It has been studied in patients either at risk of or experiencing shock from a variety of causes: trauma, hemorrhage, myocardial infarction, pulmonary embolism, sepsis, and ruptured ectopic pregnancy. While HR and SBP have traditionally been used to characterize shock in these patients, they often appear normal in the compensatory phase of shock and can be confounded by factors such as medications [2].

An increase in SI has been related to severe adverse maternal outcome and death, requirement of massive transfusion, low fibrinogen levels, and transfusion of blood

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volume and fresh frozen volume [3]. Nathan et al. (2015) [4] recommend SI > 0.09 as the initial trigger in low resource settings and SI > 1.7 to identify critically ill subjects. Le Bas et al. [5] have proposed a range of 0.7–0.9 for normal shock index in pregnancy, compared to a reported range of 0.5–0.7 in non-pregnant populations. When the SI was ≥ 1.1, the need for blood products was 89%. El-Ayadi et al. [3] reported that a shock index threshold of ≥ 0.9 had a high sensitivity (100.0). They have recommended a threshold of > 0.9 for need for referral, ≥ 1.4 indicating urgent need for intervention in tertiary facility and ≥ 1.7 indicating high chance of adverse outcome.

Thresholds of SI have been proposed (SI < 0.9, SI 0.9–1.69 and SI ≥ 1.7), based on retrospective cohorts of women with hemorrhage and sepsis in various settings to indicate increased risk of adverse outcomes. These previously proposed SI thresholds have not yet been prospectively validated in an Indian context. This study was conducted to evaluate the various cut-off levels of SI in prediction of adverse maternal outcomes in the setting of a tertiary level referral hospital.

Subjects and Methods

This was a prospective observational study on 1004 consecutively enrolled subjects presenting to the Labor Room. Age, Parity, Height, Weight, Body Mass Index, singleton/multifetal pregnancy, duration of labor, mode of delivery (vaginal or caesarean section), type of anesthesia, severe anemia (Hb < 7gm/dl), Pregnancy-Induced Hypertension (PIH), pre-eclampsia and eclampsia were recorded. Vital signs HR, BP, MAP, and SI were recorded at admission, then 30 min and 2 h after delivery. Blood Pressure was recorded using a sphygmomanometer with subject in left lateral position. The worst data set was included for analysis. Shock index was calculated as follows: HR/SBP. Obstetric complications such as PPH, placenta previa, abruption placenta, rupture uterus and sepsis were recorded.

Normal and adverse maternal outcomes were recorded. Adverse outcomes were recorded as based on WHO "critical interventions" criteria [6] as follows:

- ICU admissions
- Blood transfusions > 4 units
- Maternal death
- Emergency hysterectomy
- Severe end organ dysfunction (MODS)

SI thresholds were analyzed with respect to obstetric complications and adverse outcomes.

Data were entered in an excel sheet and analyzed using Medcalc software version 14.2. SI values have been reported as Median (IQR) and Mean (SD). Parametric tests such as Chi-square, comparison of proportions, and comparison of mean were used. Diagnostic indices and ROC analysis were performed. A p value < 0.05 was considered significant.

The study was approved by the Institutional Ethics Committee. Informed consent was obtained.

Results

Three thirty-two subjects had SI < 0.9, 613 subjects had SI between 0.9 and 1.3 and 59 subjects had SI ≥ 1.4. The number of adverse outcomes was highest 55/59 (93.22%) in the group of subjects with SI ≥ 1.4 and it was 132/613(21.53%) in the group with SI between 0.9 and 1.3. The mean SI value in the vaginal delivery group was 1.02 ± 0.26 and it was 0.95 ± 0.033 in the caesarean delivery group. This observation was highly significant at $p < 0.0003$.

Obstetric complications were seen in 220 subjects. Of these 220 subjects who had obstetric complications, 167 had adverse outcomes such as ICU admission ($N = 164$), surgical intervention ($N = 24$), Multiple Organ Dysfunction syndrome (MODS) ($N = 45$), blood transfusion > 4 units ($N = 112$) and maternal death ($N = 39$). Table 1 shows the SI values (Mean and SD) for the obstetric complications and adverse outcomes; traumatic and atonic PPH, placenta previa and abruption placenta and rupture uterus. In all these conditions the mean SI was ≥ 1.1. The values of SI ((Mean and SD) for ICU admission were (1.23 (± 0.35)), for (MODS) it was (1.47 (± 0.84)), for blood transfusion > 4 units it was (1.15 (± 0.41)), for surgical intervention it was (1.58 (± 0.51)) and for maternal death (1.39 (± 0.85)).

Table 2 shows that the mean and SD for the subjects with pregnancy-induced hypertension group was 0.87 ± 0.20 as compared to the rest of the group (1.03 ± 0.3). The mean SI

Table 1 Shock Index mean and SD for obstetric complications and adverse outcomes

Obstetric complications	SI mean(SD)	Adverse outcome	SI mean (SD)
Traumatic PPH	1.17 (0.37)	ICU admission	1.23 (± 0.35)
Atonic PPH	1.15 (0.39)	Blood transfusion ≥ 4 units	1.15 (± 0.41)
Placenta Previa	1.15 (0.34)	Surgical intervention	1.58 (± 0.51)
Abruptio placenta	1.41 (0.6)	MODS	1.47 (± 0.84)
Rupture uterus	1.04 (0.31)	Death	1.39 (± 0.85)

Table 2 SI values in PIH/eclampsia versus rest of study population

SI	SI			*P* value
	N (%)	Mean	SD	
With PIH/ Eclampsia (*N* = 149)	149 (14.8%)	0.87	0.2	*P* < 0.0001
Without PIH/ eclampsia (*N* = 855)	855 (85.15%)	1.03	0.3	

Table 3 SI values in severe anemia versus rest of study population

SI	SI			*P* value
	N (%)	Mean	SD	
With severe anemia (Hb < 7gm/dl)	387 (38.54)	1.15	0.41	*P* < 0.0001
Without severe anemia	617 (61.45)	0.91	0.12	

Table 4 Median (IQR) for vital signs

Vital Sign	Median	IQR
SI (*N* = 1004)	0.92	0.87–1
Heart rate	96.00	92–104
SBP	100.00	100–110
DBP	70.00	60–70
MAP	83.33	76.67–83.33

to the group without anemia in whom it was 0.91 ± 0.12. In subjects with severe anemia and an adverse outcome, this value was 1.34 ± 0.51as compared to 0.96 + 0.11 in subjects who had severe anemia and normal outcome.

Table 4 shows the median with IQR values for SI and vital signs. SI median 0.92 (IQR 0.87–1), heart rate was 96 (IQR 92–104), SBP was 100 mmHg (IQR 100–110 mmHg) and DBP was 70 mmHg (IQR 60–70 mmHg), MAP was 83.33 mmHg (IQR 76.67–83.33).

Table 5 shows the performance indices for SI. For SI ≥ 0.9, and morbidity as outcome, the sensitivity was 95.62% (92.29–97.79), specificity was low at 17.5%(12.5–23.49); For SI ≥ 0.9 and death as outcome, sensitivity was 92.31% (79.13–98.38), specificity was 34.2% (31.2–37.29) and NPV was 99.1 (97.38–99.81); For SI ≥ 1.4, sensitivity was 26.82% (21.09–33.19); specificity 100%(99.53–100), PPV was 100% and NPV was 82.96%(81.8–84.06). In this table, morbidity includes ICU admission, MODS and surgical intervention.

Table 6 shows the results of the ROC analysis. The area under the curve (AUC) with 95% CI values for the adverse outcomes: ICU admission, surgical intervention, MODS, death and blood transfusion. For ICU admission the values were 0.8 (0.78–0.83) for surgical intervention 0.8 (0.77–0.8), for death it was 0.9 (0.6–0.66), for blood transfusion it was 0.68 (0.65–0.72). The p-values were highly significant for each observation.

Discussion

This prospective observational study of 1004 subjects found

Table 5 Performance of SI ≥ 0.9 in Adv. maternal outcome

SI ≥ 0.9	Sensitivity (95% of CI)	Specificity (95% of CI)	Positive *LR (95% of CI)	Negative LR (95% of CI)	**PPV (95% of CI)	***NPV (95% of CI)
Normal	61.35% (57.84–64.7%)	13.18% (9.01–18.3%)	0.71 (0.66–0.7)	2.93 (2.07–4.16)	71.58% (68.00–74.96%)	8.73% (5.93–12.30%)
Morbidity (MODS, ICU admission)	95.62% (92.29–97.7%)	17.5% (12.50–23.4%)	1.16 (1.08–1.2)	0.25 (0.13–0.48)	59.26% (54.30–64.09%)	76.09% (61.23–87.41%)
Death	92.31% (79.13–98.3%)	34.2% (31.20–37.2%)	1.4 (1.27–1.5)	0.22 (0.08–0.67)	5.38% (3.80–7.37%)	99.1% (97.38–99.81%)

*Likelihood ratio

**Positive predictive value

***Negative predictive value

value of subjects with PIH who had no adverse outcome was 0.84 ± 0.12 as compared to 36/149 subjects who had adverse outcome, whose mean SI value was 0.93 ± 0.35.

Table 3 shows that 387 (38.54%) subjects had severe anemia, in whom the mean SI value was 1.15 ± 0.41as compared

that an SI ≥ 0.9 was significantly associated with maternal adverse outcomes: ICU admission, MODS, surgical intervention, need for blood transfusion and death with good AUC values on ROC analysis.

Table 6 AUC with 95% CI for SI ≥ 0.9 and its accuracy for adverse maternal outcome

Outcome	AUC	95% CI	*P* value
ICU admission	0.8	0.78–0.83	< 0.0001
Surgical intervention	0.8	0.77–0.8	< 0.001
Mods	0.6	0.64–0.69	< 0.009
Death	0.9	0.6–0.66	< 0.002
Blood transfusion	0.68	0.65–0.72	< 0.001

The mean SI value in the vaginal delivery group was higher than the value in the caesarean delivery group. Borovac Pinheiro [7] and Kohn et al. [8] found that the mean intrapartum SI tended to be higher for women who delivered vaginally. The possible explanation given was that SI values are sensitive to small changes in their components and during caesarean delivery the anesthesiogist have more strict control over vital signs which would mask the sign of PPH.

The mean SI value was significantly higher for those subjects who had an adverse outcome as compared to those who had normal outcomes. Most authors have determined a threshold of ≥ 0.9 for the detection of adverse outcomes. Le Bas et al. [5] have proposed a range of 0.7 -0.9 for normal SI in pregnancy. When SI ≥ 1.1 the need for blood products was 89%.

El Ayadi et al. [3] have recommended the threshold of ≥ 0.9 for the need for referral, ≥ 1.4 for urgent intervention, ≥ 1.7 as indicating high chance of adverse outcome.

Different authors have suggested different SI thresholds for the need of massive transfusion. The present study found that 91% of subjects who required > 4 units of transfusion were in the SI ≥ 0.9 group. Guerrero De Leon in 2018 in a study based in Brazil found that a SI ≥ 0.9 was associated with massive transfusion and recommended a cut off ≥ 0.9 for predicting the need for massive transfusion [9]. Kohn et al. in 2017 found that SI ≥ 1.412 predicted PPH and need for transfusion with 100% specificity [8].

The median and IQR for the vital signs shown in present study are different from those found in other studies. In the study by Nathan et al. in 2016, the median with 95% reference range was 120 mmHg (100–145) for SBP, 75 mmHg (58–90) for DBP, 90 mmHg (73–108) for MAP, 81 bpm (61–102) for heart rate and 0.66 (0.5–0.89) for SI. These values are for the first-hour postpartum [4]. El-Ayadi et al. have developed their own vital sign threshold in relation to SI. So SI ≥ 0.9 was equivalent to pulse of 100 bpm and SBP of 110 mmHg. For SI of ≥ 1.4 the pulse was 112/min and SBP was 80 mmHg and for SI 1.7 pulse was 130/min and SBP of 70 mmHg [3].

Subjects with PIH/eclampsia tend to have lower mean SI values as compared to the rest of the study population, suggesting that SI may not be a reliable indicator in subjects with PIH/eclampsia. These findings are in agreement with those by Kohn et al., who found that the mean SI during the last antenatal visit was 0.636 ± 0.105 in women with pre-eclampsia, as compared to those without (0.748 ± 0.101). This significant difference in SI value persisted at admission and in the intrapartum period [8].

The present study found that subjects with severe anemia had a higher baseline SI value as compared to those without this anemia even in the absence of a complication or adverse outcome. Thus SI alone may not be a reliable indicator in this condition.

Regarding the performance of SI in the prediction of morbidity and death, the sensitivity was above 90% but specificity was low. A cut-off of > 1.4 however had poor sensitivity and 100% specificity. El Ayadi et al. [3] found that at SI ≥ 0.7 sensitivity is was 100% but specificity was very low. A threshold of 0.9 again had increased sensitivity and decreased specificity. But since most women with adverse outcome were identified with this threshold, authors suggest that it represents relevant threshold for high risk and medical intervention.

Kohn et al. [8] found that specificity of SI ≥ 0.9 for PPH was only 24% and sensitivity was 85%.For SI ≥ 1.143 the sensitivity was 41% and specificity was 93% for PPH. Thus they have proposed peak SI ≥ 1.14 as a initial threshold due to higher specificity and peak SI > 1.4 as a critical level threshold due to its improved sensitivity. Nathan et al. (2019) found that SI < 0.9 performed well as a rule out test and SI < 0.69 and SI ≥ 0.7 indicated increased risk. They found that for "first" SI < 0.9 the sensitivity was 100% for maternal death and specificity was 55.2%. They suggest that this threshold of SI < 0.9 can be used as a rule out test [10].

Conclusion

Shock Index performed well as a screening tool in the detection of subjects with adverse maternal outcomes. In all subjects who had obstetric hemorrhage as complication, the SI threshold was ≥ 1.1. The study proposes an SI cut-off of 0.9 for referral and a cut-off of 1.1 for intervention in a tertiary care hospital. SI was not a reliable predictor of adverse outcome in the presence of PIH/eclampsia and severe anemia. In subjects with PIH/eclampsia, SI was lower and in patients with severe anemia, SI was higher. More studies are required to determine the SI thresholds in these two groups.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics Approval Obtained From Institutional Ethics Committee.

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