

# The Effectiveness of Shock Index in Detecting Hemorrhages Following Cesarean Delivery in Early Stages: A Descriptive Study

## Sezaryen Sonrası Kanamaların Erken Evrede Tespitinde Şok İndeksinin Etkinliği: Tanımlayıcı Bir Çalışma

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### ABSTRACT

**Aim:** Postpartum hemorrhage (PPH) is a significant cause of maternal mortality and morbidity during the postpartum period that can be prevented by early detection. This study aims to determine whether shock index can be used as noninvasive indicators for detecting postpartum hemorrhage and hypovolemic shock.

**Methods:** This descriptive study analyzed the medical records of 155 women who underwent cesarean delivery (C/S) at a single center between October 2022 and December 2022.

**Results:** The results indicate strong correlations between pulse rate and shock index at the first 30 minutes and one hour after surgery (AUC=0.915 and 0.904;  $p<0.001$ ). According to regression analysis, postoperative pulse rate, hemoglobin levels and hemoglobin change were factors that significantly predicted shock index ( $p\leq 0.05$ ).

**Conclusion:** Postpartum hemorrhages can significantly be predicted by the shock index. It can also help obstetrics and midwives in the decision-making process regarding blood transfusions and surgical interventions based on the patient's response to treatment. It is a reliable parameter that can assist healthcare providers in predicting postpartum hemorrhage. Despite its simplicity, it is often overlooked and should be emphasized in educational and practical programs, particularly in low- and middle-income countries.

**Keywords:** Postpartum hemorrhage; shock; mortality; shock index.

### ÖZ

**Amaç:** Doğum sonrası kanama (PPH), doğum sonrası dönemde anne ölümleri ve hastalıklarının önemli bir nedenidir ve erken tespitle önlenebilir. Bu çalışmanın amacı, doğum sonrası kanama ve hipovolemik şokun tespitinde şok indeksinin invaziv olmayan göstergeler olarak kullanılıp kullanılmayacağını belirlemektir.

**Yöntem:** Bu tanımlayıcı çalışmada, Ekim 2022 ile Aralık 2022 tarihleri arasında tek bir merkezde sezaryen (C/S) ile doğum yapan 155 kadının tıbbi kayıtları analiz edilmiştir.

**Bulgular:** Sonuçlar, ameliyattan sonraki ilk 30 dakika ve birinci saatte nabız hızı ile şok indeksi arasında güçlü bir korelasyon olduğunu göstermektedir (AUC=0.915 ve 0.904;  $p<0.001$ ). Regresyon analizine göre postoperatif nabız, hemoglobin düzeyleri ve hemoglobin değişimi, şok indeksini anlamlı şekilde yordayan faktörlerdir ( $p\leq 0.05$ ).

**Sonuç:** Şok indeksi, doğum sonrası kanamaların öngörülmesinde önemli bir göstergedir. Bu indeks, hastanın tedaviye verdiği yanıt doğrultusunda kan transfüzyonu ve cerrahi müdahale kararlarında kadın doğum uzmanlarına ve ebeye yardımcı olabilir. Basit ve güvenilir bir parametre olan şok indeksi, sağlık çalışanlarının doğum sonrası kanamaları öngörmesine yardımcı olabilir. Her ne kadar basit olsa da sıklıkla göz ardı edilmekte ve özellikle düşük ve orta gelirli ülkelerde eğitim ve uygulama programlarında daha fazla vurgulanmalıdır.

**Anahtar Kelimeler:** Doğum sonrası kanama; şok; anne ölümü; şok indeksi.

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## INTRODUCTION

Postpartum hemorrhage (PPH) is a significant cause of maternal mortality and morbidity during the postpartum period that can be prevented by early detection (1). According to the Association of Ontario Midwives Clinical Practice Guideline, Prevention and Management of Postpartum Hemorrhage, postpartum hemorrhage is defined as blood loss equal to or greater than 1000 mL, or any amount of blood loss that results in clinical signs and symptoms of hypovolemic shock or hemodynamic instability. This definition emphasizes that postpartum hemorrhage is not solely determined by the volume of blood lost, but also by the individual's physiological response, highlighting the importance of monitoring vital signs and symptoms alongside estimated blood loss (2). In severe postpartum bleedings, it can lead to hypovolemic shock, which is a medical emergency and require immediate intervention (3). Postpartum hemorrhages still account for approximately 27% of all maternal mortality, despite advances in care and promotion management of complications and it is the leading cause of mortality in areas with limited resources (4). Due to the literature, delivery methods are significantly associated with postpartum hemorrhages, and the prevalence of PPH after cesarean delivery (CS) is estimated at 3% to 15% worldwide (5, 6).

According to World Health Organization (WHO) guidelines, most cases of obstetric hemorrhages can be diagnosed by estimating visual blood loss, clinical symptoms and monitoring vital signs (7). However, studies have shown that visual estimation often underestimates blood loss in patients. Due to the International Federation of Gynecology and Obstetrics' (FIGO) recommendations on managing postpartum hemorrhage in 2022, the conventional method of measuring vital signs may no longer be helpful (8).

Currently, the shock index is regarded as an effective indicator of blood loss severity, and this ratio is used to assess the overall physiological response to shock. It can also be used to detect potentially life-threatening conditions (9). The shock index was first introduced in 1967 by Dr. Richard L. Dunn, who suggested that high values of the shock index could indicate poor cardiac output and oxygen delivery to the tissues. Since then, the shock index has become an essential parameter in clinical practice and has been studied extensively in various patient populations (10). A normal shock index value is typically between 0.5 and 0.7, indicating a balanced response to shock. A value greater than 0.7 suggests an increased mortality risk, while a value greater than 1.0 indicates a severe shock state and a high mortality risk (11). According to previous studies, a shock index threshold of  $\geq 0.9$  indicates the need for referral,  $\geq 1.4$  suggests urgent intervention, and  $\geq 1.7$  is associated with a significantly high risk of adverse

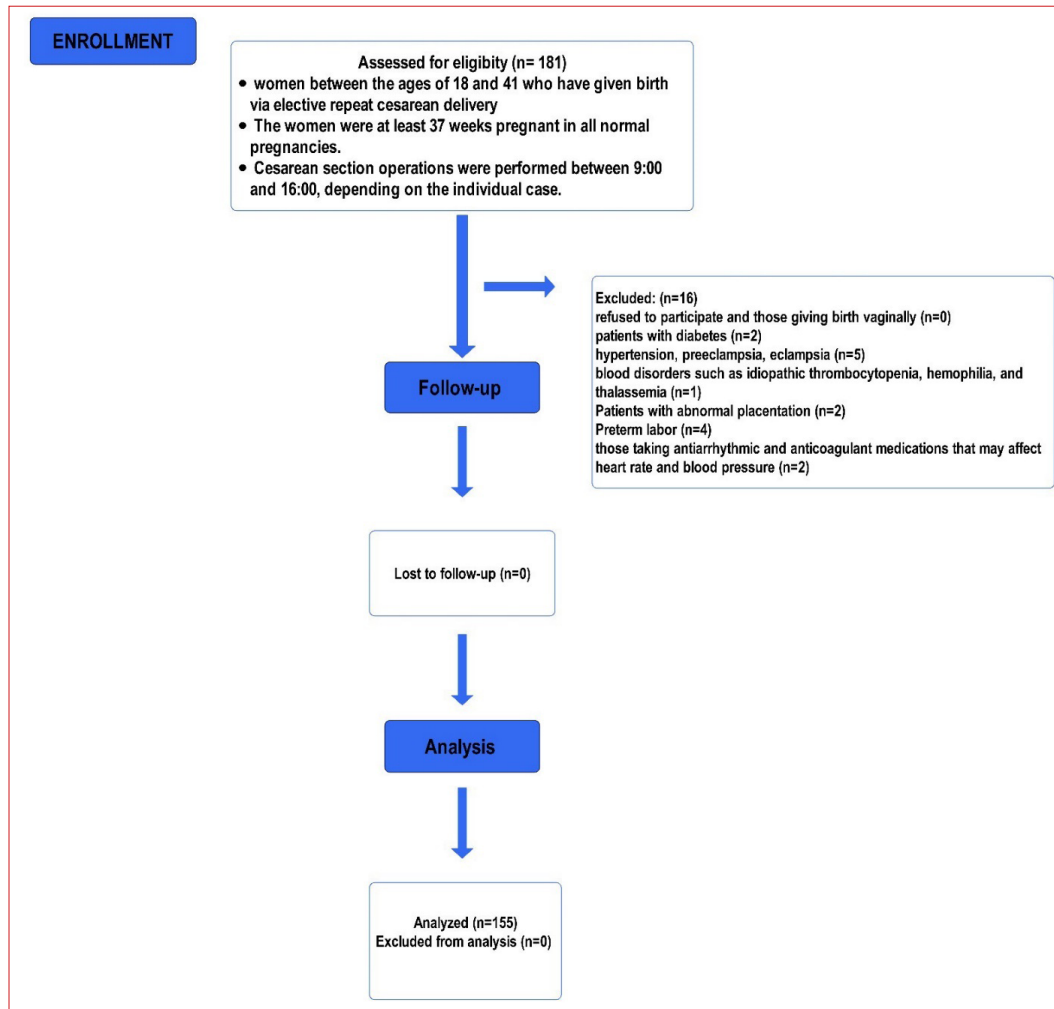
maternal outcomes. In addition, a decreasing shock index over time may suggest a positive response to treatment, while an increasing shock index may indicate worsening shock and a need for invasive interventions (12). Due to previous studies, the higher obstetrics shock index value is likely attributed to the specific physiological changes that occur in the cardiovascular system during pregnancy. It's been reported that the pulse rate in pregnant women remains higher, compared to the antepartum state, despite normal systolic blood pressure by the third trimester (13). Based on this, 0.7–0.9 should be the accepted range for the Obstetrics Shock Index instead of 0.5–0.7 reported for non-pregnant individuals (14).

This study aims to determine whether shock index ranges are associated with the demographics and clinical characteristics of patients undergoing elective repeat cesarean deliveries. Study investigators also seek to determine whether shock index can be used as noninvasive indicator for detecting postpartum hemorrhage and hypovolemic shock. Furthermore, the study aims to provide valuable insight into how these parameters can be used to predict complications, guide clinical decisions, and improve maternal health outcomes.

## METHODS

### Study design and study participants

This prospective, monocentric, descriptive study analyzed the medical records of 155 women who underwent elective repeat cesarean delivery (C/S) at a single center between October 2022 and December 2022 at Sakarya Training and Research Hospital. The sample size was calculated using the G-Power version 3.1.9.7 (Franz Faul, Universität Kiel, Germany). The minimum sample size of patients included in the study was 138, with a two-tailed alpha error of 0.05 and a power of 0.95. In this study, we included 155 patients and the power analysis with a two-tailed alpha error of 0.05 was derived 0.97. The study consisted of women between the ages of 18 and 41 who have given birth via elective repeat cesarean delivery, met the research criteria, and consented to participate. The inclusion and exclusion criteria for the study is shown in Figure 1. The authors followed a Declaration of Helsinki, and the study protocol was approved by the ethics committee of our institution by the number **E-71522473-050.01.04-171467-285**. The patients were informed of the study by the authors particularly and asked to sign the informed consent forms to participate in the study. The demographics and clinical characteristics of the patients were collected from the patients face-to-face and also from the clinical chart.



**Figure 1.** The flowchart of inclusion and exclusion criteria for the study population

### Data collection

The patients' demographic characteristics, including age, education level, income, region of residence, previous diagnosis of postpartum hemorrhage, body mass index (BMI) (kg/m<sup>2</sup>), gestational age, gravida, parity, the reason for cesarean delivery collected from the patients face-to-face after signing the consent forms. Patients' body mass and height were measured at their first hospital visit and recorded in the clinical chart by the midwives/nurses as well as informed to the patients. The clinical chart of the patients also indicated gestational age based on first-trimester ultrasound and last menstrual period (LMP) and the reason for the cesarean operation. Body Mass Index (BMI) was calculated as weight divided by height squared (kg/m<sup>2</sup>). In this survey, education levels, income, region of residence, gravida, and parity were self-reported.

The patients' clinical characteristics, including vital signs such as Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Pulse Rate (PR), Body Temperature (BT), Respiratory Rate (RR),

Pulse Oximetry (PO2), Urine Output, and Hemoglobin Level one day before and routinely eight hours after the cesarean section, was retrieved from the patients' clinical chart at 30 minutes and one-hour intervals following the cesarean section in the Postpartum unit.

An Omran M2 intellisense automatic blood pressure monitor (Kyoto, Japan) was used to measure blood pressure and pulse rate, an MI7 finger sensor pulse oximeter (India) was used to measure pulse oximetry, and a non-contact digital DR VAKU infrared thermometer (India) was used to measure patients' body temperature. After surgery, all patients had urine catheters, and urine output was recorded every hour until 6 hours after surgery. The authors calculated the shock index (SI) by dividing HR by SBP.

### Statistical analysis

Descriptive statistics, Pearson correlation analysis, receiver operating characteristic (ROC) analysis, and multiple linear regression analysis were performed. For ROC analysis, sensitivity, specificity, and the area under the curve (AUC) were calculated.

**Table 1.** Correlation between shock index, after the surgery with variables (shock index < 7)

Variables	Mean ± SD n=155	Shock index 30 minutes after the surgery				Shock index 1 hour after the surgery			
		r	p	AUC (95% GA)	p (ROC)	r	p	AUC (95% GA)	p (ROC)
Age (Year)	29.43 ± 6.08	0.079	0.328	0.497 (0.378-0.617)	0.964	0.077	0.341	0.511 (0.398-0.624)	0.838
Body Mass Index (BMI) (Kg/M2)	30.59 ± 6.83	-0.036	0.656	0.476 (0.266-0.586)	0.679	-0.064	0.431	0.518 (0.418-0.619)	0.732
Gravida	2.97 ± 1.31	0.103	0.202	0.502 (0.393-0.611)	0.973	0.070	0.388	0.492 (0.387-0.598)	0.888
Parity	2.39 ± 0.84	0.127	0.116	0.495 (0.39-0.6)	0.928	0.125	0.122	0.5 (0.398-0.601)	0.999
Gestational age (Weeks)	38.48 ± 0.70	-0.021	0.795	0.491 (0.379-0.604)	0.883	-0.044	0.590	0.463 (0.363-0.564)	0.494
Birth weight (Gram)	3099.53 ± 566.76	-0.064	0.432	0.438 (0.331-0.544)	0.283	-0.072	0.375	0.448 (0.351-0.545)	0.334
<b>Systolic blood pressure (SBP), mm Hg</b>									
30 minutes after the surgery	110.40±8.28	<b>-0.537</b>	<b>&lt;0.001</b>	<b>0.33 (0.234-0.426)</b>	<b>0.001</b>	<b>-0.345</b>	<b>&lt;0.001</b>	<b>0.364 (0.27-0.458)</b>	<b>0.011</b>
1 hour after the surgery	109.30±7.83	<b>-0.220</b>	<b>0.006</b>	<b>0.345 (0.241-0.448)</b>	<b>0.003</b>	<b>-0.395</b>	<b>&lt;0.001</b>	<b>0.348 (0.25-0.446)</b>	<b>0.005</b>
<b>Diastolic blood pressure (DBP), mm Hg</b>									
30 minutes after the surgery	56.08±4.13	<b>-0.533</b>	<b>&lt;0.001</b>	<b>0.328 (0.233-0.424)</b>	<b>&lt;0.001</b>	<b>-0.347</b>	<b>&lt;0.001</b>	<b>0.361 (0.268-0.453)</b>	<b>0.047</b>
1 hour after the surgery	55.52±3.86	<b>-0.222</b>	<b>0.006</b>	<b>0.351 (0.248-0.453)</b>	<b>0.004</b>	<b>-0.400</b>	<b>&lt;0.001</b>	<b>0.355 (0.257-0.452)</b>	<b>0.007</b>
<b>Pulse rate (PR), beats per min</b>									
30 minutes after the surgery	84.15±7.39	<b>0.700</b>	<b>&lt;0.001</b>	<b>0.904 (0.85-0.957)</b>	<b>&lt;0.001</b>	<b>0.553</b>	<b>&lt;0.001</b>	<b>0.852 (0.78-0.924)</b>	<b>&lt;0.001</b>
1 hour after the surgery	83.38±8.03	<b>0.573</b>	<b>&lt;0.001</b>	<b>0.915 (0.873-0.957)</b>	<b>&lt;0.001</b>	<b>0.743</b>	<b>&lt;0.001</b>	<b>0.934 (0.899-0.969)</b>	<b>&lt;0.001</b>
<b>Body temperature (BT), °C</b>									
30 minutes after the surgery	36.42±0.21	0.060	0.455	0.522 (0.402-0.642)	0.719	0.032	0.696	0.486 (0.38-0.591)	0.787
1 hour after the surgery	36.41±0.21	-0.030	0.708	0.505 (0.398-0.612)	0.93	-0.006	0.939	0.523 (0.423-0.623)	0.669
<b>Respiratory rate (RR), breaths per minute</b>									
30 minutes after the surgery	17.23±1.24	-0.114	0.158	0.602 (0.493-0.71)	0.066	-0.130	0.106	0.553 (0.45-0.656)	0.321
1 hour after the surgery	17.80±0.92	-0.126	0.119	0.503 (0.389-0.617)	0.958	-0.005	0.948	0.519 (0.415-0.622)	0.729
<b>Pulse oximetry (PO2)</b>									
30 minutes after the surgery	97.29±1.38	0.015	0.838	0.537 (0.431-0.644)	0.519	-0.052	0.490	0.489 (0.39-0.589)	0.844
1 hour after the surgery	97.46±1.34	-0.015	0.840	0.511 (0.405-0.617)	0.851	-0.032	0.670	0.512 (0.417-0.607)	0.824
<b>Urine output, ml</b>									
30 minutes after the surgery	361.84±261.96	-0.021	0.792	0.518 (0.407-0.629)	0.746	0.030	0.713	0.509 (0.404-0.613)	0.872
1 hour after the surgery	535.64±324.51	-0.006	0.937	0.538 (0.423-0.653)	0.52	0.074	0.360	0.536 (0.428-0.645)	0.496
<b>Preoperative hemoglobin levels (one day before the surgery)</b>	<b>11.32±1.33</b>	<b>-0.172</b>	<b>0.033</b>	<b>0.362 (0.273-0.45)</b>	<b>0.002</b>	<b>-0.249</b>	<b>0.002</b>	<b>0.384 (0.297-0.471)</b>	<b>0.030</b>
<b>Postoperative hemoglobin levels (eight hours after the surgery)</b>	<b>9.83±1.24</b>	<b>-0.427</b>	<b>&lt;0.001</b>	<b>0.151 (0.09-0.212)</b>	<b>&lt;0.001</b>	<b>-0.464</b>	<b>&lt;0.001</b>	<b>0.199 (0.123-0.275)</b>	<b>&lt;0.001</b>
Hemoglobin variation	-1.55±0.67	<b>-0.445</b>	<b>&lt;0.001</b>	<b>0.125 (0.069-0.181)</b>	<b>&lt;0.001</b>	<b>-0.361</b>	<b>&lt;0.001</b>	<b>0.159 (0.092-0.226)</b>	<b>&lt;0.001</b>
<b>Visually estimated bleeding 30 minutes after the surgery</b>									
n1: 1/4 pad	64.5%	0.061	0.452	0.521 (0.411-0.631)	0.719	0.138	0.086	0.542 (0.44-0.645)	0.427
n2: 2/4 pad	9.0%								
n3: 3/4 pad	13.5%								
n4: 4/4 pad	12.9%								
<b>Visually estimated bleeding 1 hour after the surgery</b>									
n1: 1/4 pad	64.5%	0.047	0.561	0.52 (0.409-0.63)	0.731	0.129	0.109	0.529 (0.427-0.631)	0.585
n2: 2/4 pad	9.7%								
n3: 3/4 pad	12.9%								
n4: 4/4 pad	12.9%								

**Table 2.** Multiple linear regression analysis predicting shock index

Clinical Characteristics	Shock index 30 minutes after the surgery*					Shock index 1 hour after the surgery**				
	B	SE	$\beta$	t	p	B	SE	$\beta$	t	p
<b>Systolic blood pressure (SBP), mm Hg</b>										
30 minutes after the surgery	0.044	0.045	0.984	0.981	0.328	0.077	0.044	1.562	1.729	0.086
1 hour after the surgery	-0.029	0.028	-0.595	-1.039	0.301	<b>-0.055</b>	<b>0.027</b>	<b>-1.046</b>	<b>-2.026</b>	<b>0.044</b>
<b>Diastolic blood pressure (DBP), mm Hg</b>										
30 minutes after the surgery	-0.095	0.091	-1.49	-1.043	0.298	-0.147	0.089	-1.499	-1.657	0.099
1 hour after the surgery	0.035	0.056	0.36	0.63	0.53	0.073	0.055	0.682	1.327	0.186
<b>Pulse rate (PR), beats per min</b>										
30 minutes after the surgery	<b>0.01</b>	<b>0.004</b>	<b>0.206</b>	<b>2.344</b>	<b>0.02</b>	-0.003	0.004	-0.048	-0.605	0.546
1 hour after the surgery	<b>0.015</b>	<b>0.004</b>	<b>0.332</b>	<b>3.809</b>	<b>&lt;0.001</b>	<b>0.033</b>	<b>0.004</b>	<b>0.658</b>	<b>8.391</b>	<b>&lt;0.001</b>
<b>Preoperative hemoglobin levels</b> (One day before the surgery)	-0.053	0.021	-0.186	-2.497	0.013	<b>-0.052</b>	<b>0.023</b>	<b>-0.17</b>	<b>-2.278</b>	<b>0.024</b>
<b>Postoperative hemoglobin levels</b> (Eight hours after the surgery)	<b>-0.058</b>	<b>0.018</b>	<b>-0.191</b>	<b>-3.191</b>	<b>0.002</b>	<b>-0.048</b>	<b>0.018</b>	<b>-0.146</b>	<b>-2.714</b>	<b>0.007</b>
Hemoglobin variation	<b>-0.118</b>	<b>0.033</b>	<b>-0.215</b>	<b>-3.602</b>	<b>&lt;0.001</b>	<b>-0.131</b>	<b>0.032</b>	<b>-0.221</b>	<b>-4.112</b>	<b>&lt;0.001</b>

\*Model Fit:  $F(9,168) = 24.826$ ;  $p < 0.001$ ,  $R^2 = 0.542$ ,  $R^2_{adj} = 0.52$

\*\*Model Fit:  $F(9,168) = 35.544$ ;  $p < 0.001$ ,  $R^2 = 0.629$ ,  $R^2_{adj} = 0.611$

$p$ -value  $\leq 0.05$  was considered statistically significant. All analyses were conducted using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA).

## RESULTS

In total, 155 patients were included in the study. The mean age of study participants was  $29.43 \pm 6.08$ , and the mean gestational age of pregnancy in patients was  $38.48 \pm 0.706$ . Immediately after the cesarean, the patients were transferred to the postpartum unit, and the vital sign of the patients was monitored every 15 minutes until 2 hours after the surgery. The patients' clinical signs were obtained in the following intervals: at the first 30 minutes and 1 hour after the surgery.

A shock index level between 0.80 and 0.89 was recorded in 23% of women and 0.90 or more in 7% of women 30 minutes after surgery. One hour after surgery, 31.4% of women had shock index levels between 0.80 and 0.89, and 3.9% had a shock index of 0.9 or more. Shock index values of over 0.9 were treated clinically by oxytocin, methylergometrine, or misoprostol, and blood transfusions were required, but no ICU admissions were necessary.

The correlation between shock index 30 minutes and 1 hour after surgery and demographic characteristics, SBP, DBP, PR, RR, pulse

oximetry, pre- and postoperative hemoglobin levels, Hb variation, urine output, and visual estimation of bleeding have been shown in Table 1. However, there was no significant correlation between respiratory rate, body temperature, urine output, visual estimation of bleeding and shock index 30 minutes and 1 hour after surgery ( $p \geq 0.05$ ). At the first 30 minutes of evaluation, clinical signs of the patients: The pulse rate and shock index are strongly correlated ( $r=0.700$ ;  $p \leq 0.05$ ), and systolic blood pressure (SBP) and shock index have a moderate negative correlation ( $r=-0.537$ ;  $p \leq 0.05$ ). There is also a moderate negative correlation between diastolic blood pressure (DBP) and shock index ( $r=-0.533$ ;  $p \leq 0.05$ ). It suggests that the shock index increases as SBP and DBP decrease. There is a weakly negative correlation between preoperative hemoglobin levels and shock index ( $r=-0.172$ ;  $p \leq 0.05$ ), and a moderately negative correlation between postoperative hemoglobin levels ( $r=-0.427$ ;  $p \leq 0.05$ ), hemoglobin variation ( $r=-0.445$ ;  $p \leq 0.05$ ).

**One hour after the surgery:** The pulse rate and shock index are strongly correlated ( $r=0.743$ ;  $p \leq 0.05$ ), and systolic blood pressure (SBP) and shock index have a moderate negative correlation ( $r=-0.395$ ;  $p \leq 0.05$ ). There is also a moderate negative correlation between diastolic blood pressure (DBP) and shock index ( $r=-0.400$ ;  $p \leq 0.05$ ). It suggests that the shock index increases as SBP and DBP decrease. There is a weakly negative correlation between preoperative hemoglobin levels and shock index ( $r=-0.249$ ;  $p \leq 0.05$ ), and moderately negative correlation between

postoperative hemoglobin levels ( $r=-0.464$ ;  $p\leq 0.05$ ), hemoglobin variation ( $r=-0.361$ ;  $p\leq 0.05$ ).

According to the ROC analysis in Table 1, postoperative 1st hour pulse rate and 30th minute pulse rate values were found to have high accuracy in distinguishing individuals at risk of shock (AUC=0.915 and 0.904;  $p<0.001$ ). Respiratory rate (30 minutes after surgery) showed a moderate discrimination (AUC=0.602;  $p>0.05$ ). On the other hand, AUC values for systolic and diastolic blood pressure and hemoglobin levels were  $<0.6$ , which seems to be weak in terms of discrimination.

Regression analysis was performed for variables that were found to be significant according to correlation and ROC analysis (Table 2). According to multiple linear regression analysis, variables that significantly predicted shock index at 30 minutes after surgery were postoperative hemoglobin level ( $B=-0.058$ ;  $p\leq 0.05$ ), hemoglobin variation ( $B=-0.118$ ;  $p<0.001$ ), and pulse rate at 30 minutes ( $B=0.010$ ;  $p\leq 0.05$ ). Postoperative pulse ( $B = 0.033$ ,  $p<0.001$ ), hemoglobin level ( $B=-0.048$ ;  $p\leq 0.05$ ), and hemoglobin change ( $B=-0.131$ ;  $p<0.001$ ) were determined as significant predictors for shock index at 1 hour after surgery. Both models are statistically significant ( $p<0.001$ ) and explain 52% and 61% of the variance, respectively.

## DISCUSSION

This study aims to demonstrate the importance of a non-invasive methods such as shock index for early detection of postpartum hemorrhage. Women in low-resource areas are increasingly suffering from postpartum hemorrhage (PPH) and reducing PPH incidence could significantly impact maternal health outcomes and advance progress toward sustainable development goals (15). Nowadays, CS rates worldwide are increasing, contributing to rising PPH rates which have been identified as one of the principal reasons for mortality and morbidity globally (16, 17). Our study demonstrated several advantages of using the shock index to predict PPH early. It can identify patients at risk of hypovolemic shock and allow early intervention. Furthermore, this simple and noninvasive approach facilitates the assessment of treatment efficacy and supports evidence-based decision-making regarding the initiation of blood transfusions or surgical interventions. Its implementation has the potential to markedly decrease the reliance on invasive procedures, particularly in the context of fertility preservation among reproductive-aged women, thereby contributing to improved health outcomes and enhanced quality of life (18). In a study by Kohn et al. published in 2019, the shock index was also found to be an effective indicator of postpartum hemorrhages and maternal

deterioration (14). We emphasize the need to enhance the clinical competencies of midwives and nurses in accurately assessing blood loss and evaluating patient condition, with the aim of facilitating earlier diagnosis of postpartum hemorrhage beyond the limitations of visual estimation. Midwives' and nurses' skill in estimating blood loss has been shown to result in improved maternal survival rates and improved obstetric care by Zhang et al. in 2023 (19). In our study, visual estimates of bleeding by healthcare providers were not significantly correlated with shock index which indicates that visual methods can yield inaccurate and uncertain results. According to Pacagnella in 2013, visual estimation of blood loss is generally underestimated by over 50%, regardless of WHO recommendations (20). It was also shown by Giouleka et al. in 2022 that blood loss, clinical symptoms, and vital sign monitoring can be used to diagnose obstetric bleeding but have limitations for accurate detection (21). Numerous studies have demonstrated that visual estimation of blood loss (VEBL), while widely used in clinical practice, is prone to significant underestimation, which can result in delayed clinical decision-making and suboptimal or mistimed interventions (5, 20, 22). According to the World Health Organization, visual estimation remains the most commonly employed method for diagnosing postpartum hemorrhage (PPH), particularly in low-resource settings (23). However, its inherent subjectivity and inaccuracy limit its reliability, especially in the early stages of bleeding. In our study, no significant correlation was found between visually estimated blood loss and the shock index, further supporting the evidence that VEBL is not a dependable indicator for the early detection of obstetric hemorrhage. Given these limitations, the shock index has emerged as a simple, accessible, and cost-effective tool that relies on vital signs and can detect hemodynamic changes before overt clinical signs or substantial blood loss become evident. This is particularly important, as even small volumes of blood loss may lead to shock symptoms in some patients due to individual variability. In contrast to VEBL, the shock index offers objective physiological data, making it a valuable complementary parameter for the timely identification and management of PPH especially in low- and middle-income countries where resources for direct measurement methods are often limited.

In 2022, Pacagnella et al. demonstrated that changes in the cardiovascular system might delay early detection and treatment of hypovolemia during bleeding during pregnancy and postpartum, thereby increasing morbidity and mortality by underestimating blood loss (24). According to a study by Ghosh in 2017, blood pressure decreases when women lose up to 30% of their blood volume. However, physiological hemodynamic responses are spontaneously activated when severe bleeding occurs in order to prevent decreases in blood pressure; therefore, a rise in heart rate occurs. Heart rate increases are usually regarded as an indicator of hypovolemia

but can change due to a wide range of physiologic, pathologic, internal, and external factors. In this study, we demonstrated that pulse rate and shock index are strongly correlated, and systolic blood pressure (SBP) and shock index have a moderate negative correlation, and the shock index parameter can be used as a practical tool in the early diagnosis of complications (25). A study conducted by El Ayadi et al. in 2016 demonstrated that the shock index is a consistently strong predictor of adverse outcomes in women with postpartum hemorrhage. The findings of this study showed that shock index was among the top two most reliable predictors across a range of maternal complications. According to this study, shock index is significantly more accurate than pulse and pulse pressure in predicting maternal death, and better than diastolic blood pressure and pulse pressure for identifying severe maternal outcomes. Furthermore, it outperformed systolic and diastolic blood pressure, mean arterial pressure, and pulse pressure in predicting both severe maternal outcomes and the need for critical interventions. A threshold of  $\geq 0.9$  for the shock index demonstrated excellent sensitivity, while thresholds of  $\geq 1.4$  and  $\geq 1.7$  offered higher specificity with consistently strong negative predictive values (26). Agaba et al in 2022 also mentioned that the shock index can be an effective indicator of blood loss severity and can help identify potentially life-threatening conditions. This simple calculation can help transform unstable parameters into a more accurate predictor of hypovolemia, and it is calculated by dividing heart rate by systolic blood pressure. It has been shown that there is a significant association between increasing shock index values and higher rates of blood transfusions, invasive surgery interventions, and intensive care unit admissions (27).

The findings of our ROC analysis indicate that pulse rate measured at both 30 minutes and 1 hour postoperatively demonstrates high diagnostic accuracy for identifying patients at risk of developing shock, with AUC values of 0.904 and 0.915, respectively ( $p < 0.001$ ). These results underscore the clinical utility of pulse rate as a reliable and noninvasive early warning parameter in the immediate postoperative period following cesarean delivery. In contrast, the respiratory rate at 30 minutes post-surgery showed only moderate discriminatory ability (AUC = 0.602) and was not statistically significant, while traditional markers such as systolic and diastolic blood pressure and hemoglobin levels exhibited poor predictive value (AUC  $< 0.6$ ). This suggests that relying solely on these conventional parameters may not provide sufficient sensitivity for early detection of hemodynamic instability.

Despite its routine use in clinical monitoring, pulse oximetry did not show statistically significant correlation with shock index in our study. This may be due to the physiological limitations of pulse oximetry in detecting early hypovolemia. In the initial stages of

hemorrhage, peripheral perfusion may still be maintained due to compensatory vasoconstriction, thus masking oxygen saturation changes. Moreover, in severe hemorrhagic states, peripheral vasoconstriction can lead to inaccurate readings by decreasing blood flow to distal capillaries (28). Additionally, pulse oximetry measurements obtained shortly after cesarean section may be confounded by perioperative factors such as supplemental oxygen administration and the pharmacological effects of anesthesia, which can artificially elevate SpO<sub>2</sub> levels (29). These factors combined may explain the absence of discriminatory value for SpO<sub>2</sub> in our ROC analysis and highlight its limited utility as an early indicator of hemorrhage compared to hemodynamic parameters like pulse rate and shock index.

Multiple linear regression analysis further reinforced the predictive strength of pulse rate, hemoglobin levels, and hemoglobin variation in relation to shock index values. Specifically, both postoperative hemoglobin levels and hemoglobin changes were significantly and negatively associated with shock index at both time points, while pulse rate was a positive predictor. These variables collectively accounted for 52% and 61% of the variance in shock index at 30 minutes and 1 hour, respectively ( $p < 0.001$  for both models). These findings highlight the importance of integrating dynamic, easily measurable clinical parameters—particularly pulse rate and hemoglobin trends—into early postpartum monitoring protocols. Their predictive strength supports the inclusion of shock index-based assessment models for improving the timely detection and management of postpartum hemorrhage, especially in resource-limited settings where laboratory diagnostics may be delayed. The findings of Makkadan et al. (2016) align with and indirectly support the present study by highlighting the significant associations between pulse rate, blood pressure, and parameters indicative of bleeding status. Although their study did not directly evaluate shock index or postpartum hemorrhage, their results demonstrated a significant positive correlation between pulse rate and both bleeding time and clotting time, and a negative correlation between clotting time and systolic and diastolic blood pressure. These associations reinforce the relevance of vital signs—particularly pulse rate and blood pressure—in detecting hemodynamic alterations related to bleeding. In our study, similar trends were observed, where pulse rate emerged as a strong predictor of shock index, and blood pressure variables showed moderate to weak associations. These findings underscore the value of integrating simple, noninvasive physiological measures in the early detection and monitoring of hemorrhagic complications, supporting the utility of shock index as a practical clinical tool (30).

In low-resource settings, routine hemoglobin measurement may be impractical due to cost, invasiveness, and delays in laboratory

processing. Using the shock index as an early indicator of hemorrhages can save lives even in low resource settings. Shock indexes can provide a unique perspective on each patient, which differs according to their condition. Following the same routine of postpartum care for all patients can also result in some missing cases.

Overall, the shock index is a simple, noninvasive, and clinically valuable tool that enhances early detection of postpartum hemorrhage and informs timely intervention strategies. These factors are non-invasive and easily obtainable parameters that can provide important information about the overall physiological response to shock and can help guide management decisions. It is strongly related to the patients' vital signs and can prevent invasive interventions to improve outcomes for pregnant women and decrease mortality and morbidity rates worldwide.

### Limitation

The observations are limited to a relatively small population, so a larger data set should be analyzed in the future. It is possible that the results cannot be generalized since the elective cesarean rate varies by country. Shock index measurement in obstetric populations also needs to be studied prospectively to fully understand its value and accepted ranges. Correlation simply indicates a statistical relationship between two variables but does not establish a cause-and-effect relationship, and other potential factors may be involved. An integrated clinical assessment incorporating vital signs, laboratory values, and patient history is necessary to evaluate a patient's condition holistically and guide treatment.

## CONCLUSION

Postpartum hemorrhage can be predicted using the shock index, and hypovolemic shock can be more effectively prevented and managed when identified early through this tool. It is a simple and reliable tool that can assist healthcare providers in postpartum bleeding management. It can also help obstetrics and midwives in the decision-making process regarding blood transfusions and surgical interventions based on the patient's response to treatment.

We believe obstetrics, midwives, and nurses can significantly affect women's health by accurately diagnosing and managing excessive postpartum hemorrhages. Clinical practice and education guidelines recommend using the shock index to predict postpartum hemorrhages. Despite its simplicity, the shock index remains underutilized and should be emphasized in both clinical training and obstetric protocols, particularly in low- and middle-income countries. It can be easily and quickly quantified, making it a highly

cost-effective parameter and a valuable tool for the early detection of hypovolemic shock in maternal near-miss cases.

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