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Original Research Article

A STUDY ON THE ROLE OF SHOCK INDICES IN PREDICTING MORTALITY AND MORBIDITY IN CHILDREN WITH SHOCK ADMITTED TO THE PAEDIATRIC INTENSIVE CARE UNIT

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ABSTRACT

Background: Early recognition of circulatory deterioration is essential in pediatric shock because hypotension may occur late. Shock indices derived from routinely measured physiological variables may provide simple bedside tools for early risk stratification.

Materials and Methods: This prospective observational study included **150 children with shock** admitted to the Pediatric Intensive Care Unit. Heart rate, systolic blood pressure, mean arterial pressure, and respiratory rate were recorded serially. Shock Index (SI), Modified Shock Index (MSI), Reverse Shock Index (RVSI), Reverse Modified Shock Index (RVMSI), Respiratory-Associated Shock Index (RASI), and Age-Associated Shock Index (ASI) were assessed at predefined intervals. Mortality and duration of PICU stay were recorded. ROC analysis was used to compare mortality prediction.

Results: The mean age was **6.55 ± 5.05 years**; 52% were males. Normotensive shock was present in 88% and hypotensive shock in 12%. Sepsis was the most frequent clinical category. Overall mortality was **6%**, with 141 (94%) children discharged alive. Non-survivors had persistently higher SI, MSI, and RASI and lower RVMSI values. RVMSI showed the highest mortality discrimination at 1, 6, and 24 hours, with AUCs of **0.825, 0.891, and 0.936**, respectively, followed closely by MSI (**0.823, 0.888, and 0.933**). RASI achieved an AUC of **0.917 at 24 hours**, whereas ASI showed poor predictive performance.

Conclusion: RVMSI and MSI were the most reliable shock indices for predicting mortality in children with shock. Serial assessment improved prognostic discrimination and may provide a useful, inexpensive bedside approach for early risk stratification in the PICU.

Keywords: Pediatric shock; Shock Index; Modified Shock Index; Reverse Modified Shock Index; RASI; mortality; PICU.

INTRODUCTION

Shock is a life-threatening state of circulatory failure characterized by inadequate tissue perfusion and oxygen delivery. In children, compensatory tachycardia and vasoconstriction may maintain blood pressure until late in the course; therefore, early identification of hemodynamic deterioration is essential. The Shock Index (SI), calculated from heart rate and systolic blood pressure, provides a simple bedside measure that may identify circulatory compromise before overt hypotension develops.[1]

Interpretation of shock indices in children is complicated by age-related physiological variations in heart rate and blood pressure. Pediatric age-adjusted shock indices have therefore been developed to improve risk stratification, particularly for identifying children at increased risk of deterioration, intervention, and adverse outcomes.[2]

Recent evidence indicates that pediatric age-adjusted shock indices can provide useful prognostic information for mortality and severity of illness.[3]

Several modifications of the conventional SI, including the Modified Shock Index (MSI), Reverse Shock Index (RSI), Reverse Modified Shock Index (RVMSI), Age-Adjusted Shock Index (ASI), and Respiratory-Associated Shock Index (RASI), incorporate additional physiological information and may improve early identification of critically ill children. Reverse shock-based indices have demonstrated prognostic utility in pediatric populations,[4] while age-adjusted indices have also been associated with mortality risk.[5] Serial rather than isolated measurements may further improve recognition of evolving circulatory compromise and identify patients requiring intensive monitoring and resuscitation.[6]

Hence, the present study was undertaken to determine the association of different shock indices with mortality and morbidity and to identify the most useful shock index for predicting outcome among children with shock admitted to the Pediatric Intensive Care Unit (PICU).

MATERIALS AND METHODS

Study Design and Setting

This was a **prospective observational study** conducted over a period of **18 months** in the **Pediatric Intensive Care Unit (PICU), Indira Gandhi Institute of Child Health, Bengaluru**. Children admitted to the PICU with shock constituted the source population.

Study Population and Data Collection

Children fulfilling the predefined inclusion and exclusion criteria were enrolled. Following informed parental consent and assent for children aged above 7 years, demographic characteristics, clinical history, examination findings, and associated comorbidities were recorded using a prestructured proforma.

Clinical parameters including **heart rate (HR), systolic blood pressure (SBP), mean arterial pressure (MAP), and respiratory rate (RR)** were recorded at **0, 1, 2, 3, 4, 5, 6, and 24 hours**. Children were categorized according to provisional diagnosis and the type and severity of shock. Duration of PICU stay and mortality were documented as outcome measures.

Assessment of Shock Indices

The relevant physiological parameters were used to calculate the different shock indices for each participant at the predefined time intervals. The indices evaluated included **Shock Index (SI), Modified Shock Index (MSI), Reverse Shock Index (RSI), Reverse Modified Shock Index (RVMSI), Age-Associated Shock Index (AASI), and Respiratory-Associated Shock Index (RASI)**. The respiratory-associated index incorporated heart rate, systolic blood pressure, and respiratory rate.

Serial values of these indices were recorded in the case record form and subsequently compared according to the physiological severity of shock and final outcome.

Sample Size

Sample size was calculated using observations reported by **Gupta et al.**, in which the sensitivity of Shock Index for predicting mortality among patients with sepsis at 6 hours was **85%**. Assuming a prevalence of **50%**, absolute precision of **10%**, and 95% confidence level, the sample size was calculated using:

$$n = \frac{Z_{1-\alpha/2}^{2} \times Sensitivity(1 - Sensitivity)}{d^2 \times Prevalence}$$

The estimated sample size was **98 subjects**. After allowing for a **20% non-response rate**, it increased to 118 and was subsequently rounded to a final sample size of **150 children**.

Outcome Measures

The primary outcome was the association of serial shock indices with **mortality**. Morbidity was assessed principally in relation to the **duration of PICU stay**. The predictive performance of the different shock indices was compared to determine the index with the greatest ability to identify adverse outcomes.

Statistical Analysis

Data were entered into **Microsoft Excel** and analyzed using **IBM SPSS Statistics version 26**. Categorical variables were expressed as frequencies and proportions. Normality of continuous variables was assessed using the **Kolmogorov–Smirnov and Shapiro–Wilk tests**, and normally distributed continuous variables were presented as mean ± standard deviation.

The **Chi-square test** was used for qualitative variables, while **Fisher's exact test/Yates correction** was applied when Chi-square assumptions were not fulfilled. The **independent-samples t-test** was used to compare normally distributed quantitative variables between two groups, whereas the **Mann–Whitney U test** was used for skewed quantitative data. A **p-value <0.05** was considered statistically significant.

RESULTS

A total of 150 children with shock admitted to the PICU were included. The mean age was 6.55 ± 5.05 years. The largest proportion belonged to the 1–5-year age group (36.0%), followed by 6–10 years (28.7%). There were 78 males (52.0%) and 72 females (48.0%).

Most children had normotensive shock (132/150; 88%), whereas 18 (12%) had hypotensive shock. Sepsis was the most frequent system/etiological category, accounting for 55 children, followed by other causes (n=37), gastrointestinal involvement (n=24), respiratory involvement (n=23), CNS involvement (n=9), and cardiovascular involvement (n=2).

Table 1: Baseline characteristics, type of shock, and clinical distribution of study subjects

Variable	Frequency (n)	Percentage (%)
Age group		
<1 year	18	12.0
1–5 years	54	36.0
6–10 years	43	28.7
11–15 years	25	16.7
15–17 years	10	6.7
Gender		
Male	78	52.0
Female	72	48.0
Type of shock		
Hypotensive shock	18	12.0
Normotensive shock	132	88.0
System affected		
Respiratory system	23	15*
Cardiovascular system	2	1*
Gastrointestinal system	24	16*
Central nervous system	9	6*
Sepsis	55	36*
Others	37	24*

Mean age: 6.55 ± 5.05 years.
*Percentages are reproduced as reported in the thesis table; the corresponding frequencies are the original study counts.

Outcome

Of the 150 children, 141 (94.0%) were discharged alive and 9 (6.0%) died. The overall mean duration of hospital/PICU stay was 7.49 ± 6.01 days.

Shock Index values were consistently higher among non-survivors. At 1 hour, mean SI was 2.00 ± 0.52 among children who died compared with 1.51 ± 0.42 among survivors (p=0.001). At 24 hours, the corresponding values were 2.04 ± 0.83 versus 1.24 ± 0.36 (p<0.001). Differences were significant at 1, 2, 3, 4, 5, and 24 hours, whereas the difference at 6 hours was not statistically significant.

Table 2: Comparison of selected shock indices between survivors and non-survivors

Index/time	Death (n=9), Mean ± SD	Discharged alive (n=141), Mean ± SD	p-value
Shock Index (SI)			
1 hour	2.00 ± 0.52	1.51 ± 0.42	0.001
6 hours	2.03 ± 0.74	1.45 ± 1.34	0.200
24 hours	2.04 ± 0.83	1.24 ± 0.36	<0.001
Reverse Modified Shock Index (RVMSI)			
1 hour	0.36 ± 0.11	0.53 ± 0.17	0.003
6 hours	0.35 ± 0.15	0.63 ± 0.19	0.001
24 hours	0.33 ± 0.15	0.73 ± 0.45	0.010
Respiratory-Associated Shock Index (RASI)			
1 hour	8.11 ± 3.02	5.54 ± 2.82	0.009
6 hours	8.05 ± 2.64	4.61 ± 5.81	0.081
24 hours	8.08 ± 3.10	3.69 ± 1.74	<0.001

RVMSI was significantly lower among non-survivors at most recorded intervals. At 24 hours, non-survivors had an RVMSI of 0.33 ± 0.15, compared with 0.73 ± 0.45 among survivors (p=0.010). In contrast, RASI was consistently higher among children who died; at 24 hours it was 8.08 ± 3.10 versus 3.69 ± 1.74 (p<0.001).

Shock indices according to physiological type of shock

Children with hypotensive shock generally demonstrated greater hemodynamic derangement than those with normotensive shock. Mean SI at 1 hour was 1.87 ± 0.66 in hypotensive shock compared with 1.50 ± 0.39 in normotensive shock. At 24 hours, SI remained higher in the hypotensive group (1.72 ± 0.72) than in the normotensive group (approximately 1.23 ± 0.37).

RVMSI demonstrated the opposite direction, with lower values indicating greater circulatory compromise. At 1 hour, RVMSI was 0.38 ± 0.19 in hypotensive shock compared with 0.54 ± 0.16 in normotensive shock; at 24 hours the corresponding values were 0.45 ± 0.21 and 0.74 ± 0.46.

Table 3: Selected shock indices according to type of shock

Index/time	Hypotensive shock (n=18)	Normotensive shock (n=132)	p-value
SI, 1 hour	1.87 ± 0.66	1.50 ± 0.39	0.001
SI, 24 hours	1.72 ± 0.72	1.23 ± 0.37	0.001
RVMSI, 1 hour	0.38 ± 0.19	0.54 ± 0.16	<0.001

RVMSI, 6 hours	0.42 ± 0.22	0.64 ± 0.18	<0.001
RVMSI, 24 hours	0.45 ± 0.21	0.74 ± 0.46	0.012
RASI, 1 hour	6.76 ± 2.87	5.61 ± 2.87	0.122
RASI, 6 hours	6.22 ± 2.47	4.64 ± 6.00	0.288
RASI, 24 hours	5.46 ± 2.72	3.75 ± 1.95	0.001

Predictive accuracy for mortality

ROC analysis demonstrated that RVMSI and MSI were consistently the best-performing indices for mortality prediction. At 1 hour, RVMSI had the highest AUC (0.825), closely followed by MSI (0.823). SI and RVSI also showed good discrimination, whereas ASI showed essentially no useful discrimination (AUC 0.512).

At 6 hours, predictive performance improved, with RVMSI achieving an AUC of 0.891, MSI 0.888, and RASI 0.878. ASI remained poorly predictive with an AUC of 0.520. By 24 hours, RVMSI achieved the highest discrimination (AUC 0.936), followed closely by MSI (AUC 0.933) and RASI (AUC 0.917).

Table 4: ROC analysis of different shock indices for predicting mortality

Shock index	AUC at 1 hour	AUC at 6 hours	AUC at 24 hours
Shock Index (SI)	0.796	0.779	0.800
Modified Shock Index (MSI)	**0.823**	**0.888**	**0.933**
Reverse Shock Index (RVSI)	0.800	0.778	0.798
Reverse Modified Shock Index (RVMSI)	**0.825**	**0.891**	**0.936**
Respiratory-Associated Shock Index (RASI)	0.736	0.878	0.917
Age-Associated Shock Index (ASI)	0.512	0.520	0.532

Overall, serial SI, MSI, RVMSI, and RASI measurements were associated with clinical outcome, with greater abnormalities persisting among non-survivors. RVMSI showed the highest AUC at 1, 6, and 24 hours, closely followed by MSI, while RASI gained substantial predictive value over time. In contrast, ASI consistently demonstrated poor discriminatory ability, with AUC values close to 0.5. The findings therefore indicate that RVMSI and MSI were the most useful shock indices for early mortality risk stratification in this cohort of children admitted to the PICU with shock.

DISCUSSION

In the present study, 150 children with shock admitted to the PICU were evaluated using serial shock indices. The mean age was 6.55 ± 5.05 years, with a slight male predominance. Most children had normotensive shock, while 12% presented with hypotensive shock. Sepsis was the most frequent clinical category. Huang et al. similarly demonstrated that pediatric age-adjusted shock indices can provide useful prognostic information regarding morbidity and mortality in critically ill children.[7]

Children with hypotensive shock showed greater hemodynamic derangement than those with normotensive shock. This finding is clinically relevant because hypotension is generally a late manifestation of pediatric circulatory failure, occurring after compensatory mechanisms begin to fail. Current pediatric sepsis guidelines emphasize early recognition of impaired perfusion and timely hemodynamic support before progression to overt hypotension and organ dysfunction.[8] Similar recommendations have been emphasized in international critical care guidance for pediatric septic shock.[9]

Mortality in the present study was 6%, with 141 children discharged alive. Non-survivors had persistently higher SI, MSI, and RASI values and lower RVMSI values compared with survivors. Sankar et al. also reported that deranged shock index and related perfusion markers were associated with adverse outcomes in children with septic shock.[10] Rousseaux et al. demonstrated the prognostic value of shock index in pediatric septic shock and reported that abnormal SI was associated with greater severity and mortality risk.[11]

ROC analysis showed that RVMSI and MSI were the strongest predictors of mortality. At 1 hour, AUCs were 0.825 and 0.823, respectively; at 6 hours they increased to 0.891 and 0.888; and at 24 hours they reached 0.936 and 0.933. RASI also demonstrated good predictive ability at 24 hours with an AUC of 0.917. These findings suggest that serial assessment may provide greater prognostic information than an isolated measurement. The recently proposed international pediatric sepsis criteria similarly emphasize objective identification of children at increased risk of organ dysfunction and mortality.[12]

The Phoenix pediatric sepsis framework further supports the use of measurable physiological and organ dysfunction variables for identifying high-risk children.[13] In contrast to the strong performance of MSI and RVMSI, the age-associated shock index showed poor discrimination in the present cohort, with AUC values close to 0.5 at all evaluated time points. The usefulness of pediatric age-adjusted shock indices may therefore vary according to patient population, disease profile, and outcome studied. Recent pediatric trauma data have nevertheless demonstrated that age-adjusted shock indices can be useful for early risk stratification in selected clinical settings.[14]

The main strengths of the present study were the prospective design, serial assessment at multiple time points, and simultaneous comparison of six shock indices. However, the single-centre design and relatively small number of deaths may limit the generalizability and precision of mortality prediction. Larger multicentre studies are required to establish optimal pediatric cut-off values for MSI, RVMSI, and RASI.

CONCLUSION

Serial shock indices are simple, non-invasive bedside tools for risk stratification in children with shock. RVMSI and MSI showed the highest predictive accuracy for mortality, particularly at 24 hours, while RASI also demonstrated good prognostic performance. ASI showed poor discriminatory ability in this cohort. Incorporating serial MSI and RVMSI measurements into routine PICU assessment may help identify high-risk children requiring closer monitoring and aggressive management.

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