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Validation of the Shock Index, Modified Shock Index, and Shock Index-Paediatric age-Adjusted (SIPA) for predicting length of stay and outcome in children admitted to a paediatric intensive care unit

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Abstract

Background: Maintaining hemodynamic stability requires constant complex interaction between multiple vascular and extravascular factors. There are varieties of parameters that determine the same and few of them are used to predict the hemodynamic instability at earliest. Shock Index (SI), Modified Shock Index (MSI) and Shock Index-Pediatric age-Adjusted (SIPA) have been studied constantly in different clinical settings. They are best non-invasive measures for early prediction in resource poor setting or at community referral centers. We would like to compare the predictive value of each parameter in our tertiary care center.

Methods: It was a retrospective study carried out in PICU of a tertiary care centre and includes data collected from 15 August 2019 to 14 August 2021 over a period of 2 years. We recorded demographic data, age, gender, final diagnosis, outcome, and length of stay in PICU. We compared Outcome (Survived/Expired) and length of stay with SI $\geq$ 0.7 or < 0.7, MSI $\geq$ 1.3 or < 1.3 and SIPA > 1.22 or < 1.22 (age 4–6 years) > 1 or < 1 (7–12 years) and > 0.9 or < 0.9 (13–16 years).

Results: This study includes 235 children who were admitted to PICU during study period. The median age was 8 years the median length of stay was 5 days and mortality rate being 11.48% (27). Median SI, MSI were 0.78, 1.6 respectively. 61.70% (145) of patients had SI > 0.7. Median value of SI for septic shock patients was 0.92 on admission. The mortality of the patients with SI > 0.7 was 13.10% (19) and those with MSI > 1.3 was 14.89% (21). Mortality in accordance with SIPA for ages 4–6 years, 7–12 years, and 13–16 years were 15.25% (9), 23% (9) and 19.23% (5) respectively. Basically, SIPA was designed to monitor post trauma cases but in our study we got significant correlation with outcome and length of stay in conditions other than trauma.

Conclusions: The SI, MSI, and SIPA are simple bedside parameters may be used for prioritizing the patients who require strict monitoring on admission to PICU and intervention whenever required. These parameters were best in predicting the severity of sepsis and septic shock in comparison to other diagnosis. SIPA can be generalised for monitoring any high-risk case.

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Keywords: Shock Index, Modified Shock Index, Shock Index Pediatric age-Adjusted, Pediatric intensive care unit

Background

Ischemia and reperfusion injury is a critical pathophysiologic event common to several clinical conditions that can result from any acute event pertaining to vast number of causes [1]. Child may go into a state of acute circulatory dysfunction that results in a failure to deliver sufficient oxygen and other nutrients to meet the metabolic demands of the tissues. Shock and circulatory collapse initially may be masqueraded by compensatory mechanisms until late stages [2]. Once patient reaches a decompensated state, it is hard to manage with exponential increased risk of mortality and morbidity. Hence, early recognition and prompt treatment of shock and hemodynamic instability plays an important role in decreasing short term and long-term sequel [3]. In resource-poor setting, simple measures such as Shock Index (SI), Modified Shock Index (MSI) and Shock Index Pediatric age-Adjusted (SIPA) may be used as tools for triaging and treating children admitted to PICU [4]. In this study we are comparing these three simple parameters to determine which index among the three can be used as more effective tool for early prediction of mortality and length of PICU stay.

Methods

Patient and public involvement

Not involved.

This is a retrospective observational study conducted in a PICU of tertiary care centre. It included all children aged between 4 and 16 years, who were admitted to PICU for monitoring and management between 15 August 2019 and 14 August 2021 over a period of 2 years. Patients less than 4 years of age and > 16 years of age were excluded. Demographic data was collected. Heart rate or pulse rate, admission blood pressure (BP) and mean arterial blood pressure (MAP) on admission were charted. Length of PICU stay, and mortality were documented at the end. Children were categorised according to provisional diagnosis at admission. SI, MSI, and SIPA were calculated for individual patients and tabulated in case record form. The following formulas and cut off values were used for study purpose: (1) SI = heart rate/systolic blood pressure [5, 6], (2) MSI = heart rate/mean arterial pressure, and [7, 8] (3) Shock Index-Pediatric age-Adjusted (SIPA) > 1.22 (4–6 years), > 1 (7–12 years), > 0.9 (13–16 year) will be considered as upper normal limit [9–11].

The patients were divided into two categories: those with an SI > 0.7 and those with an SI $\leq$ 0.7, as this is the most commonly used threshold point, mortality, and length of stay (LOS) were calculated [4, 12]. The patients were also separated according to their MSI, using a threshold of 1.3 and according to their corresponding SIPA using a threshold according to age-adjusted norms, for each of these groups their respective LOS and outcome with respect to median were calculated [13]. Chi-square test was used to compare the variables among the groups. Paired test was applied only in selected cases where we found statistical significant association. All analyses were performed using the SAS (Windows version 9.3) and the R software. *P* values less than 0.05 were considered statistically significant.

Results

Our study included 235 children, who were aged between 4 and 16 years. Out of which 208 cases survived and 27 cases expired. Median LOS in PICU was 5 days with overall mortality of 11.48%. We had the maximum number of patients with diagnosis of sepsis (56) followed by pneumonia (45) and acute gastroenteritis (39) as illustrated in Table 1.

SI was calculated for all cases enrolled in study. Out of 235 patients included in the study, 90 patients (38%) had SI of $\leq$ 0.7. Out of 90 children with SI $\leq$ 0.7, 82(91%) went home and 8(9%) patients succumbed. The remaining 145 cases (62%) had SI > 0.7, of which 126(86%) cases survived and 19 (84%) cases expired as shown in Table 2.

Patients were divided into 3 groups based on age, i.e., 4–6 years, 7–12 years and 13–16 years. We had 104

Table 1 Distribution of cases based on diagnosis

Diagnosis	Number of cases
Sepsis	56 (23.83%)
Pneumonia	45 (19.15%)
Acute gastroenteritis	39 (16.60%)
Congenital heart disease	24 (10.21%)
Acute renal failure	20 (8.51%)
Urinary tract infection	16 (6.81%)
Central nervous system	15 (6.38%)
Poisoning	13 (5.53%)
Diabetic ketoacidosis	4 (1.70%)
Miscellaneous	3 (1.28%)
Total	235

Table 2 SI on admission with statistical significance in predicting outcome

	Total	Survived	Expired	*P* value
SI ≤ 0.7	90	82	8	0.324
SI > 0.7	145	126	19	

Table 3 MSI on admission with statistical significance in predicting outcome

	Total	Survival	Death	*P* value
MSI ≤ 1.3	94	88	6	0.045
MSI > 1.3	141	120	21	

patients aged 4 and 6 years, of which 40 cases (38%) had SI value of ≤ 0.7 with mortality of 5% (2). Similarly, 64 patients had SI > 0.7 with 12.5% (7) mortality. On applying chi-square test for this age group, we got *p* value of 0.207 (> 0.05) depicting no statistical significant association. Among children between 7 and 12 years (73), 28 (38.3%) cases had SI of ≤ 0.7 with 14.3% (4) mortality and among 45 cases who had SI > 0.7, the mortality rate was 15.66% (7). Chi-square test showed no statistical significant association of SI with mortality with *p* value-0.882 (> 0.05). Fifty-eight cases were aged between 13 and 16 years of which 22(37.9%) had SI of≤ 0.7 with mortality of 4.6% (1) and 36 cases had SI > 0.7 with mortality of 14% (5). On applying chi-square test, *P* value was 0.256 (> 0.05) showing no statistical significant association of SI with mortality for this age group.

Similarly, MSI was applied for each patient in the study group. Ninety-four (40%) among 235 had MSI ≤ 1.3 and 141 patients had MSI > 1.3. 88(93%) of 94 with MSI ≤ 1.3 survived and 6 patients expired with median LOS of 3 days. Those with MSI > 1.3, 120 (85%) survived and 21 expired with median LOS of 6 days. Chi-square test revealed statistical significance, with *p* value of 0.045 as set out in Table 3.

Patients were categorised into 3 groups according to age. In 4–6 years category, total patients were 94, of which 50 cases (55.5%) had MSI of ≤ 1.3 and 44 had MSI > 1.3. Those with MSI ≤ 1.3 had mortality of 4% (2) with LOS of 3 days. Children with MSI > 1.3 had mortality of 18% with LOS of 6 days. Chi-square test revealed statistical significant association of MSI value > 1.3 with mortality (*p* value 0.026) for age group 4–6 years. Among children of 7–12 years, 34 had MSI of ≤ 1.3 with 5.88% (2) mortality and among children with MSI > 1.3, mortality rate was 23% (9). Chi-square test illustrated statistical significant association of MSI value > 1.3 with mortality (*p* value 0.04) for children aged between 7 and 12 years. In children of 13–16 years age group, 32 (55%) had MSI of ≤ 1.3 and 26 (44%) had MSI > 1.3, with 3.1% (1) and 19.23% (5) of mortality respectively with MSI. On applying chi-square test, we got *p* value of 0.045 which suggested statistical significant association of MSI (value > 1.3) with mortality (outcome) as shown in Table 4.

Forty-five (43.2%) patients in 4–6 years age group had a SIPA score of ≤ 1.22 (*p* value 0.0255 significant), with survival of 44(97.7%) and 1 (2.3%) mortality with LOS of 4 days. Similarly, 50 (84.7%) survived and 9 (15.25%) expired among patients with SIPA > 1.22 with LOS of 4 days.

SIPA score adjusted for children aged between 7 and 12 years, showed 34 (46.5%) had SIPA ≤ 1 and 39 had SIPA > 1 with mortality of 5.88% (2) and 23.07% (9) respectively. Chi-square test yielded *p* value of 0.04 (< 0.05) showing statistical significant association. In 13–16 years age, 32 (55.1%) had SIPA ≤ 0.9 and 26 had SIPA > 0.9. Children with SIPA ≤ 0.9 had mortality of 3.12% (1) and those with SIPA > 0.9 had mortality of 19.23% (5). *P* value was 0.045 (< 0.05) from chi-square test, showing statistical significant correlation as mentioned in Table 5.

Discussion

Early recognition and treatment of shock and hemodynamic instability plays an important role in the management of patients admitted to PICU. In our study, we compared Shock Index (SI), Modified Shock Index (MSI) and Shock Index Pediatric age-Adjusted (SIPA) for triaging and treating children admitted to PICU. All the three indices were compared to determine which

Table 4 Age wise distribution of SI and MSI with results of chi-square test

Age (years)		4–6			7–12			13–16		
		Survived	Expired	*P* value	Survived	Expired	*P* value	Survived	Expired	*P* value
SI	≤ 0.7	38	2	0.207	24	4	0.882	21	1	0.257
	> 0.7	56	8		38	7		31	5	
MSI	≤ 1.3	48	2	0.026	32	2	0.04	31	1	0.045
	> 1.3	36	8		30	9		21	5	

Table 5 Age wise distribution of SIPA with results of chi-square test

Shock Index Pediatric age-Adjusted (SIPA)				
Age (years)		**Survived**	**expired**	***P* value**
4–6	SIPA ≤ 1.22	44	1	0.025
	SIPA > 1.22	50	9	
7–12	SIPA ≤ 1	32	2	0.04
	SIPA > 1	30	9	
13–16	SIPA ≤ 0.9	31	1	0.045
	SIPA > 0.9	21	5	

index of the three can be used as a more effective tool for early prediction of mortality and length of PICU stay.

In a study done by Kim SY et al., SI, MSI, and age multiplied SI were compared [13]. Study group was categorized into stable and unstable groups according to indices on admission to emergency department. Study included a total of 45880 cases, 97.8% of cases had SI < 1 and 2.2% of cases had SI ≥ 1. In hospitalized patients, 98.2% of survivors and 63.4% of non-survivors had SI of < 1. Similarly, in emergency department 99.1% of survivors and 43.9% of non-survivors had SI < 1.

In our study, out of 235 children, average LOS was 5 days with mortality rate of 11.48%. Sepsis, diabetic keto acidosis and pneumonia consisted majority of cases. Among 235 cases 38% had SI of ≤ 0.7 with mortality of 9%. In the remaining 62% of total cases with SI > 0.7, about 14% of patients expired. In the age group of 4 to 6 years, 40 cases (38 %) had SI value of ≤ 0.7 of which 95% of cases survived. Similarly, 64 cases (61.5%) had SI of > 0.7, out of which 56 cases survived (87.5%) and 12.5% of cases died. Among children aged between 7 and 12 years, 38.3% of cases had SI of ≤ 0.7 and 14.3% of cases died. 61.7% had SI value of > 0.7 and 84.44% survived. A total of 58 cases were aged between 13 and 16 years. 37.9% of cases had SI of ≤ 0.7, of which 95.4% survived. Sixty-two percent of cases had SI > 0.7, of which 86% of patients survived and 14% died as summarized in Table 4.

In another study by Rassameehiran S et al. [14], on utility of shock index for risk stratification in patients with acute upper gastrointestinal (GI) bleeding, a total of 214 admissions among all age groups with mean age of 59 ± 15.9 years, and mean shock index of 0.78 ± 0.21 was found. It was found that SI is good tool with potential for short-term adverse outcomes when present with upper GI bleeding.

In this study of 235 children, patients were grouped according MSI as > 1.3 or ≤ 1.3. Overall, those with MSI ≤ 1.3 had mortality of 6.3% and that of MSI > 1.3 was 14.8%. In 4–6 years age group, out of 94 cases, 55.5% had MSI of ≤ 1.3 and 4.5% of them expired. 44.5% of cases had MSI > 1.3 with survival of 81%. Among children of 7–12 years age, 51.6% had MSI of ≤ 1.3 and 94% survived. While 44 cases had MSI > 1.3 out of which 28.2% died. In children of 13–16 years age, 59.6% had MSI of ≤ 1.3 with mortality of 3.2%, 23% of cases with MSI of > 1.3 expired.

In the study done by Kim SY et al. [13], out of 45,880 cases, 97.3% had MSI of < 1.3 and 2.2% had MSI of ≥ 1.3. 97.8% of survivors and 61.4% of non-survivors had MSI < 1.3.

In a study of 18,478 adults, conducted by Sotello et al. [4], 97.1% of cases were alive before discharge and had MSI ≤ 1.3. The observed mortality of patients with an MSI ≤ 1.3 was 2.9% and the mortality of those with an MSI > 1.3 was 10.3%.

From our study as specified in Table 5, on age adjusting SI for children between age 4 and 6 years, 97.7% of cases who had a SIPA score of ≤ 1.22 survived with median hospital stay of 4 days. 84.7% patients with SIPA > 1.22 survived with median hospital stay of 4 days. Among children aged between 7 and 12 years, 94% of cases with SIPA ≤ 1 survived with median length of hospital stay of 3 days. However, 76.9% of patients with SIPA > 1 survived with median length of hospital stay of 5 days. In 13–16 years age group, 32 had SIPA ≤ 0.9 of which 96.5% of cases survived and 3.5% had expired. Out of 26 cases with SIPA > 0.9, 80.7% survived with median hospital stay of 6 days.

In study done by Acker S N, et al. [9], Shock Index Pediatric age-Adjusted (SIPA) was more accurate than age-adjusted hypotension for trauma team activation; children of ages 4–16 years were included in the study. Inclusion criteria for trauma team activation included blood transfusion, emergency operation, or endotracheal intubation. A total of 559 cases were included. Thirty percent of patients who required operative intervention showed increased SIPA over time. Similarly, 40% of children on mechanical ventilator had increase in SIPA score. In the same line, 53% of children requiring blood transfusion showed progressive increase in SIPA score. It was demonstrated that SIPA is superior to age-adjusted hypotension to identify injured children who required trauma team activation.

In another study done by Kim SY et al. [13], age-adjusted SI was taken in total of 45,880 cases, majority of cases (78.1%) had age-adjusted SI < 50. Among admitted cases, 78.7% of survivors had age-adjusted SI of < 50 and 69.4% of non-survivors had age-adjusted SI of ≥ 50. Similarly, at emergency department, 81.2% of survivors had age-adjusted SI of < 50 and 83.1% of non-survivors had

age-adjusted SI $\geq$ 50. In a similar study done by Sotello et al. [4], among 18,478 adult case, 97.5% cases were alive at discharge with age-adjusted SI $\leq$ 50 and 10% of cases with age-adjusted SI > 50 expired.

Conclusion

The SI, MSI, and SIPA are very useful measures for early detection of circulatory disturbances leading to shock. These parameters can be easily assessed at community health centre and peripheral hospital to aid early detection and prompt referral with appropriate measures. The same indices can be used at tertiary care centres for monitoring of patients in PICU. However, it needs further studies to prove the same. We recommend to use SIPA for monitoring critical patients as we got significant evidence to support the same from our study.

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Authors' contributions
MN: methodology, data curation, and writing—original draft preparation. HK: visualization, investigation, and supervision. MK: software, supervision, reviewing, and editing. PU: conceptualization, software, visualization, investigation, supervision, reviewing, and editing. NV: visualization, supervision, writing—reviewing, and editing. BKS: data curation, reviewing, and editing. The authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during this study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approval was obtained from the institutional ethics committee (Adichunchanagiri Institute of Medical Sciences) IEC number-AIMS/IEC/489/2021. Written informed consent was obtained from parents/guardian of the children enrolled in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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References

1. Zingarelli A (2008) Shock and reperfusion injury. In: Nichols DG, Ackerman AD, Argent AC (eds) Rogers' textbook of pediatric intensive care, 4th edn. Wolters Kluwer, Philadelphia, pp 252–265
2. Bisset WM, Beath SV, Jenkins HR et al (2008) Acute infective diarrhoea. In: Mcintosh N, Helms P, Smyth R et al (eds) Forfar and arneil's textbook of pediatrics, 7th edn. Elsevier, Philadelphia, pp 626–629
3. David A, Turner M, Ira M, Cheifetz (2019) Shock. In: Kleigman RM, Stanton BF, St Geme JW III et al (eds) Nelson textbook of pediatrics, 21st edn. Elsevier, Philadelphia, pp 572–583
4. Sotello D, Yang S, Nugent K (2019) Comparison of the shock index, modified shock index, and age shock index in adult admissions to a tertiary hospital. Southwest Respir Crit Care Chron 7(28):18–23
5. Schroll R, Swift D, Tatum D et al (2018) Accuracy of shock index versus ABC score to predict need for massive transfusion in trauma patients. Injury. 49(1):15–19
6. Rady M, Nightingale P, Little R et al (1992) Shock index: a re-evaluation in acute circulatory failure. Resuscitation. 23(3):227–234
7. Abreu G, Azevedo P, Braga CG et al (2008) Modified shock index: a bedside clinical index for risk assessment of ST-segment elevation myocardial infarction at presentation. Rev Port Cardiol 37(6):481–488
8. Liu Y, Liu J, Fang Z et al (2012) Modified shock index and mortality rate of emergency patients. World J Emerg Med 3(2):114–117
9. Acker SN, Bredbeck B, Partrick DA et al (2017) Shock index, pediatric age-adjusted (SIPA) is more accurate than age-adjusted hypotension for trauma team activation. Surg. 161(3):803–807
10. Reppucci M, Phillips R, Meier M et al (2021) Pediatric age-adjusted shock index as a tool for predicting outcomes in children with or without traumatic brain injury. J Trauma Acute Care Surg 91(5):856–860
11. Phillips R, Acker S, Shahi N et al (2020) The shock index, pediatric age-adjusted (SIPA) enhanced: Prehospital and emergency department SIPA values forecast transfusion needs for blunt solid organ injured children. Surg. 168(4):690–694
12. Koch E, Lovett S, Nghiem T et al (2019) Shock index in the emergency department: utility and limitations. Open Access Emerg Med 11:179–199
13. Kim SY, Hong KJ, Shin SD et al (2016) Validation of the shock index, modified shock index, and age shock index for predicting mortality of geriatric trauma patients in emergency departments. J Korean Med Sci 31(12):2026–2032
14. Rassameehiran S, Teerakanok J, Suchartlikitwong S et al (2017) Utility of the shock index for risk stratification in patients with acute upper gastrointestinal bleeding. South Med J 110:738–743

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