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Assessment of shock index and associated outcome in children with sepsis/septic shock at the tertiary care hospital

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ABSTRACT

Background: Shock index is the ratio of heart rate to the systolic blood pressure. The use of shock index for risk stratification or as an indicator of clinical improvement is helpful in early recognition of shock and optimizing treatment in sepsis and septic shock. **Aims and Objectives:** The objective of the study was to assess the shock index and associated outcome in children with sepsis/septic shock at the tertiary care hospital. **Materials and Methods:** A cross-sectional study was conducted among 95 patients admitted with sepsis or septic shock to the pediatric intensive care unit and pediatric wards of a tertiary center in Surat. The study was done over a period of 2 years from January 2020 to December 2021. The study was carried out after obtaining ethical approval from the Human Research Ethics Committee, GMC Surat. Through-out the study privacy and confidentiality was maintained at all cost for each participant by coding of patients data. **Results:** The mean age of the study population was 3.12 ± 2.40 years, with age range from 1 month to 12 years. The gender distribution of the study population had 51.6% male and 48.4% female. On analysis of the shock index to the mortality of the patients at 0, 1, 2, 4, and 6 h after admission, the cutoff value of shock index at 1.6, 1.7, 1.7, 1.4, and 1.3 had a sensitivity of 89.4%, 84.8%, 78.8%, 82.3%, and 86.4%, with a specificity of 62.4%, 69%, 75.9%, 72.4%, and 75.9%, respectively. The cutoff values of the various age groups decrease as the ages of the patients increase. The overall survival rate in the study was 30.5% and mortality rate at 69.5%. **Conclusion:** The study concluded that shock index can be used in emergency for triage of critically ill patients. Shock index and mortality were higher compared to other studies as majority of the study participants were referred cases and were in critical stages of shock on admission to the tertiary care center.

Key words: Shock index; Sepsis; Septic shock; Intensive care; Outcome

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INTRODUCTION

Sepsis and septic shock are associated with high mortality and morbidity rates in children.[1] Shock index is a predictor of mortality in pediatric intensive care unit (PICU) admissions. The use of shock index for risk stratification or as an indicator of clinical improvement is helpful in early recognition of shock and optimizing treatment in sepsis and septic shock.[2] As early recognition and aggressive resuscitation of shock is associated with better outcome.[3] Shock index may have the advantage of distinguishing from suppressed sympathetic state, use of anticholinergic drugs, sedation, which can be confounding factors while assessing critically ill patients as heart rate and blood pressure (BP) individually cannot differentiate the above states. It is difficult to define the normal values of shock index in children.[4]

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Shock index reflects both the vascular and myocardial dysfunction and has been shown to correlate with other indices of end-organ perfusion such as central Venous oxygen saturation and lactate concentration.[5,6] The variability in heart rate and BP in the different age groups in children results in age-specific shock index values more specific than the standard adult cutoff value of 0.9 in identifying the sickest children.[7,8] Shock index pediatric age-adjusted (SIPA) was confined to trauma patients but recent studies noted that elevated SIPA values and the trends in the SIPA at 24 h accurately identified children at a risk of high mortality, ventilator support, inotropic support, adverse outcomes, and a long hospital stay.[9] This study was undertaken with the objective to assess the shock index and associated outcome in children with sepsis/septic shock at the tertiary care hospital.

Aims and objectives

The aims and objective of the study was to assess the shock index and associated outcome in children with sepsis/septic shock.

MATERIALS AND METHODS

Study design

A cross-sectional study was conducted among 95 patients admitted with sepsis or septic shock to the PICU and pediatric wards of a tertiary center in Surat. The study was done over a period of 2 years from January 2020 to December 2021. The objective of the study was to assess the shock index and associated outcome in children with sepsis/septic shock at the tertiary care hospital.

Ethical clearance

The study was carried out after obtaining ethical approval from the Human Research Ethics Committee, GMC Surat before initiation of study vide letter no. GMCS/STU/ETHICS/Approval/2869/20. Through-out the study privacy and confidentiality was maintained at all cost for each participant by coding of patient's data. The data collected were documented and analyzed statistically to draw a useful conclusion.

Inclusion criteria

Patients aged 1 month to 12 years admitted in PICU and pediatric wards with sepsis or septic shock as per International Pediatric Sepsis Consensus Conference 2005. The study included only those cases where consent was given.

Exclusion criteria

Patients diagnosed with congenital heart disease, congenital immunodeficiency syndromes, on high dose of steroids, hemato-oncologic patients who received chemotherapy. Other types of shock such as neurogenic shock, anaphylactic shock, and obstructive shock were excluded from the study.

Systemic inflammatory response syndrome (SIRS)

Two of the four criteria in one of which must be abnormal temperature or abnormal leucocyte count:

1. Core temperature >38.5°C (101.3°F) or <36°C (96.8°F) (rectal, bladder, oral, or central catheter)
2. Tachycardia: Mean heart rate >2 SD above normal for age in absence of external stimuli, chronic drugs, or painful stimuli
3. Unexplained persistent elevation over 0.5–4 h or in children <1 year of old, persistent bradycardia over 0.5 h (mean heart rate <10 percentile for age in absence of vagal stimuli, beta blocker drugs, or congenital heart disease)
4. Respiratory rate >2 SD above normal for age or acute need for mechanical ventilation not related to neuromuscular disease or general anesthesia
5. Leucocyte count elevated or depressed for age (not secondary to chemotherapy) or >10% of immature neutrophils.

Sepsis

SIRS plus a suspected or proven infection.

Severe sepsis

Sepsis plus one of the following:

Cardiovascular organ dysfunction, defined as:

- Despite >40 mL/kg of isotonic intravenous fluid in 1 h
- Hypotension <5th percentile for age or systolic BP <2 SD below normal for age

"Or"

- Need for vasoactive drug to maintain BP

"Or"

- Two of the following:

1. Unexplained metabolic acidosis: base deficit >5 mEq/L
2. Increased arterial lactate: >2 times upper limit of normal
3. Oliguria: urine output <0.5 mL/kg/h
4. Prolonged capillary refill: >5 s
5. Core to peripheral temperature gap >3°C
6. Acute respiratory distress syndrome as defined by the presence of PaO_2/FiO_2 ratio <300 mmHg, bilateral infiltrates on chest radiographs, and no evidence of left heart failure.

"Or"

- Sepsis plus two or more organ dysfunctions (respiratory, renal, neurologic, hematologic or hepatic).

Septic shock

Sepsis plus cardiovascular organ dysfunction as defined above.

Shock index

Shock index is the ratio of heart rate to systolic BP. It is a clinical tool used for monitoring children with sepsis or severe sepsis or septic shock. Heart rate, systolic BP, and diastolic BP were measured at 0, 1, 2, 4, and 6 h of admission. Heart rate was noted by auscultation and BP measured with digital monitoring device with appropriate cuff size according to the age of child over a period of 1 min after calming the child or before or after a painful procedure. Child on vasoactive therapy (dopamine, epinephrine, norepinephrine, or milrinone) was noted for time of starting of therapy, dosage, any increase in the rate, and add on or change of therapy.

Measurement of heart rate

Heart rate was determined by direct auscultation of the heart and using multipara monitor.

Measurement of BP

Mode of measurement of BP was non-invasive using multipara monitor with different cuff size according to the age of the patients. BP cuffs used for various age groups covered two-third of the length of the arm as shown in Table 1. The inflatable bladder covered the entire arm with no overlapping over a period of 1 min in the right arm at the heart level in a supine position or sitting position according to the general condition of the patients. Brachial artery was palpated, located, and position the BP cuff placed such that artery marker points to the brachial artery attach to an automated device with a manual inflate mode connected to multipara.

Statistical analysis

The data collected were analyzed using the Statistical Package for the Social Sciences software, namely, SPSS 22.0. Frequencies and percentage were used to represent the categorical data. Test of significance for qualitative data was analyzed by Chi-square test. Mean and standard deviation was used to represent continuous data. ANOVA test was used to check the association between more than two groups. Receiver-operating characteristic (ROC) curve was used to estimate sensitivity, specificity, positive predictive value, and negative predictive value. ROC analysis was used to find out the cutoff value of shock index among the children with mortality as outcomes at different time interval. $P<0.05$ was considered as statistically significant.

RESULTS

The study included 95 patients admitted in PICU and pediatric wards with sepsis or septic shock. The age distribution had majority of 44.2% study subjects aged <1 year of age, 36.8% were in the age group between 1 and 6 years, and 18.9% were aged more than 6 years of age. The mean age of the study population was 3.12±2.40 years. The gender distribution of the study population had 48.4% female and 51.6% male.

On assessment based on Glasgow coma scale (GCS) at the time of admission, 51.6% of the subjects were classified as moderate with GCS Score 9–12, 37.9% were classified as severe with GCS Score 3–8, and 10.5% were classified as mild with GCS Score 13–15. Among the study population, 31.6% subjects had sepsis and 68.4% had septic shock at the time of admission. The basic characteristic of the study population is listed in Table 2.

On analysis of the association between shock index with the age group of the study subjects, the shock index gradually decreased from the time of admission after the initiation of treatment till the study endpoint with significant P-value between all the groups at 0 h, 1 h, 2 h, 4 h, and at 6 h interval of the study, as shown in Table 3.

On analysis of the association between shock index with the severity of sepsis in the study subjects, the shock index gradually decreased from the time of admission after the initiation of treatment till the study endpoint in both the sepsis and septic shock group with a significant P-value. The shock index was higher in the septic shock group than the sepsis group in the present study, as shown in Table 4.

On analysis of the association between shock index with outcome in the study subjects, the shock index gradually decreased from the time of admission after the initiation of treatment till the study endpoint in both those who survived and those did not with a significant P-value, as shown in Table 5.

Table 1: Blood pressure cuff size according to age group and site of measurement[4]

Age	Cuff size in the arm		Cuff size in the legs	
	Width	Length	Width	Length
New-born	2.5–4	5–9	6–9	17–18
Infants	4–6	10–13	8–9	20
1–2 years	6–9	13–18	12–14	25
2–8 years	7–10	17–20	14–16	28
8–12 years	8–12	20–24	16–18	30
Adolescent	12–14	22–26	18–20	32–28

In the study, the overall survival rate of the study subjects was 30.5% and mortality rate was 69.5%. However, the association between age group and gender with outcome of the study subjects was statistically insignificant, as shown in Table 6.

On analysis of the shock index with the mortality of the study subjects at the time of admission, the cutoff value of shock index 1.6 was found to be have a sensitivity of 89.4% and specificity of 62.1% (Figure 1). At 6 h after admission, the cutoff value of shock index 1.3 was found to have a sensitivity of 86.4% and specificity of 75.9% (Figure 2).

Table 2: Basic characteristics of the study population with sepsis or septic shock (n=95)

Characteristics	Frequency %
Age in years	
<1 year	42 (44.2)
Between 1 and 6 years	35 (36.8)
More than 6 years	18 (18.9)
Gender	
Male	49 (51.6)
Female	46 (48.4)
Glasgow coma scale score	
Mild (13–15)	10 (10.5)
Moderate (9–12)	49 (51.6)
Severe (3–8)	36 (37.9)
Severity of sepsis	
Sepsis	30 (31.6)
Septic shock	65 (68.4)

DISCUSSION

Sepsis is the outcome of a chain of illnesses brought on by infection that requires early detection and treatment during the critical first few hours to improve the prognosis. In our study, majority of the subjects who presented with shock were aged <1 year. Gupta and Alam,[10] in their study, reported infancy as the period when majority presented with sepsis and septic shock which is comparable to the findings of our study. The mean age of the study population was 3.12±2.40 years. A similar study done by Rajendran et al.[4] reported a mean age of 4.4±3.4 years. In our study, the gender distribution had 51.6% male and 48.4% female. A similar study by Huang et al.[9] reported comparable findings with 58.3% male and 41.7% female.

In our study, 31.6% subjects had sepsis and 68.4% had septic shock. Rajendran et al.,[4] in their study, reported sepsis in 40% and septic shock in 30% which can be compared to our study findings. There exists a wide normal range of

Table 3: Association between shock index at 0, 1, 2, 4, and 6 h after admission with age group of the study subjects

Shock index in time	Age						ANOVA test
	<1 year		Between 1 and 6 years		More than 6 years		
	Mean	SD	Mean	SD	Mean	SD	
Shock index at 0 h	2.5357	0.5851	2.0500	0.4960	1.5928	0.4440	F=21.63 P=0.0001
Shock index at 1 h	2.4024	0.5585	1.9486	0.4749	1.5722	0.4170	F=18.86 P=0.0001
Shock index at 2 h	2.2488	0.6402	1.7857	0.4306	1.4611	0.3415	F=16.41 P=0.0001
Shock index at 4 h	2.0226	0.6260	1.7200	0.4255	1.3878	0.3058	F=10.34 P=0.0001
Shock index at 6 h	1.8048	0.6378	1.6114	0.4078	1.3167	0.2572	F=5.98 P=0.004

SD: Standard deviation

Table 4: Association between shock index at 0, 1, 2, 4, and 6 h after admission with severity of sepsis of the study subjects

Shock index in time	Severity of sepsis				Independent T-test
	Sepsis		Septic shock		
	Mean	SD	Mean	SD	
Shock index at 0 h	1.4883	0.4559	2.4965	0.4141	T=−10.68, P=0.0001
Shock index at 1 h	1.4567	0.4240	2.3646	0.4125	T=−9.886, P=0.0001
Shock index at 2 h	1.3333	0.3252	2.2038	0.4909	T=−8.846, P=0.001
Shock index at 4 h	1.2893	0.3071	2.0223	0.4906	T=−75.19, P=0.0001
Shock index at 6 h	1.2200	0.2250	1.8354	0.5194	T=−6.212, P=0.0001

SD: Standard deviation

Table 5: Association between shock index at 0, 1, 2, 4, and 6 h after admission with outcome of the study subjects

Shock index in time	Outcome				Independent T-test
	Death		Survived		
	Mean	SD	Mean	SD	
Shock index at 0 h	2.3920	0.5306	1.6914	0.5880	T=5.799, P=0.0001
Shock index at 1 h	2.2864	0.5141	1.6034	0.4799	T=6.081, P=0.0001
Shock index at 2 h	2.1311	0.5612	1.4690	0.4115	T=5.708, P=0.0001
Shock index at 4 h	1.9644	0.5383	1.3959	0.3695	T=5.170, P=0.0001
Shock index at 6 h	1.8000	0.5398	1.2793	0.2744	T=4.913, P=0.0001

SD: Standard deviation

Table 6: Association between age group and gender to the outcome of the study subjects

Characteristics	Outcome		P-value
	Death	Survived	
Age (years)			
<1	30 (45.5)	12 (41.4)	0.350
Between 1 and 6	26 (39.4)	9 (31.0)	
More than 6	10 (15.2)	8 (27.6)	
Gender			
Male	33 (50.0)	16 (55.2)	0.642
Female	33 (50.0)	13 (44.8)	

shock index in pediatric age groups due to the confounding effect of the vast range of normal vital sign variations in each age group. In our study, we noted the association of shock index with age group to be statistically significant at all point of intervention with P<0.05. Furthermore, the difference in the shock index among patients with septic shock and sepsis was found to be statistically significant.

In our study, mortality was noted in 69.5% of the subjects and only 30.5% of the subjects survived. The outcome of the study subjects and association of the shock index value was found to be statistically significant at 0 h, 1 h, 2 h, 4 h, and 6 h of admission. This finding is comparable to a study done by Hirani et al.,[11] with reported mortality of 70% in those with sepsis. Makhija et al.,[12] in their study, reported mortality of 70% in sepsis cases at 72 h after admission. The higher mortality rate is attributed to the late reporting and late referral from the peripheral center to the tertiary care center and also the availability of adequate resources in the hospital settings. Gupta and Alam,[10] in their study, reported early mortality of 50% in those with septic shock. A study done by Rajendran et al.,[4] reported mortality rate of 32% which is in contrast to the findings of our study.

In our study, the use of inotropic agents led to improved vitals and reduced the shock index. This difference in shock index between the subjects administered with inotropes was statistically significant at 0 h, 1 h, 2 h, 4 h, and 6 h after admission in hospital. Hirani et al.,[11] in their study, reported positive outcomes in septic shock with usage of inotropes.

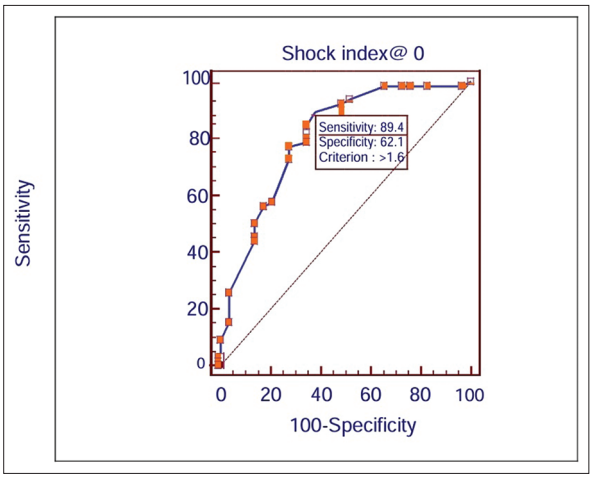

Figure 1: Receiver-operating characteristic curve analysis of shock index and mortality among study subjects at 0 h

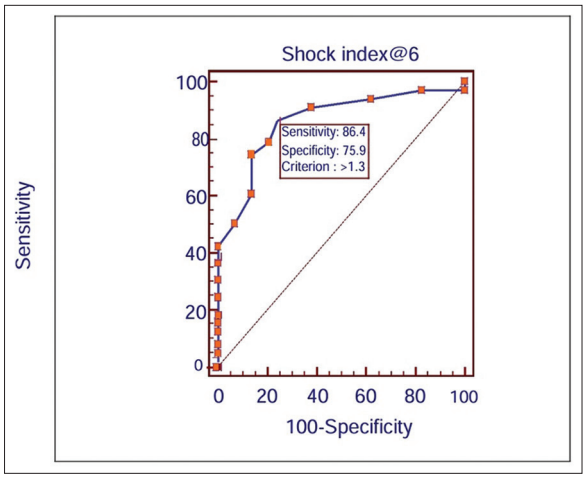

Figure 2: Receiver-operating characteristic curve analysis of shock index and mortality among study subjects at 6 h

On plotting ROC curve analysis for determining the mortality outcome for the shock index at the time of admission, the cutoff value of shock index was 1.6 with a sensitivity of 89.4% and specificity of 62.1%. The cutoff value of shock index was 1.3 with a sensitivity of 86.4% sensitivity and specificity of 75.9% at 6 h after admission. P-value was statistically significant for all ROC curve done

Table 7: Summary of cutoff value of shock index in different age group among study subjects

Age (years)	Time to treatment (h)	Cutoff value of shock index	Sensitivity (%)	Specificity (%)
<1	At 0	2.4	90.0	75.0
	At 1	2.2	90.0	75.0
	At 2	2.1	83.3	83.3
	At 4	1.9	80.0	75.0
	At 6	1.8	66.7	100.0
Between 1 and 6	At 0	1.6	84.6	77.8
	At 1	1.5	88.5	77.8
	At 2	1.4	80.8	77.8
	At 4	1.3	88.5	77.8
	At 6	1.5	73.1	100
More than 6	At 0	1.3	90	75
	At 1	1.4	90	75
	At 2	1.4	80	87.5
	At 4	1.4	70	100
	At 6	1.3	70	100

for mortality on comparing shock index at 0 h, 1 h, 2 h, 4 h, and 6 h.

In a study done by Rousseaux et al.,[3] the shock index was significantly different between survivors and non-survivors at 0, 4, and 6 h after admission. Rady et al.,[13] in their study, reported that a shock index of 0.9 at admission was associated with the need for immediate treatment, higher hospital admission rates, and intensive therapy on admission. This suggests that shock index may be a useful tool for the early recognition and evaluation of critical illnesses in the emergency department as well as for monitoring the progress of resuscitation. Since the range of vital signs change with age, it is challenging to establish a normal range of shock index in the pediatric population as shown in Table 7. Those subjects with sepsis/septic shock with high shock index benefited from intensive treatment and quick resuscitation.[14]

Strutt et al.,[15] in their study, investigated the use of age-adjusted shock index to predict adverse outcomes in pediatric trauma patients, finding that increased shock index may reliably predict morbidity and death in sepsis/septic shock.

The cutoff value of shock index in this study is higher as compare to SIPA cutoff values at 1.6 for 1–6 year and 1.3 for those more than 6 years. In our study, shock index was clinically relevant and a calculated predictor of mortality. It could be a better measure of hemodynamic status than heart rate and systolic BP alone, allowing for the early recognition of severe sepsis.

Limitations of the study

The majority of the study participants were referred cases in critical stages of shock with multiple-organ dysfunction syndrome and catecholamine resistant shock. Hence, shock index and mortality were higher in this study. There may be bias in the recruitment of study participants as it is a tertiary hospital-based study and almost all patients admitted in PICU were critically ill. Only one clinical variant of septic shock was measured which is cardiovascular system. Furthermore, no significant decrease in shock index was observed in those with mortality but shock index decreased significantly in those who survived.

CONCLUSION

The conclusion drawn from this study is that shock index can be used in emergency for triage of critically ill patients. Shock index and mortality was higher in our study compared to other studies as most of the patients admitted to the tertiary care center were in shock for a prolonged period when referred from other centers. The risk of mortality rises with higher shock index values and children with elevated shock index may benefit from aggressive treatment and intensive care. There is a need for more study in this area for more sensitive and precise cutoff values for the various age groups.

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GM- Definition of intellectual content, design, concept, literature survey, implementation of study protocol, data collection, data analysis, manuscript preparation; **MMK-** Manuscript preparation, editing and revision, statistical analysis and interpretation; **PDT-** Design of study, statistical analysis and interpretation, review manuscript; **DN-** Coordination and manuscript revision, **ADK-** Coordination and manuscript revision.

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