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Trends in pediatric adjusted shock index predict morbidity and mortality in children with severe blunt injuries☆,☆☆,★

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ABSTRACT

Purpose: The utility of measuring the pediatric adjusted shock index (SIPA) at admission for predicting severity of blunt injury in pediatric patients has been previously reported. However, the utility of following SIPA after admission is not well described.

Methods: The trauma registry from a level-one pediatric trauma center was queried from January 1, 2010 to December 31, 2015. Patients were included if they were between 4 and 16 years old at the time of admission, sustained a blunt injury with an Injury Severity Score ≥ 15, and were admitted less than 12 h after their injury ($n = 286$). Each patient's SIPA was then calculated at 0, 12, 24, 36, and 48 h after admission and then categorized as elevated or normal at each time frame based upon previously reported values. Trends in outcome variables as a function of time from admission for patients with an abnormal SIPA to normalize as well as patients with a normal admission SIPA to abnormal were analyzed.

Results: In patients with a normal SIPA at arrival, 18.4% of patients who developed an elevated SIPA at 12 h after admission died, whereas 2.4% of patients who maintained a normal SIPA throughout the first 48 h of admission died ($p < 0.01$). Among patients with an elevated SIPA at arrival, increased length of time to normalize SIPA correlated with increased length of stay (LOS) and intensive care unit (ICU) LOS. Similarly, elevation of SIPA after arrival in patients with a normal initial SIPA correlated to increased LOS and ICU LOS.

Conclusions: Patients with a normal SIPA at time of arrival who then have an elevated SIPA in the first 24 h of admission are at increased risk for morbidity and mortality compared to those whose SIPA remains normal throughout the first 48 h of admission. Similarly, time to normalize an elevated admission SIPA appears to directly correlate with LOS, ICU LOS, and other markers of morbidity across a mixed blunt trauma population. Whether trending SIPA early in the hospital course serves only as a marker for injury severity or if it has utility as a resuscitation metric has not yet been determined.

Type of study: Prognostic.

Level of evidence: Level II.

The shock index (SI), defined as heart rate (HR: beats per minute) divided by systolic blood pressure (SBP: in mmHg) was initially described by Allgower and Buri in 1967 [1]. Within the adult population a normal SI ranges from 0.5 to 0.7 and an SI ≥0.9 has been considered a "break point" for increased severity of illness [2–4]. The use of SI has been studied the most within the adult trauma population. Elevation of SI at the time of arrival in the emergency department (ED) following polytrauma has been shown to predict need for massive transfusion, intensive care admission, and mortality [4–6]. Additionally, a persistently elevated SI, either prehospital to ED or ED to admission, has been shown to predict mortality [2,3,5].

However, application of SI within the pediatric trauma population is difficult secondary to differences in HR and SBP in children as a function of age. Recently Acker et al. have defined pediatric-adjusted SI (SIPA) values for children based upon vital signs across accepted age ranges and validated this model as a predictor for injury severity in blunt trauma [7]. Cutoff values for SIPA are as follows: 1.22 (ages 4–6 years), 1.0 (ages 7–12), and 0.9 (ages 13–16) with values above these cutoffs considered abnormal. Since publication of this study, additional work has shown that SIPA has utility in identification of severe head injury, identification of severe isolated blunt liver/spleen injury, need for trauma team activation, and need for abdominal CT after blunt trauma injury [8–12].

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Table 1
Demographics and outcomes for children by age group.

	Age 4–6 (n = 66)	Age 7–12 (n = 134)	Age 13–16 (n = 86)	p-value
Male, n (%)	41 (62.1%)	85 (63.4%)	63 (73.3%)	0.269
ISS, mean (SEM)	22.5 (0.9)	24.2 (0.8)	23.2 (0.9)	0.388
Head AIS median (IQR)	4 (0–4)	4 (0–4)	3 (0–4)	0.381
Elevated SIPA on Arrival, n (%)	12 (18.2%)	44 (32.8%)	23 (26.7%)	0.091
ICU LOS (days) Median (IQR)	1.5 (0–3)	1 (0–3)	1 (1–4)	0.323
Hospital LOS (days) Median (IQR)	5 (3–8)	4 (2–8)	4.5 (3–10)	0.284
Mechanical Ventilation (days) Median (IQR)	0 (0–1)	0 (0–1)	0 (0–2)	0.558
Discharge to Rehabilitation n, %	11 (16.7%)	24 (17.9%)	16 (18.6%)	0.683
Blood transfusion in first 24 h of Admission n, %	16 (24.2%)	33 (24.6%)	24 (27.9%)	0.098
Ventilator Associated Pneumonia n, %	5 (7.6%)	8 (6.0%)	9 (10.5%)	0.560
Urinary Tract Infection n, %	2 (3.0%)	4 (3.0%)	5 (5.8%)	0.882
Surgical Site Infection n, %	0 (0%)	3 (2.2%)	2 (2.3%)	0.954
Bacteremia n, %	0 (0%)	6 (4.5%)	4 (4.7%)	0.865
All Infections n, %	7 (10.6%)	15 (11.2%)	16 (18.6%)	0.198
Death prior to discharge n, %	5 (7.6%)	13 (9.7%)	6 (7.0%)	0.504

ISS: Injury Severity Score; SEM: Standard Error of the Mean; IQR: Interquartile Range; AIS: Abbreviated Injury Score; LOS: Length of Stay.

While validity for SIPA as an initial marker for injury severity has been established, the utility of following SIPA after admission has not been determined. The purpose of this study was to determine if following trends in SIPA for the first 48 h (h) in pediatric patients with severe blunt injuries correlated with morbidity and mortality.

1. Methods

In order to evaluate trending SIPA in a population where it has been validated, the inclusion/exclusion criteria created by Acker et al. were utilized [7]. The trauma registry from a single institution (Riley Hospital for Children at IU Health, Indianapolis, Indiana) was queried for all patients sustaining blunt injuries with an Injury Severity Score (ISS) of ≥15 from January 1, 2010 to December 31, 2015. Children were excluded from the study cohort if they were less than 4 years old or greater than 16 years old. Additionally, patients were excluded if they presented to our institution more than 12 h after injury. SIPA values were calculated for each patient at the time of arrival and every 12 h thereafter until 48 h after admission. These scores were then categorized as either "elevated" (i.e. above normal SIPA score for age range) or normal. Additionally, outcome variables related to SIPA previously reported by Acker et al. were reviewed along with demographic data (Table 1) [7]. Measured outcome variables included: Intensive Care Unit (ICU) length of stay (LOS), total hospital LOS, days on mechanical ventilation, discharge to rehabilitation, blood transfusion within the first 24 h of admission, and in-hospital mortality. Patients were then categorized into two groups based upon their SIPA score at admission (i.e. elevated or not elevated). Trends for outcomes for both groups at each subsequent 12-h time interval based upon the presence or absence of an elevated SIPA were compiled. Chi-squared analysis and Kruskal-Wallis tests were performed when appropriate with a p-value <0.05 considered statistically significant.

Because the aggressiveness of resuscitation as well as ongoing bleeding after initial evaluation may contribute to alterations in SIPA over the study period, several common variables were analyzed. The amount of packed red blood cells transfused (in mL/kg) and amount of intravenous crystalloid/colloid ("IVF"; in mL/kg) administered were calculated for the first 12 h after admission, the second 12 h after admission, and the first 24 h of admission for all patients with available data over this period. In a similar manner urine output (UOP; in mL/kg/h) for the first and second 12 h after admission was also calculated and reported as either less than or equal to/greater than 1 mL/kg/h. Hematocrit levels (in percentage) were also recorded. These variables were then analyzed against trends in SIPA in a similar manner as previously discussed. Other common variables such as serum lactate and base deficit were not drawn routinely enough for adequate statistical analysis in this study population.

2. Results

During the study period, 286 patients were identified that met inclusion/exclusion criteria. Demographics and outcome variables for each age range were evaluated and there were no statistically significant differences between age groups (Table 1). Among these patients, 79 (27.6%) had an elevated SIPA at the time of arrival (Table 1). Additionally, among those children with a normal SIPA at arrival, 57 (19.9%) developed an elevated SIPA at 12 h and/or 24 h after admission. Trends in outcome variables previously mentioned for patients with elevated SIPA at arrival or those that developed an elevated SIPA after admission were evaluated. P-values given include analyzed time points that were not included in the tables for simplicity.

2.1. In-hospital mortality

Among patients with an elevated SIPA at the time of arrival, 19% of patients who normalized their SIPA within 12 h died, whereas 31% of those

Table 2
Trends in SIPA for binomial outcome variables.

	Elevated SIPA at arrival (n = 79)		Normal SIPA at Arrival (n = 207)		
	Normalized by 12 h (n = 37)	Normalized within 13–24 h (n = 16)	Always Normal SIPA (n = 124)	Elevated SIPA at 12 h (n = 38)	Elevated SIPA at 24 h (n = 19)
Death (n; %)	7 (18.9%)	5 (31.2%)	3 (2.4%)	7 (18.4%)	0 (0%)
Survival to discharge (n; %)	30 (81.1%)	11 (68.8%)	121 (97.6%)	31 (81.6%)	19 (100%)
p-value	0.152		<**0.001**		
Transfusion in first 24 h (n; %)	11 (29.7%)	10 (62.5%)	14 (11.3%)	14 (36.8%)	4 (21.0%)
No transfusion in first 24 h (n; %)	26 (70.3%)	6 (37.5%)	110 (88.7)	24 (63.2%)	15 (78.0%)
p-value	0.082		**0.010**		
Discharge to Rehabilitation (n; %)	5 (13.5%)	5 (31.2%)	11 (8.9%)	8 (21.0%)	3 (15.8%)
Rehabilitation not Needed (n; %)	32 (86.5%)	11 (68.8%)	113 (91.1%)	30 (79.0%)	16 (84.2%)
p-value	0.152		<**0.001**		