The association of delta shock index and mortality in children with shock

I Made Darma Yuda, Dyah Kanya Wati, I Nyoman Budi Hartawan, Ida Bagus Suparyatha

Abstract
***Background*: Shock remains one leading cause of morbidity and mortality in hospitalized children. Delta shock index is a simple tool to assess and evaluate shock.**
***Objective*: To investigate whether delta shock index might be related to mortality in children with shock.**
***Methods*: Prospective cohort study.**
***Setting*: Emergency Room (ER) and Pediatric Intensive Care Unit (PICU) of Sanglah University Hospital, Bali from March 2015 to March 2016.**
***Patients and participants*: Children aged 1-month to 12-year-old that were diagnosed with shock during admission or during hospitalization. Subjects were divided into delta shock index (DSI)≤0 group and DSI>0.**
***Results*: From March 2015 to March 2016 a total of 80 subjects were recruited. There were 40 cases with DSI≤0 and 40 cases with DSI>0. Mortality was found in 28 (70%) patients with DSI≤0 group. Chi-square analysis showed significant association between DSI and mortality (RR 1.9, 95%CI:1.2-2.9; p=0.004). Survival analysis showed median time survival was 5 days for the group with DSI≤0 and 7 days for the group with DSI>0 (log-rank 0.03). Cox regression analysis showed that DSI≤0 (RR 1.895, 95%CI:0.989-3.623; p=0.037) and age (RR 0.988, 95%CI:0.979-0.997; p=0.015) were risk factors for mortality in children with shock.**
***Conclusion*: DSI≤0 was associated with mortality in children with shock.**

Key words: Children, delta shock index, mortality, shock.

Introduction

Shock is a life-threatening condition that occurs due to an inadequate supply of oxygen and nutrients to meet tissue's metabolic demands. (1) Shock is a complex clinical syndrome caused by the failure of the primary cardiovascular system. The circulation function was affected by several factors such as blood volume, vascular tone, and cardiac function. The disruption of these components will cause shock in children. (2)

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Resuscitation is an early procedure in shock condition to normalize hemodynamic and laboratory conditions such as heart rate, blood pressure, central venous pressure, and lactic acid. However, several studies show that the improvement of hemodynamic parameters are not always followed by the decrease in morbidity and mortality in shock patients. (3)

In 1960, Allgower and Buri introduced shock index (SI), a ratio of heart rate and systolic blood pressure as a hemodynamic parameter. (4) The normal values of SI in adult range from 0.5 to 0.7. Studies in adults demonstrated that SI value and the increase in value of the initial SI >0.9 were associated with the cardiac dysfunction, tissue hypoxia, and increased of mortality. (5,6)

Study in children revealed that high initial SI value was associated with increased risk of mortality, but the exact cutoff point was undetermined. SI cutoff point in pediatric patients was difficult to measure due to wide range of heart rate and systolic blood pressure. (3) SI was difficult to predict stroke volume index (SVI). Decrease of SI≥0.02 was not sensitive and not specific for detecting low SVI in children. (7)

Acker et al. (8) in 2015 found that SI value corresponding to age group was more accurate in assessing hemodynamic condition in children who experienced severe trauma, intraabdominal trauma requiring transfusion, and had highest risk of death. SI value can be used as a predictor of mortality that occurred in pediatric patients with septic shock. Hemodynamic condition that was improved within first 6 hours after resuscitation gave better outcomes in children with shock. (9)

The difference between SI at first assessment of shock and 6 hours post-resuscitation is called delta shock index (DSI). The DSI based on age group showed a significant correlation with mortality. (3) DSI study with pediatric subjects is very limited. Our study objective was to investigate the association between DSI and mortality in children with shock. Primary outcome was the association between DSI and mortality in children with shock. Secondary outcome was the association between DSI≤0, age, nutritional status and mortality. We also investigated length of stay of DSI≤0 group and DSI>0 group.

Methods

A prospective cohort was conducted at the Emergency Room (ER), and Pediatric Intensive Care Unit (PICU) of Sanglah University Hospital, Bali during March 2015 until March 2016. Subjects were children aged 1-month to 12-year-old that diagnosed with shock during admission or hospitalization and parents agreed to participate in the study. Subjects were divided into DSI≤0 group and DSI>0 group, and followed until discharged from the hospital. Exclusion criteria were subjects who died less than 6 hours after admission, refused medical treatment, diagnosed as cardiogenic shock, or had congenital heart disease. This study was approved by Ethics Committee of Sanglah hospital.

DSI is defined as SI on admission minus SI at hour 6. DSI>0 means improvement of SI after 6 hours and DSI≤0 means no improvement or worsening SI after 6 hours. Heart rate, systolic blood pressure, and DSI data were collected every hour until 6 hours after resuscitation. Data of PIM II and inotropic or vasoactive drugs used were also collected. Subjects were followed until they were discharged from hospital or died.

Results

During study period there were 83 subjects met the inclusion criteria. Three patients were excluded due to refusing medical action. The characteristics of subjects are presented in **Table 1**. Underlying diseases for each group are presented in **Table 2**.

Heart rate at hour 0 was higher in DSI≤0 group compared to DSI>0 group (median 150 vs 139 beats/minute, respectively). Heart rate at hour 6 was higher in DSI≤0 group compared to DSI>0 group (median 150 vs 104 beats/minute, respectively). Systolic blood pressure at hour 0 was higher in DSI≤0 group compared to DSI>0 group (median 80 vs 68 mmHg, respectively). Systolic blood pressure at hour 6 was lower in DSI≤0 group compared to DSI>0 group (median 70 vs 100 mmHg, respectively). Data of DSI are presented in **Table 3**.

Table 4 showed significant association between DSI≤0 and non-survived subjects (RR 1.9, 95%CI:1.2-2.9; p=0.004). Analysis of survival showed median survival time of DSI>0 group was 7 days while DSI≤0 group was 5 days, with log-rank 0.03 (**Figure 1**). Multivariate analysis of DSI, age, and nutritional status were performed. DSI≤0 was significantly associated with mortality (p=0.037; hazard ratio 1.895, 95%CI:0.989-3.624). Age was significantly associated with mortality (p=0.015; hazard ratio 0.988, 95%CI:0.979-0.997). Nutritional status was not significantly associated with mortality (p=0.12; hazard ratio 0.732, 95%CI:0.498-1.091) (**Table 5**).

Discussion

Shock is a life-threatening state that occurs when the oxygen and nutrient delivery is insufficient to meet tissue metabolic demands. (1) During the shock state, the body's compensatory mechanisms attempt to maintain vital organ function. The progression of the shock state is commonly divided into three phases: compensated, uncompensated, and irreversible shock. During compensated shock, oxygen delivery to the brain, heart, and kidney is maintained at the expense of less vital organ. In compensated shock phase, there is an increment in heart rate and systemic vascular resistant to maintain a normal cardiac output and normal blood pressure. (10) As shock progresses to the uncompensated phases, the body's compensatory mechanisms cannot maintain normal hemodynamic body. It results in a decrease in cardiac output and blood pressure. (1,10) The irreversible state of shock implies irreversible organ injury, especially of the vital organs such as the brain, heart, and kidneys. (1,2,10) In conventional shock, vital signs (heart rate and blood pressure) are commonly measured to evaluate hemodynamic stability and response to resuscitation. (11)

This study obtained a decline of heart rate at hour 6 in DSI>0 group, but no significant decline in DSI≤0 group. Rousseaux in 2013 found significant decline of heart rate in survival patients diagnosed with septic shock at hour 0 compared to hour 6, but no significant relationship was found between heart rate and outcome. (9) The heart rate is notoriously labile in response to a variety of internal and external stimuli, but the presence of tachycardia is generally regarded as an early warning sign in the setting of shock. (12)

Allgower and Buri in 1960, for the first time, introduced the SI, the ratio of heart rate to systolic blood pressure as a parameter of hemodynamic. Studies in adults demonstrated that the value of the initial SI and the increase in value of SI more than 0.9 was associated with cardiac dysfunction, tissue hypoxia, and increased mortality. (4)

This study obtained that on hour 0, SI in DSI≤0 group was lower than in DSI>0 group (1.8 vs 2.2, respectively). This was similar to the study from Yasaka et al. in 2013, that higher SI was associated with increased risk of mortality in children with septic shock. Nevertheless, Yasaka et al. did not get clear SI cutoff point. The potential reason was due to the wide range of normal vital signs depending on ages that led to wide SI range. (3)

Pediatric index of mortality (PIM) II is a scoring tool to predict mortality among children admitted to PICU. PIM II≥30% is associated with increased risk of mortality in PICU patients. (12,13) Our study obtained that PIM II in DSI≤0 group was higher than in DSI>0 group. This result might show that DSI≤0 group had higher mortality risk compared to DSI>0 group, but further investigation is needed.

Resuscitation is an early procedure in shock condition to normalize hemodynamic system which is marked by the improvement in hemodynamic parameters. (1,2) The achievement of therapeutic targets at 6 hours after shock resuscitation was associated with survival improvement. (3) DSI was SI at hour 0 minus SI at hour 6. In this study, DSI≤0 showed significant association with mortality in pediatric patients with shock. Yasaka et al. in 2013 found that DSI was not related to mortality in children with shock, but a reduction of SI within 6 hours after intensive care admission was an additional tool to assess the responsiveness of resuscitation therapy. (3) Joseph et al. in 2015 found that positive DSI (the first SI measurement was higher than the second one) was significantly associated with shock, hypovolemia, and ongoing hemorrhages in adult trauma patients. This was evident with higher hazard of death, complications, and need for exploratory laparotomy in patients with positive DSI. (11)

The limitation of our study was that we did not perform analysis on underlying diseases that might involve multi organ system, which may also take a role on mortality.

Conclusion

DSI≤0 was significantly associated with mortality in children with shock.

Table 1. Subject characteristics

Characteristics	DSI	
	≤0 (n=40)	>0 (n=40)
Age (months), median (range)	19.5 (1-142)	46.5 (1-136)
Gender (male), n (%)	22 (55)	18 (45)
Body weight (kg), median (range)	10 (2.4-65)	16.5 (4.4-60)
Height (cm), median (range)	89 (47-159)	105 (49-154)
Nutritional status, n (%)		
Obese	5 (12.5)	5 (12.5)
Overweight	0 (0)	8 (20)
Normal	21 (52.5)	20 (50)
Underweight	11 (27.5)	7 (17.5)
Severe malnutrition	3 (7.5)	0 (0)
Length of stay (days), median (range)	4 (1-12)	4 (1-22)
PIM II scores, n (%)		
≥30%	16 (40)	7 (17.5)
<30%	24 (60)	33 (82.5)
The use of inotropic or vasoactive, n (%)		
Yes	27 (67.5)	17 (42.5)
No	13 (32.5)	23 (57.5)
Inotropic and vasoactive type, n (%)		
Dopamine	2 (6.5)	29 (93.5)
Dobutamine	1 (7.7)	12 (92.3)
Epinephrine	1 (2.2)	25 (96.2)

Table 2. Underlying diseases

Underlying diseases, n (%)	DSI	
	≤0 (n=40)	>0 (n=40)
Septic shock	23 (57.5)	13 (32.5)
Dengue shock syndrome	17 (42.5)	29 (72.5)
Pneumonia	12 (30)	3 (7.5)
Acute respiratory distress syndrome	8 (20)	3 (7.5)
Electrolyte imbalance	18 (45)	15 (37.5)
Peritonitis	1 (2.5)	0 (0)
Acute diarrhea with severe dehydration	4 (9.1)	10 (90.9)
Disseminated intravascular coagulopathy	5 (12.5)	8 (20)
Acute kidney injury	5 (12.5)	4 (10)
Liver failure	1 (2.5)	0 (0)
Intracranial bleeding	2 (5)	0 (0)
Intracranial infection	3 (7.5)	3 (7.5)

Table 3. Heart rate and systolic blood pressure

	DSI	
	≤0 (n=40)	>0 (n=40)
Heart rate (beats/minute), median (range)		
Hour 0	150 (90-185)	139 (102-218)
Hour 1	150 (80-180)	127 (90-200)
Hour 2	150 (86-170)	121 (84-190)
Hour 3	140 (80-180)	113 (75-190)
Hour 4	147 (81-180)	111 (75-190)
Hour 5	142 (88-180)	109 (80-190)
Hour 6	150 (90-185)	104 (76-190)
Systolic blood pressure (mmHg), median (range)		
Hour 0	80 (50-120)	68 (40-104)
Hour 1	80 (50-110)	80 (50-115)
Hour 2	80 (50-110)	85 (50-125)
Hour 3	80 (50-110)	90 (50-120)
Hour 4	80 (50-110)	95 (50-118)
Hour 5	80 (50-110)	100 (60-120)
Hour 6	70 (44-110)	100 (60-120)
SI, median (range)		
Hour 0	1.8 (0.9-3.4)	2.2 (1.1-4.5)
Hour 1	1.9 (0.9-3.4)	1.7 (0.8-3.6)
Hour 2	1.9 (0.9-3.2)	1.4 (0.7-3.2)
Hour 3	1.8 (0.8-3.4)	1.3 (0.6-3.6)
Hour 4	1.9 (0.8-3.2)	1.1 (0.7-3)
Hour 5	1.8 (0.8-3.2)	1 (0.8-2.7)
Hour 6	2 (0.9-3.4)	0.9 (0.8-3.2)

Table 4. Association of DSI and mortality

		Outcomes				RR	95%CI	p*
		Not survived		Survived				
		n	%	n	%			
DSI	≤0	28	70	12	30	1.9	1.2-2.9	0.004
	>0	15	37.5	25	62.5			
Total		43	53.8	37	46.3			

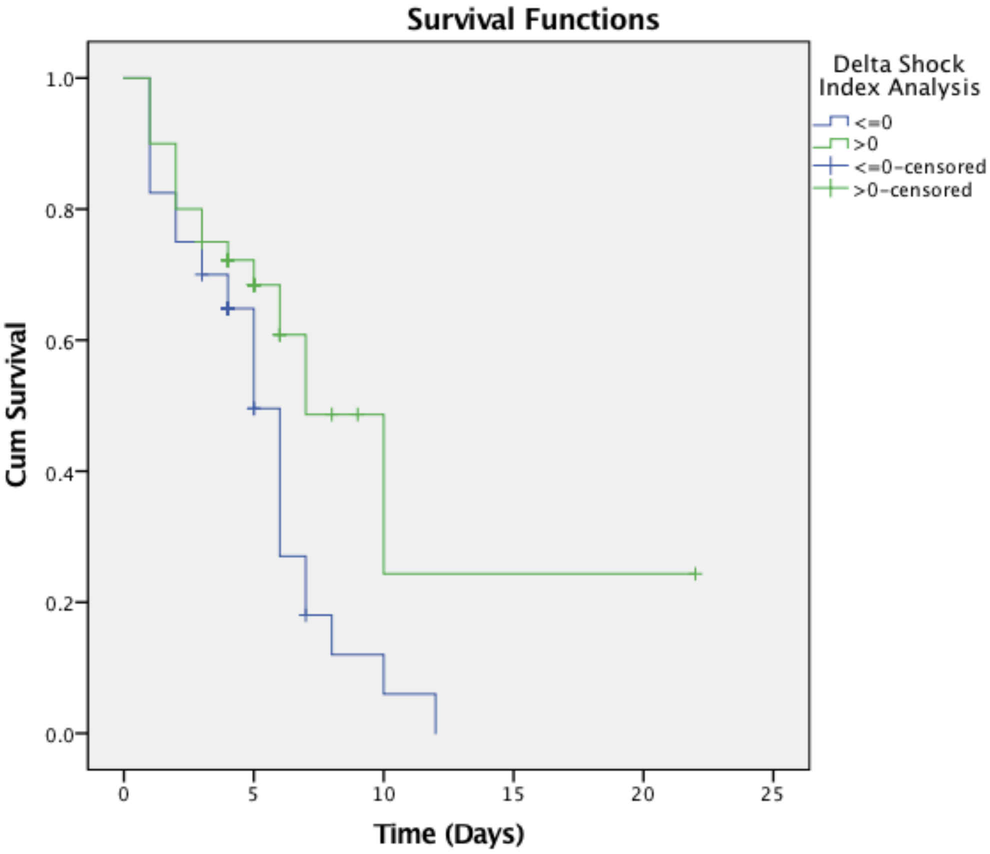
Legend: *=using Chi-square test; CI=confidence interval; RR=relative risk

Table 5. Multivariate analysis

Variables	HR	95%CI	p*
DSI≤0	1.895	0.989-3.634	0.037
Age	0.988	0.979-0.997	0.015
Nutritional status	0.732	0.498-1.091	0.120

Legend: *=using Cox regression test; CI=confidence interval; HR=hazard ratio

Figure 1. Kaplan-Meier survival analysis



References

1. Yager P, Noviski N. Shock. Pediatrics in review. 2010;31:311-8.
2. Mackway-Jones K. The child in shock. In: Mackway-Jones K, Molyneux E, Philips B, Wieteska S, editors. Advanced Paediatric Life Support: The Practical Approach. 4th ed. Manchester: Blackwell Publishing; 2005.
3. Yasaka Y, Khemani RG, Markovits BP. Is shock index associated with outcome in children with sepsis/septic shock? Pediatr Crit Care Med 2013;14:e372-9.
4. Allgower M, Buri C. Shock index. Dtsch Med WochenschrI. 1967;46:1-10.
5. Rady MY, Nightingale P, Little RA, Edwards JD. Shock index: a re-evaluation in acute circulatory failure. Resuscitation. 1992;23:227-34.
6. Rady MY, Smithline HA, Blake H, Nowak R, Rivers E. A comparison of the shock index and conventional vital signs to identify acute, critical illness in the emergency department. Ann Emerg Med 1994;24: 685-90.
7. Danusantoso MM, Pudjiadi AH, Djer MM, Widodo DP, Kaban RK, Andriastuti M. Pengukuran indeks syok untuk deteksi dini syok hipovolemik pada anak dengan takikardia: telaah terhadap perubahan indeks isi sekuncup. Sari Pediatri 2014;15:319-20.
8. Acker SN, Ross JT, Partrick DA, Tong S, Bensard DD. Pediatric specific shock index accurately identifies severely injured children. Journal of Pediatric Surgery. 2015;50:331-4.
9. Rousseaux J, Grandbastein B, Dorkenoo A, Lampin ME, Leteuetre S, Leclerc F. Prognostic value of shock index in children with septic shock. Pedatr Emer Care. 2013;29:1055-9.
10. Wheeler DS, Basu RK. Pediatric shock: an overview. The Open Pediatric Medicine Journal. 2013;7:2-9.
11. Joseph B, Haider A, Ibraheem K, Kulvatunyou N, Tang A, Azim A, et al. Revitalizing vital signs: the role of delta shock index. Shock 2016;46:50-4.
12. Imamura T, Nakagawa S, Goldman RD, Fujiwara T. Validation of pediatric index of mortality 2 (PIM2) in a single pediatric intensive care unit in Japan. Intensive Care Med. 2012;38:649-54.
13. Qureshi AU, Ali AS, Ahmad TM. Comparison of three prognostic scores (Prism, Pelod, and PIM 2) at pediatric intensive care unit under Pakistani circumstances. J Ayub Med Coll Abbottabad.2007;19:49-53.