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Electrical cardiometry for non-invasive cardiac output monitoring in children with dengue hemorrhagic fever and shock in comparison between referral and non-referral

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Abstract

***Objective*: Shock in dengue hemorrhagic fever (DHF) is mostly caused by plasma leakage. Hemodynamic monitoring is essential for improving the quality of management and the outcome. We sought to find the hemodynamic profile of dengue hemorrhagic fever children with shock.**

***Design*: a cohort prospective study.**

***Setting*: Pediatric Intensive Care Unit (PICU) at tertiary general hospital in Surabaya, Indonesia.**

***Patients and participants*: Children <18-year-old admitted to the PICU with diagnosis DHF with shock.**

***Intervention*: All patients underwent measurement of hemodynamic profile with electrical cardiometry ICON Osypka™ after the first fluid resuscitation.**

***Measurements and results*: There were 37 patients with DHF grade 3. All patients had normal blood pressure on first examination, with the mean of systolic and diastolic blood pressure were 82.5±9.21 mmHg and 51.8±16.32 mmHg, respectively. They had low stroke volume (66.7%), high heart rate (60.6%), low cardiac output (49%), and high systemic vascular resistance (55%). Mean resuscitation fluid volume was 35.30±31.99 ml/kg, where referral patient had significantly higher resuscitation fluid volume (49.45±39.46 ml/kg) than non-referral (19.75±0.60 ml/kg), p=0.002. Thoracic fluid content were significantly higher in referral (75%) than those in non-referral patients (16.7%), p=0.001.**

***Conclusion*: After first fluid resuscitation, children with DHF grade 3 obtained normal blood pressure but still in hypovolemic state. Referral patients had higher fluid volume resuscitation and thoracic fluid content than those in non-referral.**

Key words: Hemodynamic profile, DHF, electrical cardiometry, referral, non-referral.

Introduction

Dengue viral infection is one of the leading cause of infectious disease in children, 18 cases in 100,000 person-year, with fatality rate of 0.73%. (1) Mortality in dengue is highly associated with shock syndrome. Increased vascular permeability, together with myocardial dysfunction and dehydration, contribute to development of shock, with resultant multiorgan failure. (2)

The hallmark of dengue hemorrhagic fever (DHF) is the increased vascular permeability resulting in plasma leakage, contracted intravascular volume, and shock in severe cases. (3) The leakage is unique in that there is selective leakage of plasma in the pleural and peritoneal cavities. When fluid is administered too rapidly, acute respiratory distress syndrome could happen in DHF patients with prolonged shock and tissue hypoxia. (4) Another factors associate with overload fluid are referral case, total duration of fluid therapy and total amount of fluid given that not matched between planned and given. (5)

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Hemodynamic or physiologic monitoring plays an important role in diagnosing the type of circulatory shock present based on the pathophysiologic process, enabling proper patient management. (6,7) The primary hemodynamic parameters include heart rate (HR) and blood pressure (BP), while the advanced hemodynamic parameters include stroke volume (SV), cardiac output (CO), and total peripheral resistance (TPR). (6,8) Despite the fact that HR and BP give vital information, however, they do not respond to substantial changes in intravascular volume, e.g. fluid administration or fluid loss, due to their regulated nature frequently. Age and pre-existing cardiovascular morbidity may complicate interpretation of these parameters. In contrast, CO and especially cardiac SV are sensitive to deviations in preload. (9) Recently, non-invasive methods for the evaluation of hemodynamic parameters have been developed, and the results of these techniques are highly correlated with those of invasive methods for determining the type of circulatory shock. (6,10,11) This study was aimed to evaluate hemodynamic profile in dengue shock syndrome and to compare referral and non-referral patients using electrical cardiometry.

Materials and methods

Study design

This cohort prospective study aimed to evaluate hemodynamic profile of DHF children with shock and compare between referral and non-referral.

Electrical cardiometry

An ICON^{TM} (Osypka Medical, Berlin, Germany) was used to record hemodynamic profile, including heart rate, stroke volume, cardiac output, and systemic vascular resistance of patient with dengue shock syndrome on admission in PICU after being resuscitated at emergency department or prior hospital and after the patient have been stabilized.

Patients and sample characteristics

Pediatric patients with DHF and shock admitted to PICU Dr. Soetomo Hospital in period of March to May 2016. This study was approved by the ethics committee of Dr. Soetomo Hospital. Parental written informed consent was obtained prior to data collection.

Data collection and statistics

Total sampling was performed in this study. Inclusion criteria were DHF children with shock and have already got fluid resuscitation for the first time in emergency department or prior hospital. The exclusion criteria were patients with inotropic and non-adequate information on resuscitation. The type of fluid was not considered in this study because of various of fluids that were given to the patients. Descriptive statistic and chi-square analysis were performed using SPSS 21 (SPSS Inc., Chicago, Illinois).

Results

There were 42 cases of DHF with shock in children admitted to PICU Dr. Soetomo Hospital during March to May 2016. Five cases of DHF grade 4 and 37 cases of DHF grade 3, in which 5 cases of DHF grade 4 were excluded. Thirty-seven patients were enrolled in this study where 17 patients were referral and 20 patients were non-referral. Baseline characteristics of patients were male (19 patients) and female (18 patients), preschool and school age was most prevalent, and most of patients have normal nutritional status (**Table 1**).

Following fluid resuscitation in emergency department and prior hospital, all patients had good blood pressure, with the mean of systolic and diastolic blood pressure were 82.5±9.21 and 51.8±16.32 mmHg, respectively. However, hemodynamic profile on admission in PICU as assessed by electrical cardiometry, showed that most of patients still experienced high heart rate, low stroke volume, low cardiac output, high systemic vascular resistance, and high in thoracic fluid content (**Table 2**).

There were no differences in hemodynamic profile between referral and non-referral patients, except for thoracic fluid content, where referral patients had higher thoracic fluid content than non-referral (**Table 3**). Accordingly, the resuscitation fluid volume was statistically significant between referral and non-referral patients i.e. 49.45±39.46 and 19.75±0.60 ml/kgBW, respectively (p=0.002).

After the patients have been stabilized in PICU, the hemodynamic profile in most patients showed normal heart rate, stroke volume, cardiac output, and systemic vascular resistance, but their thoracic fluid content was still high (**Table 4**). No differences in hemodynamic profile between referral and non-referral patients, although referral patient had higher thoracic fluid content than non-referral (**Table 5**).

Discussion

Hemodynamic profile monitoring in dengue hemorraghic fever should not be based on classic hemodynamic parameter such as blood pressure. This study revealed that the blood pressure of patients was better after they had first fluid resuscitation. However, electrical cardiometry showed that these

patients were still in hypovolemic state. Normal blood pressure should not be solely value in assessing hemodynamic status in dengue hemorraghic fever. Measures of tissue perfusion, fluid balance, and capillary leak may be required. This possible using the emerging non-invasive technology such as electrical cardiometry that is able to indicate changes in cardiovascular status. These parameters are important as measures for a more proper fluid management in dengue hemorraghic fever. Goal of therapy in dengue shock is different from that in septic shock, as the physiologic and homeostatic context of the cardiovascular system is distinct in these two syndromes. (12)

When the patients admitted to the PICU, they received fluid resuscitation and their hemodynamic was good. Referral patients had higher fluid resuscitation volume than non-referral. However, according to the study result from all hemodynamic profile in dengue patient only thoracic fluid content that influenced by the fluid resuscitation volume. Higher fluid resuscitation volume will result in higher thoracic fluid content, that led to higher risk of overload. This is because of plasma leakage in dengue hemorraghic fever. If dengue progresses into shock, caused by fluid leakage, management should be in an intensive care setting with the ultimate goal is to maintain tissue perfusion. Intensive care protocols such as surviving sepsis bundles will often be applied, but should be tempered by recognition of the different context of fluid shifts in dengue compared with septic shock. (13)

After patients have been stabilized and through the acute phase, their hemodynamic profile was assessed by electrical cardiometry. Most of patients showed normal heart rate, stroke volume, and systemic vascular resistance. The thoracic fluid content was still high in most of patients. During the time of defervescence, the DHF patients developed localised plasma leakage, manifested as accumulation of fluid in pleural and abdominal cavities and haemoconcentration. The leakage lasted approximately 48 hours and was followed by spontaneous and rapid resolution. The extent of plasma leakage was varie between individuals and might lead to intravascular volume depletion that requiring fluid resuscitation. In addition, hepatic failure and encephalopathy might develop secondary to prolonged shock. Mortality is usually due to a delay in the recognition and treatment of plasma leakage. (14)

Conclusions

Hemodynamic profile in dengue shock syndrome as assessed by electrical cardiometry showed that plasma leakage had a hallmark sign of hemodynamic disturbance. Aggressive fluid resuscitation would not give benefit except increase in thoracic fluid content. Fluid therapy was wisely aimed to maintain good hemodynamic and perfusion, and not result in overload.

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Table 1. Baseline characteristic of patient

Age (years)	
- 0-5	14
- 6-10	12
- 11-15	8
- >15	3
Sex	
- Male	19
- Female	18
Nutritional status	
- Malnutrition	10
- Normal	22
- Overweight	1
- Obesity	4

Table 2. Hemodynamic profile of patients after first resuscitation

Parameter	Low (%)	Normal (%)	High (%)
HR	0	39.4	60.6
SV	66.7	27.3	6
CO	48.5	39.4	12.1
SVR	6.1	36.4	54.5
TFC	12.1	42.4	45.5

Legend: HR=heart rate; SV=stroke volume; CO=cardiac output; SVR=systemic vascular resistance; TFC=thoracic fluid content.

Table 3. Comparison of hemodynamic profile between referral and non-referral

	High HR (%)	Low SV (%)	Low CO (%)	High SVR (%)	High TFC (%)
Referral	60.0	46.0	33.3	35.7	80.0
Non-referral	72.0	83.3	61.6	72.0	16.7
p value	0.428	0.065	0.324	0.108	0.001

Legend: HR=heart rate; SV=stroke volume; CO=cardiac output; SVR=systemic vascular resistance; TFC=thoracic fluid content.

Table 4. Hemodynamic profile of patients after stabilization

Parameter	Low (%)	Normal (%)	High (%)
HR	6.25	62.5	31.25
SV	43.8	50	0
CO	43.8	50	6.2
SVR	0	50	50
TFC	12.5	31.25	56.25

Legend: HR=heart rate; SV=stroke volume; CO=cardiac output; SVR=systemic vascular resistance; TFC=thoracic fluid content.

Table 5. Comparison of hemodynamic profile between referral and non-referral after stabilization

	HR (%)			SV (%)			CO (%)			SVR (%)			TFC (%)		
	L	N	H	L	N	H	L	N	H	L	N	H	L	N	H
Referral	11	56	33	33	56	11	44	44	12	0	56	44	0	25	75
Non-referral	0	71	29	71	29	0	57	43	0	0	57	43	0	57	43
p value	0.617			0.276			0.635			0.614			0.031		

Legend: HR=heart rate; SV=stroke volume; CO=cardiac output; SVR=systemic vascular resistance; TFC=thoracic fluid content; L=low; N=normal; H=high.

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