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ULTRASONOGRAPHIC ABDOMINAL AORTA DIAMETER CHANGES: A PREDICTOR OF HYPOVOLEMIC SHOCK CLASS 1

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ABSTRACT

Hypovolemic shock class 1 and mild to moderate dehydration are associated with normal or minimal changes in vital signs. Biochemical values markedly change only in advanced hypovolemia. Inspiration and expiration inferior vena cava diameter changes predict hypovolemic shock class 1 but in acute emergencies this method is impractical. The purpose of this study is to develop a new approach in identifying hypovolemic shock at early phase (class 1 hypovolemic shock) by measuring the diameter of aorta using ultrasound machine.

Key words: Hypovolemic shock class 1; aortic diameter changes

1. INTRODUCTION

Hypovolemia or loss of body fluids is a frequent clinical situation in critical care area or centres such as emergency department and intensive care unit. Hypovolemic shock may be caused by dehydration from diarrhoea, vomiting and environmental loss, or by rapid and substantial loss of blood from acute haemorrhage [1]. Immediate and early trauma deaths are determined by severe primary brain injuries or hypovolemia secondary to either blunt or penetrating injuries [2,3].

In trauma, rapid blood loss is the predominant cause of acute intravascular volume loss requiring aggressive fluid resuscitation. Significant loss of intravascular volume results in a reduction of systemic venous return causing reduction in the stroke volume and left ventricular filling, which is responsible for decreased cardiac output. Subsequent to the low cardiac output will be hemodynamic instability, decreases tissue perfusion, cellular hypoxia, multiple organ damage or dysfunction, shock and death [3,4].

In the absence of clinical context highly suggestive of hypovolemia (such as shock with external bleeding), the presence of documented hypotension, tachycardia or signs of tissue hypoperfusion are not sufficient to confirm the diagnosis of hypovolemia, as they are non specific. Conversely, the presence of satisfactory blood pressure with peripheral oedema does not exclude the potential benefit of volume expansion [5,6].

Laboratory parameters; commonly observed are functional renal insufficiency and hyperlactatemia; are not absolutely specific and can be present in other form of shock. Similarly, metabolic acidosis, high urea level and haemoconcentration are neither sensitive nor specific. Thus, the above parameters should not be relied heavily in clinical approach [7].

The Advance Trauma Life Support (ATLS) Manual classified hypovolemic shock into four classes. Class 1 and class 2 hypovolemic shock are referred to as compensated shock in which the adrenergic state maintains the normal blood pressure. The passage from compensated shock to decompensated shock (class 3 and 4) hypovolemic shock may occur rapidly, particularly in children and young adults. It is crucial to recognize compensated shock and intervene as early as possible [5].

It is of the essence for the physicians to detect early hypovolemic shock, identify the source of bleeding and institute early intervention including fluid resuscitation and surgical referral. The uncertainty of the initial state of hypovolemic shock may result in potentially inappropriate fluid resuscitation, either too little or too much. Unfortunately, in class 1 hypovolemic shock and mild to moderate dehydration, there are minimal changes with regards to the blood pressure, heart rate, pulse pressure and capillary refill time.

The purpose of this study is to develop a new approach in identifying hypovolemic shock at early phase (class 1 hypovolemic shock) by measuring the diameter of aorta (Ao) using ultrasound machine. We hypothesized that there is a significant mean difference of pre and post Ao diameter ratio among patients with hypovolemic shock class 1.

2. METHODS AND MATERIALS

This prospective observational study was conducted on 52 volunteers who came to the Blood Bank for blood

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The purpose of this study is to develop a new approach in identifying hypovolemic shock at early phase (class 1 hypovolemic shock) by measuring the diameter of aorta (Ao) using ultrasound machine. We hypothesized that there is a significant mean difference of pre and post Ao diameter ratio among patients with hypovolemic shock class 1.

2. METHODS AND MATERIALS

This prospective observational study was conducted on 52 volunteers who came to the Blood Bank for blood donations. Blood donors were identified by the blood bank staff, and all the necessary test were done according to the Blood Bank protocol. Subject's inclusion criteria include: age between 18 to 55 years old, weight more than 45 kg, no medical illness, not on any medications, and were able to understand and to give informed consent. Subject's exclusion criteria include: patient requiring rehydration immediately during or post blood donation, previous surgery or recipients of blood transfusion within 6 months, donor with high risk behaviour such as multiple sex partners or sharing of needle and also sex workers. Ethical Human Committee of Universiti Sains Malaysia approved the study. Permission was granted from Hospital Director and Head Department of Blood Bank of Hospital Universiti Sains Malaysia.

We applied the Central Limit Theorem (a sum of many independent and identically distributed random variables, or alternatively, random variables with specific types of dependence, will tend to be distributed according to one of a small set of attractor distributions) to determine the sample size. Therefore, the minimum number of sample size that required for this study was 30 subjects. In order to achieve experimental diversification, participants were identified by purposive selection.

The ultrasound examination was performed by the researcher who was familiar with the ultrasound machine. The researcher has obtained necessary testimonial validation by a consultant radiologist. Further validation assessment with Spearmen's rank correlation coefficient revealed a positive and significant correlation between the researcher and the radiologist score.

Upon counselling and taking informed consent, researcher measured and recorded patient's vital signs, height and weight and Ao diameter. Donors then donated 450 mls of their blood. Similar measurements were repeated and recorded post donation. Estimated time gap post donation and the time of second measurement were within 30 minutes.

The ultrasound measurement was carried out in supine position by the researcher. We used ultrasound machine of Premium Hand-Carried Colour Doppler Diagnostic Mindray Model M5 and curvilinear probe 3.5 to 5 MHz with B mode scan to measure the aortic diameter. The probe was placed underneath the xiphoid process in a longitudinal position. The Abdominal Aortic diameter was taken at 10 mm above the celiac trunk. Three readings were measured and recorded during pre and post blood donation (Figure 1 and 2).

All data were analysed with Statistical Package for Social Sciences software version 18.0. Descriptive statistical evaluation was used to analyse the demographic information such as age, race, gender, weight and height which will also be recorded, apart from Body Mass Index (BMI) value. The observed primary outcome was the difference of Ao diameter pre and post blood donation. The significance of mean difference was analysed with Paired T Test. Numerical variables were checked for normality and presented as mean and standard deviation. The significant level (p value) was set at 0.05.

Figure 1: Ultrasound of Aorta pre donation

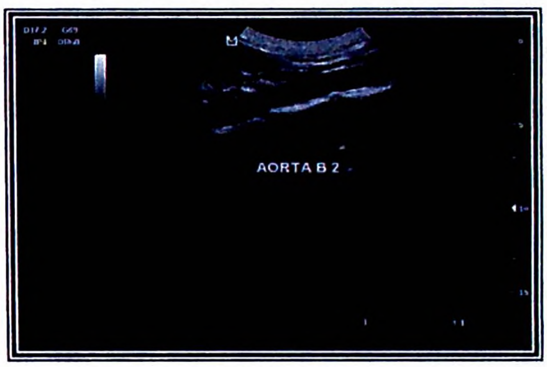

Figure 2: Ultrasound of Aorta post donation

3. RESULTS

Fifty two donors were eligible for the study. Their mean age, weight, height and body mass index were 37.64 ± 10.82 years, 72.84 ± 13.80 kg, 1.66 ± 0.09 meter (m) and 26.53 ± 5.7 kg/m^2 respectively.

The mean pre and post systolic blood pressure was 132.77 ± 11.99 mmHg and 129 ± 13.45 mmHg respectively. The mean pre and post diastolic blood pressure was 76.71 ± 8.27 mmHg and 74.94 ± 10.83 mmHg respectively.

The mean pre and post heart rate was 74.29 ± 9.95 per minute and 69.23 ± 9.92 per minute respectively. Paired T test analysis revealed no significance changes between pre and post vital signs except for the heart rate (Table 1).

The mean diameter of Ao pre and post donation was 1.46 ± 0.15 cm and 1.41 ± 0.18 cm respectively. Paired T test analysis revealed significance mean difference between pre and post Ao diameter (Table 2). There was statistically significant mean difference of Ao diameter pre and post blood donation aorta ($p < 0.05$; 95% CI= 0.50 [0.02, 0.08]).

Table 1: Paired T Test for Vital Signs

	Mean (95% CI)	t	df	P value
Systolic Pre-Post	3.67(0.32, 7.67)	1.845	51	0.07
Diastolic Pre-Post	1.77(0.59, 4.13)	1.507	51	0.14
HR Pre-Post	5.06(2.96, 7.16)	4.839	51	<0.05
SI Pre-Post	0.02(0.00-0.04)	1.974	51	0.05

Table 2: Paired T Test for Ao diameter

	Mean (95% CI)	t	df	P value
Pre Aorta – Post Aorta	0.50 (0.02,0.08)	2.9	51	<0.05

4. DISCUSSION

The ability of physicians to differentiate hypovolemic shock with the other types of shock will facilitate the initial management and resuscitation without the need to endeavour into much complicated and invasive procedures. The greatest challenge for physicians in the management of trauma is to identify those victims with hypovolemic shock class 1 as the parameter of vital signs is within the normal range.

Traditionally, vital signs have been used as a marker or indicator of hemodynamic instability. The Advanced Trauma Life Support (ATLS) guideline for hypovolemic shock classification, which has the stepwise vital sign classification, has been used widely in order to facilitate clinician evaluating hydration or volemia status [8]. However, this classification is unreferenced and there is no evidence to fully support this classification [9].

The changes in heart rate has been postulated and described as among the earlier changes in hypovolemia .The ATLS guideline enlisted the increment in heart rate as early as in class 2 shock with 15-30% of fluid loss [8]. Our study revealed among all the vital signs, i.e. systolic blood pressure, diastolic blood pressure and heart rate, only the heart rate demonstrated a significant mean reduction between pre and post blood donation. However, there were no significant mean changes in shock index (the ratio between heart rate and systolic blood pressure) pre and post blood donation.

In contrast to old believe that bradycardia indicates pre terminal and irreversible state or approaching class 4 hypovolemic shock, Secher and Bie (1985) proved the occurrence of bradycardia instead of tachycardia in earlier phase of shock [10]. We postulate that this condition occurs due to few physiologic explanations. As noted in the methodology, the vital signs measurements were done immediately after the blood donation. We postulate that the effect of vagal reflex during intravenous needle insertion still persisted until the time of measurement done, hence the bradycardia.

Biochemical or metabolic markers evaluation can identify occult hypoperfusion, which is defined as inadequate organ or tissue perfusion in the presence of normal or relatively normal vital signs. Those markers include bicarbonate, central venous oxygen saturation, base deficit, and lactic acidosis. Inadequate perfusion leads to anaerobic metabolism in cells, generating lactic acid and other acidic by-product. Unfortunately, the markers do not predict hypovolemic shock class 1 [7].

A study on the difference of Inferior Vena Cava (IVC) diameter in relation to respiratory cycle pre and post blood donation (hypovolemic shock class 1) demonstrated a statistically significant mean difference of IVC diameter changes. The changes of the IVC diameter were very well explained with the nature of the structural wall of the vessel - highly compliant with good sensitivity to changes in intravascular volume. The changes of IVC diameter was demonstrated even before there were any grossly detectable changes in vital signs [11]. However, there was disagreement among researchers regarding the difference of changes in the ratio between the IVC diameter during inspiration and expiration (IVC_i/IVC_e). Moreover, in emergency situation measuring the inspiratory and expiratory IVC diameter is impractical [12,13].

There are very limited studies on assessment the aorta diameter in detail, in relation to the level of fluid loss. An experimental study was done on 7 yorkshire pigs who underwent laparatomy [14]. The study demonstrated gradual changes of aorta diameter with increasing fluid loss from 10 to 40%. They observed that during blood loss, the aortic diameter, which was measured directly after laparatomy, gradually decreased in all subjects at the level of ascending, descending and abdominal aorta with the largest decrement in descending aorta of 38 % after 40 % blood loss. The descending aorta diameter decreases with 1.18 mm or 8.1% every time the animal losses about 10% of its blood volume [14]. The main limitation of their study was the relatively small sample size.

In our study, pre donation Ao diameter ranged from 12.3 mm to 18.9 mm (mean = 14.6 mm). The range of Ao diameter of studied subjects (Kelantan population) was smaller than those found from Pederson study (21 cm in men and 19 mm in women of normal population) [15]. This could be attributable to smaller physical size of Asian population. Sonesson et al. (1993) and Pederson et al. (1993) established the correlation between age, gender, body habitus and aortic diameter [15,16].

Our study demonstrated that the post donation Ao diameter ranged from 12.2 to 18.4 mm (mean = 14.1 mm). Interestingly, there was a statistically significant mean difference of Ao diameter between pre and post donation. The probable explanation for these changes was the release of endogenous vasoconstrictors and the direct effect of volume reduction itself. We hypothesize that in trauma, in which the production of various cytokines and other biochemical substances are overwhelming, the changes would be more marked due to earlier release of the substances. In a nutshell, the changes of Ao diameter predict the presence of hypovolemic shock class 1.

5. CONCLUSION

The routine usage of ultrasound in trauma - Focused Assessment with Sonography in Trauma (FAST), which was incorporated as an adjunct to primary survey and resuscitation in ATLS manual, has made the presence of the machine in critical area as a must. We suggest that the FAST should also include the assessment of IVC and Ao diameter as part of the assessment of hypovolemia post trauma.

6. FUTURE WORKS

Due to social reason and the feasibility of the place, only male population was involved in the study. Therefore, it does not depict the overall accurate changes in general population. In the future study, the researches should study the normal calibre of aortic diameter among healthy population including female and other races. Furthermore, a study on the disease population should be carried to evaluate the accuracy and the feasibility of this method in assessing hypovolumic shock class 1.

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