Ultrasonography Measurement of Inferior Vena Cava Diameter of Blood Donors As Predictors for Early Blood Loss in Tertiary Hospital Northeastern, Malaysia

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SUMMARY

According to the class of hypovolaemic shock, a blood loss less than 750 ml is not associated with the physiological changes. As a result it may cause a delay in fluid resuscitation. We postulate inferior vena cava (IVC) diameter reduction in inspiration and expiration may resemble the significant volume of blood loss in a healthy adult. We conducted a study to examine the changes of the IVC diameter pre and post blood donation.The inferior vena cava diameter during inspiration (IVCi) and expiration (IVCe) were measured using ultrasound (GE HEALTH) in supine position before and after blood donation of 450 ml. Paired t-test and Wilcoxin rank test were used to analyse the data. Forty two blood donors enrolled during the study period. The mean age of blood donors was 32.3 +/- 8.9 and mainly male blood donors. The mean IVCe of pre and post blood donation was 18.5 +/- 6.2 mm (95%CI 18.23, 18.74) and 16.6 +/- 6.6 mm (95%CI 16.35, 16.76) respectively. Meanwhile, the mean IVCi of pre and post blood donation was 17.1 +/- 8.6 mm (95%CI 16.89,17.30) and 15.6 +/- 6.6 mm (95%CI 15.43,15.81) respectively. The mean difference of IVCe pre and post blood donation was 1.9 +/- 0.5 mm (95%CI 1.75, 2.13) (p<0.001). In contrast, the mean difference of IVCi pre and post blood donation was 1.5 +/- 0.5 mm (95%CI 1.34, 1.68) (p<0.001). As a conclusion, the measurement of IVC diameter by ultrasound can predict the volume of blood loss in simulated type 1 hypovolaemia patient.

KEY WORDS:
Ultrasound, Inferior Vena Cava diameter, hypovolaemic shock

INTRODUCTION

Shock is a clinical condition that can arise from multiple etiologies such as trauma, dehydration, excessive fluid extraction post dialysis, burns, ruptured ectopic tubal pregnancy and many others. In trauma for example, it's very difficult to determine the amount of blood loss since there is no tool to assess the ongoing blood loss contrast to any open wound or soaked gauze which we can approximate the blood loss[1]. Seriously injured patient or with altered sensorium combine with lack of history will lead to irregularity of the physical examination and laboratory evaluation. All these unreliability leads to potentially misdiagnosed and inappropriate resuscitation.

Physical examination and vital sign in shock especially in trauma patient were unreliable and masked by many other factors. The blood pressure is an unreliable indicator of blood loss unless in the extreme shock[1]. The neurohormonal response is also inaccurate during hemorrhagic shock, especially in elderly due to cardiopulmonary status and usage of drugs or medication[2]. Proper examination and diagnosis in critically injured patient are difficult due to inability to obtain any history pertaining to the injuries especially if the condition worsens. The intra abdominal injury which is characterized by abdominal tenderness, distension may not present in the early stage of the management[3]. Laboratory parameters were also unreliable as the routine haemoglobin level does not change or decreases until after the mobilization of extra vascular fluid into the blood vessels to compensate for blood loss[4].

Many studies have been done on the inferior vena cava (IVC) diameter and have shown good correlation to the total blood volume[5]. IVC diameter has a different diameter in various places in human anatomy with no actual diameter recorded for the IVC. A larger study in India on cadavers showed that the average of the diameters differ at the different sites[5-6]. Our study objective is to determine the changes of the inferior vena cava diameter in blood donor as a simulated type 1 hypovolaemic shock with acute blood loss estimated about 450ml per donor.

MATERIALS AND METHODS

A prospective study was conducted on normal healthy blood donors who came to the blood bank for blood donations. A study was carried out in a university hospital which is a tertiary centre. Blood donors were identified by the blood bank staff and all necessary tests were done according to the blood bank criteria. Once donors were eligible for blood donations, the donors then included into the study and written consent was taken from them. Inclusion criteria are similar to the blood donors in university hospital which include adult donor age 18 to 55 years old, weight more than 45kg, no any medical illness and able to understand and to give informed consent. Exclusion criteria's include patient requires rehydration immediately during or post donation, previous surgery or delivery or received blood transfusion within 6 months, donor who is pregnant and breast feeding,

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Table I: Socio-demographic characteristic of respondents

Socio-demographic Variables	Respondents (N = 42)
Age (mean + sd)	32.33 (9.20)
Sex	
Male	42 (100%)
Female	0 (0%)
Race	
Malay	87.7%
Chinese	2.8%
Indian	9.5%

Table II: Inferior Vena Cava mean distribution and standard deviation.

Variable	Mean(sd) (mm)
Pre	
IVCi	18.49 (0.81)
IVCe	17.10 (0.67)
Post	
IVCi	16.55 (0.65)
IVCe	15.62 (0.60)
Difference	
IVCi	1.94 (0.60)
IVCe	1.51 (0.54)

Table III: Paired T test for IVC expiration

	Mean (95%CI)	t	df	p value
pre IVCe-post IVCe	1.94 (1.74,2.12)	20.7	41	<0.001

Table IV: Wilcoxon Signed Ranks Test for IVC during inspiration.

	Mean Rank	z	p value
pre IVCi-post IVCi	21.50	-5.65a	<0.001

a = based on positive rank

donor with high risk behaviour such as multiple sex partners or sharing needles and sex worker.

Each ultrasound examinations were performed by the single researcher who is familiar with ultrasound. The researcher was trained in the principle of the abdominal ultrasound and particularly IVC with hands on demonstration and measurement validation by a Consultant Radiologist in Radiology Department, Universiti Hospital with more than 25 years experience. Using the Spearmen's rank correlation coefficient, there was a significant, positive and excellent correlation between the researcher and the radiologist score (σ =0. 903, p<0.001). Subsequently the researcher performed independent ultrasound measurement of inferior vena cava on the blood donors who agreed to participate in this study.

The ultrasound measurement was carried out once donor was in a comfortable position on the blood donation bed in a supine position. The first measurements of the inferior vena cava were done during inspiration and expiration before the blood donation. Three readings were taken on each inspiration and expiration and the average value were calculated. The second measurements were done immediately after the completion of blood donation. The similar three readings during inspiration and expiration taken post blood donation and average value calculated.

The ultrasound measurement evaluation of the inferior vena cava was performed with a portable ultrasound Micro Convex GE LOGIQ BOOK, GE Health Care Service, USA. A 3.0 - 5.0 MHz curvilinear probe was used. The same model ultrasound was used for training, hands on demonstration and validation by the researcher and a radiologist. The probe with B mode scan placed longitudinally over the subxyphoid area and adjusted till able to see the IVC meeting the right atrium inlet (Figure 1). The inferior vena cava is identified with colour Doppler setting. Inferior vena cava diameter is measured 2cm from the junction of the right atrium inlet, measuring the anterior and posterior wall of IVC wall are well seen parallel to each other (Figure 2). The measurement taken during donor had a deep inspiration (IVCi) and on full expiration (IVCe). Upon visualization of the IVC, the image was frozen and using cine loop the maximal IVC diameter and the minimal IVC diameter is identified and recorded. No technical adjustment done to the ultrasound machine and the patient's position to get the pre donation and post donation IVC measurement, in an attempt to exclude the cofactors. Measurement taken before the blood donation and repeat just after the blood donation.

Statistical analysis

The data recorded from ultrasound examination which includes demographic, vital sign before and after donation were compiled and analysed using SPSS 18.0.1 which was licensed to School of Medicine, Universiti Sains Malaysia. The aim of this study was to evaluate the changes of the IVC diameter in blood donors in correlation with the type 1 hypovolemia. Paired t-test and Wilcoxon Signed Rank test are used to analyse the statistical significance of the mean values of the IVC during inspiration and expiration. P values less than 0.05 is considered to be significant.

RESULTS

There were 42 donors who fulfilled the inclusion criteria during the study time and had an ultrasound of the inferior vena cava diameter performed at the time of blood donation. All donors included in the study. Data from 42 donors were submitted for analysis. All donors were male with mean age 32.3 years (range, 21-54) (Table 1). Mean IVCe measurement before blood donation was 18.49mm (95%CI 18.23,18.74) and after blood donation was 16.55mm (95%CI 16.35,16.76). The mean IVCi before blood donation was 17.09mm (95%CI 16.89,17.30) and after blood donation was 15.62mm (95%CI

Fig. 1 : The position of probe on donor's epigastric region.

15.43,15.81) (Table II). The difference of IVCe before and after blood donation was 1.94mm (95%CI 1.75,2.13) yielding a p<0.001 (Table III). The difference of IVCi before and after blood donation was 1.51mm (95%CI 1.34,1.68) yielding a p<0.001 (Table IV). The mean duration for the blood donations is 5 min 26 seconds. No blood donors suffered from complications of blood donation.No patient excluded from the study.

DISCUSSION

Ultrasound has now become an integral part of emergency medicine and acute critical care. It is routinely used in many ED and trauma centre[7]. In view of the fast expanding of the ultrasound usage and easily available modalities with no radiation involvement, ultrasound has a potential to develop as an early blood loss detector[8]. Ultrasound has become an essential tool as a noninvasive and sensitive diagnostic modality; especially in the part of the emergency physicians (EP) practice particularly in the ED setting[8,9,10].

Vital signs are the first clinical parameters taken during any trauma cases and the most reliable tool till now in resuscitating a trauma victim. These vital signs such as blood pressure and heart rate are unreliable during condition such as trauma and these indicators are not consistent with the acute blood loss unless the shock is irreversible[4]. Quantification of occult blood loss is difficult in cases such as intra abdominal bleeding and unrevealed bleeding for example long bone fractures.

Shock is defined as circulatory insufficiency that creates an imbalance between tissue oxygen supply and oxygen demand which results in global tissue hypo perfusion and

Fig. 2 : Inferior vena measurement measure 2cm from the right atrium.

associated with decrease venous content and metabolic acidosis[10]. Hypovolemic shock usually presents with some physiological changes in large amount of blood loss[11]. Early management of shock is to restore the intravascular fluid volume, sufficient enough to reverse the hypo perfusion and limit regional hypo perfusion, maintaining adequate oxygen carrying capacity so that tissue oxygen delivery meets the critical tissue oxygen demands and limiting ongoing blood loss[12].

In this study, volunteer blood donors had been chosen as the models for trauma patients because the amount of blood withdrawn from the body in this controlled environment was 450ml. It occurs over a brief period and stimulates class 1 haemorrhage in the trauma related blood loss. IVC diameter varies from one individual to another but there are no studies to confirm such finding. IVC is a very good compliance vessel with the distensibility property influenced by the total body water and phases of respiration[13]. The change in the IVC diameter is crucial in determining the blood loss or the ongoing blood loss. The early detection of the changes of the diameter would allow an EP to start early appropriate fluid therapy. This study shared the same finding by the Lyon et al from Medical College of Georgia8. His study revealed a positive correlation between IVC diameter and intravascular volume that has been retrospectively investigated using computed tomography (CT) scan which shows flattened inferior vena cava in massive haemorrhagic patients with intra abdomen injury[14].

This study showed that there was a significant correlation between both changes in IVC on inspiration (IVCi) and IVC on expiration (IVCe) during the blood donation. The mean diameter of the IVCe of 18.5mm before blood donation was slightly bigger than a study carried out by Lyon *et al* about 17.4mm and Ando *et al* 16.7mm[8,15]. In another study by Sefidbakht *et al*, the measured IVCe was far smaller compared to our finding. The IVCe is more accurate and appropriate measurement for trauma related hypovolaemia comparison to IVCi in trauma patient for evaluating for potential haemorrhage. Both IVCe and IVCi measurement would be unreliable if certain pathological conditions were found in trauma patient such as abnormal acid base

balance, severe pain, anxiety and other factors which cause patient to forcefully breathe or irregular respiration that would lead to alteration in IVC diameter[13].

Besides that, a serial measurement was also applicable to further assess the on ongoing blood loss and easily done at bedside without any radiation hazards. Direct measurement of the fluid status via central venous pressure is not readily appropriate in trauma patient and the invasive procedure is not suitable as a routine assessment[18, 19]. The early detection of acute blood loss is becoming more important for diagnostic purpose especially with the development of the newer portable ultrasound device. Yet, in real practice, trauma cases will be managed according to Advanced Trauma Life Support (ATLS) Guidelines whereby the IVC measurement by ultrasound will be performed after completing primary & secondary survey[20]. At this point, the ultrasound may help to determine the fluid status of the patient either to detect volume loss or monitor the body response to fluid therapy.

LIMITATIONS

There were limitations in this study. Firstly, ultrasonographic examination was carried out by a single operator. Therefore the results of this study may be questionable. Multiple operators with good training and validation are necessary to perform a bigger study in view of producing more reliable results. Secondly, the sample of this study was rather small. We need a larger number of donors as a sample, and then it is comparable or even better compared to other designed studies. With a larger sample, we also believe that we can produce the average inferior vena cava diameter to the population of blood donors in Kelantan and subsequently the average diameter of Malaysian inferior vena cava diameter.

CONCLUSION

The early detection of acute blood loss is becoming very challenging and more important for diagnostic and management purposes. There were two clinical implications of this study. First, the IVC diameter changes in this simulated type 1 shock can be used to detect a volume loss even when the blood pressure still remains normal. Secondly, it's given an information of normal values of IVC diameter among our populations as a guide for future research.

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