THE CORRELATION OF BEDSIDE ULTRASOUND INFERIOR VENA CAVA DISTENSIBILITY INDEX WITH PULSE PRESSURE VARIATION AND CENTRAL VENOUS PRESSURE IN VENTILATED SEPSIS PATIENT IN ASSESSING FLUID STATUS IN INTENSIVE CARE UNIT HOSPITAL UNIVERSITI SAINS MALAYSIA

BY

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ABRREVIATIONS

CBV	Central Blood Volume
CI	Caval Index
CO	Cardiac Output
CVP	Central Venous Pressure
CVL	Central Venous Line
DIVC	Disseminated Intravascular Coagulation Cascade
ICU	Intensive Care Unit
IVC	Inferior Vena Cava
IVCd	Inferior Vena Cava Diameter
L	Litre
LV	Left Ventricle
LVDA	Left Ventricular Diastolic Area
MI	Myocardial Infarction
mm	Millimeter
P	Level of significance
PAC	Pulmonary Artery Catheter
PAOP	Pulmonary Artery Occlusion Pressure
PEEP	Positive End Expiratory Pressure

PIP	Peak Inspiratory Pressure
PPV	Pulse Pressure Variation
RA	Right Atrium
r	Correlation coefficient
RV	Right Ventricle
SD	Standard Deviation
SIMV	Synchronize Intermittent Mandatory Ventilator
SVC	Superior Vena Cava
SVV	Stroke Volume Variation
TTI	Transthoracic Echocardiography
TVP	Tekanan Veva Pusat
TPN	Total Parentral Nutrition
VASST	Vassopressin Septic Trial
VTI	Velocity Time Integral

ABSTRACT

THE CORRELATION OF BEDSIDE ULTRASOUND INFERIOR VENA CAVA DISTENSIBILITY INDEX WITH PULSE PRESSURE VARIATION AND CENTRAL VENOUS PRESSURE IN VENTILATED SEPSIS PATIENT IN ASSESSING FLUID STATUS IN INTENSIVE CARE UNIT

Inferior vena cava (IVC) distensibility index, pulse pressure variation (PPV), and central venous pressure (CVP) are known to be important variables in assessing fluid status of critically ill patients. A study showed that CVP is a poor predictor of fluid status. The aim of this study is to determine the relationship between Inferior vena cava (IVC) distensibility index, PPV and CVP with adult ventilated septic Intensive Care Unit (ICU) patients in assessing fluid responsiveness. A cross sectional study was done to 67 ventilated adult sepsis patients admitted to ICU Hospital Universiti Sains Malaysia (HUSM) from April 2014 until November 2014. Inferior vena cava (IVC) distensibility index was measured by bedside ultrasound machine, PPV calculated manually and CVP was directly measured.

There was a fair correlation between Inferior vena cava (IVC) distensibility index and PPV (r= 0.49, p- value <0.001. However there was no significant correlation between Inferior vena cava (IVC) distensibility index and CVP and between PPV and CVP. Therefore, Inferior vena cava (IVC) distensibility index and PPV was useful as a dynamic tool of measurement of fluid responsiveness in critically ill patient.

ABSTRAK

PERKAITAN ANTARA SAIZ INFERIOR VENA CAVA DENGAN TEKANAN VENA PUSAT, PULSE PRESSURE VARIASI DAN BACAAN MESIN BANTUAN HAYAT UNTUK PESAKIT YANG DIJANGKITI KUMAN DALAM MENENTUKAN KADAR CECAIR DALAM BADAN

Variasi dalam inferior vena cava, pulse pressure dan tekanan vena pusat(TVP) adalah faktor faktor penting dalam menentukan kadar cecair pada pesakit pesakit yang mendapat rawatan rapi. Kajian menunjukan tekanan vena pusat tidak lagi meramalkan kadar cecair dalam badan pesakit. Objektif kajian ini adalah untuk menentukan hubungkait antara variasi inferior vena, pulse pressure dan tekanan vena pusat pesakit pesakit dewasa yang dijangkiti kuman di dalam unit rawatan rapi.

Satu kajian keratan lintang telah dijalankan yang melibatkan 67 pesakit yang dijangkiti kuman yang mempunyai tanda tanda seperti suhu badan yang tinggi, peningkatan sel darah putih, pernafasan dan denyutan jantung yang tinggi di unit rawatan rapi Hospital Universiti Sains Malaysia (HUSM) bermula bulan April 2014 hingga November 2014. Variasi dalam saiz inferior vena cava diukur dengan menggunakan mesin ultrasound mudah alih diikuti dengan TVP dan PPV.

Terdapat hubungkait yang sederhana dan significant di antara IVC distensibility index dan PPV dengan (r =0.488, *p* value < 0.001). Walaubagaimanapun, tiada hubungkait significant anatara IVC distensibility index dan PPV dan antara PPV dan CVP. Oleh itu kedua dua cara pengukuran

yang dinamik ini adalah sangat berguna dalam menentukan kadar cecair dalam badan pesakit berbanding pengukuran yang static melalui TVP yang mana tidak menunjukan hubungkait signifikan dengan IVC distensibility index.

THE CORRELATION OF BEDSIDE ULTRASOUND INFERIOR VENA CAVA DISTENSIBILITY INDEX WITH PULSE PRESSURE VARIATION AND CENTRAL VENOUS PRESSURE IN VENTILATED SEPSIS PATIENT IN ASSESSING FLUID STATUS IN INTENSIVE CARE UNIT

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Introduction: Inferior vena cava (IVC) distensibility index, pulse pressure variation (PPV), and central venous pressure (CVP) are known to be important variables in assessing fluid status of critically ill patients. A study showed that CVP is a poor predictor of fluid status.

Objectives: The aim of this study is to determine the relationship between Inferior vena cava (IVC) distensibility index, PPV and CVP with adult ventilated septic Intensive Care Unit (ICU) patients in assessing fluid responsiveness.

Methods: A cross sectional study was done to 67 ventilated adult sepsis patients admitted to ICU Hospital Universiti Sains Malaysia (HUSM) from April 2014 until November 2014. Inferior vena cava (IVC) distensibility index was measured by bedside ultrasound machine, PPV calculated manually and CVP was directly measured.

Results: There was a fair correlation between Inferior vena cava (IVC) distensibility index and PPV (r= 0.49, p- value <0.001. However there was no significant correlation between Inferior vena cava (IVC) distensibility index and CVP and between PPV and CVP.

Conclusion: Therefore, Inferior vena cava (IVC) distensibility index and PPV was useful as a dynamic tool of measurement of fluid responsiveness in critically ill patient.

Prof Madya Mahamarowi Omar: Supervisor

Prof Madya Saedah Ali: Co-Supervisor

CHAPTER 1: INTRODUCTION

Bedside ultrasound is the most common and popular noninvasive study used in Intensive Care Unit (ICU) as well as emergency department for quick assessment of the patient illness. Ultrasound is not only a tool for radiologist or cardiologist , but it is a very important skill which need to be learned and acquired by all doctors nowadays especially those who are working in intensive care unit. One of the usages of the ultrasound that can be used is the ability to measure the size of the inferior vena cava by static or by dynamic measurement. For the past few years, doctors in ICU has incorporated IVC diameter as a part of volume assessment. Together with pulse pressure variation, clinical assessment and hemodynamic parameters, bedside IVC diameter served well as part of diagnosing tool to estimate the fluid status of the patient.

Correct and quick assessment of fluid status and the decision for volume resuscitation is difficult to make clinically especially in critically ill patients such as severe sepsis with underlying compromised renal and myocardial function. In this patient adequate preload is of outmost importance to optimize organ perfusion. A study showed that excessive positive fluid balance in critically ill patient was associated with increased mortality (Hilton & Bellomo, 2012).

Therefore, quick, non invasive and reliable method for assessment of fluid status is important. Bedside ultrasound of inferior vena cava diameter and its variation during respiration was chosen in ICU because of its non invasiveness and less time consuming.

Fluid status can be assessed by static or dynamic parameters. The concept of static parameter is based on the preload of one or both ventricles in which that lower preload increases the probability of response to volume expansion. In other words, fluid resuscitation in hypovolaemia patient will increase the right ventricular end diastolic volume, left ventricular end diastolic volume, stroke volume (SV) and cardiac output (CO) provided that the ventricular compliance is normal. If this concept is hold true, assessing fluid status by static parameter would be a useful tool in guiding decisions for fluid resuscitation.

The examples of static parameters commonly seen in ICU are central venous pressure (CVP), pulmonary artery occlusion pressure (PAOP), and right and left ventricular end diastolic volume size and inferior vena cava (IVC) diameter size. A study showed that CVP and PAOP is a poor predictor of fluid responsiveness (Osman *et al.,* 2007).

In severe hypovolaemia either due to septic shock, hypovolaemic shock or cardiogenic shock, the echocardiograhic evidence is quite obvious. The triad of small left ventricle (LV), kissing LV, and small right ventricle or normal right ventricle is strongly suggestive of severe hypovolaemia. This group of patients they will benefit from fluid resuscitation (Chew, 2012).

The concept of dynamic parameter in ventilated patients is that during positive pressure ventilation, it will increase the intrathoracic pressure hence the transpulmonary pressure (alveolar pressure – pleural pressure). This will result in reduction preload and increase Right ventricular (RV) afterload subsequently reduction of RV stroke volume at the end of insufflations. This will occur only if the ventricles are working on the steep part of the Frank Starling relationship (Levitov *et al.*, 2009).

The examples of dynamic parameters are pulse pressure variation (PPV) which was derived from analysis of arterial pressure waveform, stroke volume variation (SVV), IVC distensibility index, IVC variability index, superior vena cava collapsibility index (SVC), velocity time integral (VTI) and left ventricular diastolic area changes(LVDA) and passive leg raising test interpreted by using SVV. Inferior vena cava was measured by transthoracic echocardiography (TTE).

PPV is defined as the maximum pulse pressure minus the minimum pulse pressure divided by mean of pulse pressure maximum and pulse pressure minimum. If the PPV is more than 13%, it denotes fluid responsiveness. IVC distensibility index is measured by taking the difference between maximum diameter and minimum diameter of inferior vena cava (IVC) divided by minimum diameter of the IVC measured as shown in Figure 1.1. If the value is more than 18%, it is considered as fluid responsiveness (Levitov *et al*., 2009).

IVC variability index is almost similar to IVC distensibility index. The denominator for variability index is the mean of IVC maximum and minimum whereas in IVC distensibility index, the denominator is IVC minimum only. It is considered as fluid responsive if the value is more than 12%. These two indexes must be measured in patient with mechanical ventilation. In spontaneous breathing patient, the measurement is called IVC collapsibility index. IVC collapsibility index is measured by a maximum diameter of IVC minus the minimum diameter of IVC divided by maximum diameter. The value of more than 50% is considered as fluid responsive (Levitov *et al*., 2009).

Meanwhile for superior vena cava collapsibility index (SVC), it is considered as fluid responsive if the value is more than 36%. The velocity time integral (VTI) variation is reported as fluid responsive if the value is more than 20%. Meanwhile, for left ventricular diastolic area changes(LVDA),it is considered as fluid responsive if the value is more than 16% in mechanical ventilated patients (Levitov *et al*., 2009).

Beside those above measurements, passive leg raising test is also one of the dynamic parameter that can be used to assess the fluid status. It must be used with PPV or stroke volume variation (SVV). It can be reliably use for predicting fluid responsiveness in patients who experience spontaneous breathing (Monnet & Teboul, 2008).

Latest guidelines of sepsis defined sepsis as the presence (probable or documented) of infection together with two or more systemic inflammatory reaction syndromes (SIRS). Severe sepsis is defined as a sepsis plus organ dysfunction such as respiratory failure, heart failure, renal failure or tissue hypoperfusion as evidence by high serum lactate, poor urine output and altered mental status (Delinger *et al*., 2012).

Septic shock is defined as sepsis-induced hypotension despite of adequate fluid resuscitation. The type and volume of fluid given was not mentioned. It can be either crystalloid or colloid with the total volume of at least 30 ml per kilogram body weight. Meanwhile, sepsis induced hypotension is defined as a systolic blood pressure less than 90mmHg or mean arterial pressure (MAP) less than 70 mmHg or a systolic blood pressure (SBP) more than 40 mmHg or less than two standard deviations below normal for age in the absence of other causes of hypotension (Delinger *et al*, 2012).

Majority of the admission to ICU is due to severe sepsis. In this type of patient adequate preload is of utmost importance to optimize organ perfusion to prevent multiorgan failure. However, inapropriate fluid infusion may cause acute pulmonary edema as a result of increase hydrostatic pressure and diffuse peripheral edema when the fluid diffuse from intravascular compartment to interstitial compartment.

Other potential side effects of volume expansion are cerebral edema, electrolyte imbalance, disseminated intravascular coagulation (DIVC), allergic reaction and risks of transmission of infectious agents if it involves tranfusions of blood products.

Therefore, quick, non invasive and reliable method for assessment of fluid status is important in order to give appropriate fluid resuscitation.

$$dIVC(\%) = \frac{IVC\ max - IVC\ min}{(IVCmin)} \times 100$$

Figure 1.1: Inferior vena cava distensibility index (dIVC)

CHAPTER 2: LITERATURE REVIEW

2.1 MONITORING FLUID STATUS

2.1.1 Central venous pressure

Central venous pressure is the pressure within the thorax in the superior vena cava (SVC) which can be measured by central venous line (CVL) line placed in the SVC and right atrium (RA) junction and serves as a reasonable surrogate for the corresponding right atrial pressures. This is the most widely used technique to measure intravascular volume in critically ill patients for the past few decades (Singh *et al*., 2011).

Central venous line (CVL) can also be used for other reasons such as for vasoactive drug infusions such as noradrenaline, antibiotic and total parenteral nutrition. CVL was also indicated for difficult peripheral lines such as in cancer patient who underwent chemotheraphy. In operation theatre, CVL might be helpful in management of venous air embolism.

The main sites for central venous cannulation are the internal jugular vein and subclavian vein. The right internal jugular vein (IJV) is most preferred site than the left side for few important reasons such as avoiding injury of the thoracic duct which was present in the right IJC course. The course of the right IJV is straighter and shorter than the left IJV and can avoid the accidental injury of the vessels during introducing the guide wire.

However, in terms of infection control, subclavian vein is better than IJV. The cephalic vein can also be used, but these veins appeared to be commonly preferred in general ward in view of less complication. The most feared acute complication was pneumothorax and arrhythmia. The risk of pneumothorax is higher on the left lung in view of the high level of pleural compared to the right lung.

Central venous pressure waveform consists of three positive deflection and two descents. The positive waves are a, c, and v, meanwhile the negative waves are x and y. a wave is produced by increase venous pressure due to atrial contraction during diastole. C wave occurred when tricuspid valve displace into right atrium during initial ventricular contraction or early systole. X descent corresponds to period of atrial relaxation at the mid systole. At this time, the ventricles are ejecting blood to aorta and pulmonary artery. V wave occurred when there is a systolic filling of the right atrium during late systole. At this period, the tricuspid valve is close. The y descent occurs during early diastole when the ventricular started to fill (Miller *et al* 2010).

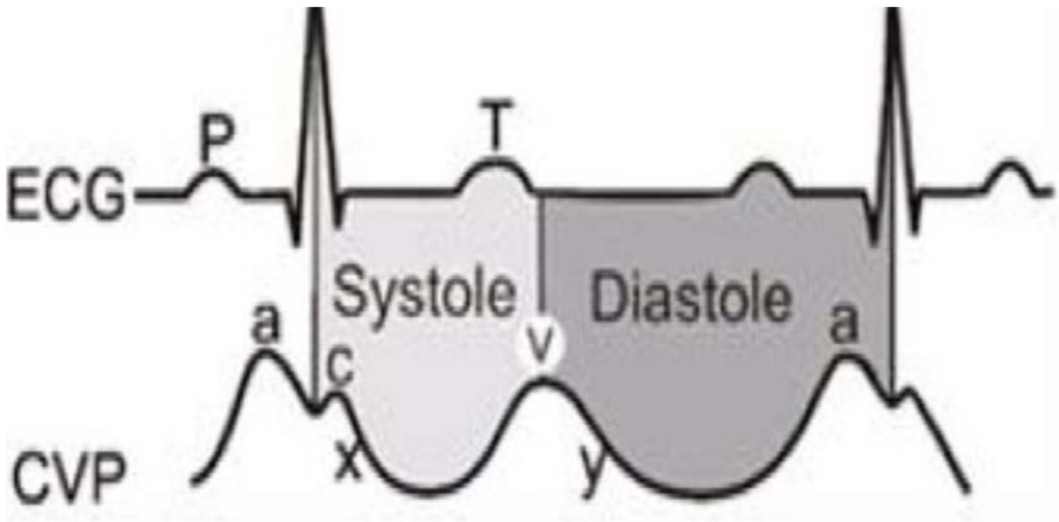

Figure 2.1: Central venous pressure waveform

Central venous pressure either can be raised, normal or decreased during measurement. The causes of raised CVP are increased intrathoracic pressure in positive pressure ventilation, impaired cardiac function such as in heart failure, cardiac tamponade, hypervolaemia and superior vena cava obstruction. During inspiration of spontaneous breathing in hypovalaemic patients, the CVP is reducing.

In intensive care unit (ICU), central venous pressure (CVP) has been used to assess fluid status for many years using central venous catheter. However many studies have argued about the effectiveness of CVP for blood volume monitoring. In septic shock, central venous pressure (CVP) may be used to guide fluid balance for less than 12 hours but becomes unreliable thereafter .In other word, CVP was correlated with fluid balance at 12 hours, However on days 1-4 onward, there was no significant correlation (Boyd *et al.*, 2011).

Furthermore this technique is also associated with some complication compared to bed side ultrasound. Subclavian and internal jugular vein insertion for CVP measurement is can be associated with pneumothorax, air embolism, arterial puncture, bleeding and infection. This method is time consuming, need trained personnel and must maintain high level of sterility to avoid complication and infection.

Numerous recent studies have shown a very poor relationship between CVP and blood volume and its ability to predict the haemodynamic response to fluid challenge (Osman *et al.,* 2007). For example, the CVP measured during the pneumoperitoneum do not seem to reflect accurate preload status to guide resuscitation (Kim *et al*., 2011).

Based on scarce data, CVP became the standard tool for guiding fluid therapy, initially in the operating room and then in the ICU. However, what was not generally appreciated is that the CVP is a measure of right atrial pressure alone and it is not a measure of blood volume or ventricular preload. Therefore, CVP should no longer be routinely measured in the ICU, operating room, or emergency department for guiding fluid administration (Marik *et al*., 2008).

Since that, the use of CVP is no longer use in intensive care in some hospitals as a tool of assessing fluid status**.** The use of central venous line (CVL) is mainly for delivering of inotropic support, antibiotic and Total Parentral Nutrition (TPN). Bedside ultrasound of IVC distensibility index and PPV are one of the common monitoring tools used and being studied for volume resuscitation in ICU.

2.1.2 Pulse Pressure Variation

Pulse pressure variation as shown in Figure 2.2 is another way to measure fluid status dynamically in ICU non-invasively provided arterial line catheter already inserted for continuous blood pressure monitoring. Almost all advanced monitor in ICU incorporated PPV as their additional parameter in order to give extra value to the ICU doctors as a guide in fluid resuscitation. The results of PPV will be presented as percentage.

However in this study, the measurement of PPV is calculated manually by using the formula in Figure 2.3.

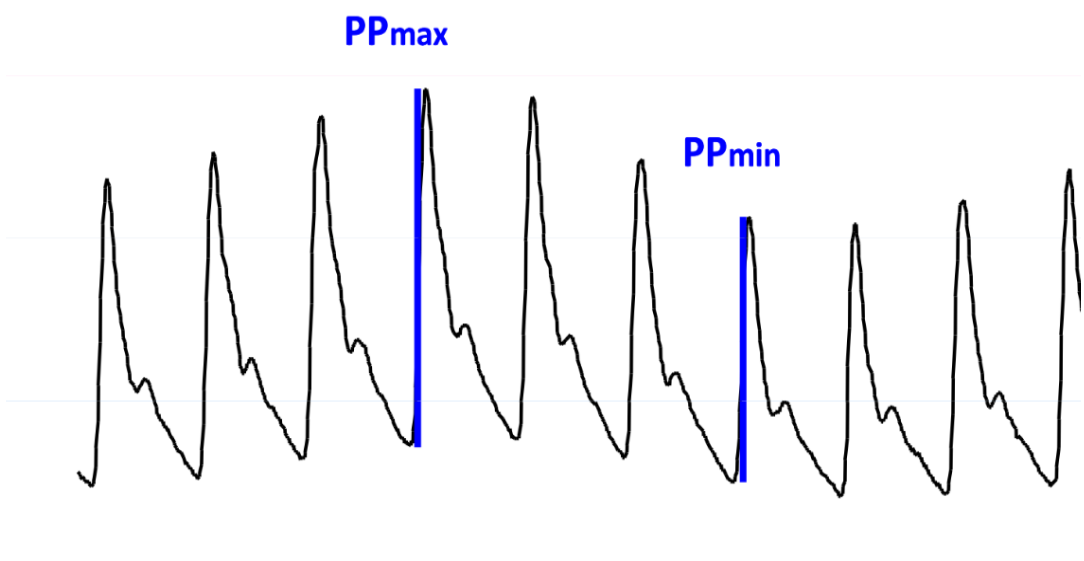

Figure 2.2: Pulse pressure pressure waveform

Pulse pressure variation is defined as the maximal pulse pressure minus the minimum pulse pressure divided by the average of these two pressures (Gunn & Pinsky, 2001). Pulse pressure variation value of more than 13% was very likely to respond to volume expansion (Michard *et al.*, 2000). A value of more 13% suggests hypovolaemia, requiring fluid. Previous studies showed that PPV to be far superior to CVP and PAOP in predicting fluid responsiveness (Daniels, 2010).

High values of delta pressure indicate responsiveness to fluid therapy. The values for PP to indicate fluid responsiveness range from 10 to 15%. If the value is over that limit, it is suggested that the patient is responsive to fluid loading. This range holds true when the limitations of the parameter have been ruled out (Ge Healthcare, 2010).

$$\text{PPV} = \frac{\text{PP max} - \text{PP min}}{(\text{PP max} + \text{PP min}) / 2}$$

Figure 2.3: Pulse pressure variation index formula

In a study of non invasive prediction of fluid responsiveness during major hepatic surgery conducted in France, the optimal PPV art threshold value (12.5%) found in the present study is in the range of those previously obtained in ICU patients (from 11 to 13%) (Solus-Biguenet *et al.,* 2006).

However, the reliability of pulse pressure variation measurements in mechanically ventilated patients must be taken into account after inspection of these four criteria which are arterial pressure tracing or waveform, well sedated patient, no arrhythmia, and tidal volume of more than 8ml/kg (Michard, 2005). PPV will increase with the increase in the level of tidal volume before and after intravascular volume expansion, contrasting with an unexpected stability of VTI (Charron *et al.*, 2006).

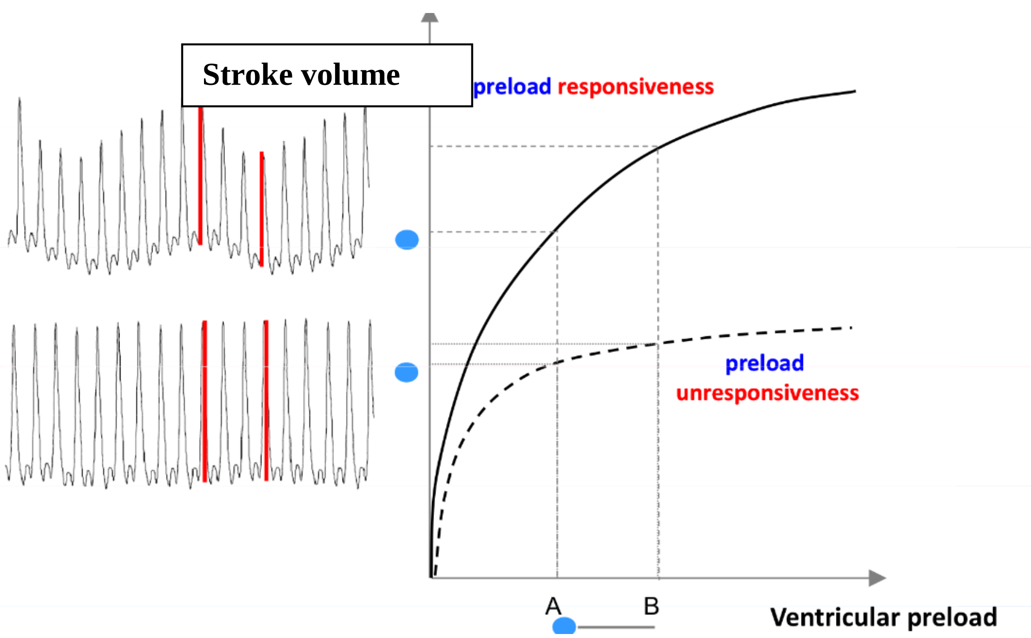

Figure 2.4: Fluid responsiveness

Aortic velocity time integral (VTI) and arterial pulse pressure PPV index are good predictors of intravascular fluid responsiveness but the divergent evolution of these two variables when tidal volume was increased needs further explanation (Charron *et al.,* 2006).

Many studies have shown that a static parameter such as CVP are generally not useful in predicting the volume responsiveness except in those patients with very low static parameters such as PAOP less than 5 mmHg or CVP less than 5 mmHg. Therefore, dynamic parameters are the best methods to assess the volume responsiveness.

2.1.3 Bedside ultrasound of inferior vena cava size diameter

Bedside ultrasound was one of the new technique choose to measure volume status in ICU patients with static or dynamic method because of its non-invasiveness and less time consuming. Traditionally, CVP was commonly inserted in ICU for fluid assessment and serve as route of for inotropes.

The trend of assessing fluid status and responsiveness in ICU is shifted from CVP toward measuring inferior vena cava diameter by using bedside echocardiography which was more reliable and due to non invasiveness (Charron *et al.,* 2006). A study showed that an IVC distensibility index is a good tool of measuring fluid responsiveness with 71% sensitivity and 100% specificity (Moretti & Pizzi 2010).

The subxiphoid area was chosen in this study since it is the best method of measuring inferior vena cava diameter by bedside ultrasound compared to other areas such as midpoint and suprailliac area with the orientation of probe in longitudinal view which is better than transverse view (Delorenzo *et al.,* 2012).

Inferior Vena Cava is a high capacitance vessel that originated by the confluence of the iliac veins at the level of umbilicus and extends to the right atrium. It consists of branches such as hepatic vein, renal vein and right gonadal vein. It can distend and collapse with fluid. During fluid loading its diameter increase and the degree of collapsibility reduces. Its diameter varies with individual and does not correlate well with body mass index (BMI) or body surface area (BSA). There no clear IVC diameter reference range in adult population. Its diameter depends on the intravascular volume status.

In adult, the normal size of inferior vena cava is 2 cm measure in greatest transverse diameter using bed side ultrasound with subxiphoid window with the cardiac probe transducer notch angulated at 12 o-clocks. The inferior vena cava is arise from right atrium and connected with the hepatic vein in the liver (Levitov *et al*., 2011). Intrahepatic portion of the inferior vena cava can be visualized by bedside ultrasound using a curve linear probe at a right lateral view at the midaxillary.

Mechanically ventilated patients in ICU will be receiving positive pressure ventilation which was different from spontaneous normal breathing patients in which the negative pressure phase of inspiration assists venous return, alleviates pressure on the pulmonary capillaries, and encourages blood flow. Therefore inferior vena cava diameter will be smaller during inspiration and larger during expiration. With positive pressure ventilation, the intrathoracic pressure increases during inspiration causing a decrease in venous return, right ventricular output, and pulmonary blood flow. Therefore, inferior vena cava diameter is higher during inspiration and lower during expiration in positive pressure ventilation (Soni & Williams, 2008).

On expiration, the intrathoracic pressure returns toward zero so that venous return will increase. If PEEP is applied, positive intrathoracic pressure continues to inhibit venous return during expiration. The reduced collapsibility of the inferior vena cava is often seen with ventilation and PEEP is a clear indicator of a degree of venous stasis (Soni & Williams, 2008). Transthoracic echocardiography is becoming a powerful, quick, reliable, and noninvasive tool in the daily care of the critically ill patients. This systemic review brings together the evidence for employing TTE to predict fluid responsiveness. Assuming that there is equipment and local expertise, TTE is a repeatable and reliable method of predicting volume responsiveness in a critically ill patient. Discriminative power is not affected by the technique selected (Mandeville & Colebourn, 2012).

In hypovolaemia, IVC might be collapse or kissing. Hypovolaemia can be classified into absolute and relative. Absolute hypovolaemia is as defined as hypovolaemia due to reduction of total circulating blood volume such as blood loss due to hemorrhage. Relative hypovolaemia occur when the distribution of the blood between the central and peripheral compartments is inadequate such as in septic shock patients.

There were many other factors known or postulated to affect IVC diameter and collapsibility including left and right ventricular function, pulmonary hypertension, and tricuspid and pulmonary valve dysfunction (Stawicki *et al.*, 2009). A potential limitation of the measurement of IVC diameter in trauma patients is that IVC diameter in patients with right-sided heart failure and severe tricuspid insufficiency may not correlate well with central blood volume (CBV) due to back pressure of the right ventricle through an incompetent valve (Sefidbakht *et al.*, 2007) **.** Another potential limitation of IVC diameter measurement may be seen in patients with elevated intraabdominal pressure because of the narrowing upper abdominal IVC which was actually unrelated to CBV than can occur in these patients (Sefidbakht *et al.*, 2007).

2.2 INFERIOR VENA CAVA

2.2.1 Anatomy of normal IVC

Inferior vena cava (IVC) is one of the large veins in the human body. It is a retroperitoneal structure and lies on the right side of the vertebral column. The inferior vena cava forms at the superior end of pelvic cavity when the common iliac veins unite. From the pelvis, the inferior vena cava ascends through the posterior abdominal wall just to the right of the vertebral column. Along its way to the right atrium in the abdomen, the IVC will be drained by a series of veins from internal organs such as gonadal, renal, suprarenal, lumbar vein and hepatic vein. In the abdomen, all blood from digestive organ will be drained to the portal vein into liver and then by the hepatic vein into the IVC. The lumbar veins receive blood from the spinal cord and muscles of the back before it enter IVC. It will anastomose with the azygous vein on the right side.

In other word, IVC drain blood from the abdomen, pelvis, thighs, legs and feet. From IVC, this blood will be delivered to the right side of the heart in the right atrium. In the veins, blood travel under little pressure. The contraction of skeletal muscles in the legs and abdominal muscle pressure generated by breathing will help in pumping of the blood in IVC ascending into the right atrium. Besides that, the vein consist of series of one way venous valves help to facilitate blood flow against the gravity from lower extremities. It will trap blood in between the muscle contraction, therefore preventing it from being pull back downs to the lower extremities by gravity.

In terms of IVC relation to other organs, the structures anterior to IVC are liver, bile duct, opening of lesser sac, first and third part of duodenum, head of pancrease, small bowel, right common iliac artery and portal vein. Posteriorly, IVC is related to right renal artery, lumbar arteries, right crus of diaphgram, right suprarenal and its artery, bodies of L3,4,5 vertebrae, right psoas, right symphatetic chain, and right coelic ganglion.

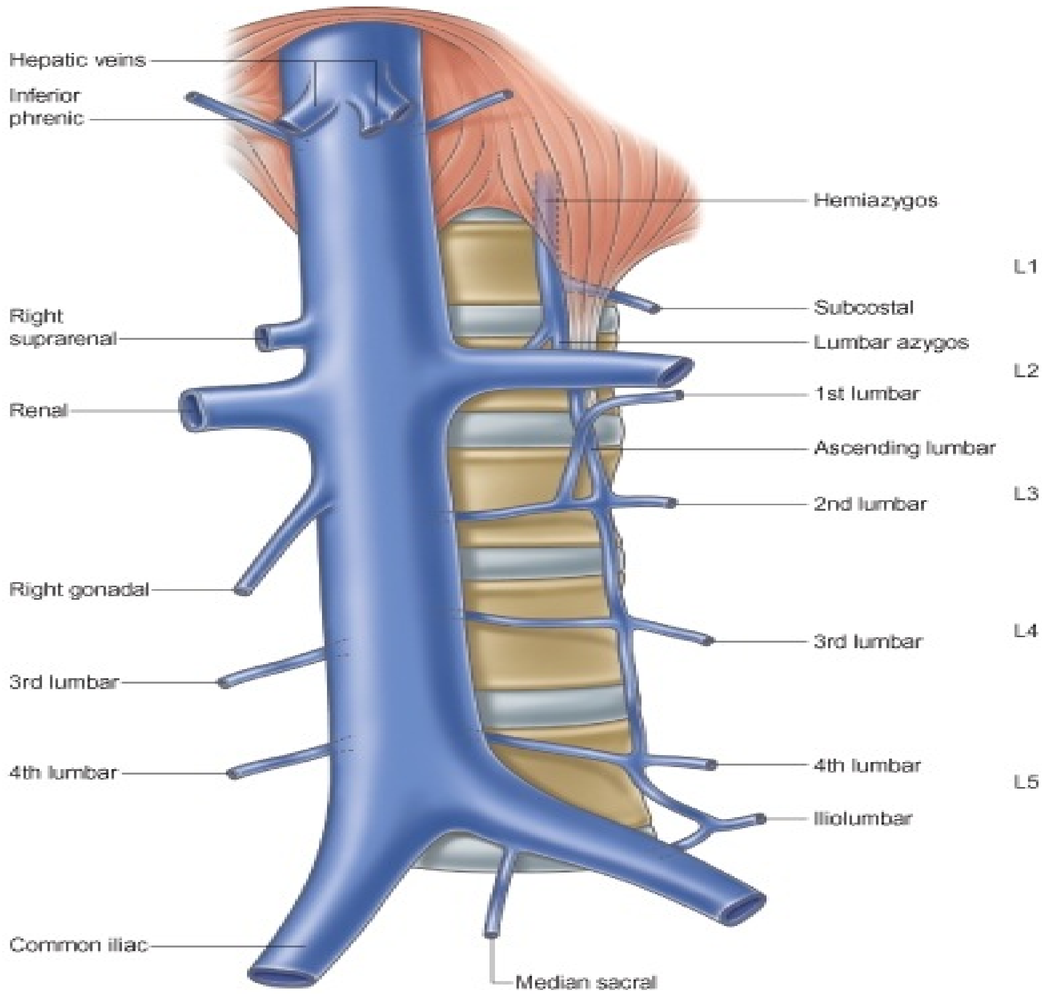

Figure 2.5: Anatomy of the inferior vena cava

(Source biswaforum.com)

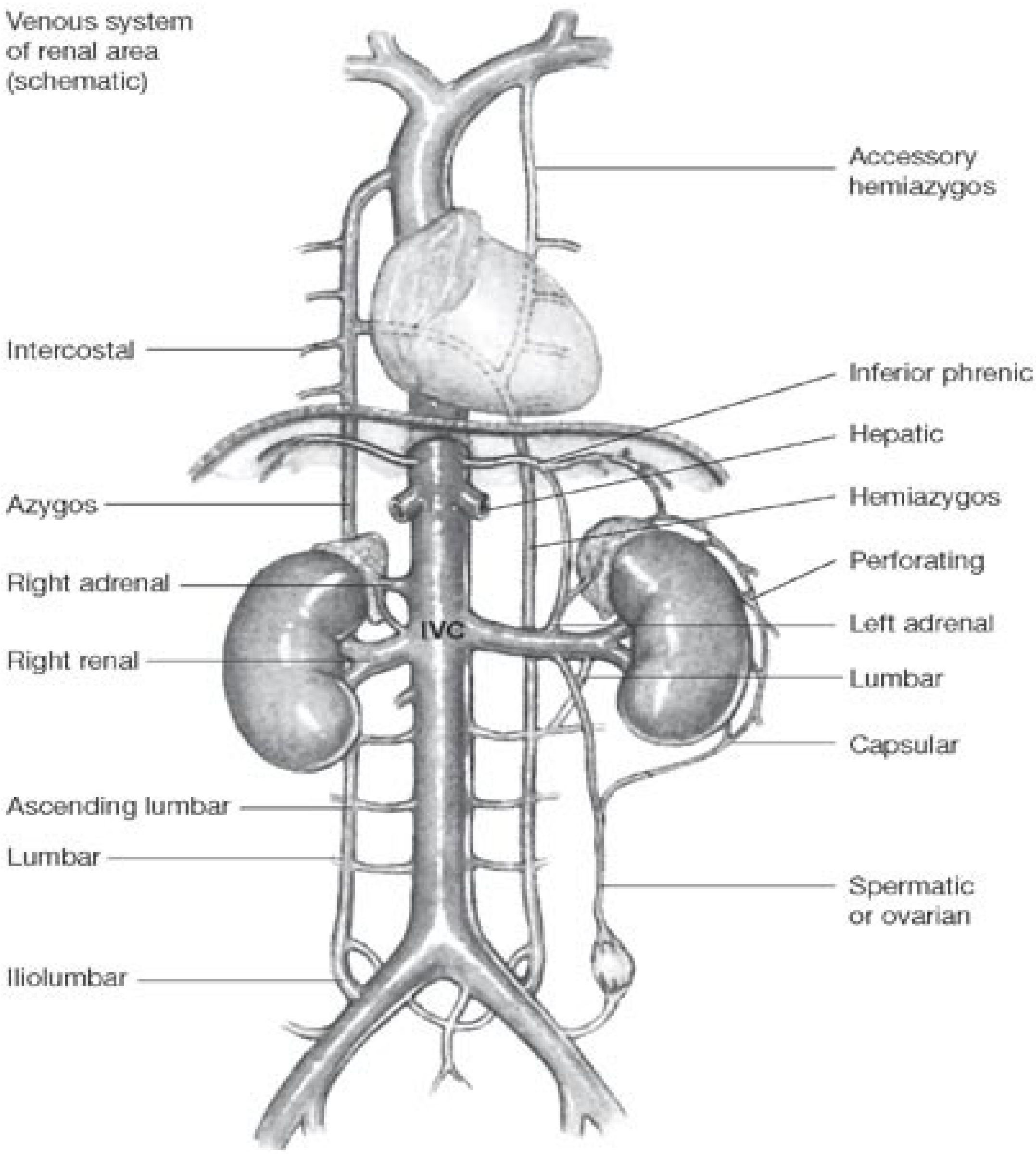

Figure 2.6: Drainage of the inferior vena cava

(Source nature.com)

2.2.2 Clinical significant IVC

IVC is a vein than can be easily distensible and collapse in human body depending on the blood flow through it before entering the heart. If the IVC flow is reducing, it will collapse and vice versa. In this study, IVC was used to assess the fluid status in ICU patients by measuring its distensibility index by portable ultrasound in mechanically ventilated patients.

Inferior vena cava is the most often associated with it external compression rather than rupture since it has low intraluminal pressure. The source of external pressure are the gravid uterus (aortocaval compression syndromes), enlarged aorta (abdominal aortic aneurysm), and abdominal malignancies, such as colorectal, ovarian, and renal cell carcinoma cancer.

Unconscious pregnant women or intra-operatively, particularly after spinal anesthesia, they should be turned on to their left side slightly to relieve pressure on IVC and facilitate the venous return. Occlusion of the IVC is very rare; however it is considered life threatening conditions if it occurs. However in septic shock patients, the blood vessels might be dilated due to the presence of inflammatory mediators released by injured endothelial cells. In this condition, the effective intravascular volume will be depleted due to capillary leakage. The patients might be edematous; however the volume is still inadequate for vital organ perfusion. As a result of this condition, the flow of blood to the IVC its diameter will be reduced when measured.

2.2.3 Measurement of IVC diameter

Figure 2.7: Sonosite Portable Ultrasound

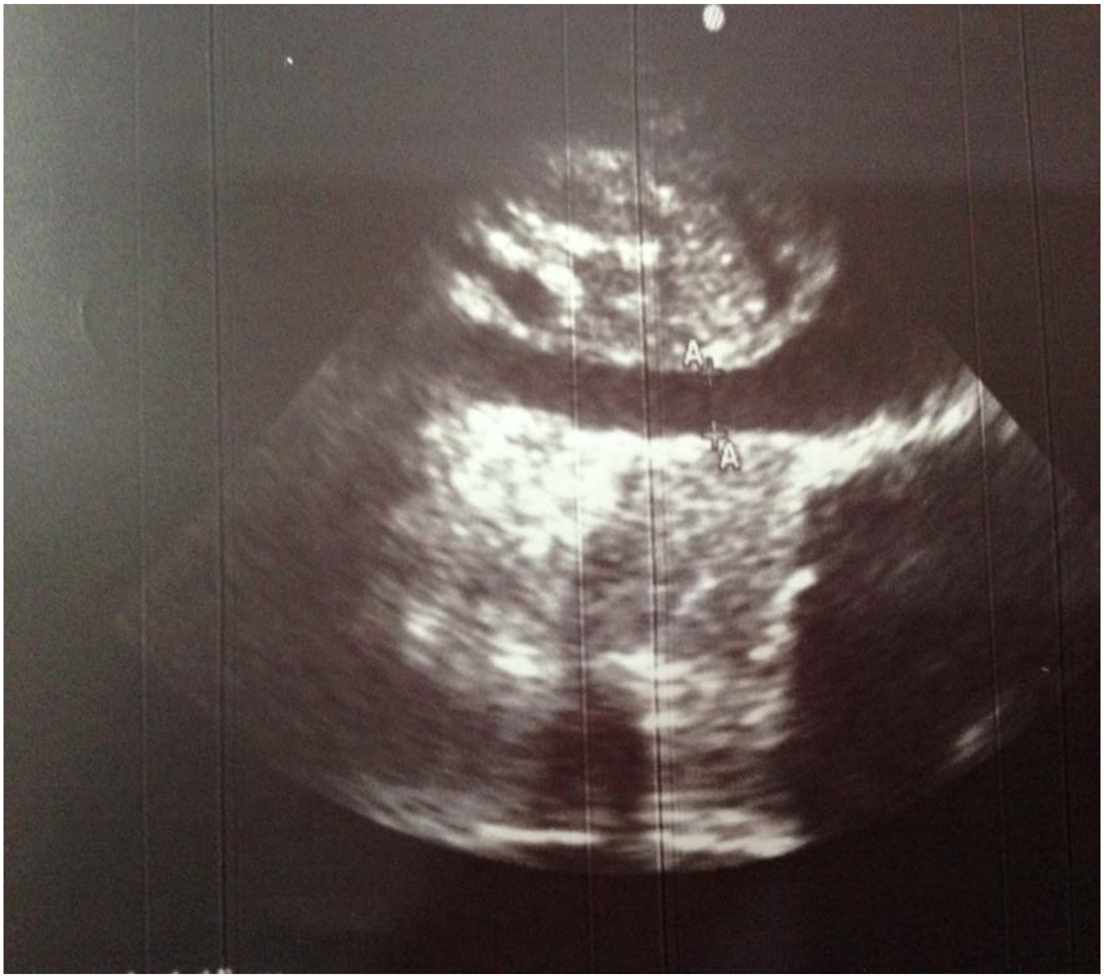

Figure 2.8: B mode IVC diameter