PROSPECTIVE COMPARATIVE STUDY OF ULTRASOUND GUIDED CENTRAL VENOUS PRESSURE MEASUREMENT USING JUGULAR VEIN AND INFERIOR VENACAVA DIAMETERS FOR POSTOPERATIVE PATIENTS ON MECHANICAL VENTILATION

Dissertation submitted to

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In partial fulfillment of the requirements for the award of the degree of

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BRANCH X

INSTITUTE OF ANAESTHESIOLOGY AND

CRITICAL CARE

MADRAS MEDICAL COLLEGE

CHENNAI - 600 003

APRIL 2017

CERTIFICATE

This is to certify that the dissertation entitled "**PROSPECTIVE COMPARATIVE STUDY OF ULTRASOUND GUIDED CENTRAL VENOUS PRESSURE MEASUREMENT USING JUGULAR VEIN AND INFERIOR VENACAVA DIAMETERS FOR POSTOPERATIVE PATIENTS ON MECHANICAL VENTILATION**" submitted by Dr**. M. SATHYASUBA**, in partial fulfillment for the award of the degree of the Doctor of Medicine in Anaesthesiology by the TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY ,Chennai is a bonafide record of the work done by her in the INSTITUTE OF ANAESTHESIOLOGY AND CRITICAL CARE, Madras Medical College, Chennai during the academic year 2014-2017.

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DECLARATION

I, solemnly declare that this dissertation entitled, "**PROSPECTIVE COMPARATIVE STUDY OF ULTRASOUND GUIDED CENTRAL VENOUS PRESSURE MEASUREMENT USING JUGULAR VEIN AND INFERIOR VENACAVA DIAMETERS FOR POSTOPERATIVE PATIENTS ON MECHANICAL VENTILATION**" has been prepared by me under the Guidance of **Prof. Dr. B. KALA M.D;D.A,** The Director, Anaesthesiology and Critical Care, Madras Medical College, Chennai, during the period 2014 to 2017 and submitted to the Tamil Nadu Dr. M.G.R. Medical College, Guindy, Chennai-600 032, in partial fulfillment of the regulations for the award of the degree of M.D (Anaesthesiology), Branch-X examination to be held in April 2017. This study was conducted in Post Anesthesia Care Unit, Institute Of Anaesthesiology and Critical care, Madras Medical College, Chennai.

I have not submitted this dissertation previously to any university for the award of any degree or diploma.

Place:

Date: **Dr. M. SATHYASUBA**

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ABBREVIATIONS

IVC	Inferior Vena Cava
IJV	Internal Jugular Vein
CVP	Central Venous Pressure
IJVmax	Maximum Internal Jugular Vein diameter
IJVmin	Minimum Internal Jugular Vein diameter
IJVarea	Internal Jugular Vein Area
IVCmax	Maximum Inferior Vena Cava diameter
IVCmin	Minimum Inferior Vena Cava diameter
IVC-CI	Inferior Vena Cava Collapsibility Index
JVP	Jugular Venous Pressure

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CERTIFICATE OF THE GUIDE

This is to certify that the dissertation entitled "**PROSPECTIVE COMPARATIVE STUDY OF ULTRASOUND GUIDED CENTRAL VENOUS PRESSURE MEASUREMENT USING JUGULAR VEIN AND INFERIOR VENACAVA DIAMETERS FOR POSTOPERATIVE PATIENTS ON MECHANICAL VENTILATION**" submitted by Dr**. M. SATHYASUBA**, in partial fulfillment for the award of the degree of the Doctor of Medicine in Anaesthesiology by the TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY ,Chennai is a bonafide record of the work done by her in the INSTITUTE OF ANAESTHESIOLOGY AND CRITICAL CARE, Madras Medical College, Chennai during the academic year 2014-2017.

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INTRODUCTION AND RATIONALE OF STUDY

Physical examination of Jugular Venous Pressure is always considered as an integral part of the cardio vascular system examination and precise bedside Jugular Venous Pressure analysis is highly desirable. Jugular Venous Pressure is important for estimation of cardiac filling pressures and it can be reliably estimated in the bedside.

Hemodynamic monitoring in the form of invasive arterial, central venous pressure and PCWP monitoring is frequently required in critically ill surgical and medical ICU patients. Also it is of utmost value in patients undergoing cardiac surgeries and surgeries involving gross hemodynamic changes.

AIMS AND OBJECTIVES

- The aim of the study is to estimate the Central Venous Pressure, using sonographic parameters.

PRIMARY OBJECTIVE

- The study evaluates the correlation between sonographically measured Central Venous Pressure, and conventionally measured invasive CVP in postoperative patients, on mechanical ventilation.

SECONDARY OBJECTIVE

- Evaluation of intravascular volume status.
- Serial monitoring of volume status in needful situations e.g. sepsis.
- Evaluation of the response to fluid resuscitation

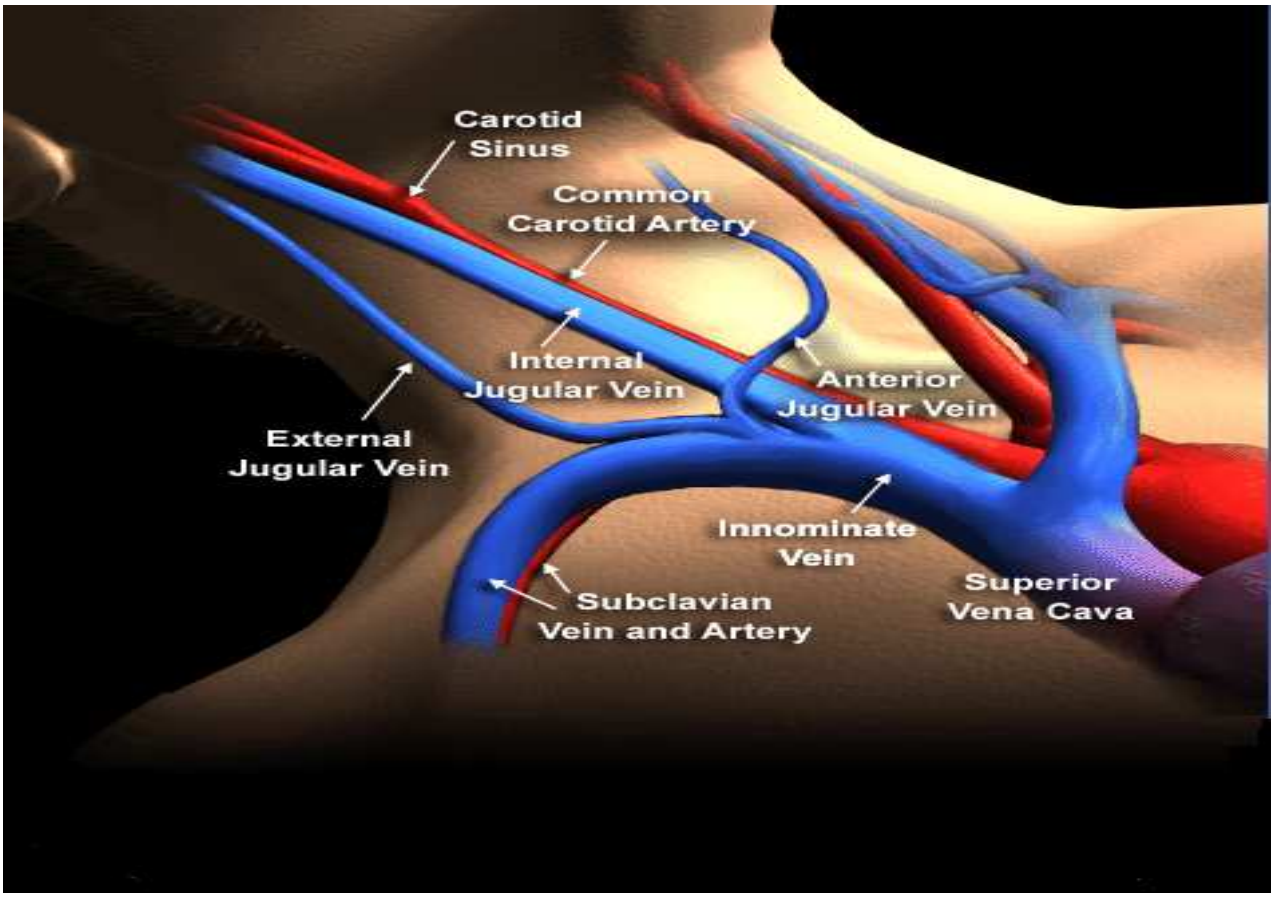
CENTRAL VENOUS PRESSURE

The central venous pressure (**CVP**) measures, the filling pressures of right atrium and right ventricle. It gives an estimate of intravascular volume status, which is an interplay of

(i) Circulating blood volume

(ii) Venous tone and

(iii) Right ventricular function.



WAVEFORMS IN A CENTRAL VENOUS PRESSURE TRACING

The normal central venous pressure waveforms consist of three upward deflections (a, c and v waveforms) and two downward deflections (x and y descents). These waveforms are produced as a result of following:

1. The **'a'** wave was produced by right atrial systole and occurs in end diastole of cardiac cycle, just after the P wave of ECG. It precedes the upstroke of carotid impulse and first heart sound (S1).

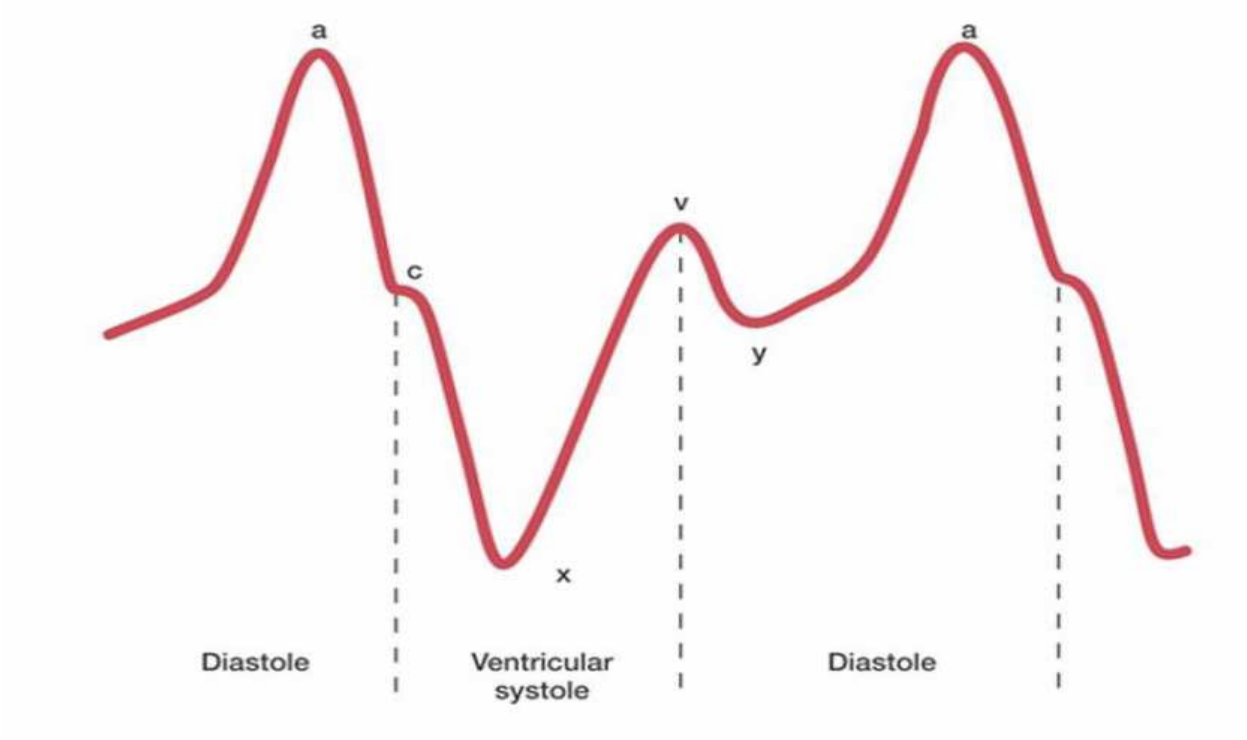
2. The **'c'** wave occurs in early systole due to iso volumetric contraction of right ventricle, making tricuspid valve to bulge into right atrium.

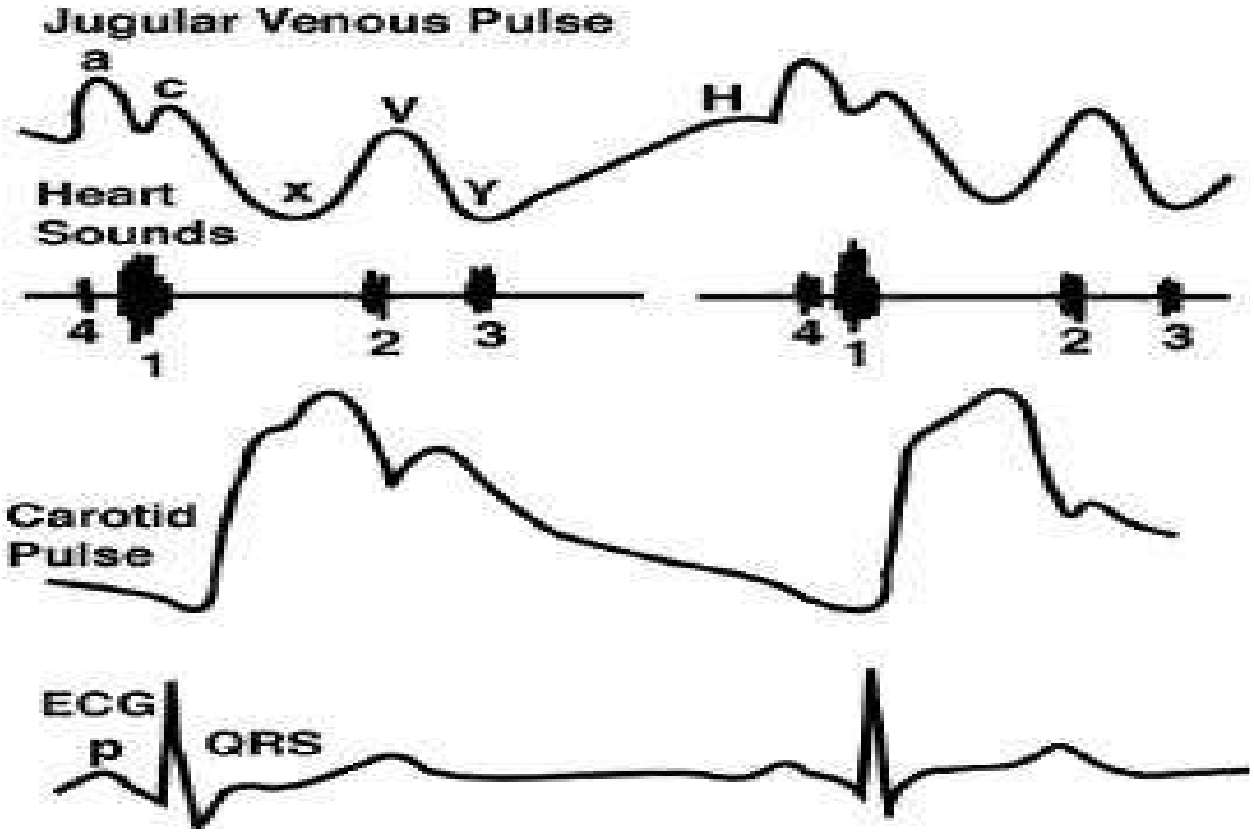
3. The pressure in the right atrium decreases due to atrial relaxation causing descent of tricuspid valve constitutes the **'x'** descent.

4. The **'v'** occurs during late ventricular systole, and is synchronous with carotid upstroke and peaks just after second heart sound (S2).

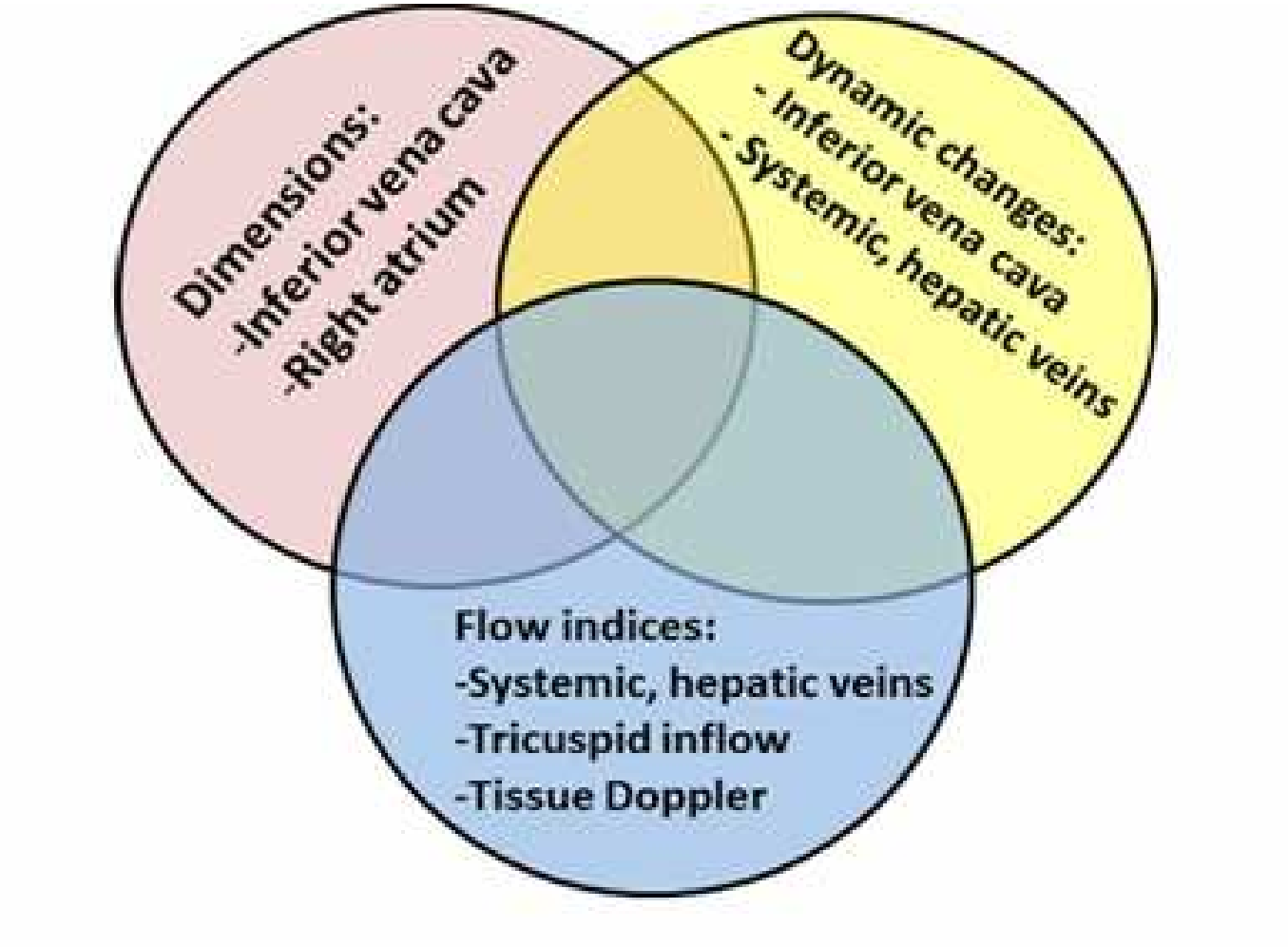
5. The **'y'** descent occurs due to opening of tricuspid valve and hence blood enters rapidly from right atrium into right ventricle during early diastole. It begins and ends during diastole well after S2.

CVP - WAVEFORMS




Jugular Venous Pulse
a
c
x
v
y
H
Heart Sounds
4
1
2
3
4
1
2
3
Carotid Pulse
ECG
p
QRS

DETERMINANTS OF CVP



INDICATIONS FOR CENTRAL VENOUS CATHETER INSERTION:

1. Major surgical procedures, which involve large fluid shifts and or blood loss.

2. Intra vascular volume assessment, when urine output is no longer a reliable indicator of volume status.(e.g.: renal failure)

3. Major trauma.

4. Surgical procedures, with high risk of air embolism such as sitting position craniotomies. In addition to monitoring, central venous pressure catheter may also be used to aspirate intra cardiac air.

5. Frequent venous blood sampling.

6. Venous access for vasoactive and inotropic agents.

7. Chronic drug administration.

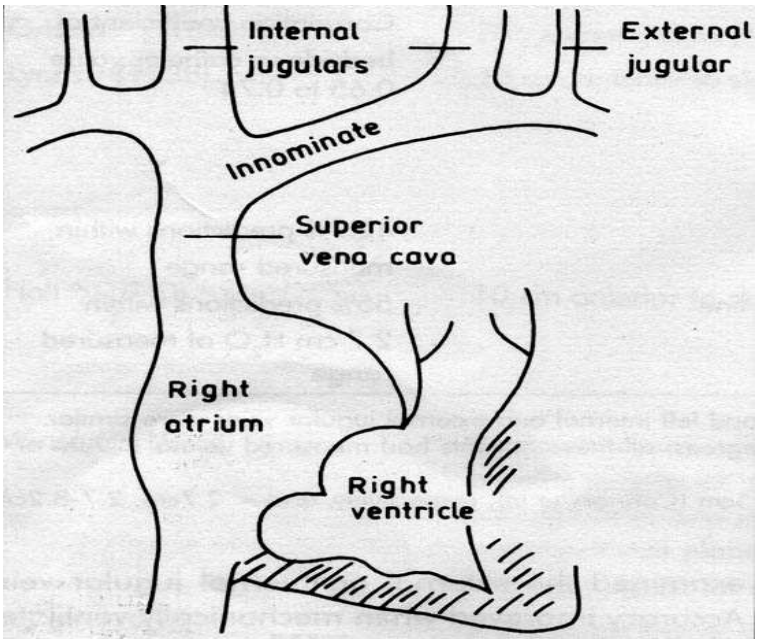
8. Inadequate peripheral intravenous access.

9. Rapid infusion of intravenous fluids (using large canula).

10. Special uses

(i) Insertion of Pulmonary artery catheters (ii) Insertion of transvenous pacing wires (iii) Haemodialysis / Plasmapheresis.

CVP reflects right atrial pressure throughout cardiac cycle. During diastole, it reflects right ventricular filling pressures.



CONTRAINDICATIONS FOR INVASIVE CVP CATHETER INSERTION:

1. Superior vena cava syndrome
2. Insertion site infection
3. Coagulation abnormality.
4. On pacemaker wires.
5. Significant carotid artery disease.
6. Contralateral diaphragmatic palsy.

CVP MEASUREMENT TECHNIQUES

INVASIVE CVP MEASUREMENT

There are numerous techniques and sites available for central vein canulation and its pressure measurement. Canulation of internal jugular vein was first described by English et al in 1969. Since then, it has gained popularity among intensive care physicians, as one of the methods of choice in monitoring CVP and right atrial pressure. The reason is being, its short and straight (right internal jugular vein IJV) having no valves, while coursing superior vena cava (SVC) and right atrium (RA). Its relative position at patient's head provides an easy access in the intra operative settings. The tip of the catheter has to be placed at SVC-RA junction, SVC or high up in RA above the tricuspid valve in order to measure CVP and RA pressure accurately.

STEPS OF CENTRAL VENOUS CANNULATION

STEPS	**SIGNIFICANCE**
Advocate ECG monitoring in all patients.	Most critical for monitoring arrhythmias
Remove the pillow and rotate the head to left. In conscious patients with raising the head off the bed.	Optimizes the landmarks
Place the patient in Trendelenberg position.	Distends the IJV, reduces air embolism risk.

Perform a careful sterile preparation and drape.	Needed for all invasive procedures.
Recheck all landmarks, local infiltration in a conscious patient . Skin wheal, and deeper infiltration with 1% lidocaine.	To confirm. To have a painless procedure.
Replace with another needle	Since it makes blood , appear as bright red.
Once the vein is punctured Remove the needle.	May interfere with repeat canulation.
Insert a 18 G venous catheter	Constant aspiration by negative suction is required as unit is advanced to see flashback of venous blood.
Look for back flow while advancing the catheter.	Confirms vene puncture.
If blood is not aspirated freely: a. Remove the needle b. Reposition and aspirate. c. Withdraw until the blood flows freely.	Against the back wall of vessel. In volume depleted patients, i.v.fluid bolus can be given to increase success rate.
Confirming an IJV placement by a. Absence of pulsatile flow. b. To Measure the pressure c. ABG.	Avoids arterial puncture
A flexible wire passed through catheter, remove the guide wire	ECG should be monitored because arrhythmias can ensue.
Finally catheter was placed over the delivery assembly.	Skin nick may be needed if larger introducer will be placed.
Sterile dressing applied.	

Invasive CVP estimation techniques have many potential complications, including

1.Mechanical-Pneumothorax, artery puncture and cannulation, hematoma, hemothorax, embolisation of broken catheter /guide wire,catheter occlusion or displacement,air embolism,arrhythmias and lymphatic system injury.

2.Infection- Sepsis,endocarditis.

3.Thrombotic-Venous thrombosis, pulmonary embolism. These complications are avoided in the non invasive technique.

THE CATHETER –TRANSDUCER CIRCUIT

The catheters used for CVP monitoring are multi lumen central venous catheters (15-20 cm in length) that are inserted either into internal jugular or subclavian veins and advanced into the superior vena cava.

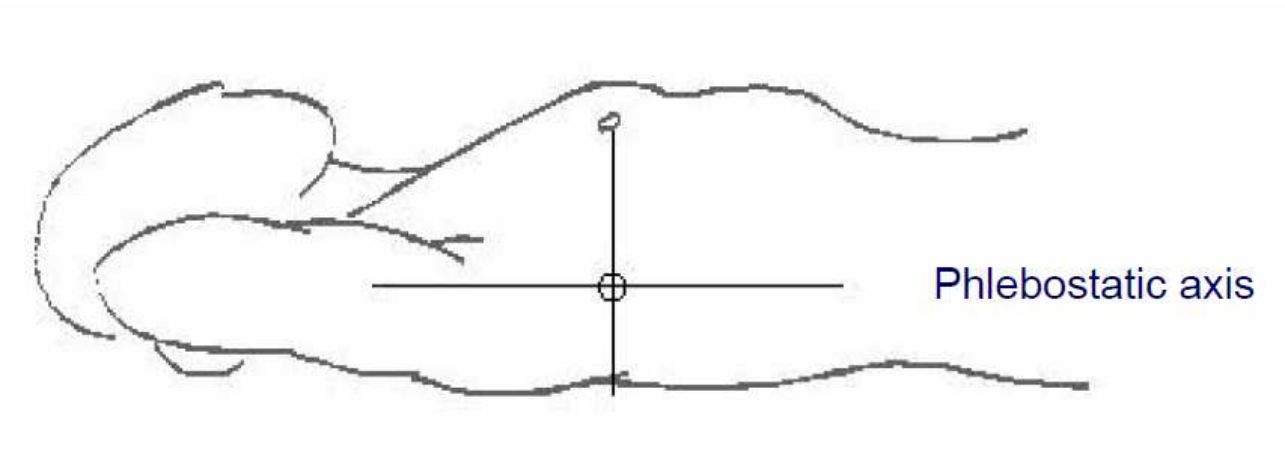
CVP can be measured using an indwelling central venous catheter and either manually using a pressure manometer or electronically using a transducer.

The manometer is used especially in the wards. After zeroing at the level of right atrium, checking the I.V patency and making the patient assume a supine or semi recumbent position, the measurements were taken.

Using the Manometer:

A three way is used to connect the manometer to an I.V drip set on one side and via the extension tubing filled with intravenous fluid to the patient on the other. The manometer arm has to be lined up with phlebostatic axis. This is done to ensure that the bubble is between the two lines of the spirit level. There should not be the presence of air bubbles and blocks in the tubings. The manometer is zeroed by moving the scale up and down, allowing the bubble to be aligned with zero on the scale. The three way tap is then turned so that it is open to the fluid bottle and

manometer but closed at the patient's end allowing manometer column to fill with fluid. However care must be taken not to overfill the manometer column. Manometer can be filled up to a level higher than the accepted CVP. Then flow from the fluid bottle is turned off and the three way tap opened from the manometer to the patient. The fluid level within the manometer column will fall to the level of CVP or when gravity equals the pressure in the central veins, the value of which can be read on the manometer scale and measures CVP in cm of water. The CVP measurement is read when the fluid stops falling. In cases where fluid moves with the patient's breathing, the measuement is read from the lower number. The manometer is closed and CVP is recorded in cm of H2O. Using the manometer is time consuming and is prone for operator errors.



Using a transducer:

The transducer just akin to manometer (fixed at the level of right atrium and connected to the patient's CVP catheter via fluid filled extension tubing) also requires similar care in order to avoid air bubbles and kinks. The transducer was zeroed to atmospheric pressure by turning its three way tap, so that it is open to the transducer and to room air, but closed at the patient side. It can also be done by removing the cap from the three way port and opening the system to atmosphere. Zero button on the monitor is pressed and calibration occurs. Then as the monitor display as "zeroed", the three way tap is turned in such a way that it is now closed to room air and opened between the patient and the transducer. A continuous CVP reading in mm of Hg is obtained.The transducer is expensive and the patient must be in a calm, environment to provide an accurate value.

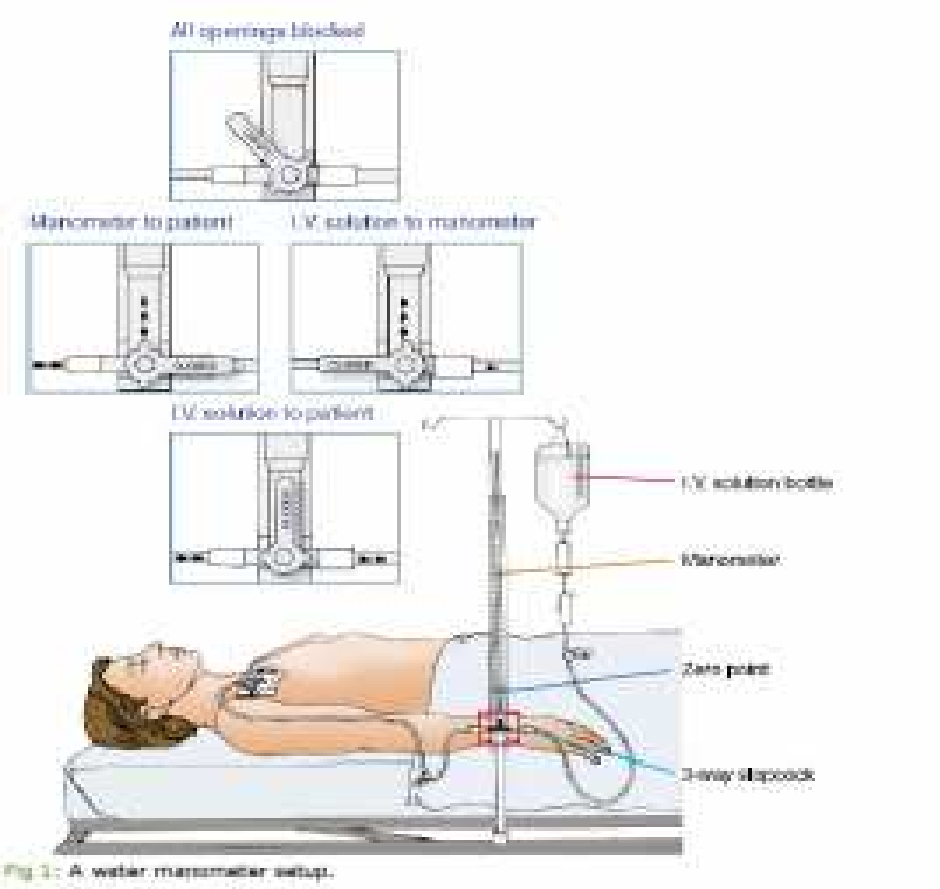


Fig 1 : A water manometer setup.

Normal value of CVP: **3 to 8 mm of Hg** or,

4 to 12 cm of water.

Normal CVP from two points of reference:

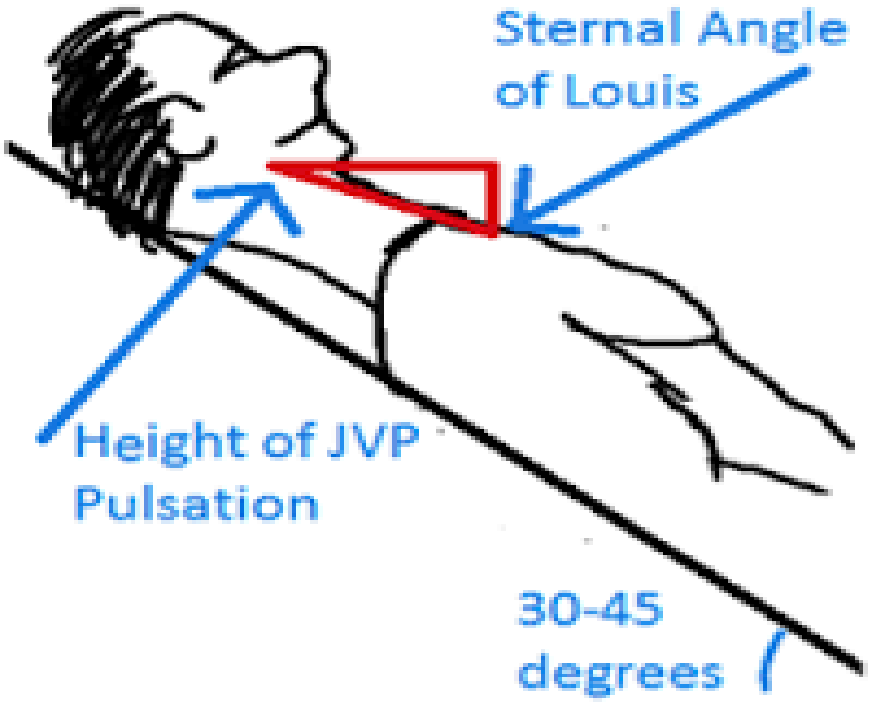
Sternum: 0 to 4 cm of water.

Midaxillary line: 8 to 15 cm of water.

THE REFERENCE LEVEL

The CVP is a hydrostatic pressure and hence it is pertinent that the fluid filled transducer is at same level as the right atrium. The traditional reference point for the right atrium is the intersection of the mid - axillary

line (midway between the anterior and posterior axillary folds) and the fourth intercostal space for a patient in the supine position. The zero point or physiological reference point is the right atrium, where the CVP is tightly regulated (i.e. no or little change during physiological state). To get reproducible measurements that are independent of position, the "zero" mark of the manometer or electronic transducer should lie at the same vertical height of this point. An alternate reference point that can be used in the semi recumbent position (up to 60°) is located 5 cm directly below the sternal angle (the angle of Louis), where the sternum meets the second rib.



As Central venous pressure (CVP) estimation is crucial in emergency and critical care medicine, both invasive and non invasive methods are advocated in estimating central venous pressure. There are potential risks

and complications associated with invasive CVP estimation. Hence the concept of non invasive CVP evaluation techniques came into vogue.

Many methods have been described to estimate CVP using bedside ultrasound such as size and collapsibility of inferior vena cava, and size and area of internal jugular vein. These methods are based on the measurement of calibers of elastic venous structures that connect to right side of the heart. These non invasive methods showed a good correlation with invasive CVP measurements.

VENOUS PRESSURE IN THORAX

The CVP and wedge pressure measurements can differ from the physiologically relevant pressure. The pressure in the superior vena cava (CVP) is recorded as an intravascular pressure, i.e., the pressure in the blood vessel relative to atmospheric (zero) pressure. However, the pressure that distends the ventricles to allow ventricular filling is the transmural pressure, which is the difference between the intravascular pressure and the surrounding intra thoracic pressure. Therefore, the recorded intra thoracic pressure will reflect the relevant transmural pressure only when the intra thoracic pressure is equivalent to atmospheric pressure. This normally occurs at the end of expiration. Therefore, the CVP and wedge pressure should be measured at the end of expiration

INFLUENCE OF INTRATHORACIC PRESSURE

When intra thoracic pressure changes during spontaneous breathing or positive pressure ventilation, the pressure change can be transmitted into the lumen of the veins within the thorax resulting in a change in the measured intravascular pressure without a change in the transmural pressure. The respiratory variation in the CVP and wedge pressure doesn't represent changes in intra ventricular filling pressures. When respiratory variations are evident the cardiac filling pressure should be measured at the end of expiration. Thus CVP recorded during spontaneous (negative pressure) breathing, the end expiratory pressure will be the highest pressure in the tracing. During positive pressure ventilation the end expiratory pressure is the lowest pressure and hence CVP will be the lowest in the tracing.

POSITIVE END EXPIRATORY PRESSURE (PEEP)

Positive end expiratory pressure (PEEP) can falsely elevate the cardiac filling pressures at end expiration because the intra thoracic pressure is higher than the atmospheric pressure. When PEEP is applied during mechanical ventilation, the patient can be briefly disconnected from the ventilator to measure the CVP. In patients with "intrinsic PEEP" due to

incomplete emptying of lungs, accurate measurement of the cardiac filling pressures can be difficult.

VARIABILITY

The CVP and wedge pressure can vary spontaneously by as much as 4 mm Hg. Any change in these pressures must exceed 4 mm Hg to be considered as clinically significant.

There are four ultrasound based methods that are commonly used for CVP estimation. They are

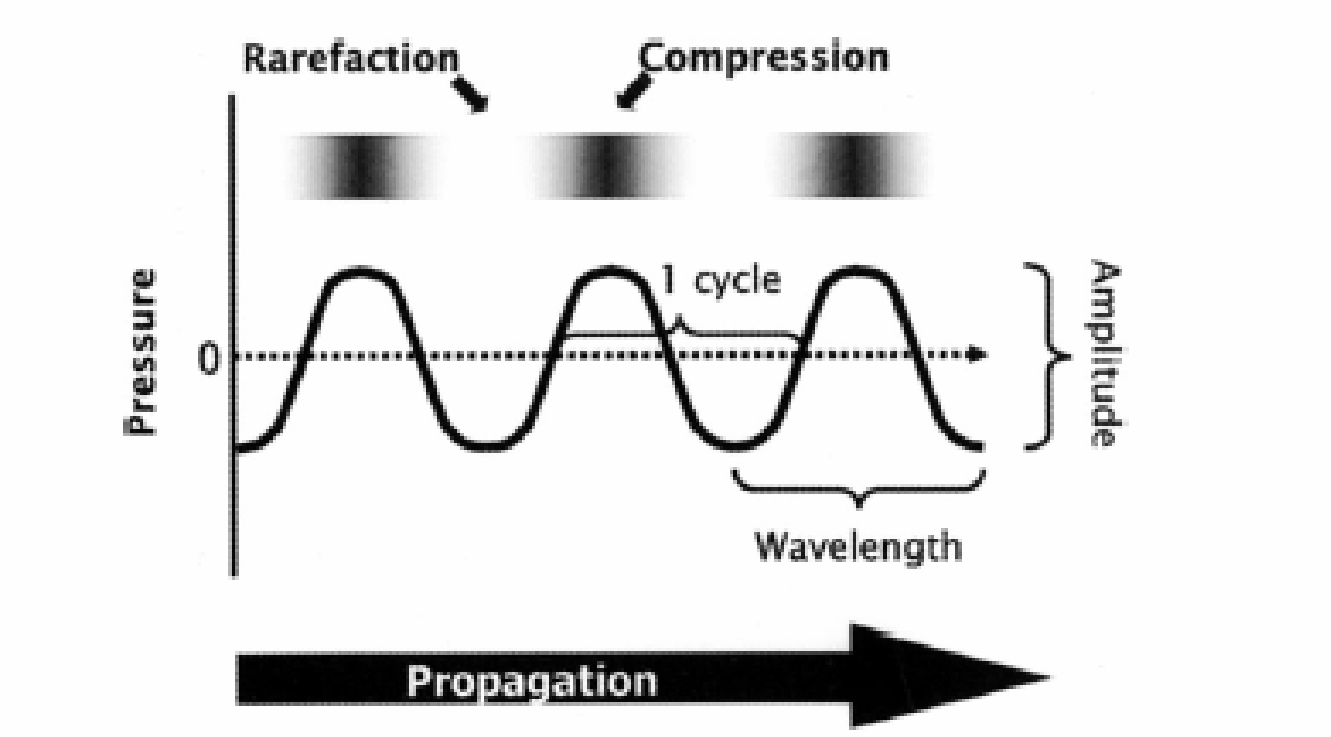
1. Internal jugular vein (IJV) diameter and jugular vein area measurements
2. Ultrasound estimation of height of jugular vein – done by identifying the top of the venous pulsation (CVP usg). The ultrasound estimation of height of IJV is more difficult and is influenced by the elevation of head of the bed and the timing of end of expiration. It is also difficult to measure the vertical distance from the top of blood column and the sternal angle.
3. Inferior vena cava (IVC) diameter
4. IVC collapsibility index – percent decrease in IVC diameter during inspiration.

CHARACTERISTICS OF ULTRASOUND

Sound is a mechanical vibration transmitted through an elastic medium. When it propagates through air, at an appropriate frequency, sound produces a sensation of hearing. Classified as

1. **Infra sound:** **< 20 Hz**
2. **Audible sound:** **20 – 20,000 Hz**
3. **Ultrasound:** **> 20,000 Hz**

Ultrasound is a continuous or intermittent train of sound waves, emitted by a transducer or wave generator. It can be directed and focused at a given specified area. It obeys the laws of reflection and refraction. As the ultrasound beam travels through a fixed point, the pressure cycle traverses continuously and regularly between a high and a low value called as compression and rarefaction. The sequence of compression and rarefaction is described as sine waves. The major disadvantages of ultrasound are that they are poorly transmitted through gaseous medium and rapidly attenuated at higher frequencies.



The ultrasound waves are characterized by the following

1. **Wavelength:** It is the distance between the two nearest points of equal pressure or density in an ultrasound beam.
2. **Velocity:** The speed of travel of waves through a medium i.e. tissues.
3. **Frequency:** The number of cycles per second, measured in hertz.
4. **Amplitude:** A measure of tissue compression.

Wavelength (**λ**), velocity (v) and frequency (f) are related as follows,

$$V = f \times \lambda$$

Within the soft tissue, the velocity of sound is fairly constant at approximately 1540 m/s.

There are four ways of interaction between ultrasound and tissue:

1. Attenuation
2. Reflection
3. Refraction
4. Scattering

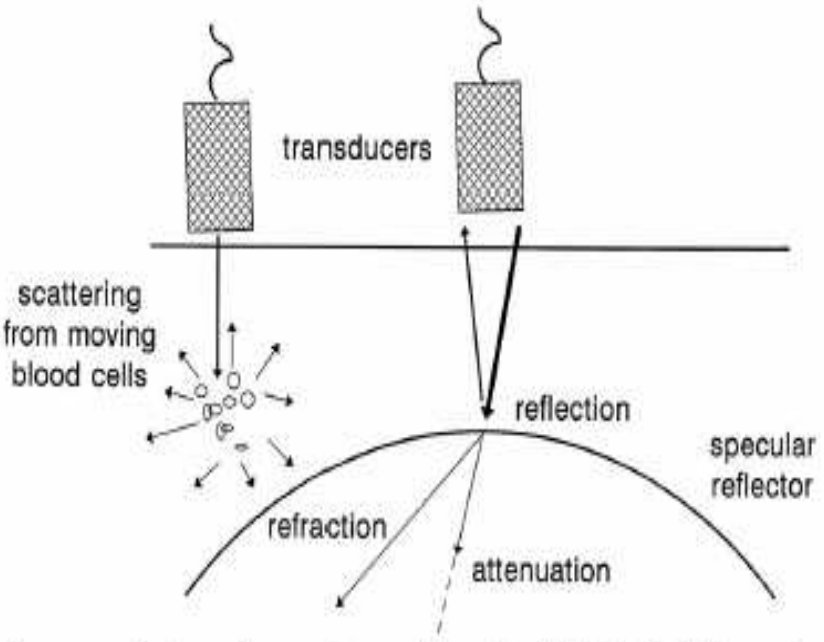


Figure 3. The four ways that an ultrasound wave interacts with biological tissue. Reproduced with permission from Otto (3).

TRANSDUCER AND PIEZOELECTRIC CRYSTAL

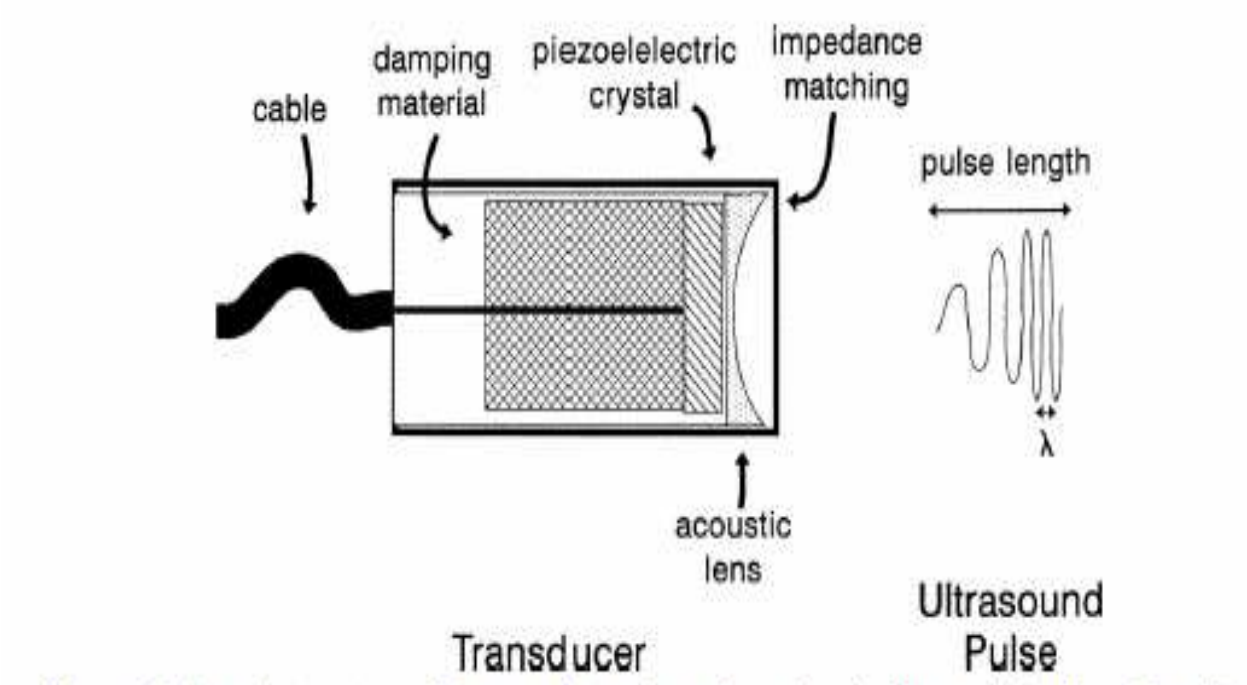
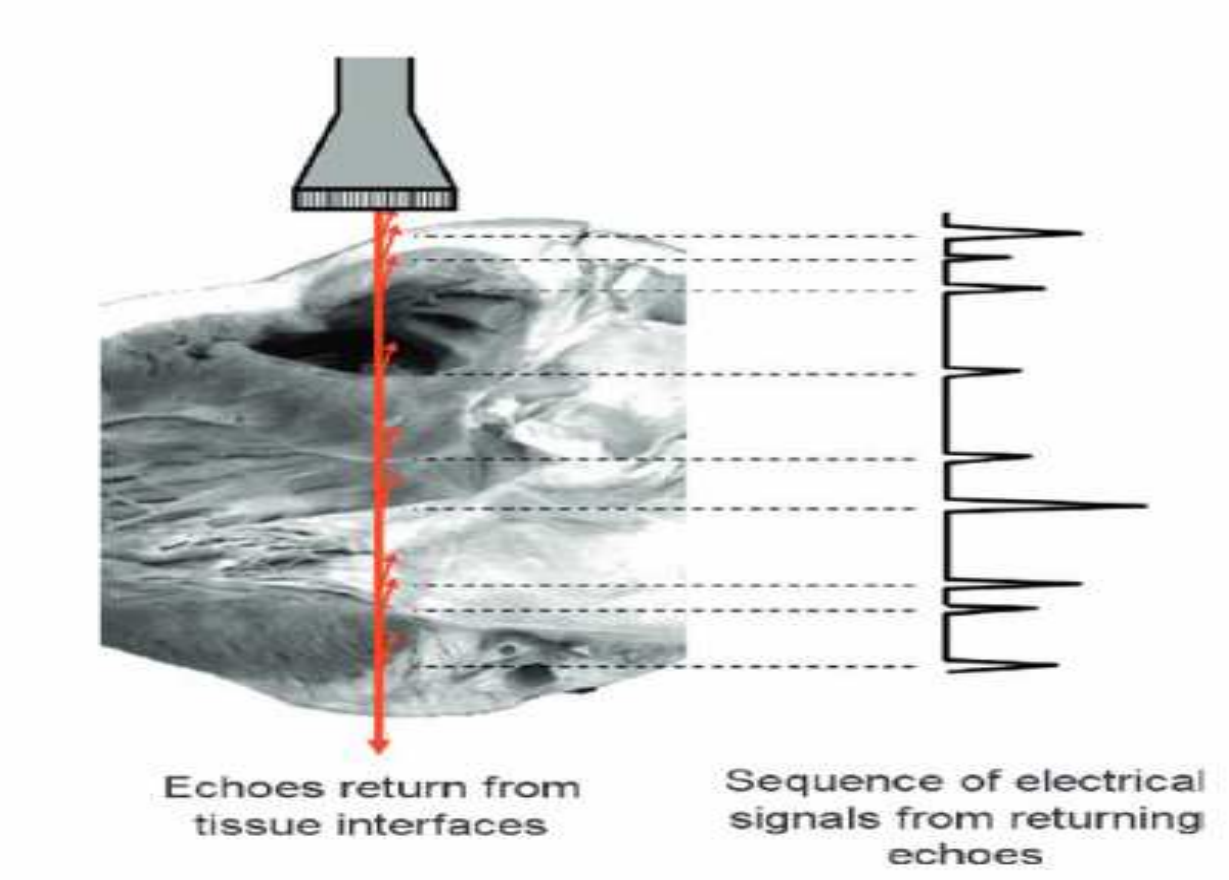


Figure 4. Schematic structure of ultrasound transducer. Reproduced with permission from Otto (3).

The piezoelectric crystal in transducer converts energy between ultrasound and electric signals. Whenever the high frequency electric signal is being emitted, the crystals produce ultrasound energy that can be directed towards the substance to be imaged. When the ultrasound waves are reflected back to the crystals, they pause for a while before repeating the cycle. The length of this cycle is known as **Pulse Repetition Frequency**. This frequency should be long enough for the signal to travel to and return from a given object. The value varies from 1 to 10K Hz resulting in 0.1 to 1.0 ms.


Echoes return from tissue interfaces
Sequence of electrical signals from returning echoes

IMAGING TECHNIQUES

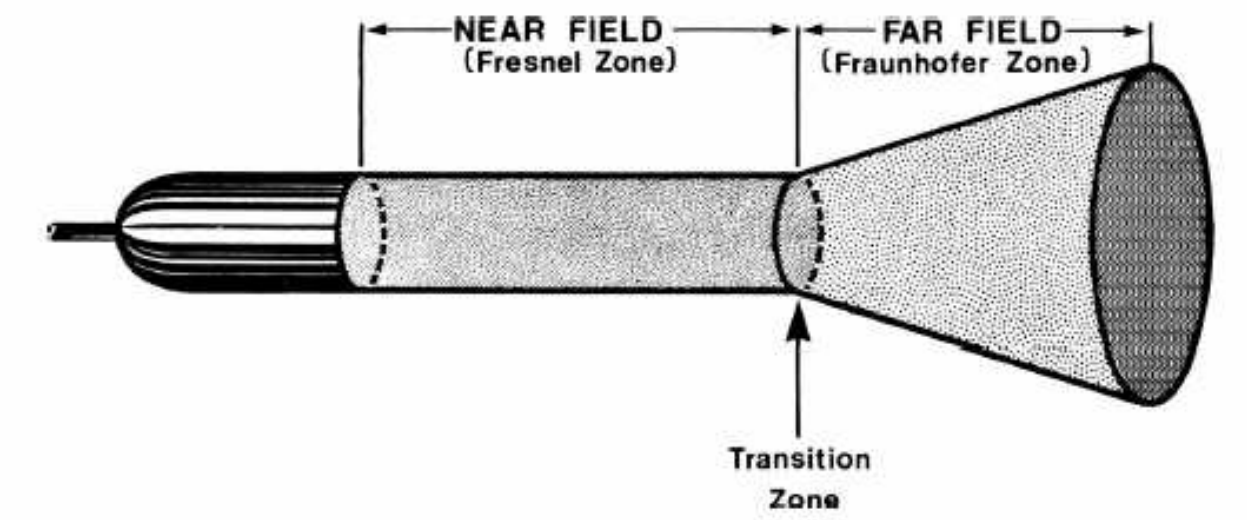
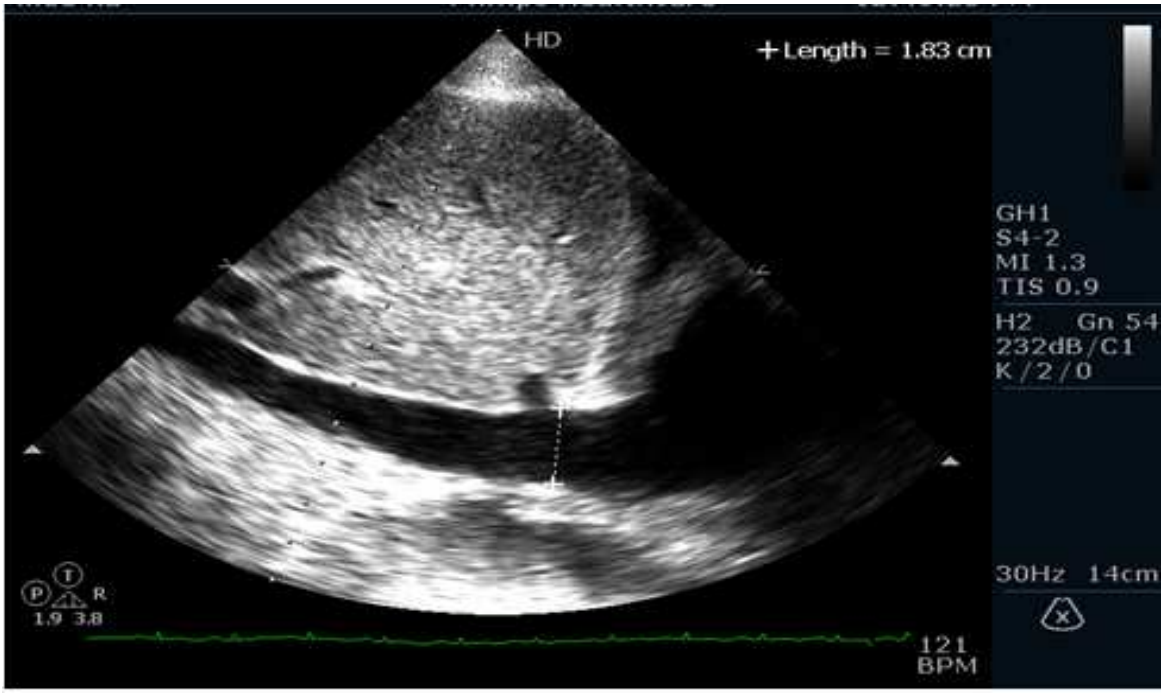


Figure 5. Schematic drawing of ultrasound beam. Reproduced with permission from Weyman (4).

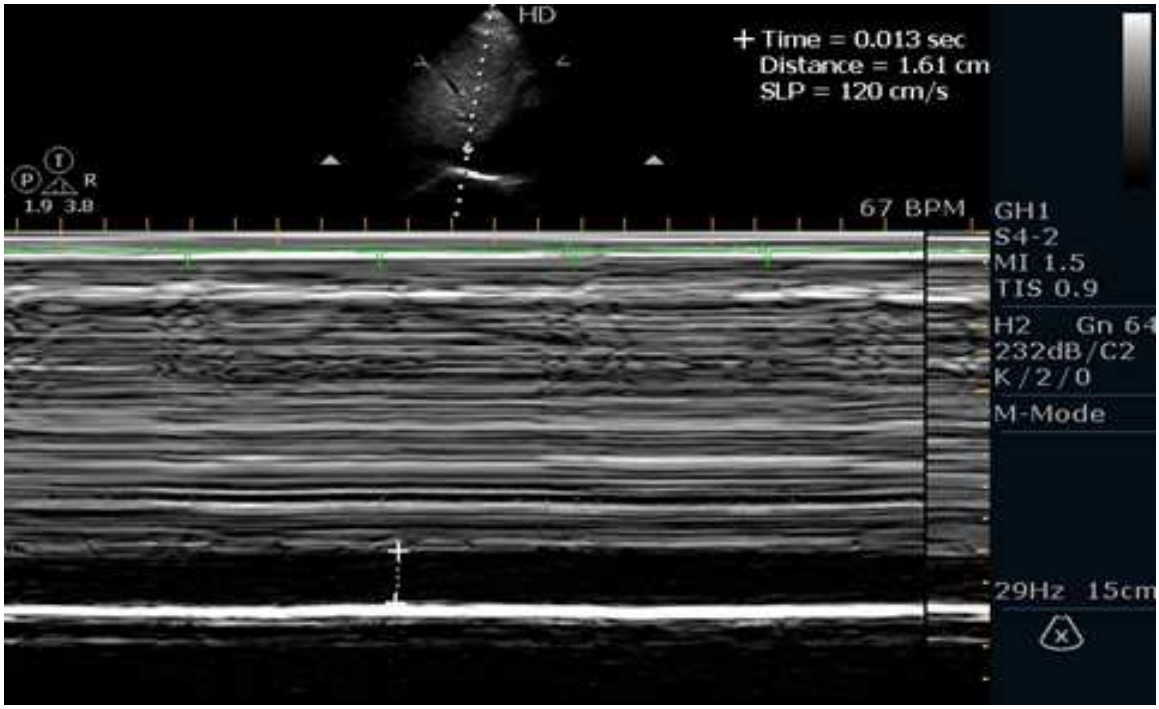
Imaging is optimal within the near field. Decreasing the wavelength or increasing the frequency, will lengthen the near field image.

The most commonly employed imaging mode. It allows repetitive scanning along many different radii within the area of interest. The generated image resembles the anatomic section, hence easily interpreted. It is very useful to image cardiac structures in detail.



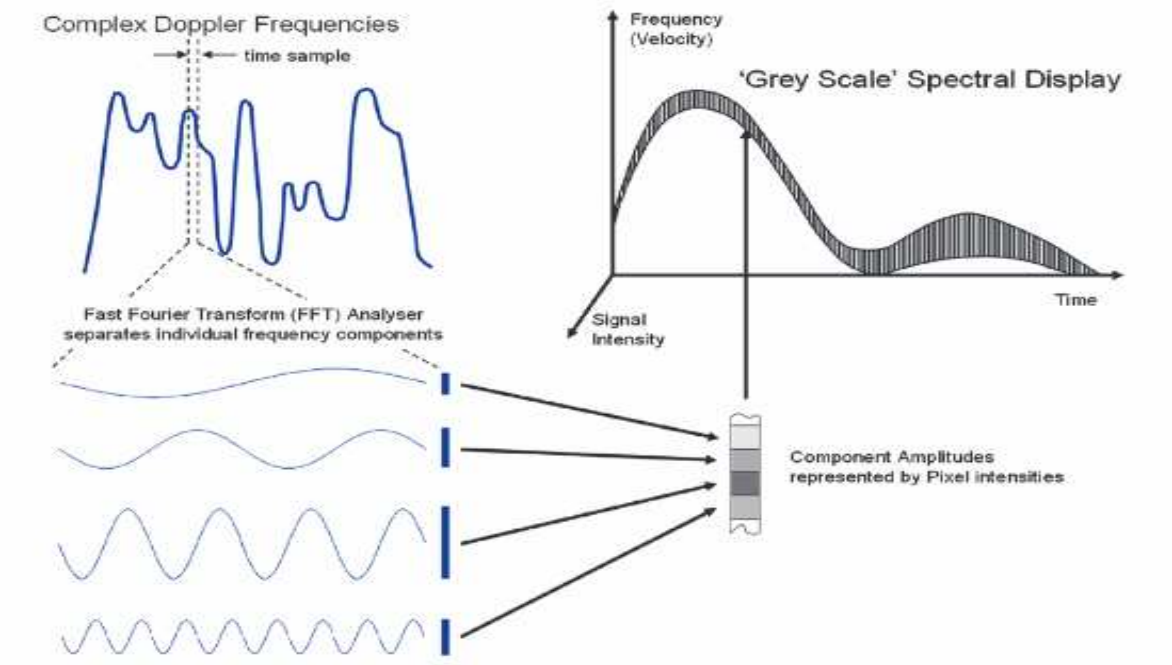
M MODE:

It is the basic mode of ultrasound imaging. The density and position of all the tissues along the path of a narrow ultrasound beam is displayed as a video scroll. It is not currently used as a primary imaging modality. It is used along with color flow Doppler for timing the abnormal flows.



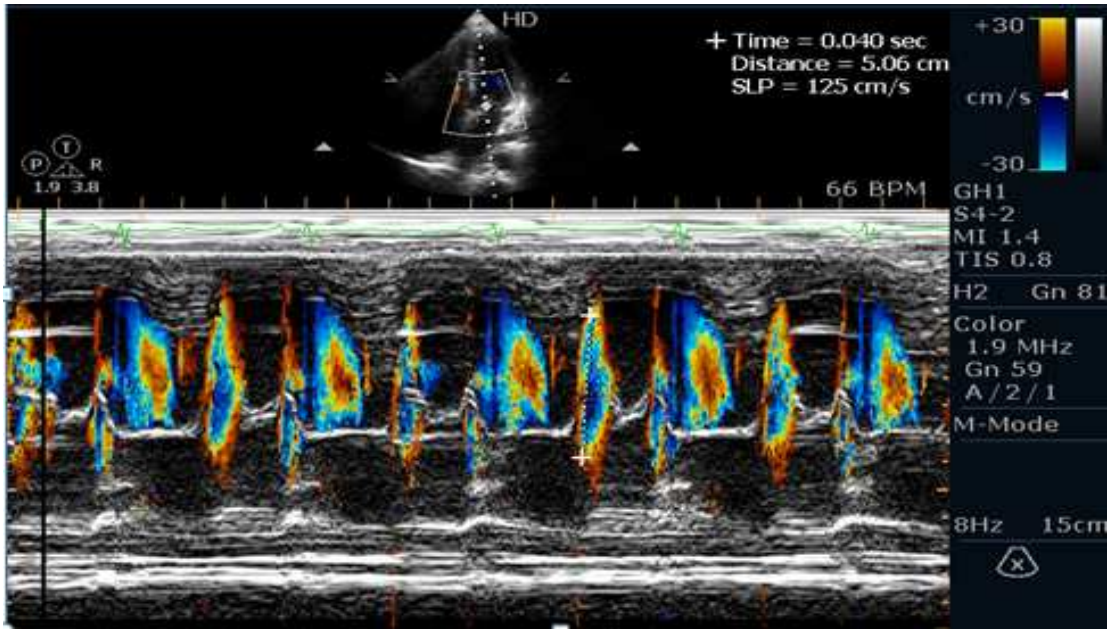
DOPPLER IMAGING:

Christian Doppler, an Austrian physicist (1842) described Doppler. Based on Doppler Effect and Shift, it is used to obtain the audio signals of blood flowing through the heart from which the velocity and direction of blood flow is calculated.



COLOUR FLOW MAPPING:

It is an advancement of Doppler imaging, wherein the real time blood flow within heart is displayed using colours.2D images are shown in black and white. It is mainly used to estimate the direction, velocity of blood flow as well as flow acceleration and differentiation between laminar and turbulent blood flow. Blood flow towards transducer is assigned as red and away from transducer is assigned as blue.



CVP ESTIMATION BY INTERNAL JUGULAR VEIN (IJV) IMAGING

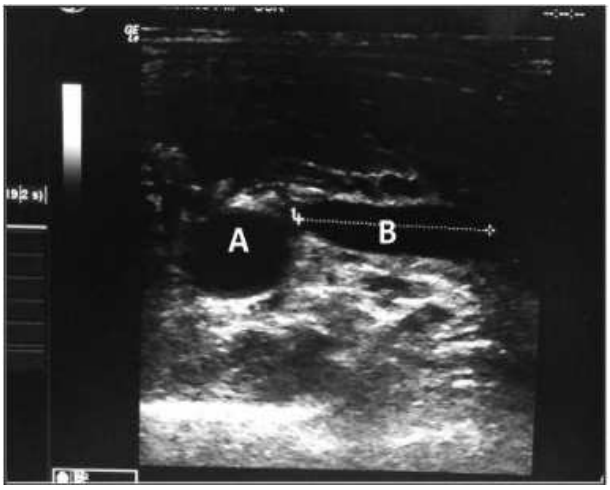
The estimation of central venous pressure is preferably done using right internal jugular vein, which is in directly communicating with right atrium. The clinical assessment of CVP will be marginally higher in left IJV. Both external jugular vein and IJV can be used. But IJV is preferred over external vein because it does not have valves and is in line with superior vena cava and right atrium.

Ultrasound estimation of height of IJV was performed by identifying the top of the venous pulsation with the patient lying at 45°. Minimal pressure has to be applied to ensure that venous occlusion should not occur with the probe. Both the transverse and longitudinal views have to be obtained. The height of the IJV was measured as the vertical distance between the top of the venous

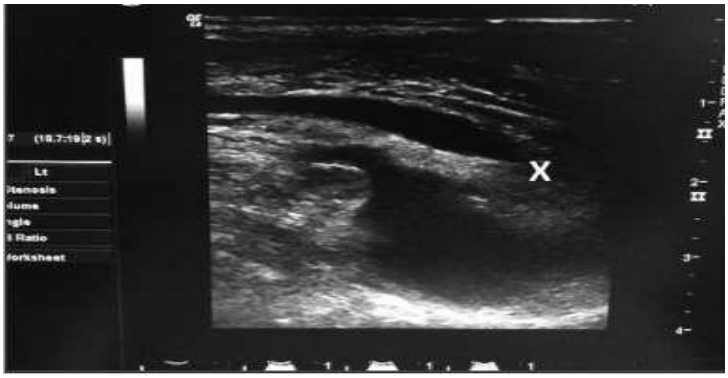
pulsation and the sternal angle. The CVP was estimated by adding 5 cm to the measured height of IJV. The top of venous pulsation is viewed in the longitudinal view and tapering of the IJV at its tip.

The high degree of correlation of CVP and IJV measurement via ultrasound can estimate CVP in non ventilated patients and can be used when ultrasound evaluation of IVC is difficult particularly in obese patients.

Transverse view of IJV and carotid artery



Longitudinal view of IJV



RELATIONSHIP BETWEEN THE IVC CALIBER AND CVP

The Inferior vena cava (IVC) is a compliant vessel; its size and hemodynamics often vary with the changes in intravascular volume and CVP. Blood flow from superior vena cava and IVC is biphasic, majority occurring during systole. There is a reciprocal relationship between the pressure and the flow. During inspiration, as IVC pressure decreases and hence flow increases due to negative intra thoracic pressure. At normal and low CVP, there is a predominant systolic flow and IVC collapses maximally during inspiration. In high CVP states, there is blunting of forward flow during systole, reduced Inspiratory collapse and eventual dilatation of IVC. The size and area of IVC are affected by position – largest being in right lateral decubitus position and least in left lateral decubitus position.

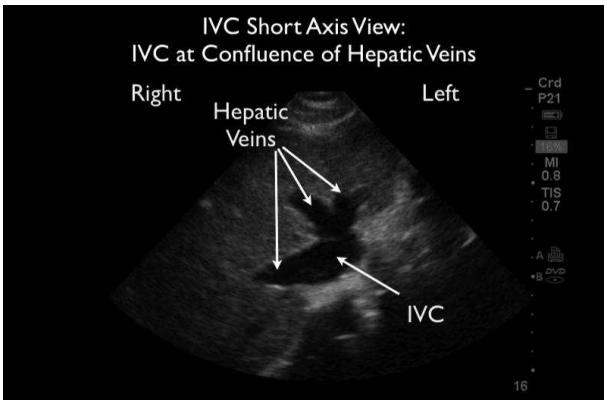
IVC SONO ANATOMY AND IMAGING

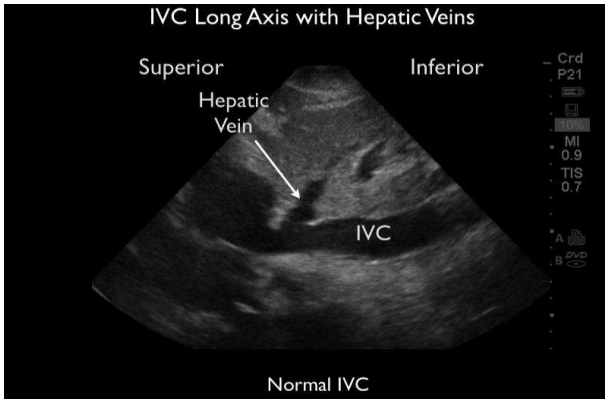
IVC lies to the right of aorta in the retro peritoneum and IVC passes posterior to liver where hepatic veins join the IVC,then drains into the right atrium. The IVC lies to the right of aorta in the retro peritoneum, is identified by its thin wall and respiratory flow variation. It is measured just at the junction with the right atrium and within three cm from that junction. A low frequency ultrasound probe is used to delineate IVC.

The American Society of Echocardiography recommends an assessment of IVC just proximal to the hepatic veins, which lies approximately 0.5 - 3.0 cm from the right atrium.

The probe is placed in the sub xiphoid four chamber position, with the probe marker oriented towards right - to identify right atrium and right ventricle. The convergence of IVC with the right atrium, is seen with the probe aimed progressively towards the spine. For the confluence of hepatic veins with IVC, the IVC should be evaluated inferiorly. For long axis evaluation of IVC, the probe should be in two chamber sub xiphoid orientation. This view delineates hepatic segment of IVC.

Short axis of IVC **Long axis of IVC**

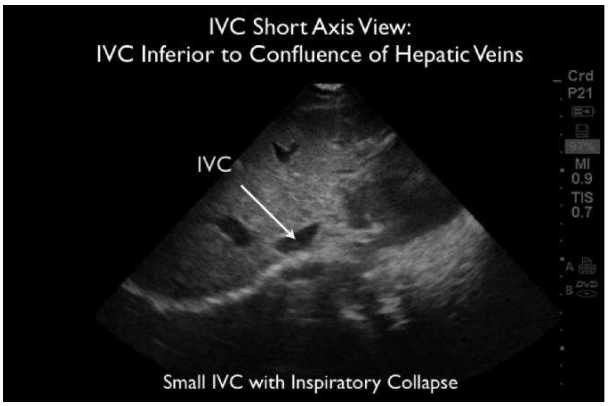


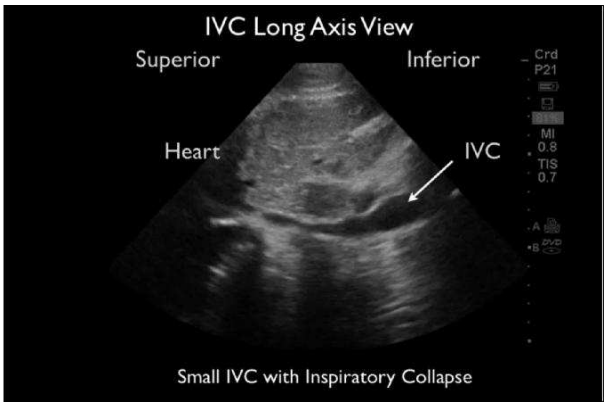


The best way to avoid underestimating the size of IVC in the longitudinal plane is to angle the probe laterally and medially, until the greatest dimension is identified as the ultrasound beam traverses the vessel longitudinally in an off centered plane. The diameter of IVC is measured,

perpendicular to the long axis of IVC at the end inspiration and end expiration.

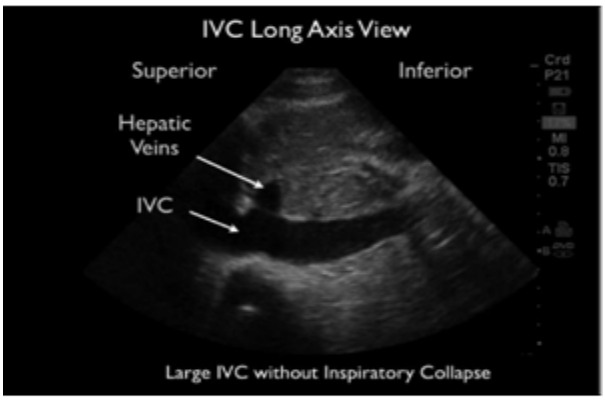
IVC short axis and long axis views showing Inspiratory collapse

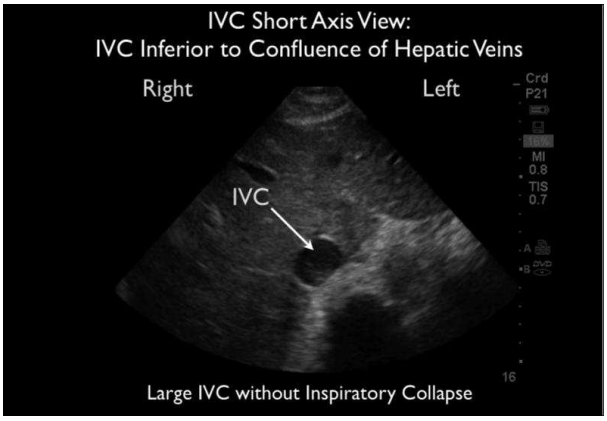




The presence of small IVC diameter with maximal inspiratory collapse due to incomplete emptying of lungs, an accurate measurement of the cardiac filling pressures can be difficult. (high collapsibility index) suggests low volume states such as hypovolemic and distributive shock. The presence of dilated IVC with minimal inspiratory collapse - suggests a high volume states such as cardiogenic and obstructive shock (low collapsibility index).The IVC is displaced relative to the probe, during inspiration and sniffing. This is circumvented by angling the probe inferiorly in short axis views and angling inferiorly and or laterally in long axis views to avoid tangential measurement. It is recommended to observe the changes of IVC through several respiratory cycles in both short and long axis views.

IVC long and short axis views showing no Inspiratory collapse

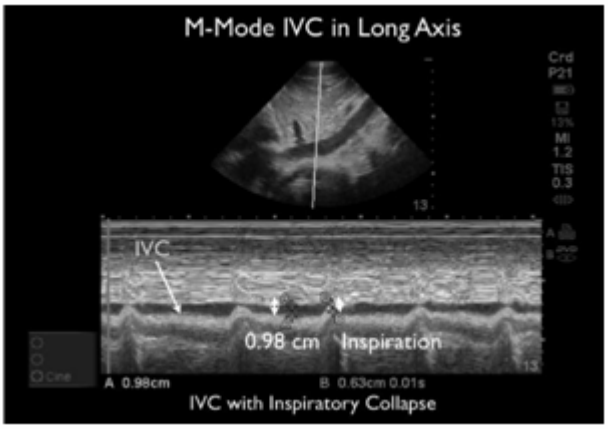


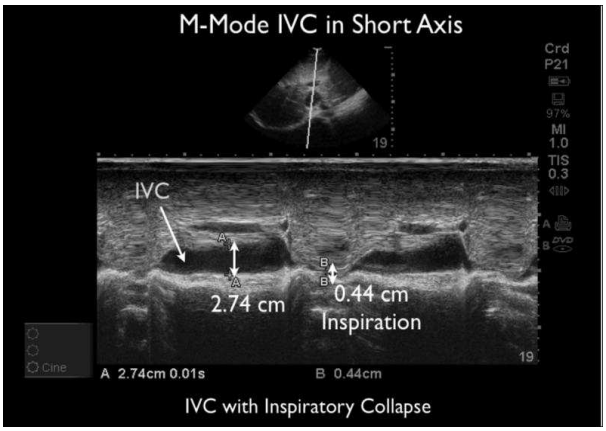


M MODE DOPPLER

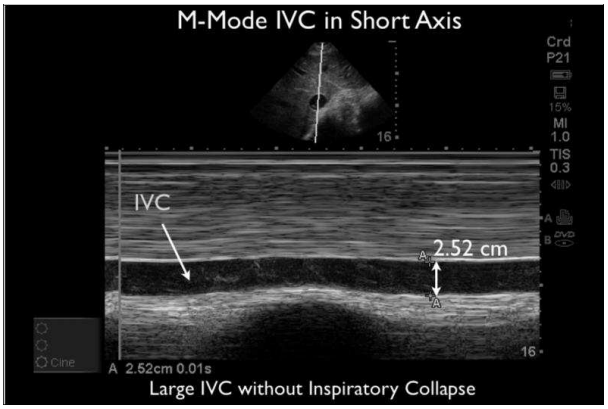
This mode is used to demonstrate graphically the absolute size and dynamic changes during phases of respiration in both short and long axial views of the IVC. This mode may show an inaccurate measurement of IVC due to its displacement relative to the probe during inspiration. IVC movement out of the plane of M-mode cursor may appear as vessel collapse. Hence M-mode should be used after adequately visualizing IVC variability in the B mode to avoid inaccurate estimation of vessel size and collapse.

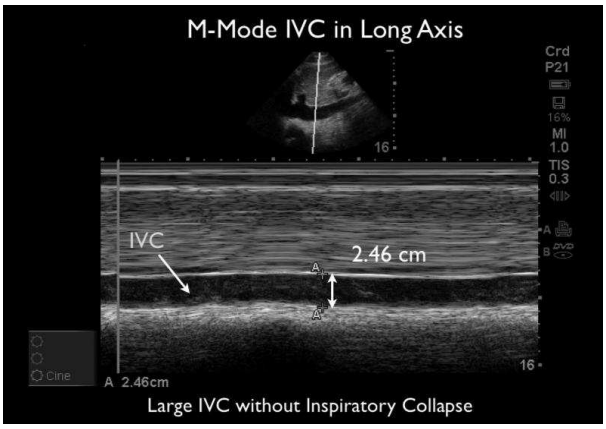
M mode short axis and long axis views showing Inspiratory collapse





M mode short axis and long axis views showing no Inspiratory collapse

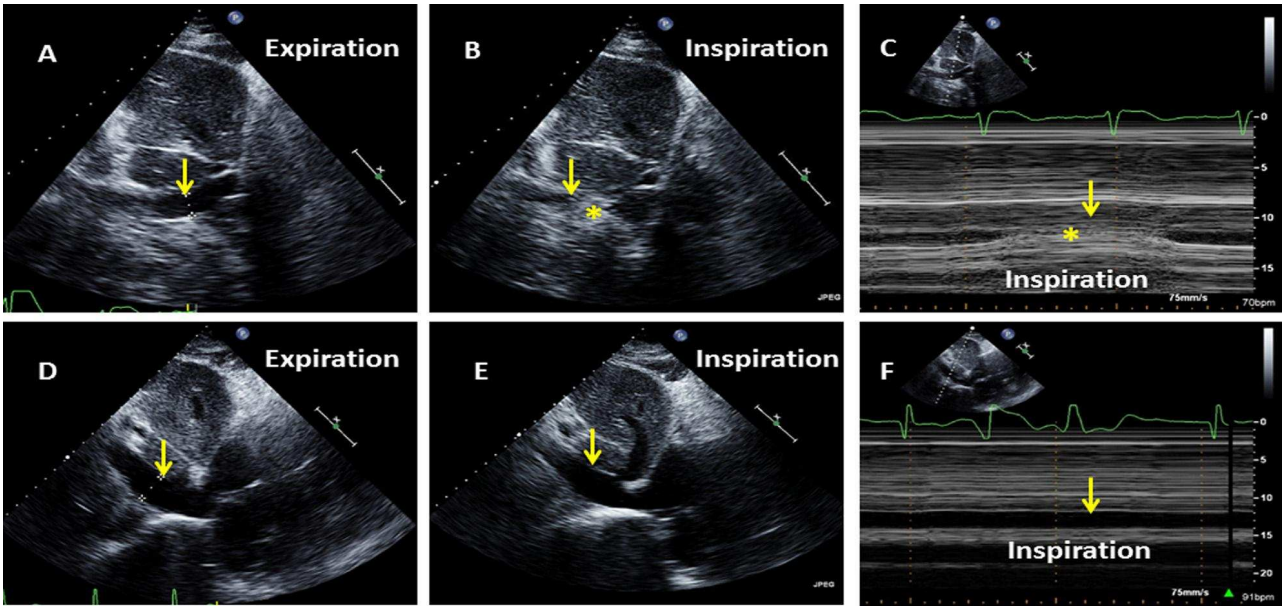




The American Society of Echocardiography (ASE) 2005 recommended maximum diameter of IVC 1-2cm from the junction of right atrium and the IVC at the end expiration and the IVC collapsibility index to estimate CVP.

ESTIMATION OF CVP USING IVC DIAMETER (ASE 2010)

IVC diameter (cm) and collapse (%)	CVP (mean) mmHg
Normal: < 2.1 cm and > 50%	0-5 (3)
Indeterminate	5-10 (8)
High: > 2.1 and < 50%	10-20 (15)



IVC COLLAPSIBILITY INDEX

The IVC collapsibility index also known as caval index is used to estimate right atrial pressure. A caval index greater than 50% suggests a low volume status especially in patients with small IVC diameter. Conversely, a low caval index with a large IVC diameter suggests a high volume state.The IVC collapsibility index is a better index to assess the intravascular volume status. During inspiration as intra thoracic pressure decreases and acts as a driving force for the venous blood from lower half of the body into right atrium. This causes transient decrease in IVC diameter. During expiration, IVC diameter increases and returns to baseline. These changes are referred as respiro phasic variability.

CORRELATION OF CVP AND IVC DIAMETER

CVP 0-5 cm: IVC totally collapses during inspiration and < 1.5 cm

CVP 5-10 cm: IVC collapses >50% during inspiration, 1.5-2.5 cm

CVP 11-15 cm: IVC collapses < 50% during inspiration, 1.5-2.5 cm

CVP 16-20 cm: IVC collapses < 50% during inspiration, > 2.5 cm

CVP > 20cm: No change in IVC during inspiration, > 2.5 cm

Mechanical ventilation reverses venous return hemodynamics. During inspiration, intra thoracic pressure increases which impede the blood flow - from IVC to right atrium. In expiration, venous return increases due to fall in intra thoracic pressure. In patients with normal right atrial pressure, there is minimal variation of IVC during respiration due to cyclic venous return.

In volume depleted patients, the IVC size increases with positive pressure ventilation since the right atrium and IVC are more compliant. The IVC assessment has been used in mechanically ventilated patients, to predict whether the fluid expansion will increase the cardiac output and stroke volume. The variation of IVC in mechanically ventilated patients - known as the distensibility index is the difference between the minimum and maximum IVC diameters divided by the minimum diameter. The IVC collapsibity index will determine the volume status, whereas the distensibility index - will assess preload dependence and predict the fluid responsiveness.

INDICES OF ELEVATED CVP IN ULTRASOUND

Dilated IVC with diminished respiratory collapse

Tricuspid E/e’ ratio > 6

Diastolic flow predominance in superior vena cava, jugular vein or hepatic veins

Bulging inter atrial septum to Left atrium

Dilated Right atrium

IVC ENLARGEMENT WITH NORMAL CVP

Mechanical ventilation

Prominent Eustachian valve

Large Body surface area

Narrowing of IVC - Right Atrial junction

Trained Athletes

HISTORICAL PERSPECTIVES

Clinicians began the association of prominent neck veins with heart disease almost three centuries ago. But the practice of actually measuring a patient's venous pressure during physical examination began just several decades ago.

In the late **1800s, Sir James Mackenzie** described most of the bedside diagnosis of JVP including a, c, v waves, cannon a waves and bedside diagnosis of atrial fibrillation (before the ECG era, based on pulse and neck veins).

In 20th century, following a direct canulation of antecubital vein, venous pressure became more important for the clinicians and they measured it directly by using manometry. Meanwhile **Ernest starling,** between **1912 - 1914,** found the correlation between the venous pressure and cardiac output.

Tinsley Harrison in his work "**Failure of circulation**" endorsed **Starling's** views and advocated increased pressure as an early and essential finding of heart failure.

Sir Lewis Thomas was **Mackenzie's** pupil and in **1930** he described a simple bedside method to measure venous pressure. It was a replacement

for the manometer. He observed that the top column of jugular vein and the top of fluid in the manometer always came to lie within 1-2 cm of the vertical distance from the sternal angle irrespective of the individual's position. Lewis concluded that if patient had neck veins above this, he had elevated venous pressure.

1867 Potain described the waveform of IJV and **Mackenzie** provided the nomenclature.

1902 Sir James Mackenzie established JVP as an essential part of cardiovascular physical examination.

1930 Sir Lewis Thomas first described about venous pressure during physical examination.

1950 Paul wood rekindled interest of estimation of CVP using sternal angle.

1953 Seldinger described the replacement of a catheter needle using guide wire during central venous canulation.

1959 Hughes and Magovern described the clinical use of CVP measurement of humans undergoing thoracotomy.

1962 Wilson and associates extended the practicality of CVP monitoring by using percutaneous infraclavicular subclavian vein catheterization.

1969 English et al described the first IJV canulation.

1978 The use of ultrasound for central venous access was first described. The skin overlying IJV was marked by Doppler localization.

1978 Ullman et al first described ultrasound to facilitate the catheter placements in IJV.

2010 Ortega et al described the methodology to use ultrasound for locating the IJV highlighting the safety and reliability of the technique.

REVIEW OF LITERATURE

. **Bruce Lipton[8], 2000** from Emergency medicine department, Kaiser, CA described a new simple technique using ultrasound to estimate dCVP. Two points on the patient were required to estimate the height of blood column in jugular veins. The first point is the position of the right atrium or zero reference point. The angle of Louis is substituted for this. The second point corresponds to the top of blood column in the jugular vein and is obtained by visualizing its point of collapse. Above this point vein is collapsed and below this, vein is distended and non-pulsatile. This point is located using real time ultrasound. The vertical distance between the top of jugular pulse and angle of Louis measured. 5 cm is added to equal the CVP in cm of water. Lipton described sonographic patterns within the IJV determining the venous collapse between the supine, semi upright and upright positions and concluded that the patient can be differentiated as those with low (< 10mm Hg), high (>10 mm Hg) and extremely high (> 20 mm Hg) CVP's.

Serenat citilciogue[46] et al 2011 did a study in Emergency medicine department, Adana Numune Education and Research hospital, Turkey (with 34 patients having spontaneous respiration and 11 requiring mechanical ventilation). Their aim was to demonstrate the relationship between IVC diameter (measured noninvasively with the help of ultrasound) and CVP

during evaluation of patient's intra vascular volume status. All patients were aged above 18 years had a central venous catheter inserted in their IJV or Sub clavian vein. IVC diameters were recorded in mm with the help of ultra sonogram both at end inspiration and end expiration. A significant relationship was found between IVC diameters measured by ultrasound at end expiration and end inspiration and the measured CVP values (for expiratory p=0.002, inspiratory p=0.001). On the contrary there was no statistically significant association between IVC diameters measured by ultrasound and CVP values in mechanically ventilated patients.

Kent28 et al, 2013 a prospective comparative study was conducted on a convenient sample of 34, surgical intensive care patients to evaluate the interchangeability of IVC - Collapsibility index and sub clavian vein - Collapsibility index. All patients underwent serial, paired assessments of IVC-CI and SCV-CI using ultrasound, vein collapsibility was calculated using the formula,

$$\textbf{Collapsibility \%} = \frac{\textbf{Maximum diameter} - \textbf{Minimum diameter}}{\textbf{maximum diameter}} \times \textbf{100}$$

Amir khalil[2] et al 2013did a cross sectional study to determine the intravascular fluid status in critically ill patients using IVC diameter. The study was done in Intensive care unit Military hospital Rawalpindi. They included 115 spontaneously breathing patients of both genders in the age

range (18 to 87) by consecutive sampling. The variables included in study were age, gender, CVP and IVC diameter.They concluded that a simplebedside ultrasound of IVC diameter correlates well with extremes of CVP values and can be useful in assessing intravascular volume status.

Nik Azlan[38] et al, 2013

The prospective cross sectional observational study was conducted in 25 nonventilated, nonintubated patients from the ED University Kebangsaan Malaysia Medical centre (UKMMC) in 2013.The aim was to determine the correlation between CVP measured by conventional central venous access and ultrasound measurement of IJV height and IVC diameter. They concluded that measurement of IJV height and IVC diameter by ultrasound correlates well with invasive CVP and is useful in assessing intravascular fluid status in critically ill patients in ED.

Ahamed Abbasian[1] et al,**2014** conducted a study on 20 patients of mean age in Emergency medicine department, Imam khomeini hospital, Tehran .Their aim was to measure the diameter and cross section of IVC and IJV using ultrasound and compare it with measured CVP via catheter and thus introduce new methods to measure circulation volume. By using this method, volume assessment of the patient in conditions where it is not possible to insert a central venous catheter (e.g. coagulation disorders,

neck injury, disorganized anatomy) can be done in a quick, easy, non invasive manner.

Jacques Rizkallah[27] et al, 2014 did a study on patients who were scheduled for their regular echocardiograms at St. Bomface Hospital's Medicine department, Winnepeg. Their objective was to non invasively evaluate CVP by clinically assessing JVP, PVC (Peripheral venous collapse) and ultrasound visualization of IVC by hand held mini echo. The relative accuracy of these techniques was compared with one another. The investigators were trainees of varying experience including a second year medical student with limited clinical experience, a second year internal medicine resident with 3 years clinical experience and a second year cardiology fellow with 6 years clinical experience. All formal echo's were completed by a trained sonographer and interpreted by a level 3 echo cardiographer who established the reference CVP based on the evaluation of IVC's caliber and response to respiration (as recommended in 2010-American society of echo guidelines). The classic PVC technique and Anthem sign had better specificity compared to the JVP. Anthem sign was introduced and validated as a new physical examination technique to assess CVP.

Bahman Naghipour[3] et al, 2015 did a prospective cross sectional study in patients requiring central venous catheterization and TEE in Emergency Department Amiralmomenin Hospital, Iran .This study had the

objective to find the best anatomical location for measuring the IVC. The precise correlation between CVP and IVC diameter using TEE was determined. Maximum IVC diameter was measured during the expiratory phase of respiratory cycle 2 cm above the level of diaphragm and at the point of entry into right atrium using TEE device. CVP was determined using an electronic transducer connected to the central line. The best location for scan was determined by calculating and comparing area under the ROC (receiver operating characteristics). Of the enrolled 39 patients, mean CVP was 6.8 ± 1.4 mm Hg, 25 patients had normal CVP, while 14 showed elevated > 6 mm Hg CVP. Upon evaluating AUC, they found that IVC diameter (p=0.01), aorta diameter (p0.01), IVC/aorta ratio (p=0.004) had an acceptable correlation with CVP. Point of entry of IVC into right atrium with AUC of 0.98(95% CI: 0.95 -1.00). They concluded that the IVC sonograghic diameter and IVC/aorta ratio had an acceptable correlation with CVP at the level of IVC entry into the right atrium. This was found to have a precise correlation between CVP and IVC diameter using TEE.

SA Aydin[44] et **al 2015** did a cross -sectional study in ED**,** Uludag University,Turkey in 102 patients with a mean age of 59, referred for non traumatic issues. Their aim was to investigate whether a correlation exists between hemodynamic parameters of critically ill patients and IVC

diameter. IVC diameters were measured by ultrasound and then CVP measured. Antero posterior (AP) diameter and Medio lateral (ML) diameter of IVC both in inspiration (IAP, IML) and expiration (EAP, EML) were measured by ultrasound.

Mucahit Avcil[35] **et al 2015** conducted a prospective comparative study Turkey among 37 non ventilated and 36 ventilated patients. For monitoring CVP, ultrasonography was performed.IJV and IVC diameters were measured during one respiratory cycle and IJV area and IVC index were calculated. Tapering portion of right IJV was defined and height from this point to the sternal angle was used to estimate CVPusg. The aim of this study was to compare four methods of non invasive CVP estimation both in high and low CVP states among critically ill patients. The parameters compared include IJV max, IJV min, IJV area, CVPusg, IVC max, IVC min, IVC CI. During comparison, CVP of 10 was selected as cutoff for high CVP and CVP 6, as cutoff for low CVP. The IJV max, IJV min, CVP usg correlated moderately with invasive CVP, whereas IVC CI, IVC min and IVC max showed poor correlation. The CVP usg cutoff value of 7 predicted CVP inv > 10 mm Hg with sensitivity of 90%, specificity 67.3% and predicted CVP inv < 6 mm Hg with sensitivity 77%, specificity 68%. IJV max, IJV min, IJV area, IVC max showed high sensitivity (90.32%.,83.87%.,90.32%.,93.10% respectively) for low CVP levels. The

IVC-CI has high sensitivity (95.2) and poor specificity (42.9) for high CVP levels. They concluded that IVC-CI and CVP usg had better diagnostic performance for estimating high CVP. IJV max, IJV area and IVC max showed high sensitivity and NPV for low CVP levels.

MATERIALS AND METHODS

STUDY CENTRE - The study was conducted in the Post Anaesthesia Care Unit (PACU), Institute of Anesthesiology and Critical care, Rajiv Gandhi Government General Hospital, Chennai. This clinical setting was selected for the study because the controlled environment of PACU, provided sufficient facilities and safety features.

Institutional ethical committee clearance was obtained prior to conduct our study. All the relatives of the participating patients were provided with informed written consent, in their own vernacular language and explanation of procedure was done in detail.

STUDY DURATION – 5 Months

STUDY DESIGN - This is a prospective comparative study. Fifty post operative patients of either sex were allocated into three groups (normal, high and low) based on their invasive CVP. Their invasive CVP values were compared with sonographically measured parameters like IJV max, IJV min, IJV area, IVC max, IVC min, IVC-Collapsibility Index.

GROUP N - NORMAL CVP GROUP

Patient having invasive CVP values between 6 to 10 mm of Hg.

GROUP H - HIGH CVP GROUP

Patient with invasive CVP values more than 10 mm of Hg.

GROUP L - LOW CVP GROUP

Patient with invasive CVP values less than 6 mm of Hg.

MATERIALS USED

In this study, we used SONORAY ultrasound machine, vascular transducer with frequency (4-12 MHz), curved probe with frequency (1-5MHz), aqueous gel.

INCLUSION CRITERIA

1. Above 18 years of age

2. Postoperative patients on mechanical ventilation requiring invasive hemodynamic monitoring who have given valid informed consent.

EXCLUSION CRITERIA

1. Deep vein thrombosis in upper extremities, Internal jugular vein thrombosis
2. H/o Radiotherapy or neck surgery
3. Clinically significant MR/TR/Dilated RA,RV/PHT/SVC obstruction
4. Patients unable to lie in supine position
5. Patients requiring special mechanical ventilation modes like Inverse Ratio Ventilation, Continuous Positive Airway Pressure
6. Peak Inspiratory Pressure > 25 mm Hg, Positive End Expiratory Pressure > 5 mmHg.

HISTORY

History of other medical illness

History of previous Radiotherapy or neck surgery

History of any coagulation abnormalities or bleeding diathesis.

PHYSICAL EXAMINATION

General condition of the patient.

Vital signs.

BMI.

STUDY PROTOCOL

The patients who satisfied the inclusion criteria were selected and their relatives explained about the nature of the study and the procedure. The detailed history of all the patients was recorded.

In PACU, monitors were connected to the mechanically ventilated patients, their baseline vital parameters recorded.

Internal jugular Vein (IJV) and Inferior vena cava (IVC) measurements were obtained using ultrasound device. We used a linear array (4-12MHz) ultrasound probe for IJV imaging and a convex phased array (1-5MHz) probe for IVC imaging. The operator (myself) underwent two hours of focused training in methods of sonograghic measurement in our hospital's radiology department.

MEASUREMENT OF IJV PARAMETERS

IJV diameter and area measurements were obtained with the patients in supine position. The vascular transducer was placed on the right side of patient's neck in a transverse plane over the internal jugular vein, 2 cm above the level of clavicle. It was ensured that at least 1 cm of subcutaneous tissue was preserved by observing on the display monitor. Internal jugular vein image was recorded for one respiratory cycle and saved on the ultrasound machine. The minimum and maximum values were recorded. The Internal jugular vein area was calculated by the ultrasound machine automatically.

MEASUREMENT OF IVC PARAMETERS

Inferior vena cava measurements were obtained with the patients lying in supine position. The IVC diameter was measured in the sub xiphoid saggital view. The junction of the inferior vena cava and the hepatic vein was observed. Measurements were done 1 cm distal to that junction. Images were recorded for one respiratory cycle and were saved on the ultrasound machine. The minimum and maximum anterior – posterior diameters were recorded.

The Inferior vena cava collapsibility index was calculated from the minimum and maximum anterior – posterior inferior vena cava diameters as follows:

$$\frac{\text{Expiratory IVC} - \text{Inspiratory IVC}}{\text{Expiratory IVC}} \times 100$$

The patient had a central venous catheter in place and distal port of the triple lumen catheter was used for measurement of CVP and it was connected to a monitor via a pressure transducer. The transducer was zeroed to the level of the heart and the values were noted after the completion of the ultrasound examination. The invasive CVP is the standard criterion to which the various ultrasound parameters were compared.

ULTRASOUND PARAMETERS OBSERVED

MAXIMAL INTERNAL JUGULAR VEIN DIAMETER (IJV max)
MINIMAL INTERNAL JUGULAR VEIN DIAMETER (IJV min)

INTERNAL JUGULAR VEIN AREA (IJV area)

MAXIMAL INFERIOR VENA CAVA DIAMETER (IVC max)

MINIMAL INFERIOR VENA CAVA DIAMETER (IVC min)

INFERIOR VENA CAVA COLLAPSIBILITY INDEX (IVC-CI)

OBSERVATION AND RESULTS

In our study, we analyzed about 50 patients during the study period. All were postoperative patients on mechanical ventilation.Four patients were excluded from the study because two had deep vein thrombosis, one had superior vena cava syndrome and another patient, we could not insert central venous pressure catheter.The Internal jugular vein diameter and area measurements were successfully recorded. The Inferior vena cava diameters (both minimum and maximum) and IVC CI were recorded.

The mean age and the percentage of males of the study participants was 45.0 years and 72.73%, 42.07 years and 50%, 41.68 years and 68% in low, high, normal CVP groups respectively. A central venous pressure of 10 mm Hg was chosen as a clinically significant cutoff for high CVP. The cutoff for low CVP was 6mm Hg.

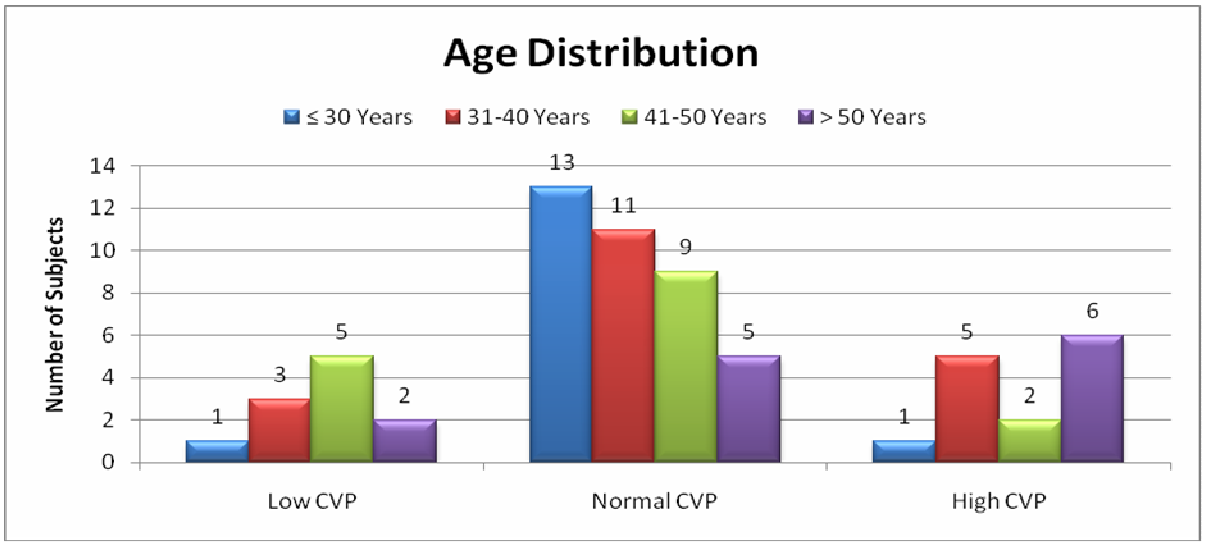
In our study, for CVP < 6mm Hg, the sensitivity of IJV max, IJV min and IVC max was high (between 100% to 97.4%).The specificity of all six parameters were 100%.The PPV was also 100%, NPV was high for IJV max, IJV min, IVC max.AUC IJV max, IJV min, IJV area, IVC max, IVC min, IVC - CI as diagnostic tests were in excellent range.For high CVP > 10mm Hg, the sensitivity was 100% for all six

parameters. The specificity was high for IVC min and IVC-CI at 98%.The PPV was high in IVC min and IVC- CI with 93.3%.The NPV was again 100% for all six parameters.AUC IJV max, IJV min, IJV area, IVC max, IVC min, IVC - CI as diagnostic tests were in excellent range.

STATISTICAL ANALYSIS

Descriptive statistics were done for all data and were reported in terms of mean values and percentages. Suitable statistical tests of comparison were done. Continuous variables were analyzed with the unpaired t test and ANOVA. Categorical variables were analyzed with the Chi-Square Test and Fisher Exact Test. Pearson's product – moment correlation coefficients were used to analyze the correlation coefficients. The accuracy analysis was reported as sensitivity, specificity, PPV, NPV and accuracy. ROC curve analysis was done to calculate area under curve. Statistical significance was taken as $P < 0.05$. The data was analyzed using SPSS version 16 and Microsoft Excel 2007.

FIGURE1: AGE DISTRIBUTION

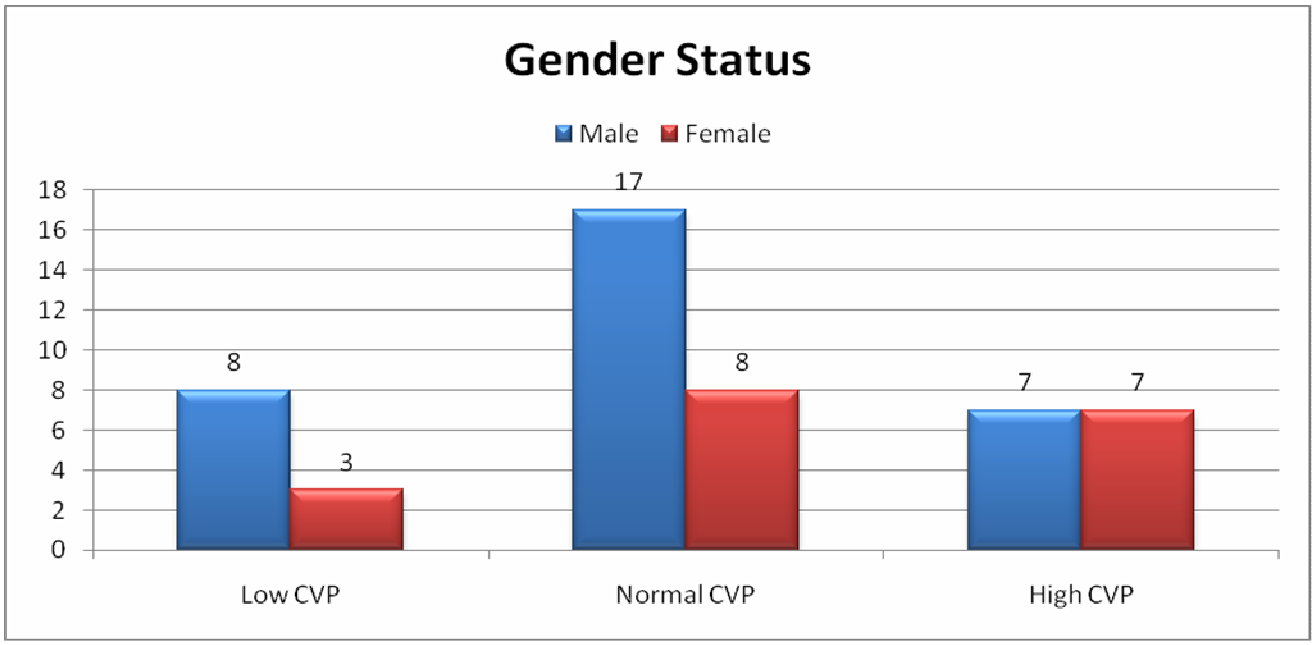


Age Distribution	Low CVP	%	Normal CVP	%	High CVP	%
≤ 30 Years	1	9.09	13	52.00	1	7.14
31-40 Years	3	27.27	11	44.00	5	35.71
41-50 Years	5	45.45	9	36.00	2	14.29
> 50 Years	2	18.18	5	20.00	6	42.86
Total	11	100	25	100	14	100

Age Distribution	Low CVP	Normal CVP	High CVP
N	11	25	15
Mean	45.00	41.68	42.07
SD	9.78	10.23	16.36
P value One way ANOVA Test		0.6654	

Majority of the low CVP group patients belonged to the 41- 50 years age class interval (n=5, 45.45%) with the mean age of 45.0 years. In the normal CVP group patients, majority belonged to the less than 30 years age class interval (n=13, 52.0%) with a mean age of 41.68 years. In the high CVP group patients, majority belonged to more than 50 years class interval (n=6, 42.86%) with the mean age of 42.07 years. The association between the study groups and age distribution is considered to be not statistically significant since $p > 0.05$ as per one way ANOVA test.

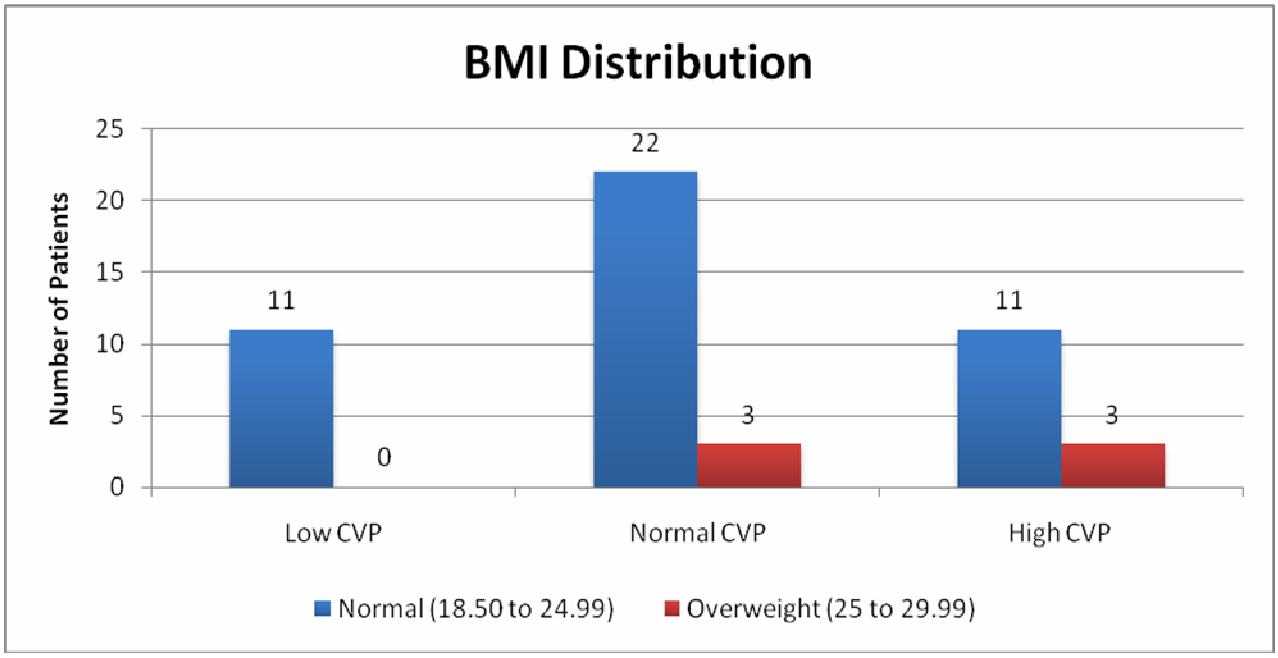
FIGURE2: GENDER DISTRIBUTION



Gender Status	Low CVP	%	Normal CVP	%	High CVP	%
Male	8	72.73	17	68.00	7	50.00
Female	3	27.27	8	32.00	7	50.00
Total	11	100	25	100	14	100
P value Fishers Exact Test			0.5047			

Majority of low CVP group patients belonged to male gender (n=8, 72.73%). In the normal CVP group patients, majority belonged to male gender (n=17, 68.00%). In the high CVP group patients, majority belonged to male gender (n=7, 50.00%). The association between the study groups and gender status is considered to be not a statistically significant since p > 0.05 as per one way ANOVA test.

FIGURE 3: BMI DISTRIBUTION

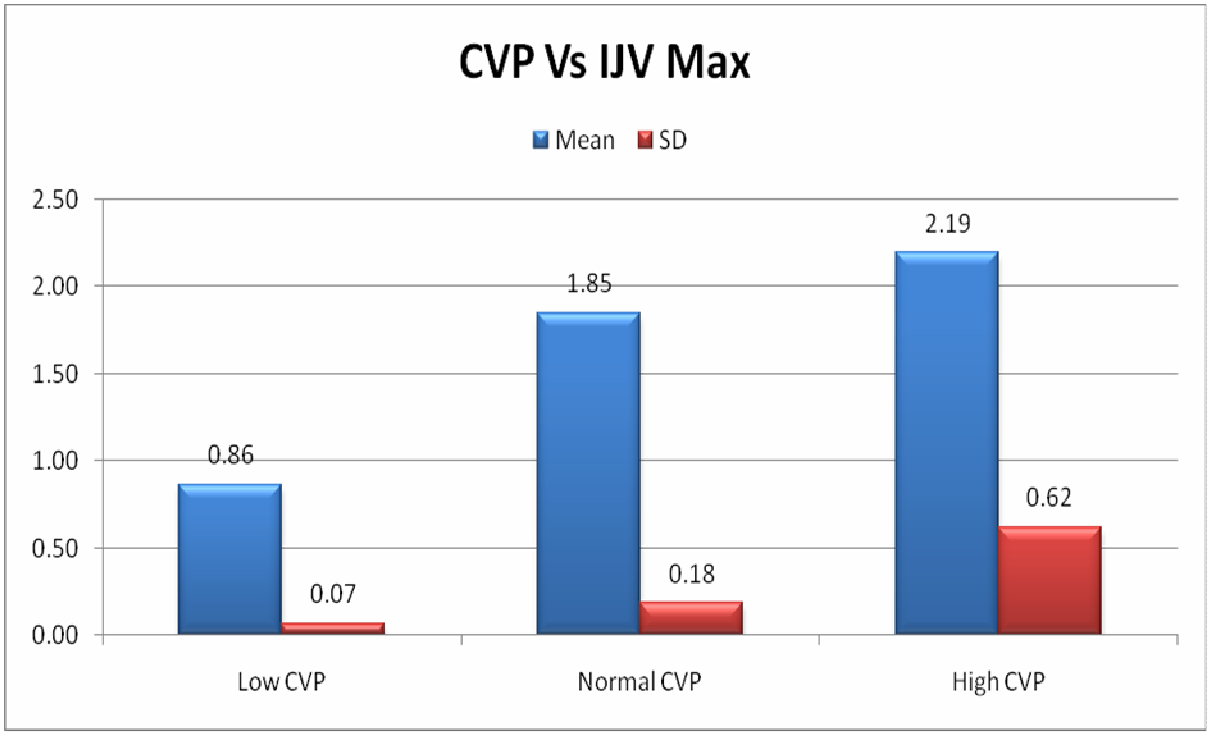


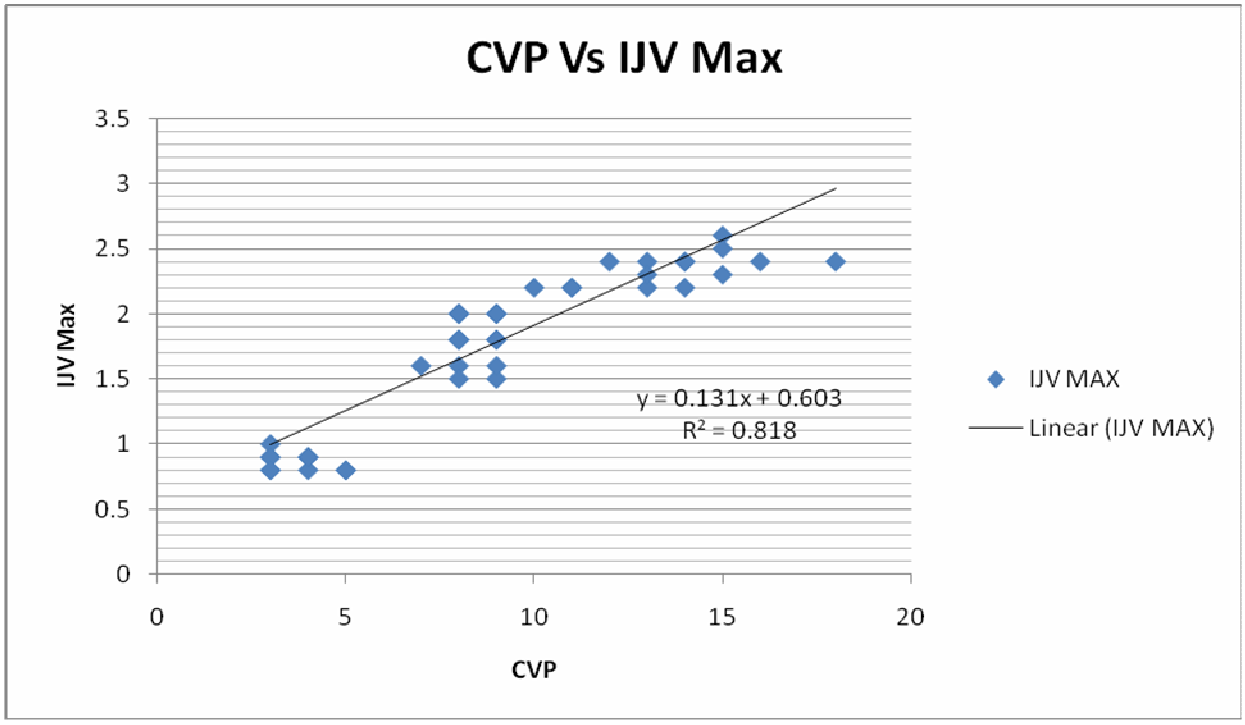
BMI Distribution	Low CVP	%	Normal CVP	%	High CVP	%
Underweight (≤ 18.49)	0	0.00	0	0.00	0	0.00
Normal (18.50 to 24.99)	11	100.00	22	88.00	11	78.57
Overweight (25 to 29.99)	0	0.00	3	12.00	3	21.43
Obese	0	0.00	0	0.00	0	0.00
Total	11	100	25	100	14	100

BMI Distribution	Low CVP	Normal CVP	High CVP
N	11	25	14
Mean	22.68	23.39	23.19
SD	1.27	1.20	2.24
P value One way ANOVA Test		0.3282	

Majority of low CVP group patients belonged to normal BMI class interval (n=11, 100%) with a mean BMI of 22.68. In the normal CVP group patients, majority belonged to the normal BMI class interval (n=22, 88.00%) with a mean BMI of 22.39. In the high CVP group patients, majority belonged to the normal BMI class interval (n=11, 78.57%) with a mean BMI of 23.19. The association between the study groups and BMI distribution is considered to be not statistically significant since $p > 0.05$ as per one way ANOVA test.

FIGURE 4: CVP Vs IJV MAXIMUM





CVP Vs IJV Max	Low CVP	Normal CVP	High CVP
N	11	25	15
Mean	0.86	1.85	2.19
SD	0.07	0.18	0.62
Pearson's "r" Correlation			0.904495
P value One way ANOVA Test			**<0.0001**

The mean IJV max diameter measurement in low CVP, normal CVP and high CVP is 0.86, 1.85 and 2.19 cm respectively. IJV max diameter measurement is 0.98 cm more in normal CVP group compared to low CVP group (53% increase), 0.35 cm more in high CVP group compared to normal CVP group (16% increase) and 1.33cm more in high CVP group (61% increase).

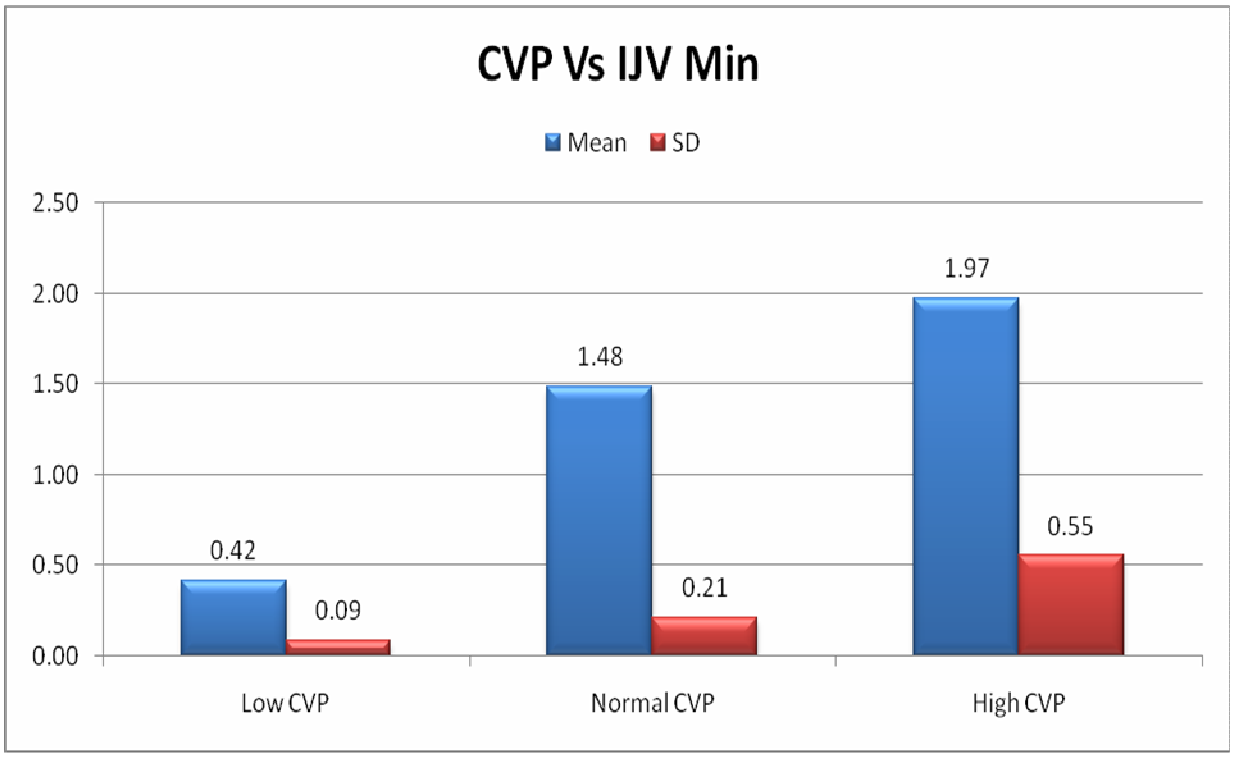
There is a strong positive correlation between IJV max diameter and increase in CVP. This is indicated by the Pearson's R correlation value of 0.904495. This means as IJV max diameter increases, the CVP increases. This means that the increase in IJV diameter due to high CVP happens 91% of times.

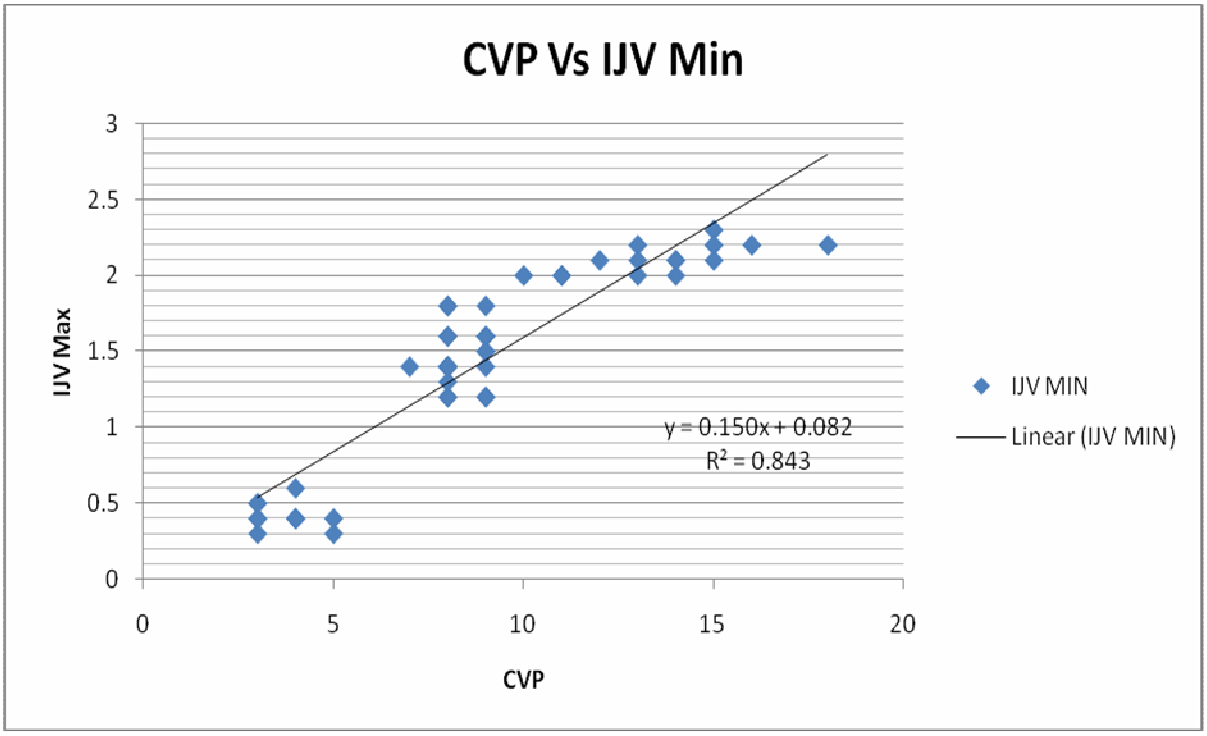
This direct positive and high correlation is significant with a p value of <0.0001 as per analysis of variance test. The percentage change is also explained in the scatter plot. This linear model explains all the variability of the response data around its mean. Since R^2 is 0.8181, "the fitted

regression equation explains 82% of the variation in Y" (Y=0.1313 (CVP measurement) + 0.603).

Thus 1 mm Hg increase in CVP causes 0.73 increase in IJV max diameter. This variation in IJV max diameter in relation to CVP levels correlates 91% of times and this variation is truly accounted 82% of times.

FIGURE 5: CVP Vs IJV MINIMUM





CVP Vs IJV Min	Low CVP	Normal CVP	High CVP
N	11	25	15
Mean	0.42	1.48	1.97
SD	0.09	0.21	0.55
Pearson's "r" Correlation			0.918336
P value One way ANOVA Test			**<0.0001**

The mean IJV min diameter measurement in low CVP, normal CVP and high CVP is 0.42, 1.48 and 1.97 respectively. IJV min diameter measurement is 1.07 cm more in normal CVP group compared to low CVP group (28% increase), 0.49 cm more in high CVP group

compared to normal CVP group (25% increase) and 1.56 cm more in high CVP group compared to low CVP group (79% increase).

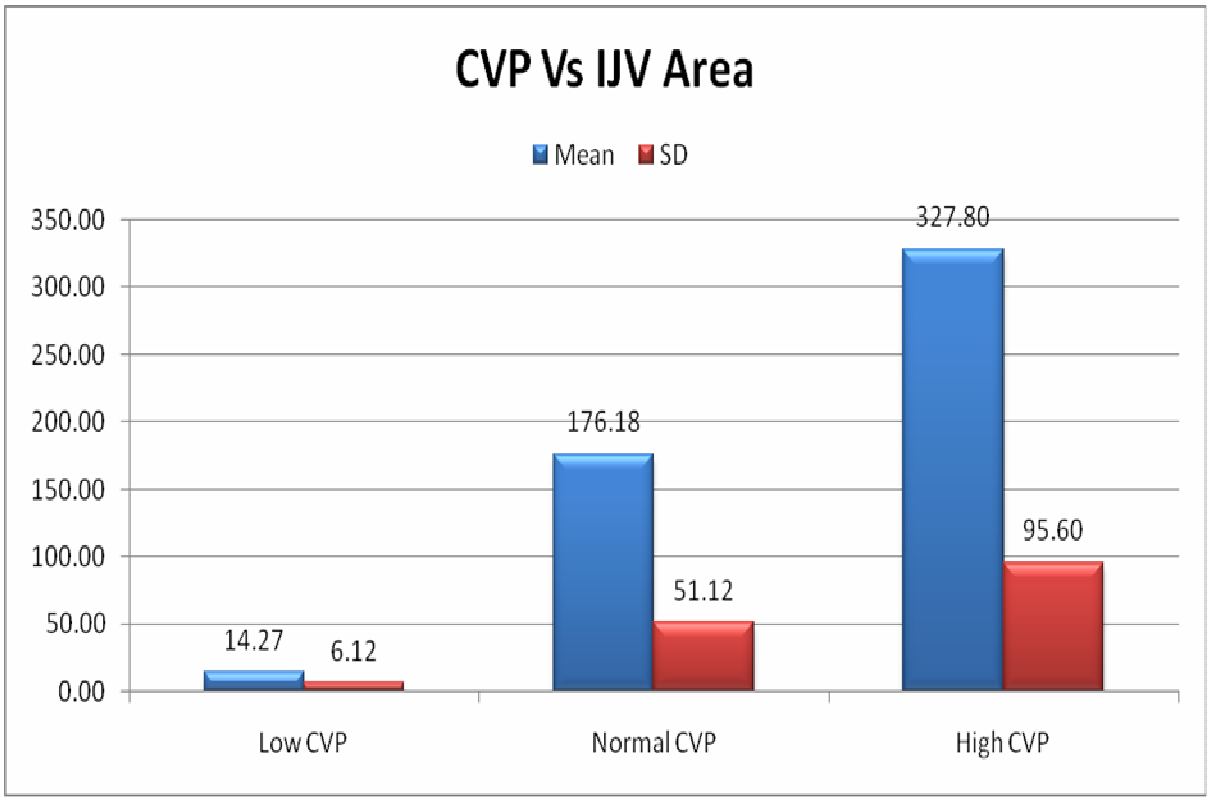
There is a strong positive correlation between the IJV min diameter and increase in CVP. This is indicated by the Pearson's R Correlation value of 0.918336. This means as IJV diameter increases, the CVP increases. This means that the increase in IJV min diameter due to high CVP happens 92% of times.

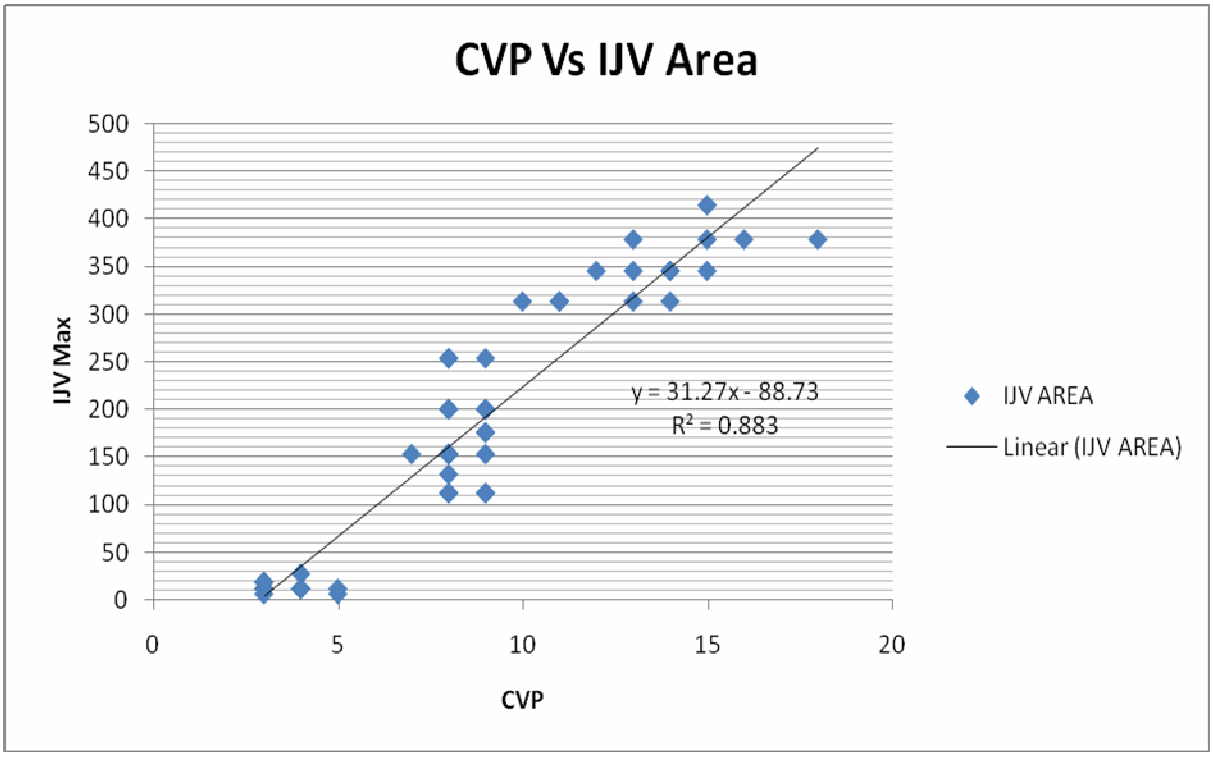
This direct positive and high correlation is significant with a p value of <0.0001 as per analysis of variance test. The percentage is also explained in the scatter plot. This linear model explains all the variability of the

response data around its mean. Since R^2 is 0.8433, “the fitted regression equation explains 84% of the variation in Y” (Y= 0.1509(CVP measurement) + 0.0828).

Thus 1 mm Hg increase in CVP causes 0.23 cm increase in IJV min diameter. This variation in IJV min diameter in relation to CVP levels correlates 92% of times and this variation is truly accounted 84% of times.

FIGURE 6: CVP Vs IJV AREA





CVP Vs IJV Area	Low CVP	Normal CVP	High CVP
N	11	25	15
Mean	14.27	176.18	327.80
SD	6.12	51.12	95.60
Pearson's "r" Correlation			0.939898
P value One way ANOVA Test			**<0.0001**

The mean IJV area measurement in low CVP, normal CVP and high CVP is 14.27, 176.18 and 327.80 cm sq respectively. IJV area measurement is 161.91 cm sq more in normal CVP group compared to low CVP group (92% increase), 151.61 cm sq more in high CVP group compared to normal CVP group (46% increase) and 313.53 cm more in high CVP group compared to low CVP group (96% increase).

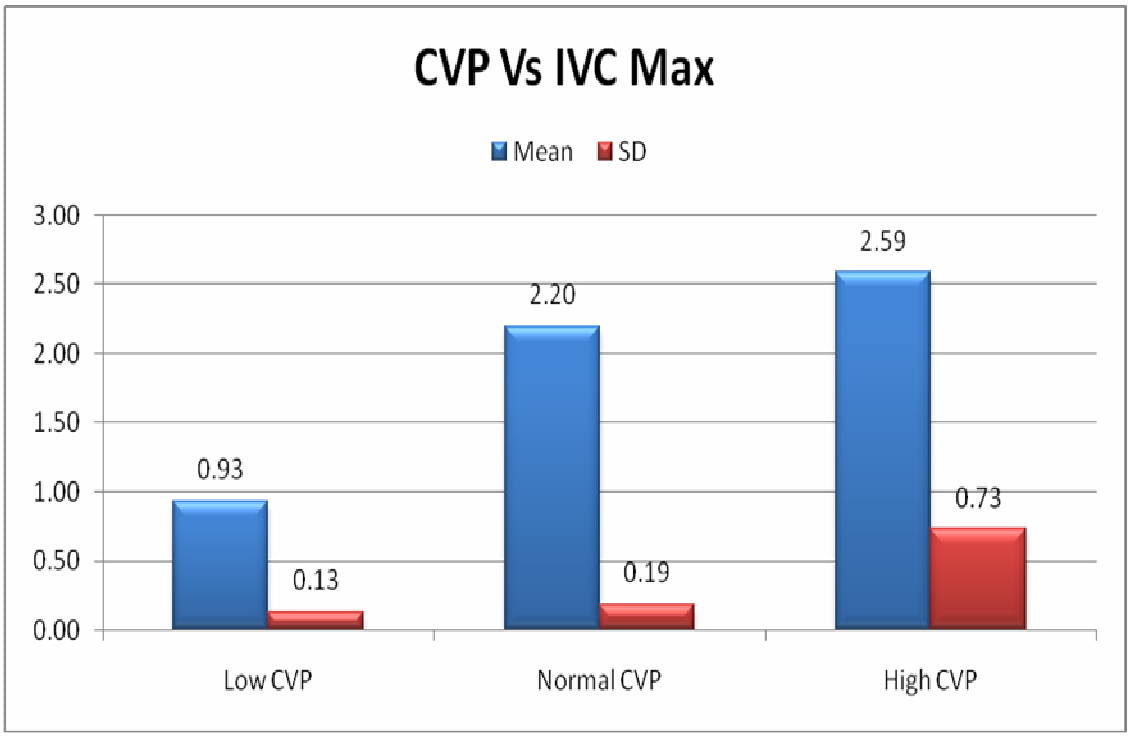
There is a strong positive correlation between the IJV area and increase in CVP. This is indicated by the Pearson's R Correlation value of 0.939898. This means as IJV area increases, the CVP increases. This means that the increase in IJV area due to high CVP happens 94% of times.

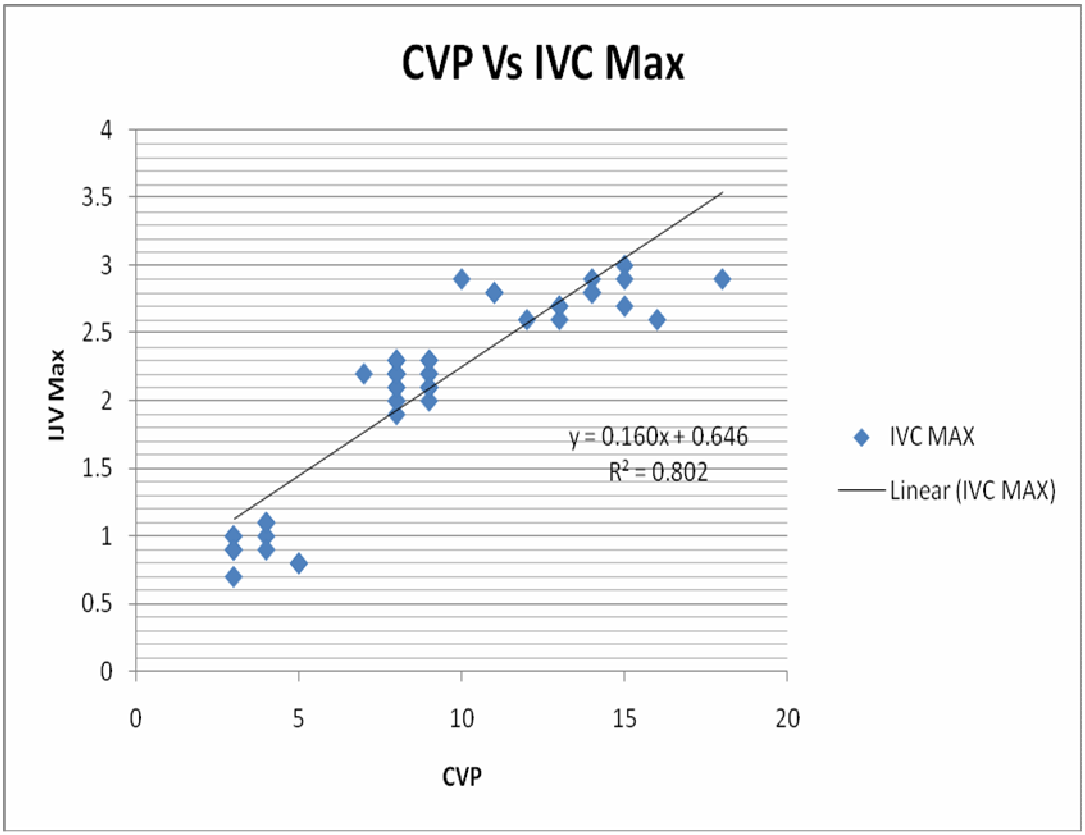
This direct positive and high correlation is significant with a p value of <0.0001 as per analysis of variance test. The percentage is also explained in the scatter plot. This linear model explains all the variability of the response data around its mean. Since R^2 is 0.8834, "the fitted

regression equation explains 88% of the variation in Y" (Y= 31.27(CVP measurement) + 88.735).

Thus 1 mm Hg increase in CVP causes 120.01 cm sq increase in IJV area. This variation in IJV area in relation to CVP levels correlates 94% of times and this variation is truly accounted 88% of times

FIGURE 7: CVP Vs IVC MAXIMUM





CVP Vs IVC Max	Low CVP	Normal CVP	High CVP
N	11	25	15
Mean	0.93	2.20	2.59
SD	0.13	0.19	0.73
Pearson's "r" Correlation			0.89597
P value One way ANOVA Test			**<0.0001**

The mean IVC max measurement in low CVP, normal CVP and high CVP is 0.93, 2.20 and 2.59 cm respectively. IVC max measurement is 1.27 cm more in normal CVP group compared to low CVP group (87% increase), 0.39 cm more in high CVP group compared to normal CVP group (15% increase) and 1.66 cm more in high CVP group compared to low CVP group (64% increase).

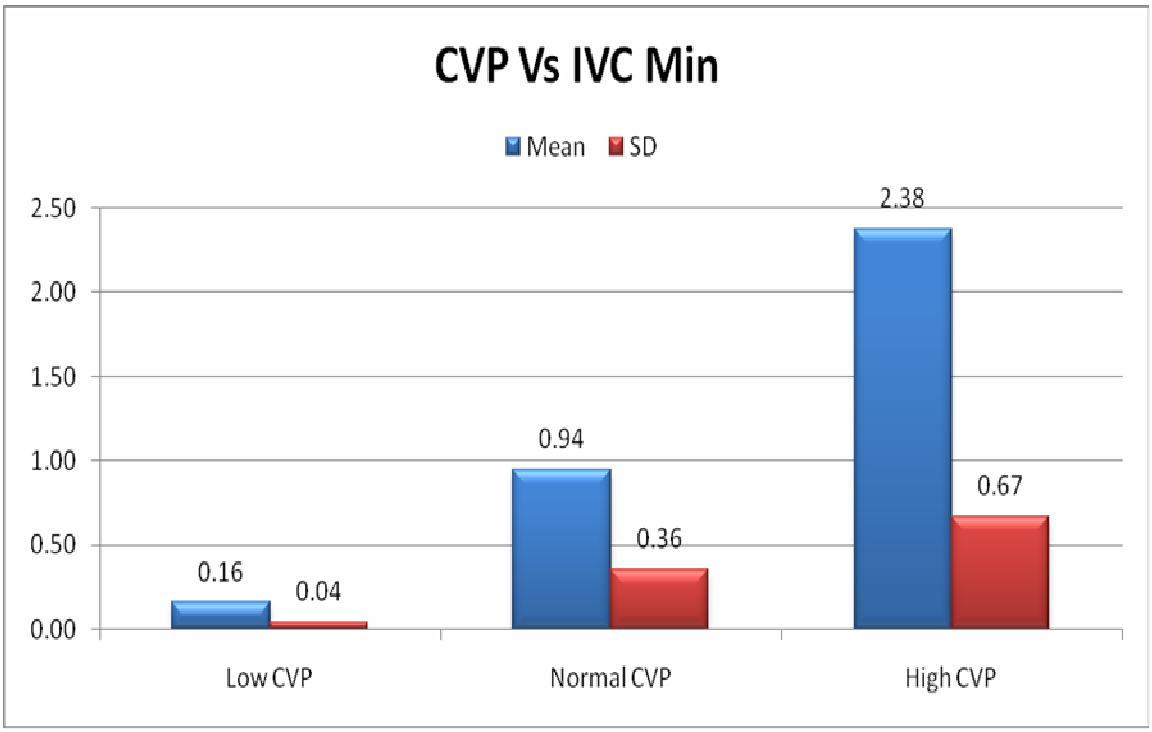
There is a strong positive correlation between the IVC max and increase in CVP. This is indicated by the Pearson's R Correlation value of 0.89597.This means as IVC max increases, the CVP increases. This means that the increase in IJV max due to high CVP happens 90% of times.

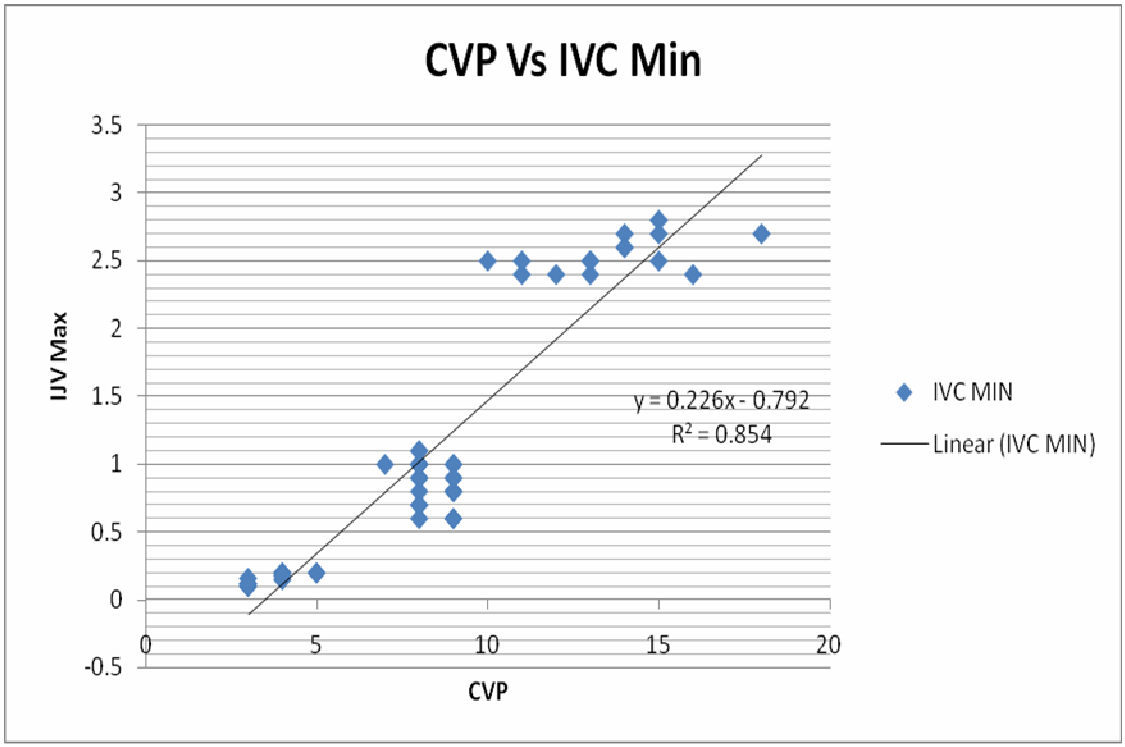
This direct positive and high correlation is significant with a p value of <0.0001 as per analysis of variance test. The percentage is also explained in the scatter plot. This linear model explains all the variability of the response data around its mean. Since R^2 is 0.8028, "the fitted

regression equation explains 80% of the variation in Y" (Y= 0.1609(CVP measurement) + 0.6461).

Thus 1 mm Hg increase in CVP causes 0.81 cm increase in IJV max. This variation in IJV max in relation to CVP levels correlates 90% of times and this variation is truly accounted 80% of times

FIGURE 8: CVP Vs IVC MINIMUM





CVP Vs IVC Min	Low CVP	Normal CVP	High CVP
N	11	25	15
Mean	0.16	0.94	2.38
SD	0.04	0.36	0.67
Pearson's "r" Correlation			0.924532
P value One way ANOVA Test			**<0.0001**

The mean IVC min measurement in low CVP, normal CVP and high CVP is 0.16, 0.94 and 2.38 cm respectively. IVC min measurement is 0.769 cm more in normal CVP group compared to low CVP group (83% increase), 1.44 cm more in high CVP group compared to normal CVP group (60% increase) and 2.22 cm more in high CVP group compared to low CVP group (93% increase).

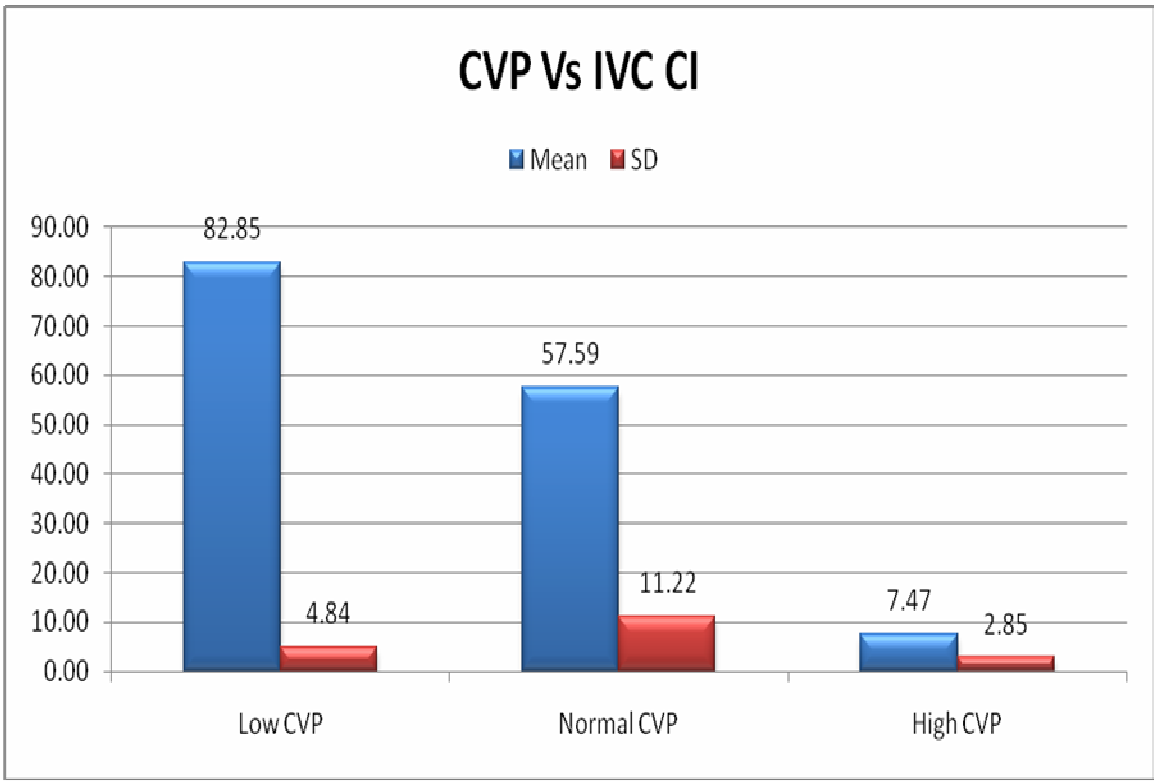
There is a strong positive correlation between the IVC min and increase in CVP. This is indicated by the Pearson's R Correlation value of 0.924532. This means as IVC area increases, the CVP increases. This means that the increase in IVC min due to high CVP happens 93% of times.

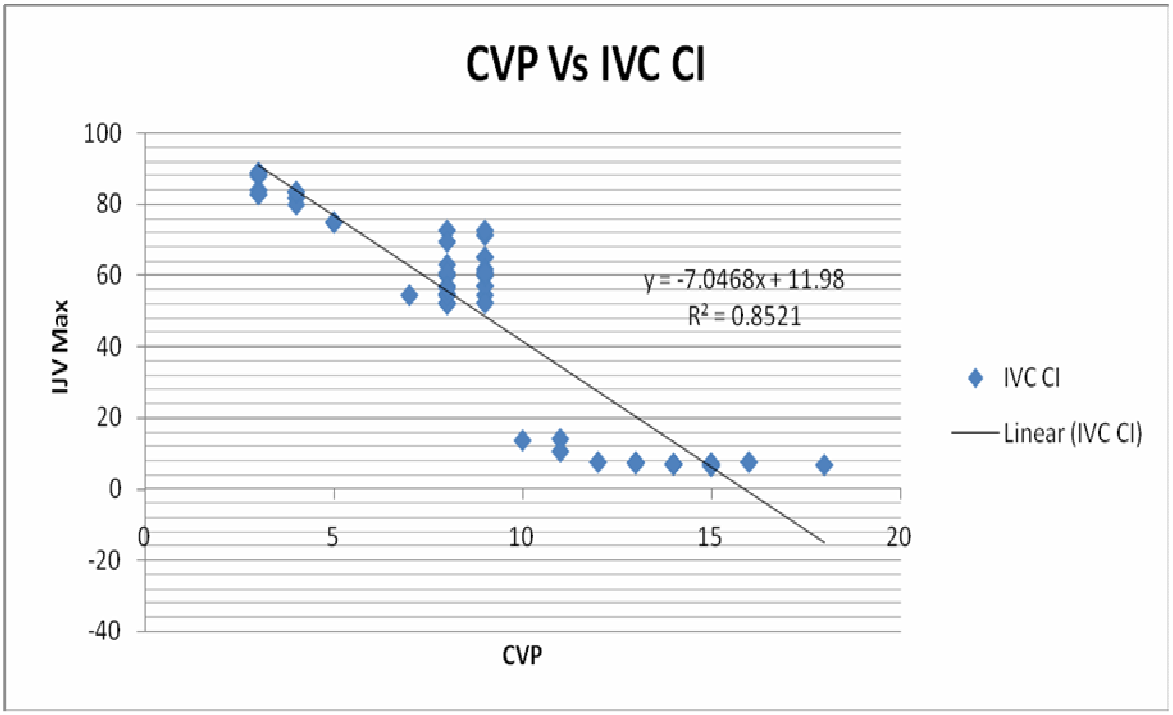
This direct positive and high correlation is significant with a p value of <0.0001 as per analysis of variance test. The percentage is also explained in the scatter plot. This linear model explains all the variability of the response data around its mean. Since R^2 is 0.8548, "the fitted

regression equation explains 86% of the variation in Y" (Y= 0.2262(CVP measurement) + 0.7925).

Thus 1 mm Hg increase in CVP causes 1.02 cm increase in IVC min. This variation in IVC min in relation to CVP levels correlates 93% of times and this variation is truly accounted 86% of times.

FIGURE 9: CVP Vs IVC CI





CVP Vs IVC CI	Low CVP	Normal CVP	High CVP
N	11	25	15
Mean	82.85	57.59	7.47
SD	4.84	11.22	2.85
Pearson's "r" Correlation			-0.92307
P value One way ANOVA Test			**<0.0001**

The mean IVC CI measurement in low CVP, normal CVP and high CVP is 82.85, 57.59 and 7.47% respectively. IVC CI measurement is 25.26% less in normal CVP group compared to low CVP group (30% decrease), 50.13% less in high CVP group compared to normal CVP group (87 % decrease) and 75.39% more in high CVP group compared to low CVP group (91% increase).

There is a strong negative correlation between the IVC CI and increase in CVP. This is indicated by the Pearson's R Correlation value of -0.92307. This means as IVC CI decreases, the CVP increases. This means that the decrease in IVC CI due to high CVP happens 92% of times.

This inverse, negative and high correlation is significant with a p value of <0.0001 as per analysis of variance test. The percentage is also explained in the scatter plot. This linear model explains all the variability of the response data around its mean. Since R^2 is 0.852, "the fitted

regression equation explains 85% of the variation in Y" (Y= -7.0468(CVP measurement) + 11.98).

Thus 1 mm Hg increase in CVP causes 4.93% decrease in IVC CI. This variation in IVC CI in relation to CVP levels correlates 92% of times and this variation is truly accounted 85% of times.

ACCURACY ANALYSIS - CVP > 10

Accuracy analysis - CVP >10	Sensitivity	Specificity	PPV	NPV	Accuracy	AUC	Cut Off	P value
IJV Max	100.00	30.60	35.90	100.00	50.00	0.996	>1.04	<0.0001
IJV Min	100.00	30.60	35.90	100.00	50.00	0.996	>0.84	<0.0001
IJV Area	100.00	75.00	60.90	100.00	82.00	0.996	>190	<0.0001
IVC Max	100.00	33.30	36.80	100.00	52.00	0.977	>1.9	<0.0001
IVC Min	100.00	97.20	93.30	100.00	98.00	0.988	>1.28	<0.0001
IVC CI	100.00	97.20	93.30	100.00	98.00	0.998	≤ 30	<0.0001
CVP	100.00	33.30	36.80	100.00	52.00	1.000	>7	<0.0001

Sensitivity of IJV max, IJV min, IJV area, IVC max, IVC min and IVC CI is high, meaning that 100% of those with CVP > 10 will have a positive test with IJV max, IJV min, IJV area, IVC max, IVC min and IVC CI.

Specificity of IJV area, IVC min and IVC CI is high, meaning that 75% of those with CVP < 10 will test negative with IJV area 97% of those with CVP < 10 will test negative with IVC min and IVC CI.

Positive predictive value is high in IVC min and IVC CI, meaning 93% of individuals with positive IVC min and IVC CI test actually have CVP > 10.

Negative predictive value is high in IJV max, IJV min, IJV area, IVC max, IVC min and IVC CI, meaning 100% of individuals with negative of IJV MAX, IJV MIN, IJV area, IVC max, IVC min and IVC CI test have CVP < 10.

The diagnostic effectiveness or diagnostic accuracy is very high with IJV area, IVC min and IVC CI.

Area under curve IJV max, IJV min, IJV area, IVC max, IVC min and IVC CI as diagnostic tests is in excellent range.It means that the overall value of IJV max, IJV min, IJV area, IVC min and IVC CI in detecting CVP > 10 as a combined screening and confirmatory case finding test is good.

ACCURACY ANALYSIS - CVP < 6

Accuracy analysis - CVP 6	Sensitivity	Specificity	PPV	NPV	Accuracy	AUC	Cut Off	P value
IJV Max	100.00	100.00	100.00	100.00	100.00	1.000	≤ 1.01	<0.0001
IJV Min	100.00	100.00	100.00	100.00	100.00	1.000	≤ 0.71	<0.0001
IJV Area	57.90	100.00	100.00	42.90	68.00	1.000	>190	<0.0001
IVC Max	97.40	100.00	100.00	92.30	98.00	1.000	>1.9	<0.0001
IVC Min	39.50	100.00	100.00	34.30	54.00	1.000	>0.7	<0.0001
IVC CI	39.50	100.00	100.00	34.30	54.00	1.000	≥ 26	<0.0001
CVP	100.00	100.00	100.00	100.00	100.00	1.000	>7	<0.0001

Sensitivity of IJV max, IJV min and IVC max is high, meaning that 100% of those with CVP < 6 will have a positive test with IJV max, IJV min and 97% of those with CVP < 6 will have a positive test with IVC max.

Specificity of IJV max, IJV min, IJV area, IVC max, IVC min and IVC CI is high, meaning that 100% of those with CVP >6 will test negative with IJV max, IJV min, IJV area, IVC max, IVC min and IVC CI.

Positive predictive value is high in IJV max, IJV min, IJV area, IVC max, IVC min, and IVC CI, meaning 100% of individuals with positive IJV max, IJV min, IJV min, IJV area, IVC max, IVC min and IVC CI test actually have CVP < 6.

Negative predictive value is high in IJV max, IJV min, meaning 100% of individuals with negative of IJV max, IJV min test have CVP > 6.

The diagnostic effectiveness or diagnostic accuracy is very high with IJV max, IJV min and IVC max.

Area under curve IJV max, IJV min, IJV area, IVC max, IVC min and IVC CI as diagnostic tests is in excellent range.

It means that the overall value of IJV max, IJV min and IVC max in detecting CVP < 6 as a combined screening and confirmatory case finding test is good. The overall value of IJV area, IVC min and IVC CI in detecting CVP < 6 as a confirmatory case finding test is good.

DISCUSSION

All the major prospective cross sectional studies conducted in the patients admitted in Intensive Care Units, Emergency Departments(for fluid monitoring and assessment of volume status) correlated the relationship between invasive CVP and ultrasound parameters such as IJV diameter, IVC diameter, IVC - CI.

There are several methods for obtaining a non invasive surrogate marker of central venous pressure in critically ill patients, a direct comparison of efficacy of these methods has been rarely performed. The primary goal of this study was to compare non invasive estimation of central venous pressure using inferior vena cava and internal jugular vein diameters with invasive CVP in postoperative patients on mechanical ventilation.

In this study the sonographically measured parameters like IJVdiameters, IVC diameters and IVC - CI correlated well within the conventional invasive CVP. There were no complications as the technique was noninvasive.

DEMOGRAPHIC PROFILE

AGE

In our study all were postoperative patients above 18 years of age.The mean age of the study population in low,high and normal CVP groups were 45.0 ,42.07and 41.68 years respectively.Majority of low CVP group patients belonged to 41 to 50 years age group.In high CVP group,majority of the patients were above 50 years of age and majority of normal CVP patients were less than 30 years of age.There was no significant relationship between age and CVP levels with age.

GENDER

In the study ,patients of both male and female genders took part.There ere 32 male and 18 female patients.There were 8 male and 3 female patients in the low CVP group.An equal distribution of 7 was found in the high CVP group among males and females.There were 17 males and 8 females in the normal CVP group. Majority of low and normal CVP patients were males(72% and 68% respectively).In high CVP group there was an equal distribution of males and females(50% each).

BMI

In our study,we included only ASA-1 and 2 patients of normal and overweight category(with BMI 18.5-24.9 and 25 -29.99 respectively).We didnot include obese patients because of the technical difficulties involved,in the diameter of IVC estimation.From the study ,we could suggest that in them,IJV diameter values could be relied upon for estimation of intravascular volume status.In the normal normal BMI group,there were 11 patients with low CVP,11 patients with high CVP and 22 patients with normal CVP.BMI also didnot have any significant relationship with CVP as per our study.

IJV max

The mean IJV max diameter in low,high and normal CVP groups were 0.86,2.19 and 1.85 cm respectively.According to our study,there is a strong positive correlation between IJV max and invasive CVP.

It means that as CVP increases ,there is also an increase in IJV diameter.Thus 1 mm Hg increase in CVP reflects a 0.73 cm increase in IJV max diameter

IJV min

The mean IJV min diameter in low,high and normal CVP groups were 0.42,1.97 and 1.48 respectively.There is a strong positive correlation between IJV min and invasive CVP.It means that as CVP increases,IJV min diameter is also found to be increased.In the study,for 1mm Hg inrease in CVP, a 0.23 cm increase in IJV min diameter is observed.

IJV area

The mean IJV area measurement in low,high and normal CVP groups were14.27 ; 327.80 and 176.18 sq.cm respectively.There is a strong positive correlation between the IJV area and increase in CVP.This means that as CVP increases ,an increase in IJV area is also noted.An increase of 1mm Hg in CVP is reflected as 121.01 sq.cm increase in IJV area.

IVC max

The mean IVC max measurement in low,high and normal CVP were 0.93,2.59 and 2.20 cm respectively.IVC max measurement correlates positively with invasive CVP. This means that, as CVP increases, an increase in IVC max diameter is observed.As per the study, an increase of 1mm Hg in CVP reflects the IVC max diameter's increase by 0.81 cm.

IVC min

The mean IVC min diameter in low, high and normal CVP is 0.16,2.38 and 0.94 respectively. There is a strong positive correlation between IVC min diameter and invasive CVP which means that an increase in IVC min diameter is noted, as CVP increases.Thus for 1 mm Hg increase in CVP an increase of 1.02 cm is seen in IVC min. diameter.

IVC-CI

The mean IVC-CI in low, high and normal CVP groups were 82.85% ,7.47 %and 57.59% respectively. IVC-CI has a strong,inverse,negative correlation with CVP.As CVP increases ,the IVC-CI decreases.

HIGH CVP STATES(>10 mm Hg)

The sensitivity of all six noninvasive parameters IJV max,IJV min,IJV area,IVC max,IVC min,IVC-CI is high with 100%.Specificity of IJV area,IVC min,IVC-CI is high between 75% to 97%.PPV is high for IVC min and IVC-CI.NPV is 100% for six parameters.The diagnostic accuracy is high with IJV area,IVC min and IVC-CI.From the study,we observe that the overall value of IJV max,IJV min,IJV area,IVC max,IVC min and IVC-CI, in estimation of CVP>10 mmHg is good.

LOW CVP STATES (<6 mm Hg)

The sensitivity of IJV max,IJV min and IVC max is high.Specificity is IJVmax100% for all six ultrasound parameters.PPV is also 100% for all of them.NPV is high and 100% for IJV ma and IJV min.The diagnostic accuracy is very high with IJV max,IJVmin and IVC max.It means that the overall value of IJVmax,IJV min and IVC max in detecting CVP < 6mm Hg is good.

Mucahit[35] et al in 2015 - compared non invasive ultrasound guided CVP with invasive CVP using bimodal analysis,(the cut off value for low CVP was <6 mm Hg and high CVP was >10 mm Hg,) We also used a similar analysis with the same cut off points .The parameters compared in their study include IJV max, IJV min ,IJV area,CVP usg,IVC max,IVC min and IVC-CI.The CVP usg ,IJV max ,IJV min correlated moderately with invasive CVP.(R^2 =0.66,0.53 and 0.54 respectively),but the value of IVC max,IVC min and IVC -CI showed poor correlation.(R^2 =0.29,0.32 and 0.27 respectively).The CVP usg cutoff value of 7 predicted invasive CVP > 10 mm Hg with 90% sensitivity and 67.3% specificity and predicted CVP inv < 6 mm Hg with sensitivity 77% and specificity 68%.IJV max,IJV min,IJV area and IVC max showed a high sensitivity (90.32%,83.87%,90.32% and 93.10% respectively) for low CVP values.IVC -CI has high sensitivity of 95.2% and poor specificity of 42.9% for high

CVP values.From their study,they concluded that IVC-CI and CVP usg has better diagnostic performance for estimating high CVP.IJV max,IJV area and IVC max showed high sensitivity and NPV for low CVP values.No objective evaluation and statistical interpretation were made regarding required for the procedure and the difficulty levels involved.We too did not have any such statistical interpretation.Thus they used a bi modal analysis having two cutoff points like a study by Siva et al in 2012. Our cutoff points were also similar in comparison with this study.The CVPusg had the highest test values for high CVP levels in their study. Our study did not include this parameter.No objective evaluation and statistical interpretation were made regarding time required for the procedure and the difficulty levels involved. We too did not have any such statistical interpretation.

Amir khalil[2] et al, 2014 - their CVP ranged from -4 to 26 cm H2O with a mean 8 cm H20(SD=6.24).Mean IVC diameters showed an increase with increase in CVP.Correlation between CVP and max IVC diameter was moderate and significant ($r=0.53, p<0.001$).Correlation between CVP and min IVC diameter was also moderate and significant($r=0.58, p<0.001$) .They did not include intubated patients. In our study, we included postoperative patients on mechanical ventilation.

SA Aydin[44] et al 2015 - detected significant correlation between the CVP and IVC diameters.The relationship between IVC diameter and CVP was evaluated and significant correlation found in IAP(Inspiratory AnteroPosterior),EAP (Expiratory AnteroPosterior) with CVP values.(p'0.001).ROC analyses done suggested significant relationship between EAP diameter and Hemoglobin,hematocrit and ScvO2 levels.

Donahue[18] et al. in **2009** demonstrated a good correlation between IJV end expiratory diameter and CVP. **Simon et al** in **2010** assessed the right IJV compliance and concluded that an increase in cross sectional area of IJV greater than 17% during the Valsalva maneuver rules out elevated CVP. **Deol et al**. **2011** compared ultrasound collapse pressure with CVP, which showed an accurate correlation, however it underestimated CVP in patients with high CVP. Hence they concluded that ultrasound collapse point does not reflect true CVP accurately.

Kent[28] et al, 2013-used bedside sonography of IVC in estimating intravascular volume status. In technically difficult patients (like obese,with bowel gas or postoperative surgical dressings), they determined the feasibility of Sub clavian vein collapsibility. In our study, for obese and post operative patients with surgical dressings,IJV diameter values could be utilised. Paired measurements were compared using correlation coefficient and Bland - Altman measurement bias analysis. Mean

APACHE2 score was 12. Paired SCV-IVC CI showed an acceptable correlation [R^2 =0.61, P<0.01] with acceptable overall measurement bias [Bland -Altman mean collapsibility difference (IVC-CI minus SCV-CI) of -3.2. In addition to it, time required to acquire and measure venous diameters was shorter for SCV-CI (70 s) when compared to IVC-CI (99 s) (p<0.02). It was concluded that SCV-CI assessment appeared to be a reasonable adjunct to IVC-CI in SICU patients with an acceptable correlation between two techniques and overall measurement bias was low.

Jaques Rizkallah[27] et al, 2014- assessed the non invasive bedside clinical examination techniques ,for CVP estimation. According to them, JVP evaluation is the most sensitive (with 86% sensitivity,improving with clinical experience(p0.01).The ideal gold standard for CVP assessment would be an invasive CVP measurement using manometer tipped catheters. They selected USG guided CVP assessment (as recommended by American Society of Echo)as its surrogate. Their study paients were out patients coming for their scheduled echos.

Nik Azlam[38] et al, 2013- In their study,the median age chosen was 63 years. A significant correlation was found between IJV height and CVP using central venous access.(r=0.64 p<0.001).Correlation between IVC diameter in end expiration and CVP was 0.74(p<0.001).An IJV height measurement >8 cm predicted a CVP >8 cm H2O(sensitivity 71.4% and specificity 83.3%).

The USG estimation of IJV height was performed by identifying the top of venous pulsation with the patient lying at 45◦. In our study we did not include IJV height (measured by USG), as it is influenced by elevation of height of bed and timing of end expiration.

Ahmed Abbasian1 et al, 2014- According to them,there are no relationship between anteroposterior diameter of IVC and CVP (p=0.257).The longest diameter of IVC in ultrasound transverse view had significant correlation with CVP (p=0.045) but in patients with BMI >25,it was not significant.Cross section of IJV had significant association with CVP of patients (p=0.003).Longitudinal diameter of IJV had no significant association with CVP of patients(0.052),but transverse diameter of IJV had significant association with CVP(0.003). Cross section of IJV had significant association with CVP (P=0.001). Volume status assessment is possible even in patients with disorganized anatomy, coagulation disorders, neck injury and patients on fibrinolytic therapy etc. A significant relationship exists between the largest diameters of IVC in transverse view with CVP. This relationship however did not apply in patients with high BMI. Our study also showed similar advantages in the above said patient groups. Their results showed that a quick, easy, non invasive assessment of CVP especially in emergency conditions. They found that CVP is an important part of diagnostic algorithm and also treatment of conditions like shock.

SUMMARY

In this study, the sonographic parameters including IJV max,IJVmin,IJVarea,IVCmax,IVCmin showed a strong positive correlation with invasive CVP, which means that as CVP increases there is a corresponding increase in the value of the above parameters.

.IVC Collapsibility Index showed a strong negative correlation with invasive CVP, which means that as CVP increases there is a corresponding decrease in the value of IVC Collapsibility Index.

By the evaluation, IJV max, IJV min, IJV area IVC max, IVC min, IVC-Collapsibility Index in detecting CVP>10 showed better results. The IJV max, IJV min and IVC max in detecting CVP < 6 also showed better results. So for high CVP states, all six parameters can be of significant value. For low CVP states IJV max, IJV min and IVC max can be of significant value.

There were no complications observed in the study as technique is non invasive.

CONCLUSION

From this study we conclude that in postoperative patients on mechanical ventilation, the sonographic CVP estimation helps in the assessment of intravascular volume status and the potential complications of invasive CVP can be avoided. Hence the non-invasive sonographically estimated CVP is a safe and feasible bed side technique that can be used for better postoperative patient management.

Thus the non invasive CVP estimation techniques can be more frequently utilised in various clinical scenarios, as they do not have potential complications of invasive techniques.

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8.Journal of Critical care.

9.Journal of Intensive care Medicine

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11.The Chest

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4.The Washinton Manual of critical care Medicine,2 nd Edition.

INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE, CHENNAI 600 003

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Telephone No.044 25305301
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CERTIFICATE OF APPROVAL

To
Dr.M.Sathyasuba
Post Graduate in M.D. (Anaesthesiology)
Inst. of Anaesthesiology and Critical Care
Madras Medical College
Chennai 600 003

Dear Dr.M.Sathyasuba,

The Institutional Ethics Committee has considered your request and approved your study titled **"PROSPECTIVE COMPARATIVE STUDY OF ULTRASOUND GUIDED CENTRAL VENOUS PRESSURE MEASUREMENT USING JUGULAR VEIN AND INFERIOR VENA CAVA DIAMETERS, FOR POSTOPERATIVE PATIENTS ON MECHANICAL VENTILATION "- NO. (II) 29032016.**

The following members of Ethics Committee were present in the meeting hold on **22.03.2016** conducted at Madras Medical College, Chennai 3

1.Dr.C.Rajendran, MD.,	:Chairperson
2.Dr.R.Vimala,MD.,Dean,MMC,Ch-3	:Deputy Chairperson
3.Prof.Sudha Seshayyan,MD., Vice Principal,MMC,Ch-3	: Member Secretary
4.Prof.P.Raghumani,MS, Dept.of Surgery,RGGGH,Ch-3	: Member
5.Dr.Baby Vasumathi, Director, Inst. of O&G,Ch-8	: Member
6.Prof.M.Saraswathi,MD.,Director, Inst.of Path,MMC,Ch-3	: Member
7.Prof.Srinivasagalu,Director,Inst.of Int.Med.,MMC,Ch-3	: Member
8.Tmt.J.Rajalakshmi, JAO,MMC, Ch-3	: Lay Person
9.Thiru S.Govindasamy, BA.,BL,High Court,Chennai	: Lawyer
10.Tmt.Arnold Saulina, MA.,MSW.,	:Social Scientist

We approve the proposal to be conducted in its presented form.

The Institutional Ethics Committee expects to be informed about the progress of the study and SAE occurring in the course of the study, any changes in the protocol and patients information/informed consent and asks to be provided a copy of the final report.

MADRAS MEDICAL COLLEGE
31 MAR 2016
CHENNAI-600 003

31/3/16
Member Secretary – Ethics Committee

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INSTITUTIONAL ETHICS COMMITTEE
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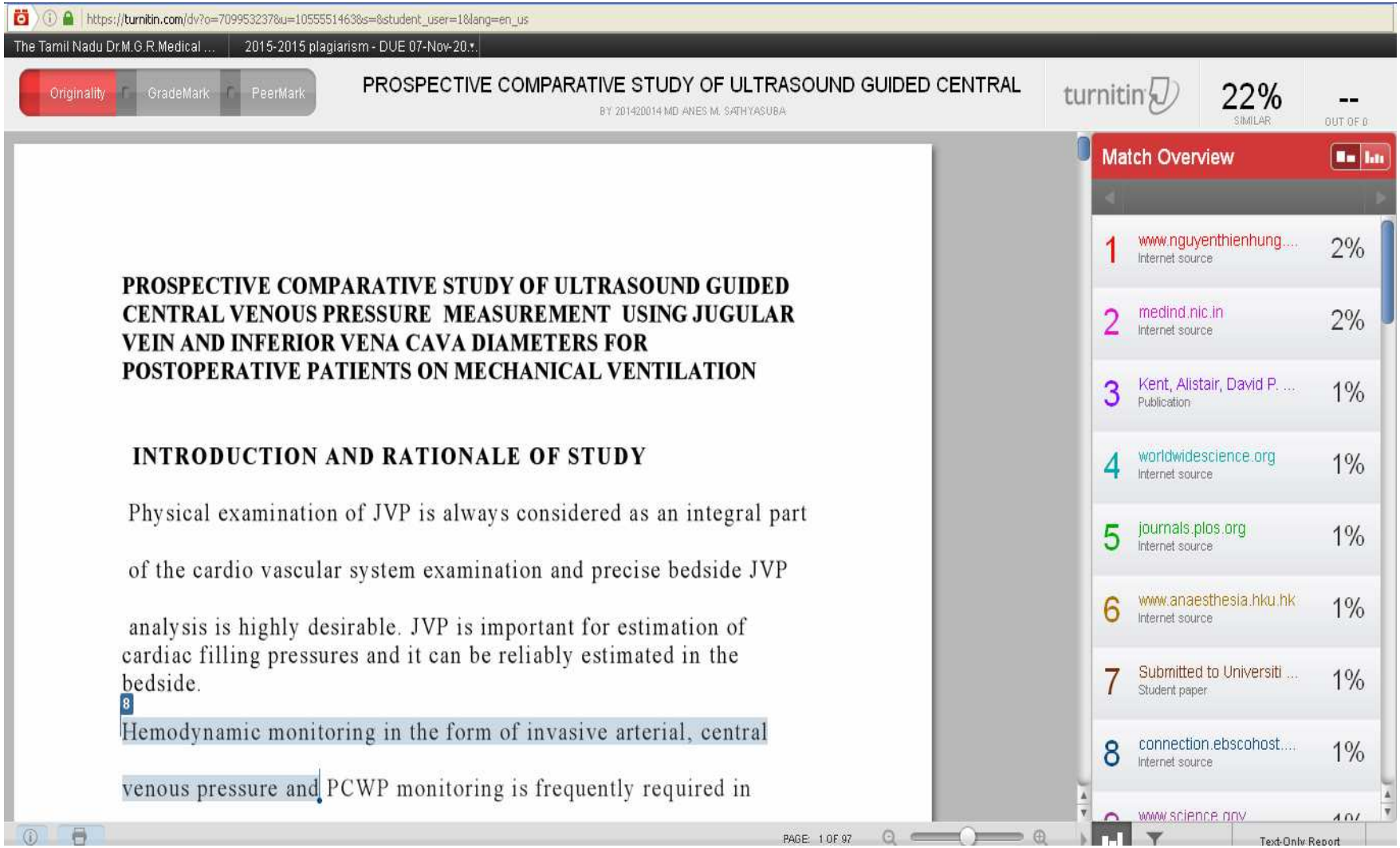
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INTRODUCTION AND RATIONALE OF STUDY
Physical examination of JVP is always considered as an integral part
of the cardio vascular system examination and precise bedside JVP
analysis is highly desirable. JVP is important for estimation of cardiac filling pressures and it can be reliably estimated in the bedside.
8
Hemodynamic monitoring in the form of invasive arterial, central
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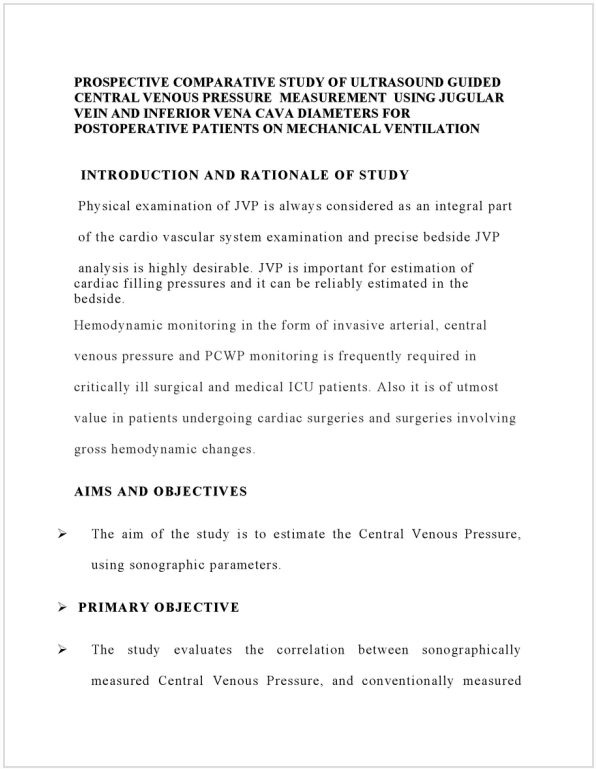

PROSPECTIVE COMPARATIVE STUDY OF ULTRASOUND GUIDED CENTRAL VENOUS PRESSURE MEASUREMENT USING JUGULAR VEIN AND INFERIOR VENA CAVA DIAMETERS FOR POSTOPERATIVE PATIENTS ON MECHANICAL VENTILATION

INTRODUCTION AND RATIONALE OF STUDY

Physical examination of JVP is always considered as an integral part of the cardio vascular system examination and precise bedside JVP analysis is highly desirable. JVP is important for estimation of cardiac filling pressures and it can be reliably estimated in the bedside.

Hemodynamic monitoring in the form of invasive arterial, central venous pressure and PCWP monitoring is frequently required in critically ill surgical and medical ICU patients. Also it is of utmost value in patients undergoing cardiac surgeries and surgeries involving gross hemodynamic changes.

AIMS AND OBJECTIVES

- The aim of the study is to estimate the Central Venous Pressure, using sonographic parameters.

- **PRIMARY OBJECTIVE**

- The study evaluates the correlation between sonographically measured Central Venous Pressure, and conventionally measured

PROFORMA

Title:

"COMPARATIVE STUDY OF ULTRASOUND GUIDED CENTRAL VENOUS PRESSURE MEASUREMENT USING JUGULAR VEIN AND INFERIOR VENA CAVA DIAMETERS FOR POSTOPERATIVE PATIENTS ON MECHANICAL VENTILATION"

DATE: IP NO:

NAME:

AGE: SEX:

DIAGNOSIS:

SURGICAL PROCEDURE:

HISTORY:

Any comorbid illness

H/O previous radiotherapy and neck surgery

CVS:

RS:

PRE OP ASSESSMENT: ASSESSMENT NO:

HISTORY:

Any Co-morbid illness

H/O previous Radiotherapy and Neck surgery

INFORMED CONSENT IN TAMIL

MONITORS

IJVmax	IJVmin	IJVarea	IVCmax	IVCmin	IVC-CI	BMI	AGE

VITAL SIGNS

SBP HR

DBP SPO2

MAP

INFORMATION TO PARTICIPANTS

Investigator :

Name of the Participant:

Title:

"**PROSPECTIVE COMPARATIVE STUDY OF ULTRASOUND GUIDED CENTRAL VENOUS PRESSURE MEASUREMENT USING JUGULAR VEIN AND INFERIOR VENA CAVA DIAMETER FOR POSTOPERATIVE PATIENTS ON MECHANICAL VENTILATION ”**.

Your relative is invited to take part in this research study. We have got approval from the Institutional Ethics Committee. Your relative is asked to participate because your relative satisfies the eligibility criteria .We want to compare and study the non invasive ultrasound based methods of central venous pressure measurement with invasive central venous pressure as standard criterion.

What is the Purpose of the Research:

The purpose of the study is to develop a new non invasive method for quantification of central venous pressure by ultrasound as invasive central venous pressure by central venous catheter has many potential complications.

The Study Design:

50 PATIENTS ON MECHANICAL VENTILATION.

Benefits:

1. The potential complications of invasive central venous pressure like Internal carotid artery puncture, pneumo thorax, vessel erosion, thrombosis, infection, hematoma formation are avoided.

2. Adequacy of volume status can be ensured.

3. Overzealous fluid correction and extreme dehydration states avoided.

Discomforts and risks:

There are apparently no complications associated with non invasive ultrasound guided methods of central venous pressure estimation.

This intervention has been shown to be well tolerated as shown by previous studies. And if you do not want your relative to participate you will have alternative, of setting the standard treatment and your relative s safety is our prime concern.

Time :

Date : Signature / Thumb Impression of RELATIVE

Place :

Patient Name:

Signature of the Investigator : _____

Name of the Investigator : _____

PATIENT CONSENT FORM

Study title :

"**PROSPECTIVE COMPARATIVE STUDY OF ULTRASOUND GUIDED CENTRAL VENOUS PRESSURE MEASUREMENT USING JUGULAR VEIN AND INFERIOR VENA CAVA DIAMETERS IN POSTOPERATIVE PATIENTS ON MECHANICAL VENTILATION"**

Study centre :

POST ANAESTHESIA CARE UNIT,
INSTITUTE OF ANAESTHESIOLOGY AND CRITICAL CARE,
MADRAS MEDICAL COLLEGE, CHENNAI.

Participant name: **I.P. No:** **Age:** **Sex:**

I confirm that I have understood the purpose of procedure of the above study. I have the opportunity to ask questions and all my questions and doubts have been answered to my satisfaction. ☐

I have been explained about the pitfall in the procedure. I have been explained about the safety, advantage and disadvantage of the technique. ☐

I understand that my relative's participation in the study is voluntary and that I am free to withdraw him/her at anytime without giving any reason. ☐

I understand that my relative's identity will not be revealed in any information released to third parties or published, unless as required under the law . I agree not to restrict the use of any data or results that arise from the study. I hereby give permission to make him/her undergo complete clinical examination and diagnostic tests including haematological, biochemical, radiological tests. ☐

I hereby agree to make him/her participate in this study. ☐

Time : Signature / thumb impression of
Date : patient's relative

Place: Patient name:

Signature of the investigator:

Name of the investigator:

IP NO.	Gender	IJV MAX	IJV MIN	IJV AREA	IVC MAX	IVC MIN	IVC CI%	CVP	HR	SBP	DBP	MAP	SP O2	BMI	AGE
28145	M	1.8	1.4	153.86	2.3	1.1	52.17	8	72	110	70	83	99	24.67	49
17890	M	1.6	1.4	153.86	2.2	1.0	54.54	8	70	120	80	93	99	21.49	45
32457	M	0.9	0.6	28.26	1.1	0.2	81.81	L 4	100	88	48	61	100	24.24	32
17798	M	0.8	0.4	12.56	1.0	0.2	80.00	L 4	112	89	50	63	97	24	d
26554	M	2.0	1.6	200.96	2.2	1.0	54.54	9	68	122	81	95	100	24.88	45
27650	M	2.0	1.8	254.34	2.1	0.9	57.14	9	70	118	75	89	100	21.78	42
29074	M	0.9	0.4	12.56	0.9	0.2	83.33	L 4	98	92	60	71	100	23.81	45
28879	M	0.8	0.3	7.06	0.8	0.2	75.00	L 4	100	88	62	69	99	21.48	60
28656	F	2.2	2.0	314.00	2.8	2.4	14.20	H 11	95	130	92	105	99	27.41	38
27412	M	1.8	1.4	153.86	2.2	1.0	54.54	8	72	128	80	96	99	23.6	48
29872	F	1.8	1.2	113.04	2.1	1.0	52.38	8	70	122	78	93	100	23.12	33
29539	M	2.0	1.6	200.96	2.3	1.1	52.17	8	69	115	72	86	100	24.35	48
29871	M	1.0	0.5	19.62	1.0	0.2	84.00	L 3	122	85	40	55	100	20.34	38
28762	M	0.9	0.4	12.56	1.1	0.2	83.63	L 4	120	88	60	69	99	22.77	40
27954	M	2.0	1.6	200.96	2.0	0.8	60.00	9	86	110	72	85	99	24.03	35
27950	F	2.0	1.4	153.86	2.2	0.6	72.72	8	72	114	70	85	100	22.03	39
28049	M	0.8	0.3	7.06	1.0	0.1	88.00	L 3	122	82	60	67	100	21.97	60
29512	F	0.9	0.4	12.56	0.9	0.1	88.88	L 3	118	80	61	67	100	24.09	47
29067	M	2.4	2.2	379.00	2.6	2.4	7.69	H 16	98	150	92	111	100	21.5	60
29910	M	1.8	1.5	176.62	2.1	0.6	71.42	9	70	130	82	98	99	21.71	60
32169	M	1.5	1.2	113.04	2.2	0.6	72.72	9	76	128	81	97	100	22.99	40
32564	M	1.6	1.4	153.86	2.3	0.8	65.21	9	74	126	78	94	100	24.11	51
27641	F	2.4	2.2	379.00	2.9	2.7	6.89	H 18	100	132	90	104	100	24.01	42
28951	F	2.6	2.3	415.00	2.7	2.5	7.40	H 15	98	130	88	102	99	21.21	53
29780	M	2.0	1.6	200.96	2.1	0.8	61.90	9	76	122	80	94	99	23.23	35

27895	M	2.0	1.8	254.34	2.3	0.7	69.56	8	78	118	78	91	100	24.78	33
28654	M	1.8	1.2	113.04	2.0	0.8	60.00	8	82	116	72	87	99	24.65	50
28051	M	2.4	2.1	346.00	2.8	2.6	7.14	H 14	92	140	92	108	99	22.38	33
29356	M	2.2	2.0	314.00	2.9	2.5	13.79	H 10	78	142	90	107	100	24.51	24
29468	M	1.8	1.4	153.86	1.9	0.7	63.15	8	80	115	78	90	100	23.88	60
29421	F	2.0	1.4	153.86	2.0	0.9	55.00	8	82	112	70	84	99	23.78	25
18769	F	2.2	2.0	314.00	2.7	2.5	7.40	H 13	90	120	80	93	100	27.06	58
18976	F	2.4	2.2	379.00	2.6	2.4	7.69	H 13	92	122	80	94	99	19.72	22
18760	F	2.3	2.1	346.00	3.0	2.8	6.60	H 15	98	125	79	94	99	22.38	58
19620	M	1.8	1.5	176.62	2.1	1.0	52.38	9	78	118	70	86	100	21.64	31
18763	F	1.5	1.3	132.66	2.3	0.9	60.86	8	76	120	80	93	99	24.03	44
18456	M	2.5	2.2	379.00	2.9	2.7	6.89	H 15	98	115	72	86	100	23.73	32
23650	M	2.2	2.0	314.00	2.8	2.5	10.71	H 11	85	116	70	85	99	20.93	56
26704	M	2.4	2.1	346.00	2.6	2.4	7.69	H 12	88	128	80	96	100	24.3	40
28059	M	1.6	1.4	153.86	2.2	1.0	54.54	7	70	120	80	93	99	22.21	38
29633	F	2.0	1.6	200.96	2.1	0.9	57.14	8	72	118	72	89	99	22.99	60
28058	M	2.3	2.1	346.00	2.7	2.5	7.40	H 13	90	130	90	103	99	21.88	42
27996	F	2.2	2.0	314.00	2.9	2.7	7.14	H 14	96	128	88	101	100	25.01	57
30167	M	2.4	2.1	346.00	2.8	2.6	7.14	H 14	92	130	89	103	100	23.07	40
32561	F	2.0	1.8	254.34	2.2	1.0	54.54	8	70	122	80	94	99	24.24	40
32169	F	1.8	1.2	113.04	2.3	0.9	60.86	9	68	120	79	93	99	24.91	40
31562	F	0.9	0.4	12.56	0.9	0.1	88.88	L 3	118	130	82	98	96	22.43	50
32018	F	0.8	0.5	19.62	0.7	0.1	82.85	L 3	120	132	85	101	98	21.64	48
30818	M	0.8	0.4	12.56	0.8	0.2	75.00	L 5	98	90	65	73	99	22.72	30
31753	F	1.8	1.4	153.86	2.3	1.0	56.50	8	75	110	70	83	99	21.22	27