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**“PREDICTION OF POST SPINAL HYPOTENSION  
USING ULTRASONOGRAPHIC CAVAL AORTA  
INDEX AND INFERIOR VENA CAVA  
COLLAPSIBILITY INDEX: A PROSPECTIVE  
COMPARATIVE STUDY.”**

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**By**

**REG NO. BA0120005**

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*KAHER, Belagavi, Karnataka,*

*In partial fulfilment of the requirements for the degree of*

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**In**

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**JUNE/JULY 2023**

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Sub: Institutional Ethical Clearance for the study.

With reference to the above, we wish to inform you that your proposed research project titled **"PREDICTION OF POST SPINAL HYPOTENSION USING ULTRASONOGRAPHIC CAVAL AORTA INDEX AND INFERIOR VENA CAVA COLLAPSIBILITY INDEX: A PROSPECTIVE COMPARATIVE STUDY"**, is ethical and justifiable. The proposed research project has been cleared by the JNMC Institutional Ethics Committee on Human Subjects Research.

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## ABBREVIATIONS

A mode	-	Amplitude mode
ACE	-	Angiotensin Converting Enzyme
ASA	-	American Society of Anaesthesiologist
B mode	-	Brightness mode
BMI	-	Body Mass Index
cms	-	Centimeters
CVP	-	Central Venous Pressure
DBP	-	Diastolic Blood Pressure
ECG	-	Electrocardiogram
HR	-	Heart Rate
i.v	-	Intravenous
ICU	-	Intensive Care Unit
IVC	-	Inferior Vena Cava
IVC:Ao	-	Caval Aorta Index
IVCCI	-	Inferior Vena Cava Collapsibility Index
LSCS	-	Lower Section Cesarean Surgery
M mode	-	Motion mode
MAP	-	Mean Arterial Pressure
MHz	-	Mega Hertz
ml	-	Millilitre
NIBP	-	Non-Invasive Blood Pressure
NICOM	-	Non-Invasive Cardiac Output Monitoring
PiCCO	-	Pulse Induced Contour Cardiac output
RAP	-	Right Atrial Pressure
SAB	-	Sub Arachnoid Block
SBP	-	Systolic Blood Pressure
TURP	-	Trans Urethral Resection of Prostate

Kg	-	kilogram
mcg	-	Microgram
inj	-	Injection
ROC	-	Receiver Operator Characteristics
AUC	-	Area Under the Curve
SD	-	Standard Deviation
min	-	Minute
5HT3	-	5-hydroxytryramine

## **ABSTRACT**

**INTRODUCTION:** Hypotension following spinal anaesthesia is the most common side effect. The aim of this study was to find out correlation between inferior vena cava collapsibility index (IVVCI), caval aorta index (IVC:aorta) and postspinal hypotension and evaluating its efficacy in predicting the same.

**METHODS:** 75 patients of age 18-60 years, undergoing elective surgery under spinal anaesthesia were included in the study, after obtaining ethical clearance, CTRI registration & informed consent. Patient undergoing emergency surgery, Pregnant women, ASA III & IV were excluded. Before subarachnoid block, ultrasonographic IVCCI & IVC:AO index were measured. Basal vital parameters (HR, SBP, DBP, MAP) were obtained. Spinal anaesthesia was performed using 3cc of 0.5% bupivacaine(H) at the level of L2-L3 or L3-L4. After spinal anaesthesia patient's vital parameters were measured immediately, followed by every 3 minutes till half hour then every 5 minutes till end of surgery. Any episode of hypotension within half hour was considered as post spinal hypotension. Statistical analysis was done using SPSS version 21

**RESULTS:** 33 patients developed hypotension following spinal anaesthesia. There was significant relation between IVCCI and post spinal hypotension (**p value < 0.0001**). Cut off value of IVCCI in predicting post spinal hypotension was found to be 39.4%. There was no significant relation between IVC:AO index and post spinal hypotension (**p value <0.6927**).

**Conclusion:** We conclude that preoperative ultrasonographic IVCCI is an easy, quick, reliable & non-invasive technique for predicting post spinal hypotension. It could be used to predict post spinal hypotension preoperatively and helps in preventing hypotension.

**KEY WORDS:** IVCCI, IVC, spinal hypotension.

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## **INTRODUCTION**

Neuraxial anaesthesia has been frequently used in clinical practice, of which spinal anaesthesia is relatively safe and easy to perform. Hypotension following subarachnoid block (SAB) - most common side effect which may lead to organ hypoperfusion and ischemic events<sup>1</sup>. Following SAB, hypotension is caused by a decrease in cardiac output as well as systemic vascular resistance<sup>2</sup>. It is difficult to predict who goes into hypotension following spinal anaesthesia, however the incidence of patients going into hypotension increases with age and comorbidities. Hypotension following spinal anaesthesia will be more in pregnant women, elderly patients, patients with hypertension and taking ACE inhibitors etc. Hypotension following spinal anaesthesia may cause adverse effects like coronary hypoperfusion, renal hypoperfusion, cerebral hypoperfusion, delirium and death. So, it is important to prevent hypotension following spinal anaesthesia<sup>3</sup>.

Many have tried to prevent hypotension following spinal anaesthesia by preloading the patients with i.v fluids before surgery or prophylactic use of vasopressors<sup>4,5</sup>. But these prophylactic measures cannot be done for emergency cases and fluid co-loading has been proven to reduce the incidence of hypotension & significant reduction in vasopressors required<sup>6</sup>. The risk of volume overload by empirical volume loading exists, particularly for people with heart illness. So, it is important to look for the hypotension indicators to prevent blind volume loading.

Heart rate variability, the passive leg lift test, as well as the perfusion index are just a few of the studies that have been conducted to predict hypotension in patients undergoing spinal anaesthesia for surgery<sup>7-11</sup>. Heart rate variability has been shown in

some research to have a positive predictive value, while other studies have determined that it is unreliable due to the fact that it can be impacted by a variety of conditions, including diabetes, ischemic heart disease, antihypertensive drugs, and anxiety<sup>12</sup>.

Assessing intravascular volume status before surgery may be helpful in predicting hypotension, but assessment of intravascular volume is a difficult task.

It became simpler to assess intravascular volume status after ultrasound was introduced into clinical practice, and numerous studies have found that the ultrasonographic “Inferior Vena Cava Collapsibility Index (IVCCI) & caval aorta index (IVC: Ao)” is a reliable, noninvasive, and simple technique for doing so<sup>13,14,15</sup>.

Some studies were done on IVCCI & IVC: Ao index for predicting hypotension post spinal hypotension and their results vary from each other. Salma ER et al found that IVC: aorta index as a powerful indicator than inferior vena cava collapsibility index in predicting hypotension following spinal anaesthesia in European population<sup>16</sup>.

There is no evidence-based data for predicting hypotension following spinal anaesthesia in Indian population. Hence we designed to do this study to find out the correlation between inferior vena cava collapsibility index (IVCCI), Caval Aorta index (IVC: aorta) and hypotension following spinal anaesthesia and evaluating its efficacy in predicting the same.

## **REVIEW OF LITERATURE**

The first spinal analgesia was given in 1885 by New York neurologist James Leonard Corning. August Bier and his helper August Hidebrandt first used cocaine to induce spinal anaesthesia on a healthy male on August 15, 1898. However, it is associated with a variety of side effects, including hypotension, hypothermia, and post-dural puncture headache, fleeting neurological symptoms, and frequently occurring nausea and vomiting. Since then, the approach has undergone a variety of adjustments to reduce the prevalence and control these complications. The most frequent side effects after spinal anaesthesia are hypotension and bradycardia which may cause a number of dreaded effects, such as delirium and coronary ischaemia<sup>17,18</sup>. Hypotension following spinal anaesthesia is mainly due to reduction in systemic vascular resistance after preganglionic sympathetic blockade<sup>19</sup>.

The majority of current prediction models that determine the risk factors of hypotension are: age > 40years, history of hypertension, emergency surgery & baseline systolic blood pressure less than 120 mmHg etc<sup>20</sup>. Intra vascular volume of the patients plays an important role in hypotension following spinal anaesthesia. Several studies have been done to predict hypotension following spinal anaesthesia.

N Meirowitz et al, conducted a study in the year 2012, where they used non-invasive cardiac output monitoring (NICOM) in 40 parturients undergoing LSCS. They conducted passive leg raise test and those who had increase in cardiac output by >12% were considered as fluid responders. They found that neither hypotension nor the need for vasopressors after spinal anaesthesia could be predicted by non-invasive measurement of the hemodynamic response to a volume load<sup>9</sup>.

Tae Dong Kweon et al, in the year 2013 studied the relation between heart rate variability and development of post spinal hypotension in 41 hypertensive patients undergoing spinal anesthesia for elective surgeries. Five separate time points, including before fluid loading (baseline), after fluid loading, and five, fifteen, and thirty minutes following spinal anaesthesia, were used to quantify heart rate variability. They concluded that in hypertensive patients, heart rate variability is not a good indicator of hypotension following spinal block<sup>8</sup>.

In the year 2017, D G Bishop et al, conducted a study in 102 elective LSCS patients and found that heart rate variability as a good tool in predicting hypotension following spinal anaesthesia<sup>12</sup>.

D R Duggappa et al, conducted a study in 2016, to correlate perfusion index and hypotension following spinal anaesthesia in 126 parturients and found that patients with perfusion index more than 3.5 before induction has a higher incidence of hypotension following spinal anaesthesia<sup>7</sup>.

Recently, several methods have been researched to determine the intravascular volume status, including central venous pressure monitoring, pulmonary arterial catheter, PiCCO, Vigileo, pulse pressure variation, stroke volume variation, transesophageal echocardiography etc<sup>21-23</sup>. Due to cost limitations, high complication rates and being an invasive procedure, their general usage is still up for debate.

After the knowledge of ultrasonography in emergency and ICU, numerous studies have identified IVCCI assessment using sonography is a simple, non-invasive method for assessing volume status.

J Matthew Brennan et al, in 2006 done a study among 89 patients undergoing haemodialysis using handheld ultrasonographic measurement of IVC. They found that in an outpatient Haemo Dialysis clinic, operators with little competence in echocardiography can estimate IVC dimensions utilizing handheld ultrasound machines<sup>24</sup>.

In the year 2012, Agarwal Dipthi et al, did a meta-analysis study, a search of 5 major databases of biomedical publication. A total of 5 studies from 4 countries including 86 cases & 189 controls were studied which revealed that compared to euvolemic level, IVC diameter is consistently lower in hypovolemic situation<sup>25</sup>.

In the year 2016, G F EL-Baradey et al, assessed IVC: Ao index & CVP in patients undergoing TURP. They compared caval aortal index & central venous pressure for intravascular volume assessment. They concluded that caval aortal index is a safe, non-invasive technique & better predictor of intra vascular volume status in patients undergoing TURP under spinal anaesthesia<sup>26</sup>.

In the year 2017, Preau Sebastien et al, conducted a study in 19 non-intubated patients with sepsis induced circulatory failure. They assessed hemodynamic state prior to and following a volume expansion brought on by a 30-minute infusion of 500 mL of 4% gelatin. Using transthoracic echocardiography, they calculated the stroke volume index and the inferior vena cava's collapsibility index during a deep, standardised inspiration. They found IVC collapsibility index as a straightforward, non-invasive bedside predictor of fluid responsiveness<sup>27</sup>.

Serkan Bilgin et al, in the year 2019 studied IVC, Abdominal Aorta diameter & their effect on intravascular volume change in 39 blood donors. IVC diameter &

IVC to Aorta ratio were measured before, after blood donation and after 500ml of normal saline infusion. At the end of the study, they concluded that IVC diameter & IVC to Aorta ratio had similar relation in assessing intravascular volume changes<sup>28</sup>.

Lakshmi Priya Menon et al, in the year 2020 studied caval aortic index & their correlation in assessing intra vascular volume status in 50 parturient and 50 non pregnant women. They also compared both transhepatic & subxiphoid view in measuring caval aortic index. They found caval aortic index as a good predictor for assessing intra vascular volume in pregnant women & trans hepatic view as a superior compared to subxiphoid view<sup>29</sup>.

Recently in the year 2021, A A Dodhy et al, studied the correlation between intravascular volume & IVC Collapsibility index in 126 critically ill patients. They found that IVC collapsibility index as a good predictor for assessing intravascular volume in spontaneous patients compared to mechanically ventilated patients<sup>30</sup>.

Based on these studies the use of ultrasound has taken over Anaesthesiology in assessing volume status of patients pre-operatively.

Jie Zang et al, in the year 2016 performed an observational study on 104 patients undergoing general anaesthesia. Prior to operation, they assessed a patient's IVC collapsibility index as well as MAP 10 minutes before and after induction. They discovered a connection between the IVC Collapsibility Index and patients experiencing hypotension in their findings. They came to the conclusion that the IVCCI served as a predictor for hypotension, with a cutoff value of 43%<sup>31</sup>.

S Ceruti et al, conducted a study in 2018, wherein IVC collapsibility index was measured preoperatively in 80 patients (IVC ultrasound group) who were

undergoing surgery under spinal anaesthesia. Fluids were preloaded in those patients whose IVC collapsibility index was greater, and they found that there was a reduced development of hypotension after spinal anaesthesia in IVC ultrasound group than in the control group who didn't receive any fluids<sup>32</sup>.

IVC collapsibility index was measured preoperatively to predict hypotension following spinal anaesthesia in a 2019 study by Jaremkol et al, on 60 spontaneously breathing patients undergoing elective knee joint replacement surgery. where they measured IVC collapsibility index before induction and 15 minutes after spinal anaesthesia, after 500 ml of ordinary saline had been administered via infusion pump. In the study, they were unable to find a correlation between IVCCI & post spinal hypotension treated with normal saline administration<sup>33</sup>.

45 pregnant women were investigated for hypotension following spinal anaesthesia by Yudhyavir Singh et al, in the year 2019. Before starting spinal anaesthesia, they used ultrasound to evaluate the IVC collapsibility index in the left lateral (with wedge) and supine (without wedge) positions. They discovered that nearly 57.5 percent of patients experienced hypotension, and that the IVCCI with wedge's area under the ROC curve for predicting hypotension after spinal surgery was 0.46 with sensitivity and specificity of 60.9 and 35.5 percent, respectively. IVCCI without a wedge had an area under the ROC curve of 0.38 to predict hypotension following spinal, with a sensitivity and specificity of 69.6 percent and 23.5 percent, respectively. They came to the conclusion that in pregnant women having an elective caesarean section, IVCCI is not a predictor of hypotension following subarachnoid block<sup>34</sup>.

In a 2019 observational study, Salma ER et al. measured IVCCI & caval aorta index, compared their correlation in predicting hypotension in a population of Europeans undergoing spinal anaesthesia. They discovered that the IVC to aorta ratio was a more effective indicator than the IVC collapsibility index in predicting post spinal hypotension<sup>16</sup>.

Ting-ting N et al, in 2022 did a study to calculate the cut-off value of IVCCI for predicting hypotension following subarachnoid block. They conducted a study in 90 patients undergoing spinal anaesthesia and measured IVC Collapsibility index using ultrasonography pre-operatively, they found that IVC Collapsibility has a sensitivity & specificity of 83.9% 76.3 respectively. They concluded that IVC Collapsibility index is a good predictor for hypotension following spinal anaesthesia<sup>35</sup>.

## **BASIC SCIENCES**

### **ANATOMY:**

#### **INFERIOR VENA CAVA:**

The inferior vena cava returns blood from all structures below the diaphragm to the right atrium of the heart. It is formed when the two common iliac veins come together at the level of vertebra L5, just to the right of midline.

#### **COURSE:**

It ascends through the posterior abdominal region anterior to the vertebral column immediately to the right of the abdominal aorta, continues in a superior direction, and leaves the abdomen by piercing the central tendon of the diaphragm at the level of vertebra T8.

During its course, the anterior surface of the inferior vena cava is crossed by the right common iliac artery, the root of the mesentery, the right testicular or ovarian artery, the inferior part of the duodenum, the head of the pancreas, the superior part of the duodenum, the bile duct, the portal vein, and the liver, which overlaps and on occasion completely surrounds the vena cava<sup>36,37</sup>

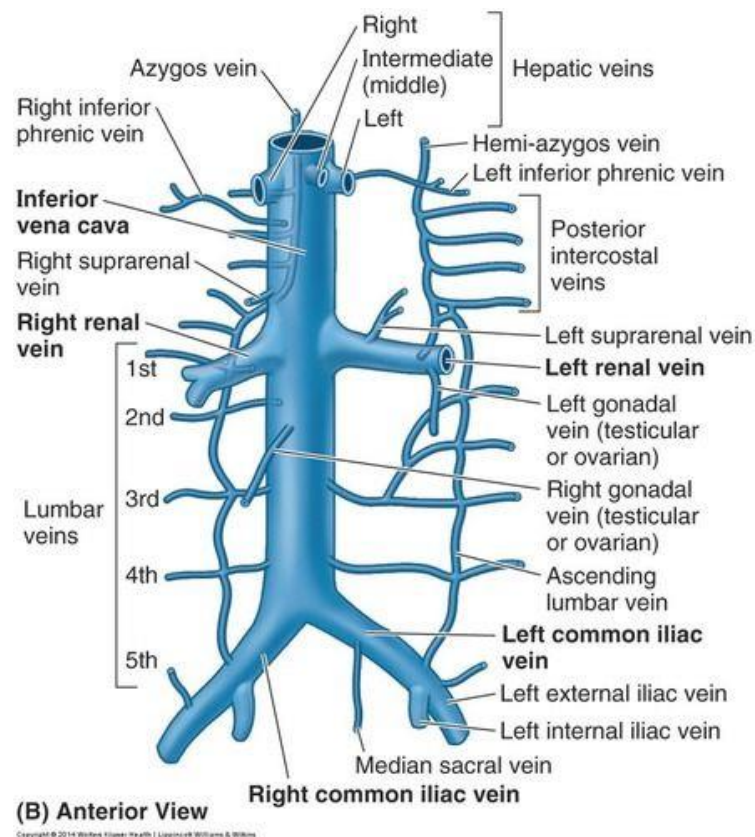
#### **TRIBUTARIES: (FIG:1)**

- Common iliac veins
  
- Lumbar veins
  
- Right testicular or ovarian vein

- Renal veins
- Right suprarenal vein
- Inferior phrenic veins
- Hepatic veins.

The inferior vena cava is ultimately responsible for the transport of almost all venous blood (deoxygenated) from the abdomen and lower extremities back to the right side of the heart for oxygenation.

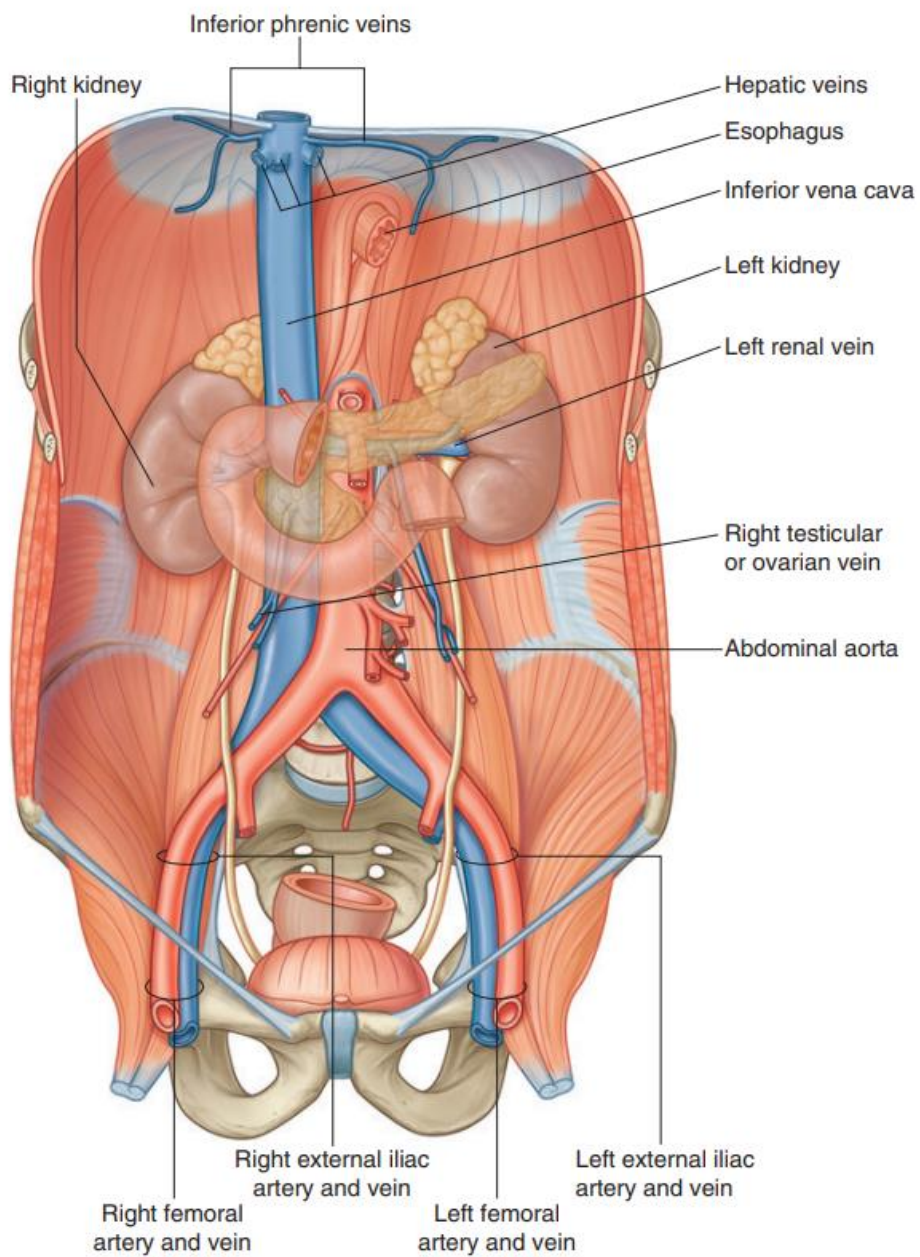
Ultrasonographic measurement of IVC diameter during inspiration and expiration helps in intravascular volume assessment.



**FIG: 1**

**ABDOMINAL AORTA:**

The aorta is the largest blood vessel in the body. It is an artery, meaning that it carries blood away from the heart. The aorta supplies oxygenated blood to most of the body.



**FIG: 2**

**COURSE:**

The abdominal aorta begins at the aortic hiatus of the diaphragm as a midline structure at approximately the lower level of vertebra T12. It passes downwards on the anterior surface of the bodies of vertebrae L1 to L4, ending just to the left of midline at the lower level of vertebra L4.

Aorta divides into the right and left common iliac arteries on the anterior abdominal wall (FIG:2) at a point approximately 2.5 cm below the umbilicus or even with a line extending between the highest points of the iliac crest<sup>36,37</sup>.

**BRANCHES<sup>36,37</sup>: (FIG:3)**

Branches of the abdominal aorta can be classified as:

1. Visceral branches supplying organs
2. Posterior branches supplying the diaphragm or body wall,
3. Terminal branches- common iliac arteries

**1.VISCERAL BRANCHES:**

There are three unpaired and three paired branches arising from abdominal aorta

Unpaired branches:

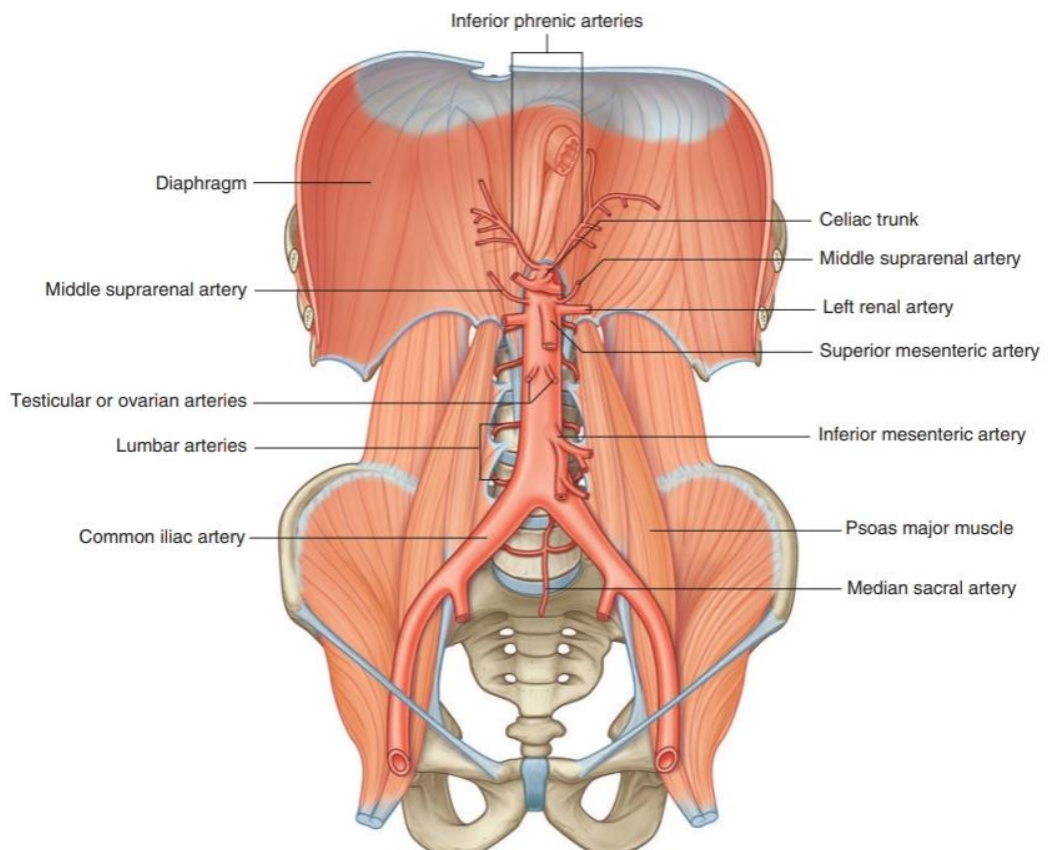
- Celiac trunk
- Superior mesenteric artery
- Inferior mesenteric artery

**PAIRED BRANCHES:**

- Middle supra renal arteries
- Renal arteries
- Testicular or ovarian arteries

**2. POSTERIOR BRANCH:**

- Inferior phrenic arteries
- Lumbar arteries
- Median sacral arteries



**FIG: 3**

## **ULTRASONOGRAPHY<sup>38-40</sup>:**

Ultrasound, which is a sound waves in frequency range of around 2 to 15 megahertz has a wide range of diagnostic and treatment application in the field of medicine. The ultrasonography works on the principle of Piezoelectric effect. This effect converts mechanical / kinetic energy into electrical energy by deformation of crystals. Piezoelectric effect can also be reversed i.e., by electrical energy the crystals can be oscillated to form ultrasound waves (mechanical energy).

The ultrasound transducer has the function of producing the ultrasound by the above said mechanism. This ultrasound produced travels through tissues and gets reflected back. The returned echo waves after reaching the transducer gets changed to electrical energy which is later processed and produce an image. The transducers work in a range of frequencies. Linear transducers with higher frequencies (5 – 7.5 MHz) are used in imaging superficial structures whereas curvilinear probe with lower frequencies (2.5 – 3.5 MHz) produce images of deeper structures.

It is on the surface that lies between tissues of varying density, the ultrasound gets reflected. If the difference in densities is higher, the sound waves that get reflected is also high and the opposite also holds true. Therefore, with very high difference of densities (bones, air, calculi) the sound will be completely reflected back. This produces the acoustic shadowing. If the tissues are homogenous in their densities then echo-free images are seen (blood, urine, ascites).

## **TRANSDUCERS:**

This is the hand-held part of the ultrasound machine. It has the function of inter-converting the energies (electrical and mechanical) based on piezoelectric effect. They contain lead zirconate titanate crystals commonly. They produce the ultrasound waves in either linear(sequential) arrays or phased array.

It comprises 5 major components:

- Crystals: possessing piezoelectric property. Can be arranged in either linear or curvilinear manner.
- Electrodes: positive and ground. For electrical connection
- Damping block: to dampen stray sound waves.
- Matching layer: one or multiple. For proper transmission of sound waves to the tissues.
- Housing.

## **LINEAR TRANSDUCER:**

- The piezoelectric crystals – Linearly arranged.
- Produce rectangular ultrasound beam.
- Used for superficial imaging.
- Footprint – wide with frequency of 2.5 – 12MHz at the centre in 2D imaging probe and frequency 7.5 – 12 MHz at the centre in 3D imaging probe (FIG:4).

Applications:

- ❖ Vascular examination, venous puncture (catheterization),
- ❖ Breast imaging,
- ❖ Thyroid imaging,
- ❖ Tendons and joints,
- ❖ During laparoscopic procedures,
- ❖ Measuring body fat thickness,
- ❖ Peripheral nerve blocks

**CURVILINEAR TRANSDUCER:**

- The Piezoelectric crystals – curvilinear arrangement.
- They produce convex ultrasound beam.
- Used to image deeper tissues.
- As depth of imaging increases, image resolution decreases.
- Foot print is wide with central frequency being, 2.5 – 7.5MHz for 2D imaging and 3.5 – 6.5MHz for 3D imaging (FIG:5).
- Applications,
  - ❖ Abdominal examinations,
  - ❖ Transvaginal and transrectal examinations,
  - ❖ Diagnosis of organs.



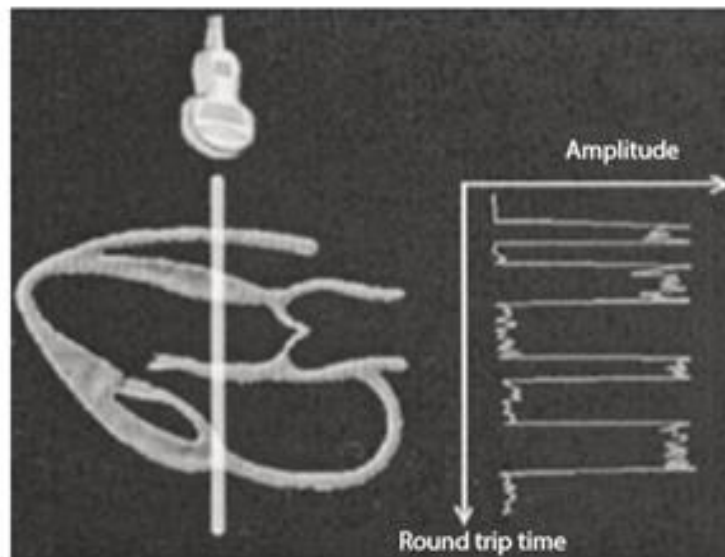
**FIG: 4**



**FIG: 5**

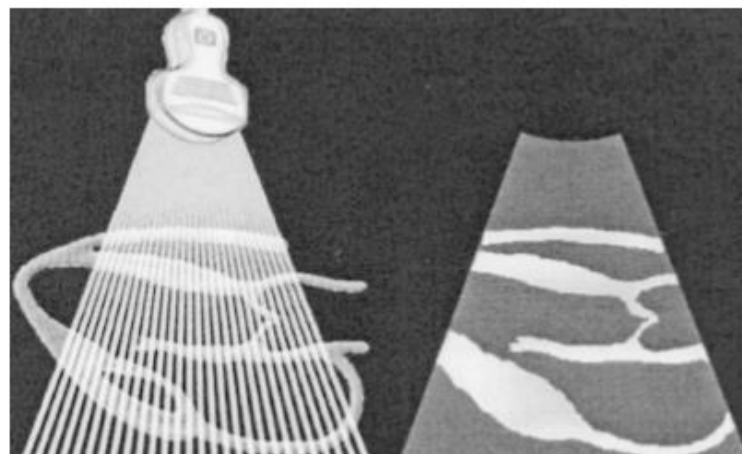
**MODES OF IMAGING:**

**A Mode:** Amplitude mode or A mode is the basic technology which was used initially. As the reflected echo returns to the probe, their amplitudes are charted as spikes (FIG:6). It is one dimensional. The amplitude of the spike corresponds to the distance of the tissue from which the ultrasound got reflected back to the transducer. Hence it is used in measuring depths and lengths. It is frequently used in ophthalmology for measuring the corneal thickness and axial length measurements.



In A-mode scanning, the amplitudes of the reflected echoes are displayed unidimensionally, representing the distances of the reflecting boundaries in the tissue from the transducer (Courtesy of Hitachi Ltd.)

FIG: 6



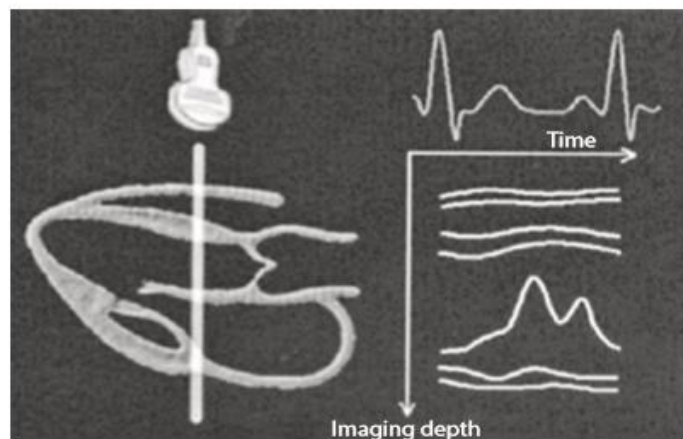
In B-mode scanning, the echoes reflected from boundaries between tissues of different acoustic impedance are displayed two-dimensionally as bright/dark spots with brightness levels representing the intensity of the reflected echoes (Courtesy of Hitachi Ltd.)

FIG: 7

**B mode:** Brightness mode or B mode scan (FIG: 7) records the reflected echo waves as dots rather than spikes as seen with A mode. Higher the amplitude (strength) of the echo wave, brighter will be the dot. The reflected waves from an emitted pulse form the dots in a straight line. Only after the reflected waves reach the transducer back (after the formation of dots from the first emitted pulse) the next pulse of ultrasound is emitted. When all the emitted waves reach the transducer back, the 2D ultrasound image (B mode) is formed

**M mode:** Motion mode or M mode or Time-Motion (TM) mode (FIG: 8), here the transducer is stationed and ultrasound beam is generated repeatedly. The ultrasound gets reflected from

moving objects in the path of the beam at different times. The M mode image is displayed in a wave like fashion depicting the movement of an object with relation to time. M mode is used in imaging moving structures like cardiac valves, lung pleura, echocardiography (wall movements). It provides a high temporal resolution.



In M-mode scanning, the temporal changes in returning echoes are displayed, representing the motion of reflecting interfaces toward and away from the transducer over time (Courtesy of Hitachi Ltd.)

**FIG: 8**

## **DOPPLER IMAGING:**

Doppler effect: Change in frequency of the sound/light wave when there is a relative motion between the source of the wave and the observer. For example, when the observer is stationary and the source is moving towards the observer, the perceived frequency by the observer will be higher than the frequency with which the wave was emitted. The reverse holds true i.e., if the source is moving away from the observer the frequency perceived will be lower than that of the frequency emitted by the source. It is also called as doppler shift. This effect is made use of in the doppler imaging to measure the flow velocity of moving blood.

While measuring the flow velocity of the blood, doppler effect occurs twice. First, when the ultrasound is emitted from the transducer towards the blood vessel the source (transducer) is stationary and the perceiver (blood) is moving. Next, when the wave gets reflected back from the red blood cells and moves towards the transducer the source (blood-RBCs) is in motion while the perceiver (transducer) is stationary. The direction of the blood flow either towards or away from the transducer determines whether the frequency of the returning wave is higher or lower respectively. The shift in frequency (doppler effect) depends upon the frequency with which it was emitted from the transducer, the velocity with which the blood cells move and the angle between the moving blood cells and the transducer. This angle is known as doppler angle (FIG: 8). It is important that the emitted beam from the transducer cannot be parallel to the moving blood cells, when the transducer is placed on the skin. This relationship between them can be expressed as the following equation,

$$F_d = F_r - F_0 = \frac{2F_0 \cdot v \cdot \cos\alpha}{c}$$

Where,  $F_d$  – doppler shift in frequency.

$F_r$  – frequency of reflected wave.

$F_0$  – frequency of the emitted wave from the source.

$v$  – velocity of the moving RBCs.

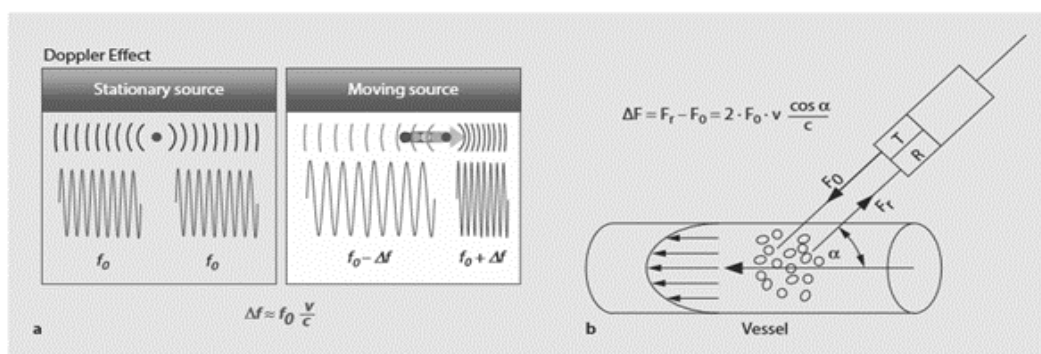
$c$  – speed with which the sound travels in the soft tissue ( $\approx 1540$  m/s).

$\alpha$  – angle between the transducer and the blood flow's direction.

from the above equation, the flow velocity ( $v$ ) of the blood can be determined by substituting the other values. The equation of measuring the velocity thus, will be,

$$v = (F_r - F_0) \cdot \frac{c}{2F_0 \cdot \cos\alpha}$$

If the transducer is placed at  $90^\circ$  to the vessel then ( $\cos 90^\circ = 0$ ) there wont be any doppler shift in frequency. Hence the velocity cannot be determined. As the angle ( $\alpha$ ) decreases the cosine function will increase and so will the doppler shift. At angles  $60^\circ$  and less the accuracy of the velocity calculated will be good.<sup>40</sup>



Doppler effect. a Dependence of the Doppler shift (change in frequency between source and receiver) on the velocity of the moving source and its direction of motion relative to the reflector. b Diagram of Doppler interrogation of a vessel with laminar blood flow. The arrows in the vessel are vectors representing different flow velocities. Blood flow is fastest in the center and decreases toward the wall. The drawing illustrates the effect of the angle of incidence on the Doppler measurement. In the equation for calculating the Doppler shift, this angle is represented by the cosine function. The Doppler shift increases with the acuity of the angle (cosine of  $90^\circ = 0$ ) (T, transmitter; R, receiver;  $F_0$ , emitted frequency;  $F_r$ , reflected frequency)

FIG: 9

**DUPLEX / PULSED WAVE DOPPLER ULTRASOUND:**

This mode is similar to that of the brightness mode, wherein pulses of ultrasound are emitted from the piezoelectric crystals and the returning echoes are received. Here the depth till which the ultrasound traveled can be determined as we have the velocity with which it travels ( $\approx 1540$  m/s) in the tissues and calculating the overall (round-two way) time travelled by the sound waves.

Initially, a pulse of wave is emitted by the system and the system goes in for temporary off mode when no returning echoes will be perceived then it goes into the receiving mode. Thus only the echoes that return during the receiving mode will be processed leaving the remaining echo waves. This time window when the system is in the receiving mode is termed 'the range gate'. By controlling this window period (range gate) one can adjust the volume of sample or doppler window. Typically the doppler window is adjusted to get the whole diameter of the vessel that is targeted. Pulse repetition frequency is the number of pulses that are emitted in one second. Thus by decreasing the pulse repetition frequency we will be able to scan deeper structures (as the time required for the echoes to return back increases).

As we know the velocity of the ultrasound in the tissues is approximately constant, just by using a time filter one can adjust the depth till which they need the scanning to be done. An electronic gate will be opened for a brief period when the returning echoes will be allowed in, while blocking the waves that come a little before or after. Hence, we will be able to record doppler signals from a particular depth selectively.

The duplex scan combines this pulsed doppler imaging and the 2D real time imaging providing us the information about the flow in a blood vessel at a defined depth. The flow velocity of the blood can be estimated using the doppler shift in frequency as using the B-mode the doppler angle can be determined<sup>40</sup>.

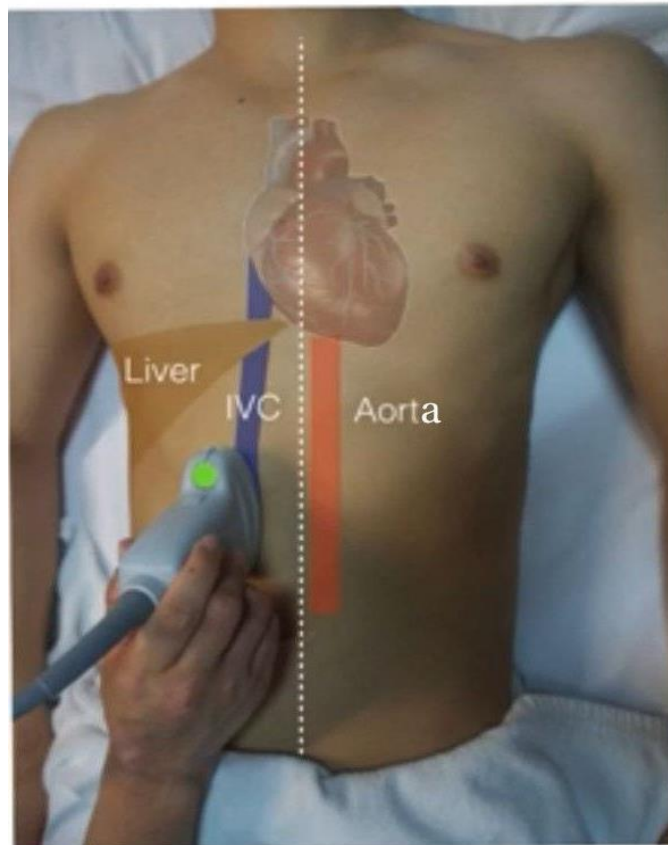
### **SONOANATOMY:**

Ultrasound evaluation of the inferior vena cava (IVC) provides rapid, noninvasive assessment of a patient's hemodynamic status at the bedside. The size of the IVC and its respiratory variability has been shown to correlate with right atrial pressure (RAP) and intravascular volume. These observations are valuable in estimating RAP, detecting changes in intravascular volume, and monitoring a patient's response to volume resuscitation.

Structurally, the IVC is a thin-walled, highly compliant vessel. Its size and dynamics vary with respiration and changes in intravascular volume. The development of negative intrathoracic pressure during inspiration increases the venous blood return from the extrathoracic veins into the right heart. This leads to an increase in the blood flow through the IVC and a subsequent decrease in its blood volume, resulting in a reduction in intraluminal pressure. These changes decrease the diameter of the IVC during inspiration relative to expiration. These observations are reversed with positive pressure ventilation in which IVC diameter increases during inspiration.

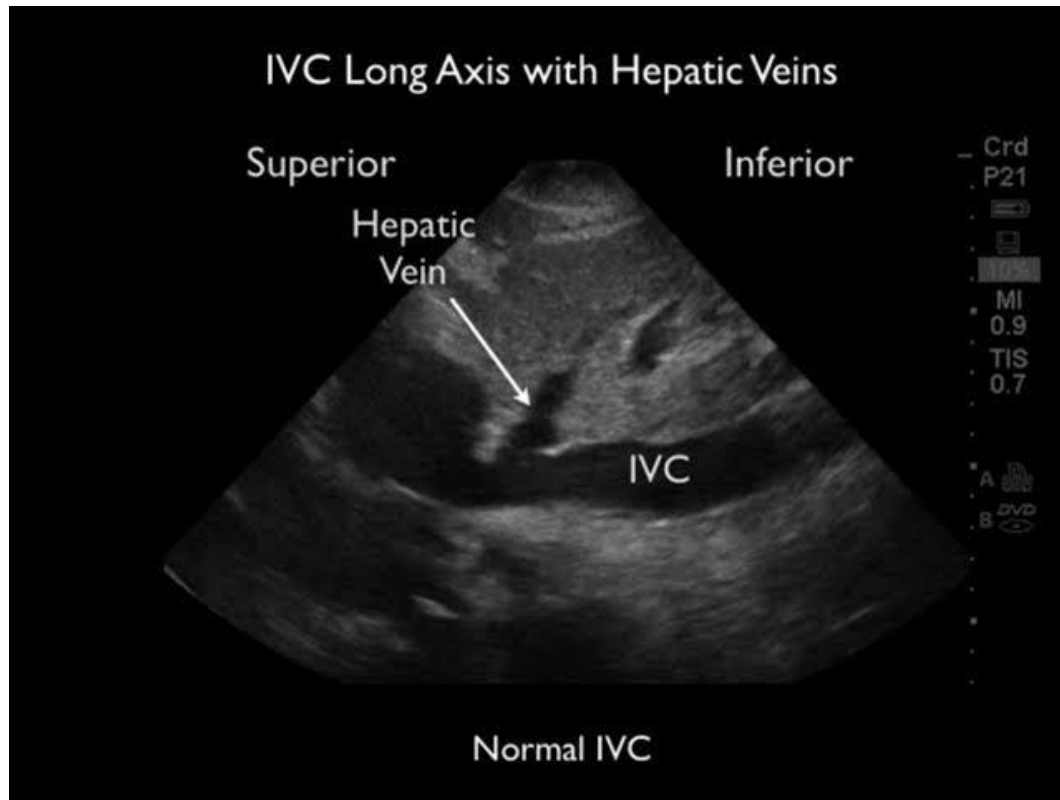
To visualize the IVC, a phased-array (frequency of 2.0–4.0 MHz) or curvilinear probe (frequency of 3.5–5.0 MHz) should be used. These relatively low-frequency probes provide better penetration and visualization of deep structures.

Aorta and IVC basically walk side by side, so the starting position can be done by placing the curvilinear probe horizontally on the subxyphoid under the xiphoid process to do a top-to-bottom transverse scan (FIG: 9), and then turn it into a longitudinal scan.



**FIG: 10**

At the same position, we move the probe a slightly right to place the target IVC in the center of the screen, and then turn the probe 90 degrees clockwise to see its vertical appearance. To standardize measurements, the IVC was measured 2 cm caudal to the junction point of the hepatic vein and IVC (FIG: 10). The inspiratory ( $IVC_{min}$ ) and expiratory ( $IVC_{max}$ ) diameters of the IVC were detected by measuring the vein lumen in a single respiratory cycle.

**FIG: 11**

The IVCCI was given by the formula  $(IVCCI = [(IVC_{max} - IVC_{min}) / IVC_{max}] \times 100\%)$

The abdominal aorta will be visualized to the left of IVC (FIG: 11).

The curvilinear probe is placed on the transverse plane in the epigastrium. After identifying the spine with the aorta on left side of patient, IVC on the right side of patient, using M mode the maximum internal diameter of the aorta will be measured during heart systole.



**FIG: 12**

The vena cava: aorta ratio will be measured by dividing the maximum internal diameter of inferior vena cava during expiration with maximum internal diameter of aorta measured during systole.

## **METHODOLOGY**

**STUDY DESIGN:** A One Year Hospital Based Prospective Observational study

**STUDY PERIOD:** One year (January 2021 – December 2021)

**PLACE:** “Department of Anaesthesiology, KLE’S Dr. Prabhakar Kore Hospital and Medical Research Centre, KAHER, Belagavi”.

**SOURCE OF DATA:** Patients between age group of 18-60 posted for elective surgery under spinal anaesthesia at KLE’S Dr. Prabhakar Kore Hospital and Medical Research Centre, Nehru Nagar, Belagavi -10.

**SAMPLE SIZE:** A total of 75 patients.

**SAMPLING PROCEDURE:** The minimum sample size formula based on prevalence rate is

$$n = z_{\alpha}^2 P(1-P)/d^2$$

where P: prevalence percentage & d: likelihood of the prevalence difference in percentage.

$z_{\alpha}$ : significance level  $z_{\alpha} = 1.96$  at a 5% level of significance.

With P = 45% and d = 25% of P = 11.25%,

Sample size = 75.

**Inclusion Criteria:**

- ASA I & II.
- 18years – 60years.
- Elective surgeries under spinal anesthesia.
- Provides Consent.

**Exclusion Criteria:**

- Patient undergoing emergency surgery.
- Patient who are unable to give consent.
- BMI more than 30kg/m<sup>2</sup>.
- Patients taking ACEI
- Obstetric patients
- Unilateral spinal anaesthesia.
- Patients with arrhythmias & CCF.
- Baseline arterial SBP < 90mmHg or MAP <70mmHg.

**Ethical Clearance:**

The approval by the institutional Ethical and Research Committee, Jawaharlal Nehru Medical College, Belagavi, was taken before starting the study.

**Informed Consent:**

All the patients who fulfilled the selection criteria were explained about the nature of the study and intervention being done. A written informed consent was obtained from all patients before enrolment in their vernacular language.

**Method of Collection of Data:**

After obtaining clearance & informed consent, a prospective, observational research was carried out on patients posted for elective surgery under spinal anaesthesia, of the age group between 18 & 60 years, of either gender, with ASA I and II.

One day prior to surgery, after thorough pre-operative assessment patients were advised to be in overnight fasting and oral clear fluids were allowed till 6 hours prior to surgery. On the day of the procedure in the pre-op room, vital parameters (pulse oximeter, NIBP & ECG) were measured. In supine position, the inferior vena cava (IVC) and aorta (Ao) were examined by an anaesthesiologist with basic knowledge about ultrasonography.

For IVC measurements, a curvilinear probe (2-5 MHZ & ultrasound Model: Fujifilm Sonosite-M turbo) was placed in subxiphoid place just distal to the junction of inferior vena cava and hepatic vein, 3 to 4 cms distal to the right atrium in longitudinal position. Doppler wave shape, compressibility & collapse with respiration were used to identify the inferior vena cava. After identifying IVC, maximum ( $IVC_{max}$ ) & minimum ( $IVC_{min}$ ), antero-posterior (AP) diameters of inferior vena cava were measured during quite expiration and inspiration using M mode. The Inferior vena cava collapsibility index was measured by the formula

$[(IVC_{max} - IVC_{min})/IVC_{max}] * 100$ . The abdominal aorta was visualized to the left of IVC and 10cm above coeliac trunk using M mode. The maximum internal diameter of the aorta was measured during heart systole. The vena cava: aorta ratio was obtained by dividing the maximum internal diameter of inferior vena cava during expiration with maximum internal diameter of aorta during systole. The IVCCI and caval aorta index were noted along with patients independent factors like age, sex, height, weight and BMI. After measuring the IVC collapsibility index and caval aorta index the patients were shifted to the operation theatre.

In the operating room, heart rate (HR), non-invasive systolic blood pressure (SBP), diastolic blood pressure (DBP) and mean arterial pressure (MAP) were measured (baseline vital parameters) along with ECG and oxygen saturation using monitor. Every patient was co-loaded with i.v. ringer lactate or normal saline at 10ml/kg/hour after administration of spinal anaesthesia.

In sitting position, lumbar puncture was performed at L2-L3 or L3- L4 intervertebral space using a 27G Whitacre spinal needle and 3cc of 0.5% of bupivacaine (heavy) was administered. Immediately following the administration of the medication, patients were then laid out in the supine posture. Spinal block was achieved till T8 to T6. Noninvasive SBP, DBP, MAP, HR and oxygen saturation were recorded immediately (0 minute) and every 3 minutes for the first 30 minutes, then every 5 minutes till the end of surgery. All the vital parameters were monitored throughout the procedure.

Post spinal hypotension: SBP <90mmHg or reduction in SBP by > 30% of the baseline value or MAP <60mmHg, for the first 30 minutes after giving spinal block (study period).

Based on the readings patients were divided into two groups: hypotensive & non hypotensive & Phenylephrine 50 mcg was administered to treat any episodes of hypotension.

Other complications of spinal anaesthesia like bradycardia, shivering etc if any present were treated accordingly. Bradycardia - defined as heart rate <60 beats per minute and if present, was treated with inj. Glycopyrrolate 0.2mg i.v and if heart rate <50 beats per minute inj. Atropine 0.6 mg i.v was given.

The ultrasound readings were blinded from the anesthesiologist who administered the spinal block and monitored the patients.

**Statistical analysis:**

With the help of SPSS version 21, statistical analysis was carried out. The mean and standard deviation of the continuous quantitative variables were computed. The data was split into two groups according to a certain qualitative attribute for the purpose of comparison. The student's unpaired t test and other appropriate statistical methods were used to compare the continuous variables. The student's paired t test was used to compare the pre- and post-treatment measurements. Median was used to represent discrete variables. Rates, ratios, and percentages were used to express the categorical data. The Chi-square test, test of proportion, or Fisher's exact test were used to determine whether there was a relationship between the outcome, clinical, and demographic data. Nonparametric tests for discrete variables were utilised. The comparison was represented using appropriate graphs. The value of p less than 5% (0.05) was deemed significant for all tests. Yoden's index was used to determine

which pair is most efficient when there were numerous sensitivities and associated specificities.

**Yoden's Index:**

Defined as  $\text{SENSITIVITY} + \text{SPECIFICITY} - 100$ .

Corresponding to the highest Yoden's Index, the value of the parameter was taken as the cut off value.

**RECEIVER OPERATOR CHARACTERISTIC ROC:**

The probability curve known as RECEIVER OPERATOR CURVE serves to fundamentally separate the "signal" from the "noise" by plotting the true positive rate against the false positive rate at various threshold values. As a summary of the ROC CURVE, the "AREA UNDER THE CURVE" (AUC) measures a classifier's capacity to distinguish between classes.

The model performance at differentiating among the positive and negative classes is improved by higher AUC.

AUC = 1 allows the classifier to perfectly differentiate among all the positive and the negative class points correctly, while AUC = 0 allows the classifier to predict all negatives as positives and all positives as negatives.

## **RESULTS**

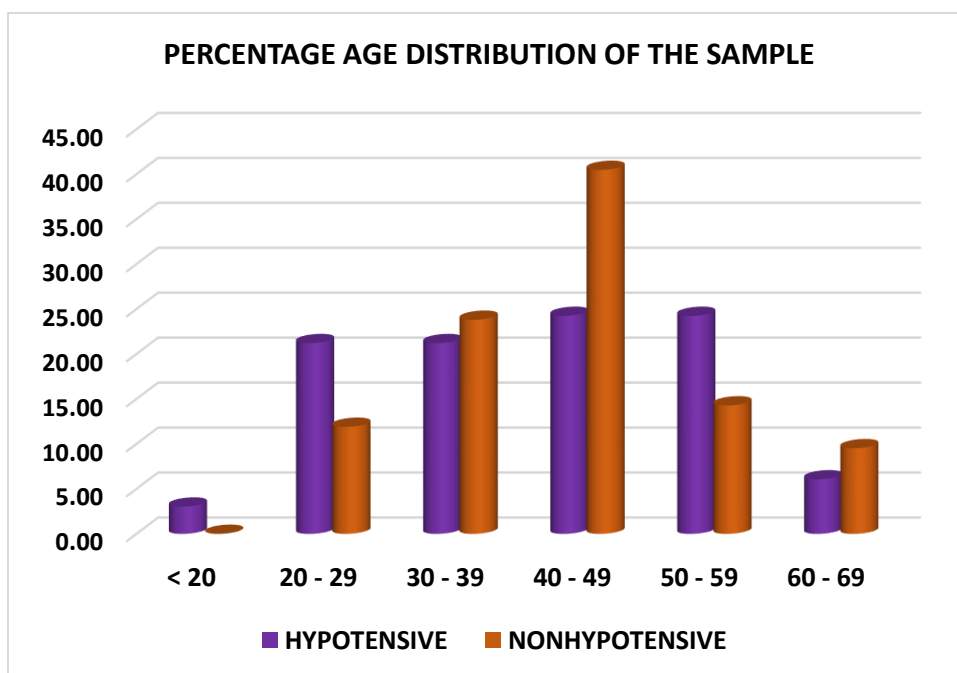
The research included a total of 75 patients from ASA I and ASA II who were undergoing elective procedures under spinal anaesthesia.

Using ultrasound, IVCCI and IVC:Ao were measured and correlated with hypotension following spinal anaesthesia. After induction of spinal anaesthesia patients were divided into two groups (hypotensive & normotensive group)

Data were entered in Microsoft excel spread sheet. Data were analysed and results were tabulated below.

**AGE DISTRIBUTION:****TABLE :1**

AGE	HYPOTENSIVE		NONHYPOTENSIVE	
	NUMBER	%	NUMBER	%
18-20	1	3.03	0	0.00
21 - 30	7	21.21	5	11.90
31 - 40	7	21.21	10	23.81
41 - 50	8	24.24	17	40.48
51 - 60	10	30.30	10	23.81
<b>TOTAL</b>	<b>33</b>	<b>100.00</b>	<b>42</b>	<b>100.00</b>

**GRAPH :1**

**TABLE: 2**

	<b>HYPOTENSIVE</b>				<b>NONHYPOTENSIVE</b>				<b>P</b> <b>VALUE</b>	<b>INFERENCE</b>
	<b>MEAN</b>	<b>S.D.</b>	<b>MIN</b>	<b>MAX</b>	<b>MEAN</b>	<b>S.D.</b>	<b>MIN</b>	<b>MAX</b>		
<b>AGE</b>	40.12	12.83	19	60	42.40	10.51	23	60	0.3996	NS

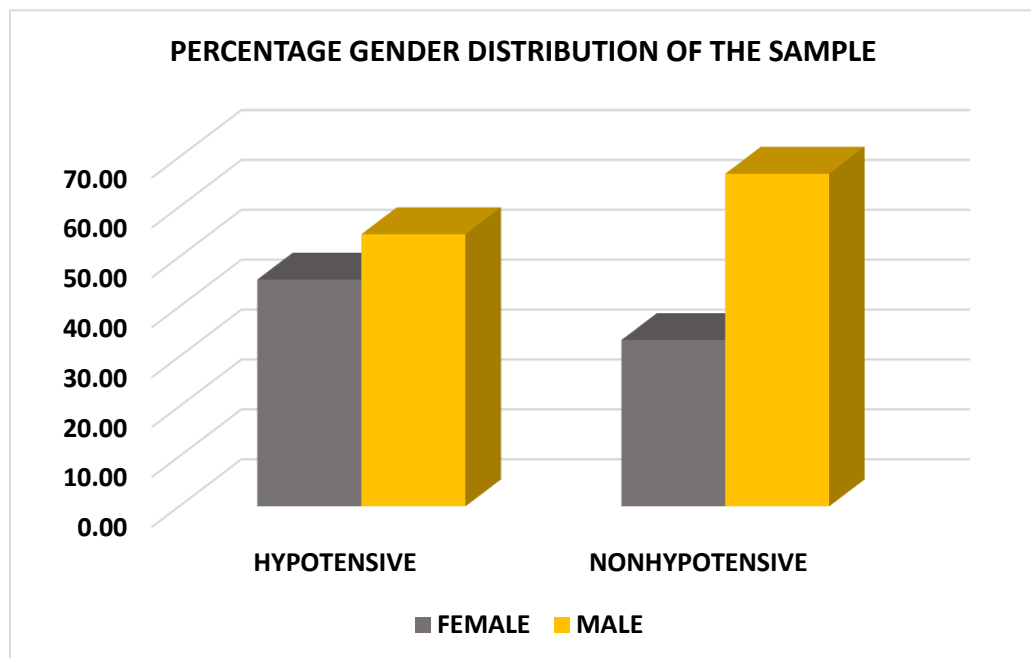
In above following tables p values are calculated, for comparing hypotensive and non-hypotensive groups, using student's unpaired t test

There is no significant relation between age of the patient and development of hypotension following spinal hypotension.

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**GENDER DISTRIBUTION**
**TABLE: 3**

GENDER	HYPOTENSIVE		NONHYPOTENSIVE	
	NUMBER	%	NUMBER	%
FEMALE	15	45.45	14	33.33
MALE	18	54.55	28	66.67
TOTAL	33	100.00	42	100.00

**GRAPH: 2**

From the above, using student's unpaired t test p value was 0.2846, this suggests that there is no significant relation between sex of the patient and development of hypotension following spinal anaesthesia.

**ASA DISTRIBUTION:****TABLE: 4**

	<b>HYPOTENSIVE</b>		<b>NONHYPOTENSIVE</b>	
<b>ASA</b>	<b>NUMBER</b>	<b>%</b>	<b>NUMBER</b>	<b>%</b>
<b>I</b>	21	63.64	21	50.00
<b>II</b>	12	36.36	21	50.00
<b>TOTAL</b>	33	100.00	42	100.00

From the above, using student's unpaired t value p value was 0.2376. This suggests that there is no significant relation between ASA grading of the patient and development of hypotension following spinal anaesthesia.

**BMI & BASE LINE VITAL PARAMETERS:****TABLE: 5**

	HYPOTENSIVE				NONHYPOTENSIVE				P VALUE	INFERENCE
	MEAN	S.D.	MIN	MAX	MEAN	S.D.	MIN	MAX		
<b>BMI</b>	24.34	3.21	18	28.5	24.72	3.18	18.5	29	0.6062	NS
<b>Baseline heart rate</b>	91.27	10.92	72	112	85.64	14.85	60	115	0.0723	NS
<b>Baseline SBP</b>	135.48	11.88	114	166	140.55	11.98	118	164	0.0724	NS
<b>Baseline DBP</b>	87.94	10.83	64	112	88.71	10.58	67	117	0.7562	NS
<b>Baseline MAP</b>	102.48	10.24	87	120	104.93	9.94	87	121	0.3004	NS

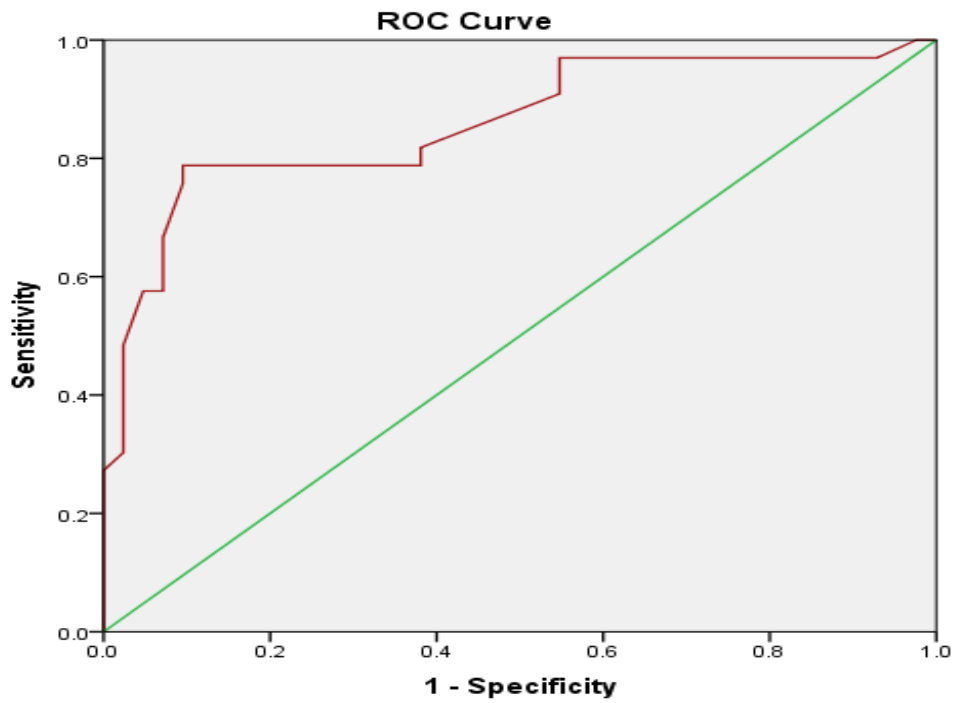
From the above, using student's unpaired t test p value was calculated and it suggests that there is no significant relation between BMI & baseline vital parameters of the patient and development of hypotension following spinal anaesthesia.

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**CORRELATION BETWEEN IVCCI & DEVELOPMENT OF POST SPINAL  
HYPOTENSION**

**ROC ANALYSIS FOR IVCCI:**

**GRAPH: 3**



**AUC = 0.8594**

TABLE: 6

IVCCI	SENSITIVITY	SPECIFICITY	YODEN'S INDEX
11.00	100.00	0.00	0.00
13.50	100.00	2.38	2.38
17.50	96.97	7.14	4.11
21.00	96.97	14.29	11.26
22.50	96.97	16.67	13.64
23.50	96.97	19.05	16.02
24.50	96.97	23.81	20.78
25.50	96.97	28.57	25.54
26.10	96.97	30.95	27.92
27.10	96.97	33.33	30.30
28.30	96.97	45.24	42.21
28.80	93.94	45.24	39.18
29.50	90.91	45.24	36.15
30.25	81.82	61.90	43.72
30.75	78.79	61.90	40.69
31.50	78.79	64.29	43.07
33.00	78.79	71.43	50.22
34.50	78.79	73.81	52.60
35.50	78.79	76.19	54.98
36.50	78.79	78.57	57.36
37.35	78.79	80.95	59.74
37.85	78.79	83.33	62.12
38.50	78.79	85.71	64.50
*39.40	78.79	90.48	69.26
39.90	75.76	90.48	66.23
40.50	66.67	92.86	59.52
41.50	63.64	92.86	56.49
42.50	60.61	92.86	53.46
43.55	57.58	92.86	50.43
44.55	57.58	95.24	52.81
45.50	48.48	97.62	46.10
46.50	42.42	97.62	40.04
47.50	36.36	97.62	33.98
49.00	30.30	97.62	27.92
50.50	27.27	100.00	27.27
51.50	24.24	100.00	24.24
52.40	21.21	100.00	21.21
53.90	18.18	100.00	18.18
56.00	9.09	100.00	9.09
57.50	6.06	100.00	6.06
59.00	3.03	100.00	3.03
61.00	0.00	100.00	0.00

\*The Cut off Value of IVCCI, Corresponding To The Highest Yoden's Index 69.26, IS 39.4

**TABLE: 7**

	HYPOTENSIVE				NONHYPOTENSIVE				Pvalue	INFERENCE
	MEAN	S.D.	MIN	MAX	MEAN	S.D.	MIN	MAX		
<b>IVCCI</b>	42.05	11.62	15	60	31.02	8.77	12	55	< 0.0001	HS

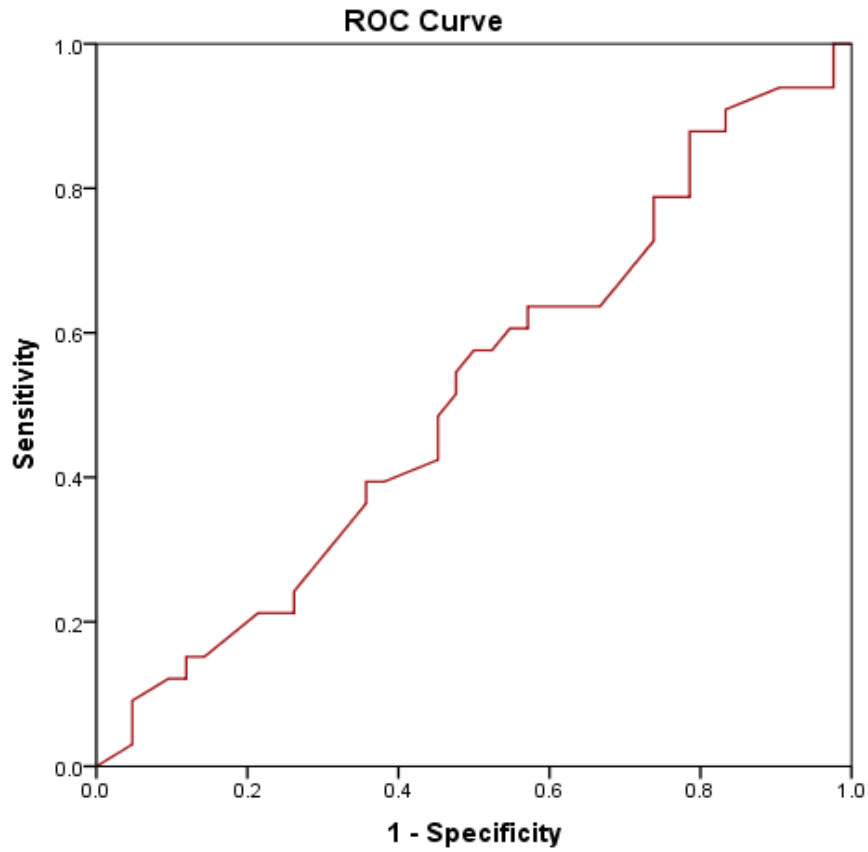
From the above table using student's unpaired t test the **p value was <0.0001**, suggesting that there is **significant** relation between IVCCI and development of hypotension following spinal anaesthesia.

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**CORRELATION BETWEEN IVC:Ao & DEVELOPMENT OF POST SPINAL HYPOTENSION.**

**ROC CURVE ANALYSIS FOR IVC:Ao:**

**GRAPH: 4**



**AREA UNDER THE CURVE = 0.5159**

TABLE: 8

IVC:Ao	SENSITIVITY	SPECIFICITY	YODEN'S INDEX
-0.68	100.00	0.00	0.00
0.37	100.00	2.38	2.38
0.46	96.97	2.38	-0.65
0.51	93.94	2.38	-3.68
0.53	93.94	4.76	-1.30
0.55	93.94	7.14	1.08
0.58	93.94	9.52	3.46
0.61	90.91	16.67	7.58
0.64	87.88	16.67	4.55
0.66	87.88	19.05	6.93
*0.68	87.88	21.43	9.31
0.74	81.82	21.43	3.25
0.78	78.79	21.43	0.22
0.79	78.79	26.19	4.98
0.80	72.73	26.19	-1.08
0.81	63.64	33.33	-3.03
0.82	63.64	42.86	6.49
0.83	60.61	42.86	3.46
0.85	60.61	45.24	5.84
0.87	57.58	47.62	5.19
0.89	57.58	50.00	7.58
0.91	54.55	52.38	6.93
0.94	51.52	52.38	3.90
0.96	48.48	54.76	3.25
0.97	45.45	54.76	0.22
0.99	42.42	54.76	-2.81
1.02	39.39	61.90	1.30
1.06	39.39	64.29	3.68
1.08	36.36	64.29	0.65
1.09	33.33	66.67	0.00
1.10	30.30	69.05	-0.65
1.12	24.24	73.81	-1.95
1.14	21.21	73.81	-4.98
1.17	21.21	76.19	-2.60
1.20	21.21	78.57	-0.22
1.21	15.15	85.71	0.87
1.24	15.15	88.10	3.25
1.27	12.12	88.10	0.22
1.29	12.12	90.48	2.60
1.33	9.09	95.24	4.33

\*IVC:Ao'S Cutoff  
Value Is **0.68**,  
Corresponding To  
Yoden's Highest  
Index Of 9.31.

**TABLE: 9**

	HYPOTENSIVE				NONHYPOTENSIVE				pVALUE	INFERENCE
	MEAN	S.D.	MIN	MAX	MEAN	S.D.	MIN	MAX		
<b>IVC:Ao</b>	0.95	0.25	0.41	1.4	0.93	0.26	0.32	1.4	0.6927	NS

From the above table using student’s unpaired t test the **p value was <0.6927**, suggesting that there is **no significant** relation between IVC:Ao ratio and development of hypotension following spinal anesthesia.

**IVCCI- GOOD PREDICTOR OF POST SPINAL HYPOTENSION**

**THE AUC FOR IVCCI- LARGER THAN AUC FOR IVC:AO**

**THE YODEN’S INDEX FOR IVCCI IS LARGE.**

**IVC:AO IS A POOR PREDICTOR OF HYPOTENSION.**

**THE AUC FOR IVC:AO - SMALLER THAN THE AREA UNDER CURVE FOR IVCCI.**

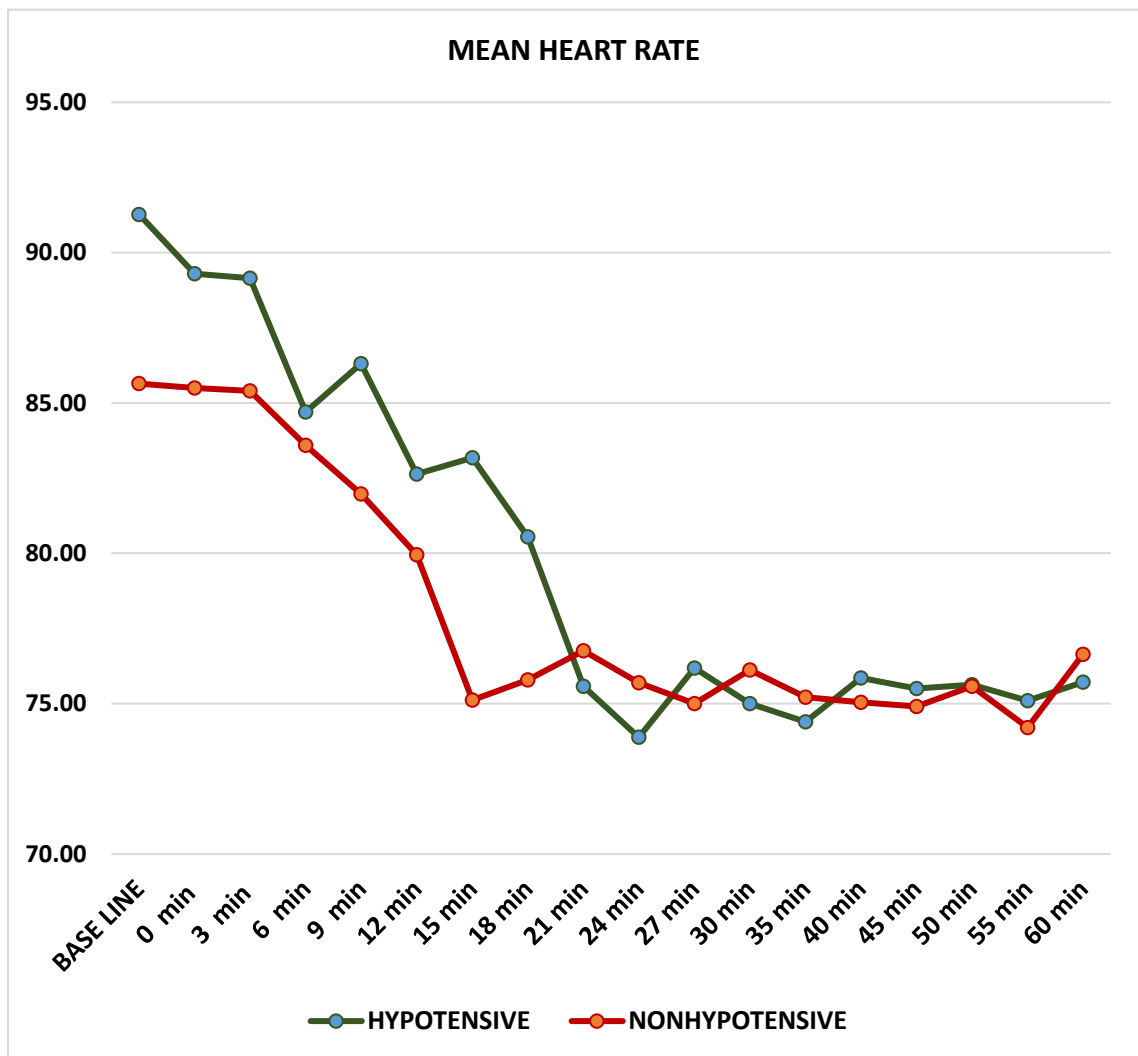
**THE YODEN'S INDEX FOR IVC:AO IS VERY SMALL.**

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**POST SPINAL HEART RATE VARIATION:**
**TABLE: 10**

	HYPOTENSIVE				NONHYPOTENSIVE				P VALUE	INFERENCE
	MEAN	S.D	MIN	MAX	MEAN	S.D.	MIN	MAX		
<b>BASE LINE</b>	91.27	10.92	72	112	85.64	14.85	60	115	0.0723	NS
<b>0 min</b>	89.30	11.24	65	120	85.50	18.13	56	130	0.2947	NS
<b>3 min</b>	89.15	16.02	64	147	85.40	17.26	58	130	0.3389	NS
<b>6 min</b>	84.70	14.60	63	120	83.60	17.85	53	126	0.7750	NS
<b>9 min</b>	86.30	16.34	57	121	81.98	18.42	52	125	0.2924	NS
<b>12 min</b>	82.64	16.50	58	115	79.95	18.00	53	126	0.5083	NS
<b>15 min</b>	83.18	19.40	55	125	75.12	20.30	10	121	0.0859	NS
<b>18 min</b>	80.55	20.43	48	131	75.79	15.81	52	120	0.2589	NS
<b>21 min</b>	75.58	17.61	45	112	76.76	16.22	50	121	0.7629	NS
<b>24 min</b>	73.88	15.40	53	102	75.69	16.16	52	120	0.6243	NS
<b>27 min</b>	76.18	18.00	48	132	75.00	15.85	50	122	0.7636	NS
<b>30 min</b>	75.00	15.96	51	124	76.12	15.63	51	120	0.7613	NS
<b>35 min</b>	74.39	15.41	53	120	75.21	14.05	54	124	0.8106	NS
<b>40 min</b>	75.85	14.45	54	117	75.05	13.68	52	123	0.8067	NS
<b>45 min</b>	75.50	13.58	51	109	74.90	14.10	52	125	0.8558	NS
<b>50 min</b>	75.63	12.18	55	108	75.58	13.85	51	126	0.9872	NS
<b>55 min</b>	75.09	11.36	53	105	74.21	12.48	52	102	0.7569	NS
<b>60 min</b>	75.72	12.92	53	115	76.64	13.24	52	111	0.7687	NS

GRAPH: 5

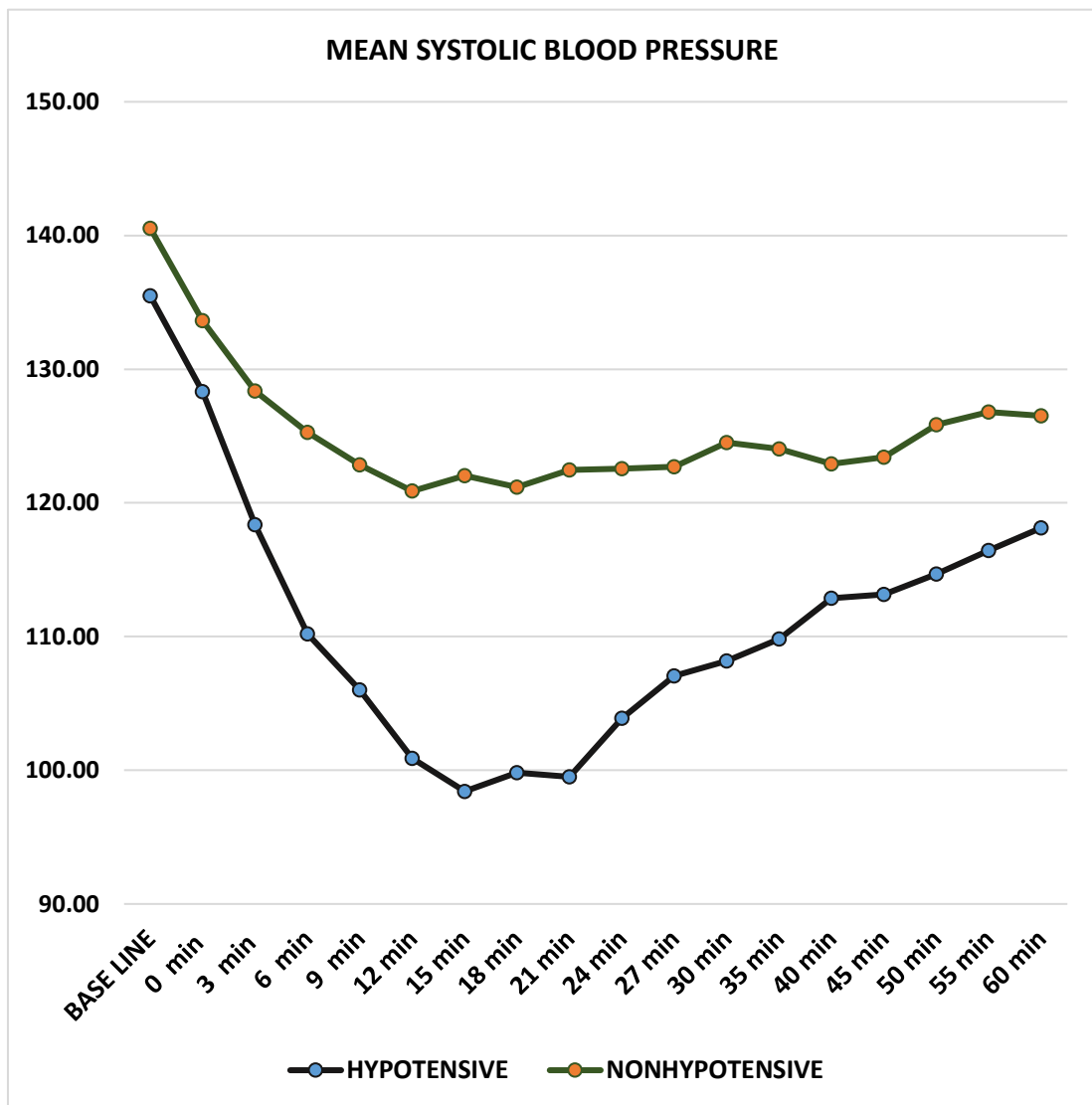


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**POST SPINAL SYSTOLIC BP VARIATION:**
**TABLE: 11**

	HYPOTENSIVE				NONHYPOTENSIVE				P VALUE	INFERENCE
	MEAN	S.D.	MIN	MAX	MEAN	S.D.	MIN	MAX		
<b>BASE LINE</b>	135.48	11.88	114	166	140.55	11.98	118	164	0.0724	NS
<b>0 min</b>	128.33	14.89	92	169	133.64	13.96	107	160	0.1166	NS
<b>3 min</b>	118.36	16.73	72	157	128.38	12.97	102	158	0.0046	VS
<b>6 min</b>	110.21	18.51	64	142	125.26	14.00	100	159	0.0001	HS
<b>9 min</b>	106.00	14.11	67	139	122.83	13.46	98	156	< 0.0001	HS
<b>12 min</b>	100.88	12.24	79	130	120.88	14.12	94	150	< 0.0001	HS
<b>15 min</b>	98.42	13.73	74	123	122.02	14.56	92	151	< 0.0001	HS
<b>18 min</b>	99.82	13.26	77	126	121.17	12.71	100	156	< 0.0001	HS
<b>21 min</b>	99.52	11.73	76	130	122.45	13.48	102	161	< 0.0001	HS
<b>24 min</b>	103.88	13.00	74	129	122.55	13.77	103	169	< 0.0001	HS
<b>27 min</b>	107.06	10.31	85	124	122.69	13.48	98	162	< 0.0001	HS
<b>30 min</b>	108.18	10.90	88	124	124.50	14.54	98	162	< 0.0001	HS
<b>35 min</b>	109.82	12.94	76	131	124.02	12.74	94	161	< 0.0001	HS
<b>40 min</b>	112.88	11.51	92	135	122.90	14.37	90	165	0.0017	VS
<b>45 min</b>	113.16	9.55	92	134	123.43	12.68	92	150	0.0003	HS
<b>50 min</b>	114.69	9.39	100	128	125.85	12.69	102	161	0.0001	HS
<b>55 min</b>	116.44	8.92	102	130	126.79	11.52	110	157	0.0001	HS
<b>60 min</b>	118.13	7.58	104	131	126.51	10.68	110	151	0.0004	HS

GRAPH: 6

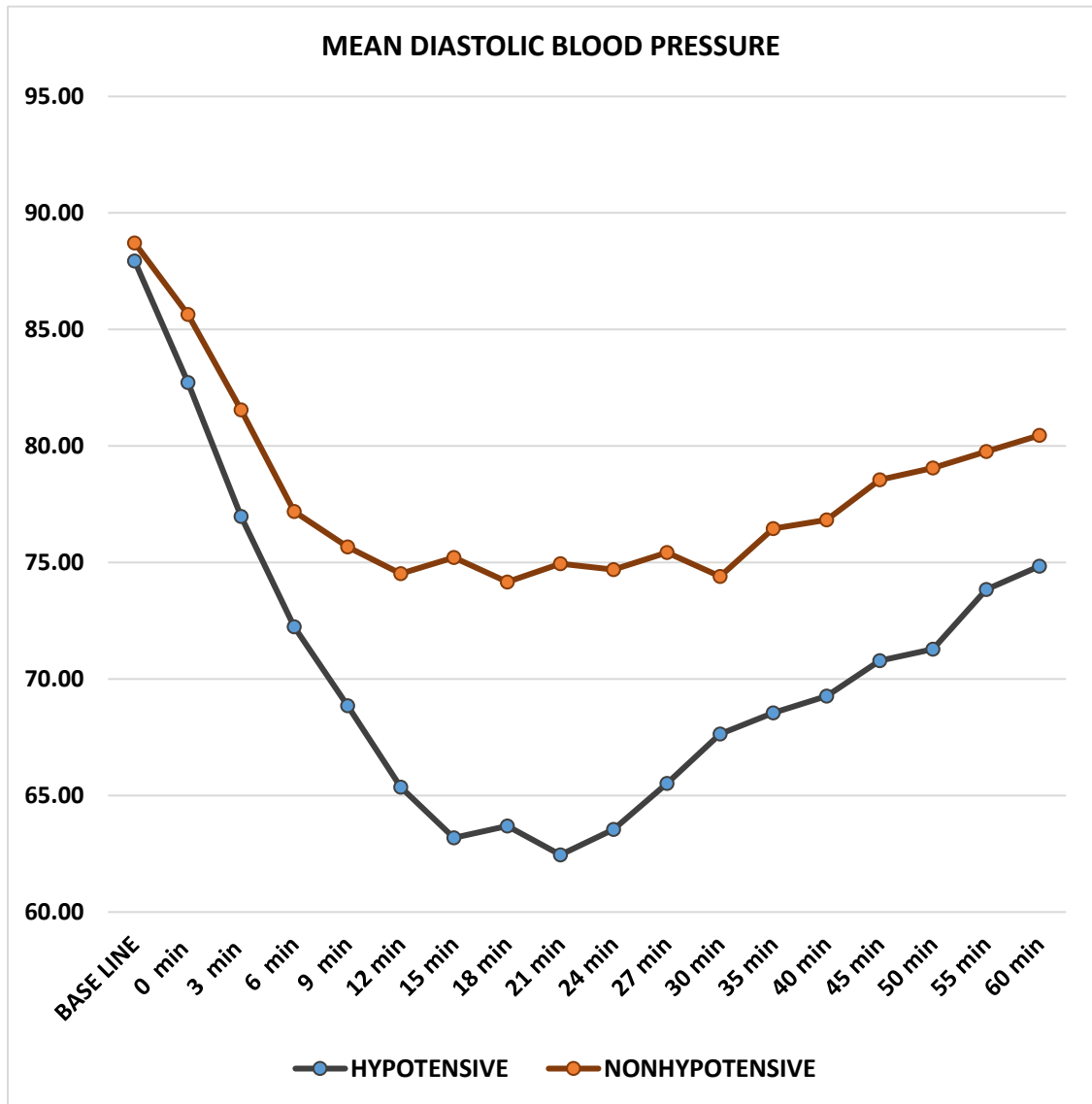


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**POST SPINAL DIASTOLIC BP VARIATION:**
**TABLE: 12**

	HYPOTENSIVE				NONHYPOTENSIVE				P VALUE	INFERENCE
	MEAN	S.D.	MIN	MAX	MEAN	S.D.	MIN	MAX		
<b>BASE LINE</b>	87.94	10.83	64	112	88.71	10.58	67	117	0.7562	NS
<b>0 min</b>	82.73	13.25	49	111	85.64	9.90	69	107	0.2789	NS
<b>3 min</b>	76.97	13.67	44	118	81.55	11.50	60	109	0.1197	NS
<b>6 min</b>	72.24	14.29	38	117	77.19	9.89	60	105	0.0810	NS
<b>9 min</b>	68.85	11.50	43	102	75.67	10.02	60	98	0.0077	VS
<b>12 min</b>	65.36	11.16	50	108	74.52	9.97	57	94	0.0004	HS
<b>15 min</b>	63.18	12.28	47	98	75.21	10.25	57	96	< 0.0001	HS
<b>18 min</b>	63.70	11.90	46	95	74.17	8.91	53	94	< 0.0001	HS
<b>21 min</b>	62.45	8.39	41	80	74.95	9.72	53	98	< 0.0001	HS
<b>24 min</b>	63.55	8.50	49	86	74.69	8.60	56	93	< 0.0001	HS
<b>27 min</b>	65.52	8.65	52	88	75.43	8.61	60	93	< 0.0001	HS
<b>30 min</b>	67.64	8.91	55	94	74.40	9.44	52	92	0.0023	VS
<b>35 min</b>	68.55	11.15	49	95	76.45	10.67	54	109	0.0026	VS
<b>40 min</b>	69.27	10.96	46	96	76.83	9.52	55	95	0.0021	VS
<b>45 min</b>	70.78	7.52	59	93	78.55	9.04	60	96	0.0002	HS
<b>50 min</b>	71.28	6.83	61	94	79.05	9.73	62	105	0.0003	HS
<b>55 min</b>	73.84	8.08	61	95	79.77	9.54	63	100	0.0069	VS
<b>60 min</b>	74.84	8.70	56	96	80.46	9.73	61	99	0.0134	S

GRAPH: 7

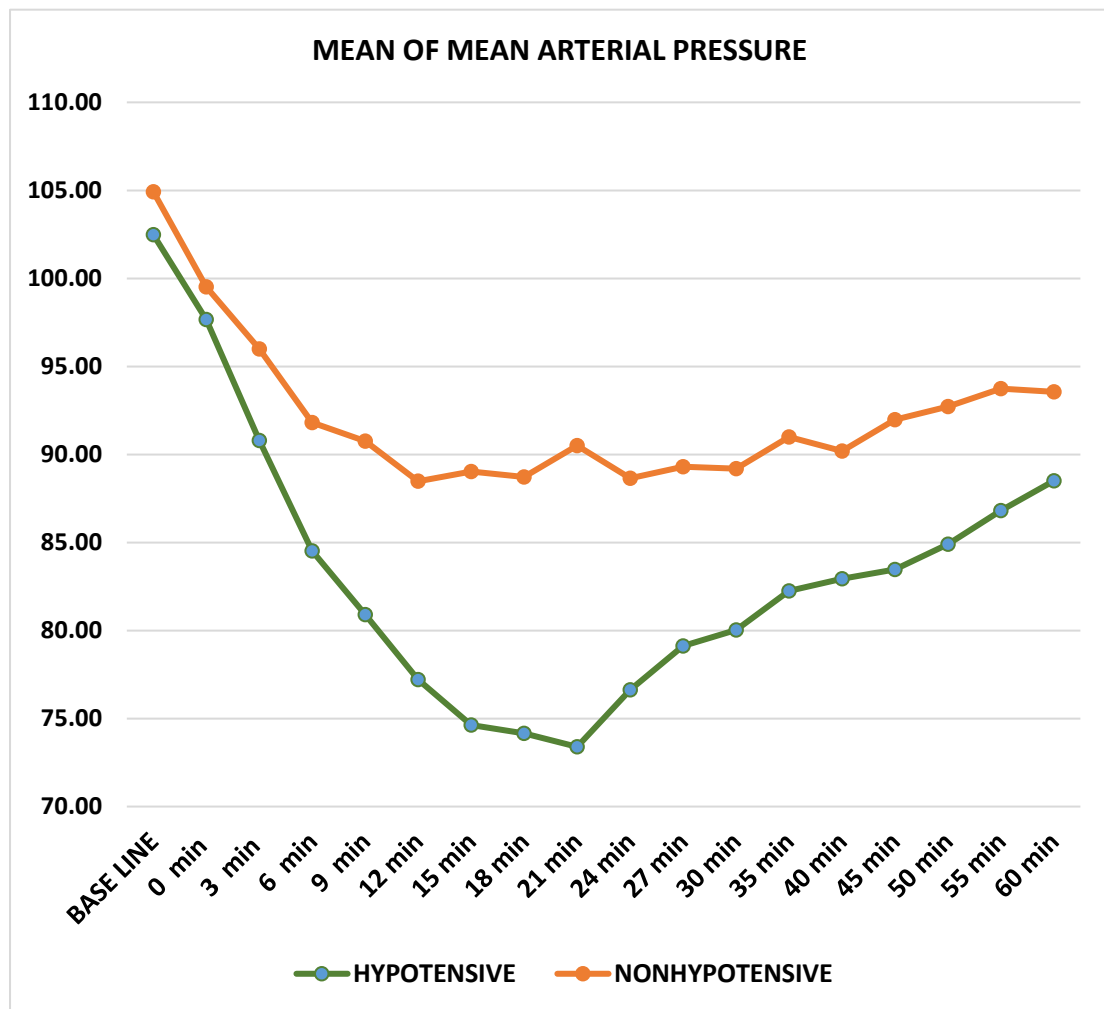


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**POST SPINAL MEAN ARTERIAL PRESSURE VARIATION:**
**TABLE: 13**

	HYPOTENSIVE				NONHYPOTENSIVE				P VALUE	INFERENCE
	MEAN	S.D.	MIN	MAX	MEAN	S.D.	MIN	MAX		
<b>BASE LINE</b>	102.48	10.24	87	120	104.93	9.94	87	121	0.3004	NS
<b>0 min</b>	97.67	13.54	63	130	99.52	10.78	80	127	0.5102	NS
<b>3 min</b>	90.79	13.83	53	127	96.00	10.44	77	118	0.0669	NS
<b>6 min</b>	84.52	15.04	47	126	91.81	11.15	70	123	0.0183	S
<b>9 min</b>	80.91	11.48	54	114	90.76	9.72	74	116	0.0001	HS
<b>12 min</b>	77.21	10.55	62	115	88.48	9.99	71	111	< 0.0001	HS
<b>15 min</b>	74.64	11.84	58	105	89.02	10.29	73	111	< 0.0001	HS
<b>18 min</b>	74.15	10.99	60	102	88.71	8.75	70	110	< 0.0001	HS
<b>21 min</b>	73.39	8.51	58	92	90.50	9.76	69	113	< 0.0001	HS
<b>24 min</b>	76.64	8.70	60	96	88.64	8.57	72	109	< 0.0001	HS
<b>27 min</b>	79.12	7.10	68	98	89.31	8.28	73	108	< 0.0001	HS
<b>30 min</b>	80.03	9.45	51	99	89.19	9.76	68	109	0.0001	HS
<b>35 min</b>	82.24	9.53	64	107	91.00	10.34	69	117	0.0003	HS
<b>40 min</b>	82.94	10.44	59	105	90.19	9.68	70	109	0.0027	VS
<b>45 min</b>	83.47	9.44	52	104	91.98	9.25	71	109	0.0003	HS
<b>50 min</b>	84.91	6.94	70	104	92.73	9.49	75	124	0.0002	HS
<b>55 min</b>	86.81	6.69	76	107	93.74	8.61	75	117	0.0004	HS
<b>60 min</b>	88.50	7.14	73	108	93.56	8.08	77	113	0.0072	VS

GRAPH: 8



**COMPLICATIONS:****BRADYCARDIA:****TABLE: 14**

<b>BRADYCARDIA</b>	<b>HYPOTENSIVE</b>		<b>NONHYPOTENSIVE</b>	
	<b>NUMBER</b>	<b>%</b>	<b>NUMBER</b>	<b>%</b>
<b>YES</b>	4	12.12	0	0.00
<b>NO</b>	29	87.88	42	100.00
<b>TOTAL</b>	33	100.00	42	100.00

From the above table, the value of p, using chi-square test, is 0.0204 the proportion of bradycardia is significantly more in hypotensive cases

**SHIVERING:****TABLE: 15**

<b>SHIVERING</b>	<b>HYPOTENSIVE</b>		<b>NONHYPOTENSIVE</b>	
	<b>NUMBER</b>	<b>%</b>	<b>NUMBER</b>	<b>%</b>
<b>YES</b>	8	24.24	11	26.19
<b>NO</b>	25	75.76	31	73.81
<b>TOTAL</b>	33	100.00	42	100.00

For the above table the value of p, using chi-square test, is 0.8473 the proportion of shivering is more or less same in the two groups

**OTHER COMPLICATIONS:****TABLE: 16**

<b>OTHER COMPLICATIONS</b>	<b>HYPOTENSIVE</b>		<b>NONHYPOTENSIVE</b>	
	<b>NUMBER</b>	<b>%</b>	<b>NUMBER</b>	<b>%</b>
<b>YES</b>	0	0.00	0	0.00
<b>NO</b>	33	100.00	42	100.00
<b>TOTAL</b>	33	100.00	42	100.00

Other complications were not present in both the groups.

## DISCUSSION

Hypotension following spinal anaesthesia is one of the most important and dreaded complication leading to organ hypoperfusion and ischemic events<sup>1</sup>. Hypotension is mainly due to sympathectomy following administration of local anaesthesia in the sub arachnoid space, causing vasodilatation and reducing the venous return to heart<sup>19</sup>. Many factors like age, use of anti-hypertensive drugs, intra vascular volume status, anaesthetic drug and level of blockade are responsible for hypotension following spinal anaesthesia. Hypotension can be prevented by preloading or co-loading the patients, but it is not advisable to preload all patients as it carries its own complications. Recent studies shows that co-loading with colloids or crystalloids are safer compared to preloading with crystalloids. So, it is important to predict the patient who can develop hypotension and treat accordingly.

There are many studies to predict hypotension following spinal anaesthesia including perfusion index, heart rate variability index, leg raise test, pulmonary arterial catheter, PiCCO, Vigileo, pulse pressure variation, stroke volume variation<sup>21-23</sup>.

Intravasacular volume and hypovolemia are the most important modifiable risk factor in predicting hypotension after spinal anaesthesia. Whereas, accurate measurement of intravascular volume is very challenging. After the introduction of ultrasonography in anaesthesia and critical care medicine several methods are available to assess the intravascular volume.

In this study we included 75 ASA I & II patients of age 18 – 60 who underwent surgery under spinal anaesthesia and looked for hypotension following the procedure.

Among those 75 patients, 29 were female (38.67%) and 46 were male (61.33%).

The mean BMI of these patients was  $24.55 \pm 3.18$  kg/m<sup>2</sup> and mean age was  $41.4 \pm 11.56$  years.

In our study after induction of spinal anaesthesia patients were divided into two groups based on development of hypotension as hypotensive and non-hypotensive group.

33 patients developed hypotension (hypotensive) following spinal anaesthesia whereas, 42 did not develop any hypotension (non-hypotensive).

When compared between hypotensive & non hypotensive group, it was found that there was no significant relation between age, sex, BMI, pre-operative baseline vitals and patients developing hypotension following spinal anaesthesia.

This correlates with many studies which state that, there is no significant relation between age, sex, BMI & pre-operative baseline vital parameters. C. Yu et al, in 2021 performed a systemic review to find the predictors of hypotension following spinal anaesthesia<sup>20</sup>. According to the study they concluded no relation between demographic and baseline vital parameters.

IVC the large vein carries blood and drains into right atrium. It is a capacitance vessel whose diameter changes during inspiration and respiration. Their

diameters measured by using ultrasonography can be used to assess the intravascular volume. Studies done stated that IVC Collapsibility index as an easy, non-invasive, reliable method to assess intravascular volume.

According to our study, there was significant relation between IVC Collapsibility and patients developing hypotension (p value <0.0001). By using Yoden's index it is found out that the cut off value of IVC Collapsibility index to be 39.4% in our study which was done on Indian population.

A A Dodhy et al. has investigated the relationship between intravascular volume and the IVC Collapsibility index in 126 critically ill patients in the year 2021<sup>30</sup>. In contrast to patients who were mechanically ventilated, they discovered that the IVC collapsibility index was a good predictor for determining intravascular volume in spontaneous individuals.

There are studies trying to correlate hypotension following spinal anaesthesia and pre-operative IVC Collapsibility index. Some studies found correlation whereas some studies didn't find correlation between them.

Jaremkol et al, in 2019 performed a study on 60 patients undergoing elective knee joint replacement surgery under spinal anaesthesia<sup>33</sup>. They measured ultrasonographic IVC Collapsibility index pre-operatively and after induction of spinal anaesthesia. And they were unable to find any correlation between IVCCI and hypotension following subarachnoid block.

Shankar Roy et al, in the year 2022 conducted study in 129 patients undergoing elective surgeries under spinal anaesthesia and failed to correlate between pre-operative IVC Collapsibility index and hypotension following spinal

anaesthesia<sup>41</sup>. The main reason for these could be the definition of spinal hypotension decrease in BP >30% was considered as spinal hypotension. Whereas, in our study apart from the above SBP < 90mmhg or MAP <60mmhg within 30 minutes after induction is considered as spinal hypotension.

In 2019 E R salma et al, and in the year 2022 Ting-Ting N et al conducted studies in predicting hypotension following spinal anaesthesia and concluded that IVC Collapsibility as a good predictor for spinal hypotension which coincides with our study results in IVC Collapsibility index being a good predictor of spinal hypotension<sup>16</sup>. Whereas, the cutoff value for IVC Collapsibility index in the above both studies were 44.7% & 42% respectively.

Similar to IVC Collapsibility index caval aorta index is a parameter which can be used to assess intravascular volume.

In our study, we found that there was no significant relation between spinal hypotension & Caval Aorta Index (p value 0.6927), and using Yodens index cut off value of caval aorta index is 0.68

G F EL-Baradey et al, tried to correlate IVC:Ao and CVP in assessing intravascular volume in the year 2016<sup>26</sup>. They conducted a study in 50 patients who underwent Transurethral Resection of Prostate (TURP) & found that caval aorta index as an useful, noninvasive, safe, quick, and easy technique with no complications to evaluate intravascular volume.

In order to examine the status of the intravascular volume in 50 pregnant and 50 non-pregnant women, Lakshmi Priya Menon and colleagues in the year 2020 studied caval aortic index and their association<sup>29</sup>. They also studied the subxiphoid

and transhepatic views while calculating the caval aortic index. They discovered that the caval aortic index is a reliable predictor of intravascular volume in pregnant women and that the trans hepatic view is superior to the subxiphoid view.

But there are not many studies regarding the use of caval aorta index in predicting spinal hypotension in Indian population.

Salma ER et al, did a study in 100 patients of European population undergoing elective surgeries under spinal anaesthesia and tried to find correlation between caval aorta index and spinal hypotension<sup>16</sup>. They found a significant relation of caval aorta index in predicting spinal hypotension.

In this study we tried to compare predictive values of IVC Collapsibility index & Caval Aorta index and to detect which is the better predictor among these two in predicting spinal hypotension. The area under the curve for IVC: Ao is very small compared to IVCCI and Yoden's index for IVC: Ao is very small. These indicate that IVC: Ao as a poor predictor for spinal hypotension.

This suggest that caval aorta index is not a better predictor for spinal hypotension in Indian population.

In our study we found that 4 patients developed bradycardia which required treatment and all 4 patients belongs to hypotensive group. Whereas, presence of shivering is same in both the groups. And we did not find any other complications in either group.

Qi hong shen, et al conducted a meta-analysis study in postoperative shivering and their prevention by using 5-HT<sub>3</sub> receptor antagonist, they state that postoperative shivering occurs irrespective of development of spinal anaesthesia<sup>42</sup>.

The limitations of this study include smaller sample size. Larger multi-centre trials might increase the sensitivity of the study. In this study we tried to find out only the predictive values of IVC Collapsibility index and Caval Aorta index, and did not study their implication in preventing the spinal hypotension. Future studies must be towards their use in preventing spinal hypotension by guiding the fluid therapy.

## **CONCLUSION**

Our study was conducted to identify the predictive value of IVC Collapsibility Index and IVC:Ao ratio in patients developing post spinal hypotension and to identify the better predictor among these two. We concluded that

1. The cut off value of IVC Collapsibility Index is found to be 39.4 using Yoden's index
2. IVC Collapsibility Index measured by using ultrasonogram is a good predictor for post spinal hypotension.
3. The cut off value of IVC:Ao was found to be 0.68 using Yoden's index.
4. But, using ROC curve it was found that IVC:Ao is not significant in identifying hypotension following spinal anaesthesia.
5. Comparing both the parameters IVC Collapsibility Index is a better predictor for post spinal hypotension
6. Ultrasound measurement of IVC is an easy, quick, non-invasive point of care technique which can be used for predicting hypotension following spinal anaesthesia.

Hence, by using ultrasound one can measure IVC Collapsibility Index pre operatively and can predict the development of significant hypotension following spinal anaesthesia if IVC Collapsibility Index is  $>39.4\%$ .

## **SUMMARY**

Our current study was done to identify the predictive value of IVC Collapsibility Index & Caval Aorta Index using ultrasonogram in detecting post spinal hypotension and to identify the better predictor among those.

In our study we included 75 patients of either sex belonging to ASA I & II undergoing elective surgery under spinal anaesthesia.

We found that IVC Collapsibility Index which was measured by using ultrasonogram pre-operatively is good predictor in identifying post spinal hypotension with a p value  $<0.0001$ . We concluded that 39.4% as the IVCCI cutoff value.

We also found that Caval Aorta index is not a good predictor of post spinal hypotension (p value 0.6927).

To summarize, our study used ultrasonographic measurement of IVC Collapsibility & Caval Aorta Index pre-operatively. We found that IVC Collapsibility Index was useful in predicting patients who may develop significant hypotension following spinal anesthesia. And that caval aorta index is not a better predictor for the same.

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## **ANNEXURE I**

### **INFORMED CONSENT FOR PARTICIPATION IN RESEARCH STUDY**

Mr. /Mrs. /Miss. \_\_\_\_\_ we are requesting you to enroll you in the study titled “**Prediction of post spinal hypotension using ultrasonographic caval aorta index and inferior vena cava collapsibility index: a prospective comparative study**”, conducted by \_\_\_\_\_ Post Graduate in M.D. Anesthesiology under the guidance of \_\_\_\_\_, Associate Professor, Department of Anesthesiology, J.N. Medical College, Belagavi under KAHER, Belagavi.

Respected Sir/Madam, we request you to participate in our study as you are eligible for it. During the study you will be asked some questions regarding your medical history and you are supposed to answer to the best of your knowledge.

Your participation in this research is voluntary. Your decision whether or not to participate in the study will not affect your relationship with J.N. Medical College. If you decide to participate you are free to withdraw at any time.

#### **Purpose of the study:**

The purpose of this study is to predict who are all going into hypotension following spinal anaesthesia and to find out the person preoperatively by using ultrasound investigation of inferior vena cava collapsibility index and caval aorta index. So that we can prevent hypotension in those persons.

**Procedure Involved:**

If you agree to enroll in my study, I will ask your present, past and family history. Then you will be clinically examined in detail. You will be investigated using ultrasonography for inferior vena cava collapsibility index and caval aorta index before the surgery.

**Voluntary Participation/Withdrawal:**

Taking part in the study is voluntary. You may choose not to enroll yourself in this study. Your decision will not change any health care services offered to you or your ward at K.L.E. S Hospital & MRC.

**Risks:**

There is almost no risk involved with ultrasonography.

**Benefits:**

Using ultrasonography we can predict those who may go into hypotension following spinal anaesthesia, so that we can prevent it from happening.

**Privacy and Confidentiality:**

The only people to know that you are a research subject are you and members of the research team. No information provided by you during the research will be disclosed to others without your written permission except:

1. In emergency to protect your rights and welfare.
2. If required by law.

**Authorization to Publish Results:**

When the results of the research are published or discussed, in a conference, no information will be displayed that would disclose your identity. Any information that is obtained in connection with this study and that can be identified with your identity remains confidential.

**Financial Incentives for participation:**

No financial incentives are being offered to enrolled patients. It is purely being done with the idea of research and all the cost of the study will be borne by the investigator.

**Compensation:**

In the events of injury related to the study, treatment will be made available through KLES Hospital and MRC, Belagavi. There is no compensation or payment for such medical treatment by law. If you get injured you may contact

**Questions:**

If you have any queries about your rights as a study subject, you may call Dr. HARSHA HEGDE, Chairman, J.N. Medical College Institutional Ethical Committee & Scientist D, National Institute of Traditional Medicine, Belagavi. Phone number-9480422500, J.N. Medical College, Belagavi.

**INFORMED CONSENT FOR PARTICIPATION IN RESEARCH TRIAL**

**PREDICTION OF POST SPINAL HYPOTENSION USING  
ULTRASONOGRAPHIC CAVAL AORTA INDEX AND INFERIOR VENA  
CAVA COLLAPSIBILITY INDEX: A PROSPECTIVE COMPARATIVE  
STUDY**

I, Mr./Ms./Mrs. \_\_\_\_\_ voluntarily agree for the participation of as a subject of study. By signing this consent form I am not giving up any of my legal rights, I may withdraw from the study anytime. I am signing the consent form after having read or been read for me in vernacular language, including the risks and the benefits and having all my questions answered.

Subject Name : \_\_\_\_\_

Signature or the Left Thumb Print of Subject/Guardian: \_\_\_\_\_

Date:

Witness Name: \_\_\_\_\_ Signature: \_\_\_\_\_

Investigators Name: \_\_\_\_\_ Signature: \_\_\_\_\_

Date:

Place : \_\_\_\_\_

## ANNEXURE II - PROFORMA

**PREDICTION OF POST SPINAL HYPOTENSION USING  
ULTRASONOGRAPHIC CAVAL AORTA INDEX AND INFERIOR VENA  
CAVA COLLAPSIBILITY INDEX: A PROSPECTIVE COMPARATIVE  
STUDY.**

Name : Age :

IP number : Gender :

Height : Weight :

Address : Date of Examination :

Occupation :

**Pre examination evaluation****Past History**

- HTN  DM  IHD  Arrhythmia  Congestive cardiac failures
- H/o previous surgery/(s)

General physical examination

BMI:                      Temperature (<sup>0</sup>F):                      Pallor:

Cyanosis:                      Pedal edema:                      Clubbing:

PR:                                      BP:                                      RR:

**Systemic examination:**

RS :                                      CNS :

CVS :                                      GIT :

**Preoperative physical status**                      ASA Grade    I  II  III  IV  V

**Diagnosis:**

**Nature of surgery:**

**Nature of anaesthesia:**

IVC Collapsibility Index	
IVC:Aorta Ratio	

PARAMETER	BEFORE INDUCTION	AFTER INDUCTION (mins)																	
		0	3	6	9	12	15	18	21	24	27	30	35	40	45	50	55	60	
Heart rate																			
Systolic BP																			
Diastolic BP																			
Mean BP																			

4) Any complications will be noted as follows:

COMPLICATION	OBSERVATION
Hypotension	
Bradycardia	
Shivering	
Any other complications	

SIGNATURE OF THE ANAESTHESIOLOGIST: \_\_\_\_\_

SIGNATURE OF THE WITNESS: \_\_\_\_\_

SIGNATURE OF THE PRINCIPAL INVESTIGATOR: \_\_\_\_\_

**ANNEXURE III PHOTOGRAPHS:**



**PHOTOGRAPH:1**



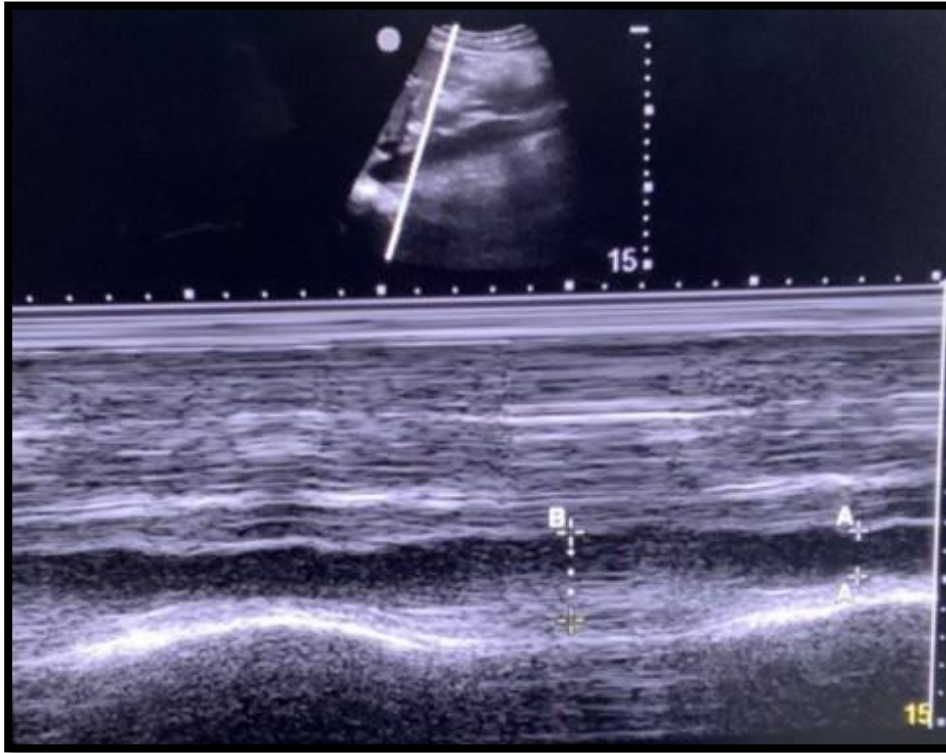
**PHOTOGRAPH:2**



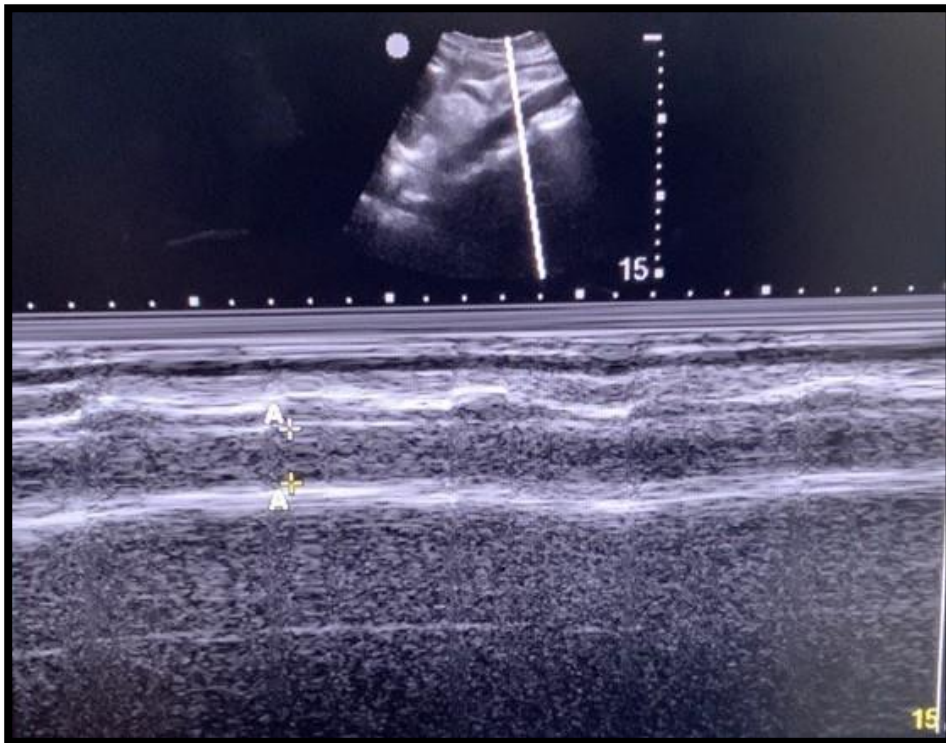
**PHOTOGRAPH:2**



**PHOTOGRAPH:4**



PHOTOGRAPH:5



PHOTOGRAPH:6

**ANNEXURE-IV**

**KEY TO MASTER CHART**

min	-	minutes
ASA	-	American Society of Anaesthesiologists
BMI	-	Body Mass Index
IVCCI	-	Inferior Vena Cava Collapsibility Index
IVC:Ao	-	Caval Aorta Index
SBP	-	Systolic Blood Pressure
DBP	-	Diastolic Blood Pressure
MAP	-	Mean Arterial Pressure
HR	-	Heart Rate
Y	-	Yes
N	-	No





Serial number	Age in Years	Sex	ASA Grade	BMI	IVCCI	IVC:AO	POST SPINAL ANAESTHESIA																														COMPLICATIONS(Yes/No)																																																					
							Baseline data						Heart Rate										Systolic Blood Pressure										Diastolic Blood Pressure						MAP						Hypotension	Bradycardia	Shivering	others																																										
							HR (bpm)	SBP (mm Hg)	DBP (mm Hg)	MAP(mm Hg)	0 min	3 min	6 min	9min	12 min	15 min	18 min	21 min	24 min	27 min	30 min	35 min	40 min	45 min	50 min	55 min	60 min	0 min	3 min	6 min	9min	12 min	15 min	18 min	21 min	24 min	27 min	30 min	35 min	40 min	45 min	50 min	55 min	60 min					0 min	3 min	6 min	9min	12 min	15 min	18 min	21 min	24 min	27 min	30 min	35 min	40 min	45 min	50 min	55 min	60 min																									
							52	60	MA	II	28	30	1	68	140	80	100	68	63	64	65	63	65	67	65	65	68	65	66	67	66	65	68	67	68	120	110	100	110	100	100	104	106	104					106	108	110	112	110	110	110	80	60	64	60	58	60	62	62	64	62	62	64	62	62	64	62	62	62	64	64	60	80	79	73	76	73	73	73	74	74	77	77	76	77	76
53	40	ma	II	29	25	1	79	140	94	110	76	89	98	90	85	79	76	80	69	66	67	65	68	66	67	66	65	68	70	62	143	138	158	134	106	121	130	143	120	113	108	113	112	114	111	111	112	90	94	105	98	72	84	85	98	82	76	73	76	74	76	75	69	76	108	109	123	110	83	96	100	113	95	88	85	88	87	89	83	84	88	N	N	N	N					
54	46	ma	I	23	20	1	70	130	74	94	68	73	64	65	58	60	56	60	62	60	58	68	65	66	62	64	64	64	132	124	120	122	111	103	108	108	118	111	107	113	113	114	110	120	121	123	80	80	81	76	79	73	63	60	64	68	65	71	71	74	70	79	78	97	95	91	93	86	76	76	76	82	82	79	85	85	87	87	93	93	N	N	Y	N						
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56	44	MA	I	27	40	1	70	130	80	97	68	68	65	61	62	62	61	61	62	65	66	62	62	61	66	67	72	120	110	112	108	106	110	108	107	108	110	110	112	112	114	110	112	116	121	85	70	70	68	70	70	68	72	74	74	70	74	74	72	78	87	83	84	81	82	83	83	82	81	81	85	86	87	87	85	85	87	85	88	Y	N	N	N							
57	41	ma	II	25	23	1	95	140	90	107	94	90	88	86	88	85	73	84	82	87	84	84	79	81	78	80	82	120	115	114	118	105	105	118	120	117	118	120	121	114	119	117	116	121	85	74	76	71	65	64	71	69	67	65	68	73	72	76	74	78	97	88	89	87	74	73	82	81	79	84	78	81	83	83	87	88	88	N	N	N	N									
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60	48	ma	II	26	24	1	86	160	98	120	71	64	63	55	66	65	63	69	64	76	71	73	78	65	85	65	98	150	130	106	115	121	139	124	132	122	140	158	133	125	136	161	157	150	99	109	71	76	70	87	87	79	79	86	84	109	70	96	105	97	95	116	116	83	89	87	104	99	97	93	104	109	117	113	N	N	N	N												
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