" A COMPARATIVE STUDY OF INFERIOR VENA CAVA COLLAPSIBILITY INDEX AND BRACHIAL ARTERY PEAK SYSTOLIC FLOW VELOCITY VARIATION WITH PASSIVE LEG RAISING IN PREDICTING HYPOTENSION AFTER INDUCTION OF GENERAL ANAESTHESIA"

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DISSERTATION

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ABBREVIATIONS

GA : General Anaesthesia

ASA : American Society of Anaesthesiologists

MAP : Mean Arterial Pressure

SBP : Systolic blood Pressure

IVC : Inferior vena cava

LV : Left ventricle

PIH : post-induction hypotension

USG : Ultrasonography

IVCCI : inferior vena cava collapsibility index

LVF : left ventricular function

PPV : pulse pressure variation

IVC-DI : Inferior vena cava distensibility index

ΔVpeak-BA : brachial artery blood flow velocity variation

ΔPP : pulse pressure variation

HCU : hand-carried ultrasound

ΔVpeakPLR : velocity variation with passive leg raise

VVpeakbrach : brachial artery peak velocity variation

SVi : stroke volume index

ΔPPrad : pulse pressure variation in radial artery

ΔSVVigileo: stroke volume variation measured by vigileo

DVpeak-CA/ δVpeak-CA: Carotid Artery Blood Flow Peak Velocity Variation

PLR : Passive Leg Raise

PVI : Plethysmographic Variability Index

ΔPVIPLR: Plethysmographic Variability Index With PLR

CI : cardiac index

HR : heart rate

VTi_TAPCarotid : Velocity Time Integral of the Transvalvular Arterial Pressure in the Carotid Artery

VTi_TAPBrachial : Velocity Time Integral of the Transvalvular Arterial Pressure in the Brachial Artery

VTi_flowCarotid : Velocity Time Integral of the Flow in the Carotid Artery

VTi_flowBrachial: Velocity Time Integral of the Flow in the Brachial Artery

SD : standard deviation

y/o : years old

dIVC min : inferior vena cava minimum diameter

dIVCmax : inferior vena cava maximum diameter

OT : operation theatre

ECG : electrocardiogram

NIBP : non invasive blood pressure

O2 : oxygen

BA : brachial artery

DBP : diastolic blood pressure

ABP : arterial blood pressure

ΔPPVPLR : Pulse Pressure Variation with passive leg raise

ΔCIPLR : cardiac index variation with passive leg raise

ΔSVIPLR: stroke volume index variation with passive leg raise

ABSTRACT

TITLE :

‘A comparative study of inferior vena cava collapsibility index and brachial artery peak systolic flow velocity variation with passive leg raising in predicting hypotension after induction of general anaesthesia.’

BACKGROUND:

Post induction hypotension is a fairly common yet avoidable complication in the perioperative period and is attributable to the volume status of the patient in most instances . Since most measures employed to predict hypovolemia are invasive , ultrasonography based non invasive indices such as IVC collapsibility index and brachial artery peak systolic flow variation with passive leg raise can be utilised . However ,evidence supporting the efficacy of velocity variation using brachial artery is still meak.

OBJECTIVE:

To compare IVC collapsibility index and brachial artery peak systolic flow velocity with passive leg raising in predicting hypotension after induction of general anaesthesia

METHODS:

In the current study, 106 American Society of Anaesthesiologists I and II healthy individuals were enrolled. Using Ultrasonography diameter of inferior vena cava and brachial artery peak systolic flow velocity in supine position and with passive leg raise were recorded . IVC collapsibility index and brachial artery peak systolic flow velocity variation were calculated using standard formulae. SBP, DBP, MAP were noted every 2 minutes from induction till incision. These intraoperative blood pressure measurements were correlated with the

collapsibility index of IVC and BA velocity variation after passive leg raise to predict intraoperative hypotension during general anaesthesia.

RESULTS:

In our study , all subjects with an IVC collapsibility index greater than 50% had brachial artery peak systolic flow velocity variation greater than 10%. IVC collapsibility index and brachial artery peak systolic flow velocity fluctuation with MAP was found to be significantly negatively correlated at each time point , according to Spearman's rank correlation test (all p-values<0.05).

CONCLUSION :

We conclude that both brachial artery peak systolic flow velocity variation with passive leg raise and IVC collapsibility index are equally effective in predicting post induction hypotension after GA.

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INTRODUCTION

Intraoperative hypotension is a common occurrence in patients undergoing general anaesthesia(GA) for non-cardiac surgeries with gruesome outcomes ranging from acute kidney injury, myocardial ischaemia and ischaemic stroke to in-hospital mortality. [1,2]

Factors such as advanced age, male, sex, hypovolemia, higher American Society of Anaesthesiologists (ASA) status, chronic treatment with antihypertensive drugs, emergency surgery and duration of anaesthesia have been implicated as potential causes of intraoperative hypotension. [3]

Despite substantial data surrounding intraoperative hypotension, consensus over a definitive definition couldn't be attained and thresholds vary markedly amongst studies. However, Intraoperative hypotension is generally described as ' MAP <60mmHg and/or a SBP < 90 mmHg as absolute numerical thresholds for hypotension'[3] .

The period between induction of anaesthesia and surgical incision is when hypotension is most prevalent and is a result of vasodilatory and cardio-depressant actions of anaesthetic drugs. [4]

It is a corollary that post induction of anaesthesia, blood pressure is mostly under control of anaesthesiologists. [5]

Given that elective surgeries require prolonged fasting, patient's pre-induction volume status may have an impact on post-induction hypotension. Decreased intravascular volume status appears to be the most frequent cause of hypotension after

induction, despite fact that pre-operative optimization for elective operations has been the focus of numerous initiatives. Other aspects, including the hypotensive effect of anaesthetic drugs, are improved.

With over 300 million non-cardiac surgeries performed annually and an estimated 5-99% incidence of intraoperative hypotension, it is essential to prevent hypotension. The perioperative physician may supply adequate fluids prior to induction by identifying latent hypovolemia in a hemodynamically stable patient. [(2)]

Blood pressure could be measured through various techniques, from non-invasive techniques like intermittent automated oscillo tonometry, radial artery applanation tonometry-based wrist cuffs, photoplethysmography-based finger cuffs, and the Penaz volume-clamp method to invasive intra-arterial monitoring. [(6)]

Inferior vena cava(IVC) collapsibility index is a dynamic parameter that influences venous return during the respiratory cycle and has evidential support in predicting fluid responsiveness. However, IVC assessment may be erroneous in the presence of imaging errors or any factors that affect IVC compliance.[(7)]

There are more dynamic factors, that include variations in pulse pressure and stroke volume, however they are invasive.

An increasing number of anesthesiologists employ ultrasonography in the operating room as a practical non-invasive technique. It is free of issues, despite several other invasive monitoring methods [(8)].

Peripheral blood flow velocity is strongly correlated with cardiac output. Studies have accounted majorly for greater arteries like carotids proving that blood flow and velocity time integral are good predictors of fluid responsiveness. [(9)]

The primary artery in the upper limb is brachial artery, which is an extension of axillary artery. Research indicates a strong correlation between respiratory alterations in brachial artery peak velocity and changes in radial artery pulse pressure, well-known indicator of fluid responsiveness. [10]

Brachial artery flow velocity is known to increase with increase in intravascular volume. In patients with hypovolemia, the intravascular volume status can be increased to some extent by passive leg raising.

To assess preload reliance in patients on mechanical ventilation, brachial artery peak velocity fluctuation in conjunction with passive leg lift could be employed as a non-invasive stand-in for LV stroke volume variation. [10]

Further research must be conducted to determine whether brachial artery peak systolic velocity fluctuation may be used to predict response to fluid therapy. So, in this study, we attempt to compare IVC collapsibility index and brachial artery peak systolic flow velocity with passive leg raising in anticipating hypotension following general anaesthetic induction.

OBJECTIVES

- To compare IVC collapsibility index and brachial artery peak systolic flow velocity with passive leg raising in predicting hypotension after induction of general anaesthesia

REVIEW OF LITERATURE

Intraoperative hypotension is a common observation after induction of general anaesthesia and has been attributed to a multitude of factors. Particularly, post-induction hypotension(PIH), occurring in conjunction with use of anaesthetic drugs and volatile agents is of greater significance to anaesthesiologists. Intravascular volume status has been a major realm of study as it is directly linked to hypotension after induction. Various new parameters, both static and dynamic, have come into existence to diagnose intravascular status.

Although they have a higher predictive value, dynamic data including pulse pressure change and stroke volume variation are invasive. Ultrasonography-based modalities, like IVC collapsibility index, have been in use in prediction of fluid status due to ease of use of USG and positive predictive value.

In a prospective research investigation of 29 patients in ICU of Peking Union Medical College in Beijing, China, "Hong-min Zhang et al. Zhonghua Yi Xue Za Zhi" compared changes in brachial artery peak velocity caused by passive leg raise with changes in left ventricle outflow tract velocity time integral after volume expansion. Among all the subjects, 15 responded to volume expansion. With a sensitivity of 73% and 87%, respectively, the research proposed that brachial artery peak velocity variations of greater than 10% brought on by passive leg elevating is a valid indicator of volume responsiveness. [(11)]

In 2016, 102 patients that underwent elective general surgery under GA with propofol as their preferred induction agent were recruited by "Marcell Szabo, Anna Bozo, Katalin Darvas, Alexandra Horvath, and Zsolt Daniel Ivanyi" at Semmelweis University in Budapest for their observational research. IVCCI has been associated

with systolic and mean blood pressure(BP) changes that occurred right after induction, and receiver operating characteristic curve analysis has been employed for evaluating IVC efficacy. The sensitivity of the targeted 50% level of IVCCI was just 45.5% but with specificity as high as 90.0%. They concluded that IVCCI ≥50% can predict PIH in spontaneously breathing patients with high specificity but low sensitivity. The study had its limitations with regards to suboptimal adherence to protocol and by the observational nature of the study, it was not free from intergroup differences. [(12)]

"Rose N, ChandraM, Nishant CC, Srinivasan R" conducted a six-month study in RajaRajeshwari College and Hospital, Bengaluru in the year 2021 which comprised 120 patients. They took IVC measurements in pre-induction period. Post-induction BP was monitored and MAP <60 mm Hg or a 30% drop from the baseline was regarded as hypotension. IVCCI with a cut-off of 37% showed 94% sensitivity and 84% specificity which was deemed statistically significant. They concluded IVCCI is a very sensitive and reliable predictor for PIH. However, for ethical reasons, they excluded patient data from the trial of those with IVCCI >50%. ASA III and above patients were not included and 23% of patients were hypertensive in the study. [(13)]

"BoYao, Jian-yu Liu and Yun–bo Sun" conducted a meta-analysis in an affiliated hospital of Qingdao University, China for the year 2016. They included nine trials with 402 patients in total to secure pooled values of specificity, sensitivity, and area of summary receiver operating characteristic curve. This procedure was performed to predict responsiveness to fluid in patients on mechanical ventilation by analyzing peripheral artery peak velocity alterations. For investigation, groups of brachial and carotid sites were established. They concluded that fluid responsiveness may be diagnosed via variation in peak velocity of carotid and brachial arteries. Yet ,

not all studies provided information on how to measure the artery's precise location. Furthermore, it was unclear if the outcomes for the left and right arteries were comparable. The study also posed some clinical heterogenicity. Therefore, additional research is required to verify accuracy of diagnosis. [14]

In 2011, Anthony J Weekes et al. compared bedside serial visual estimates of left ventricular systolic function and respiratory variation of IVC diameter with caval index and quantitative measurements in 72 hypotensive emergency department patients at Carolinas Medical Centre, Charlotte, NC, USA, during early fluid resuscitation. An observational study demonstrated that visual estimations of respiratory variations in IVC diameter and LVF correlated with bedside measurements of caval index and left ventricular function in symptomatic hypotensive patients during early fluid challenges. [15]

"Renan Muralho Pereira, Alvaro José Leite Campelo da Silva, JulioFaller, Brenno Cardoso Gomes, João Manoel Silva Jr" performed an observational controlled trial in Hospital Servidor Público Estadual, São Paulo, Brazil in 2019 to compare the collapsibility (IVCCI) and distensibility (IVC-DI) indices of IVC with pulse pressure variation(PPV) and determine the accuracy of IVCCI and IVC-DI that most accurately forecasts how surgical patients will react to intravenous fluid treatment. In surgical patients with spontaneous and artificial breathing, echocardiography revealed a correlation with pulse pressure change and IVC diameter variation. [16]

"Brennan J.Matthew , Blair JohnE.A. , Hampole Chetan , Goonewardena Sascha , Vasaiwala Samip , Shah Dipak , Spencer KirkT. , Schmidt Gregory A." conducted an observational study at University of Chicago Hospitals, Chicago in the year 2006 to ascertain whether, in patients undergoing mechanical ventilation,

"respiratory changes in the brachial artery blood flow velocity(ΔVpeak-BA) utilizing a hand-carried ultrasound (HCU) equipment could show to be an accurate substitute for pulse pressure variation(ΔPP) since both radial artery ΔPP and aortic blood flow peak velocity variation are valuable in forecasting fluid responsiveness". Doppler signal obtained from brachial artery was retrieved via HCU device in thirty patients with indwelling radial artery catheters on volume-control ventilation. A blinded ICU physician examined recordings of the central venous pressure and the radial artery pulse wave concurrently. There was minimal interobserver "variability (2.8±2.8%) [mean±SD] and significant relationship (weighted κ, 0.82) between ΔVpeak-BA and ΔPP (r=0.84). A 16% ΔVpeak-BA cutoff has been extremely sensitive with predictive value of ΔPP≥13%. A ΔVpeak-BA cutoff of 16%" bedside HCU Doppler assessment could aid in gauging fluid response as it correlated well with ΔPPV. [17]

A 2017 observational study by “Jingyi Wu MD et al” examined the effectiveness of Doppler ultrasonography in predicting fluid therapy response in septic shock patients on mechanical ventilation. The research examined 62 patients at Wannan Medical College in Wuhu, Anhui, China. Fluid responsiveness displayed a 15% stroke volume increase upon volume expansion. Twenty-eight patients in total were categorized as responders.

Fluid responsiveness has been predicted with 82.1% sensitivity and 88.2% specificity for ΔVpeakPLR values over 10.6%. VVpeakbrach values above "10.95% predicted fluid responsiveness with 78.6% sensitivity and 91.2% specificity. ΔPPV had been 94.4% when both were positive. They determined that combining Doppler ultrasound evaluation of VVpeakbrach and ΔVpeakPLR" may evaluate fluid responsiveness without invasive procedures. [18]

In 2009, “Manuel Ignacio Monge García, Anselmo Gil Cano and Juan Carlos Díaz Monrové” performed "prospective clinical investigation in a 17-bed multidisciplinary ICU in Spain on 38 mechanically ventilated patients with acute circulatory failure that required fluid administration to determine if non-invasive Doppler ultrasound of respiratory variations of brachial artery peak velocity flow could predict fluid responsiveness in mechanically ventilated" patients.

Volume expansion used 500 mL of synthetic colloid. Responses occurred when VE increased "stroke volume index (SVi) by 15% or higher. Respiratory change in ΔVpeakbrach is difference between maximum and minimum values of Vpeakbrach throughout one respiratory cycle, divided by" average and expressed as a percentage. Additionally, FloTrac/Vigileo system measured stroke volume fluctuation (ΔSVVigileo) and ΔPPrad. Fluid responsiveness had been predicted by ΔVpeakbrach value >10% with 74% sensitivity and 95% specificity. They concluded that "respiratory variations in brachial artery peak velocity could be a practical tool for the noninvasive evaluation of the response to fluid administration in patients with acute circulatory failure and" mechanical ventilatory support. [(10)]

In 2021, “Y. Song, Y. L. Kwak, J. W. Song, Y. J. Kim, and J. K. Shim” evaluated respiratory-induced phasic variations "in carotid artery blood flow peak velocity (DVpeak-CA) as predictor of fluid responsiveness in mechanically ventilated coronary artery disease patients" Fluid responders had a 15% stroke volume index increase following fluid loading (6ml/kg). To calculate δVpeak-CA, divide difference in highest and lowest peak velocity measurements in respiratory cycle by average. There was significant association in ΔPPV and δVpeak-CA, with SVI increasing with volume. "Optimal cut-off values for fluid responsiveness in ΔPPV and δVpeak-CA have been 13%(sensitivity and specificity of 0.74 and 0.71) and 11%(sensitivity and

specificity of 0.85 and 0.82)". The research determined that Doppler-based respirophasic δVpeak-CA assessment is valid and practical method for assessing fluid responsiveness in mechanically ventilated patients undergoing coronary revascularization. [19]

"Jihad Mallat, Malcolm Lemyze, and Marc-Olivier Fischer" examined that PLR-induced changes in plethysmographic variability index "(ΔPVIPLR) could accurately predict fluid responsiveness in 2023 by performing secondary analysis of an observational prospective research investigation on 29 patients receiving mechanical ventilation with acute heart failure at Arras Hospital, France. Before and during a PLR test, and also after volume" loading with 500ml of crystalloids, the Radical-7 device and echocardiography, respectively, have been utilized to measure PVI and cardiac index(CI). An increase in CI >15% demonstrated fluid responsiveness. Fluid responsiveness was found to have sensitivity of 95% and a specificity of 80% when PLR caused a drop in PVI<−24.1%.They concluded that fluid responsiveness can be accurately estimated with an optimal gray zone in sedated and mechanically ventilated patients experiencing severe circulatory distress by changes induced by PLR in PVI.[20]

From 2012-15, "Nianfang Lu, Xiuming Xi, Li Jiang, Degang Yang, Kai Yin" performed prospective observational study at "Fuxing Hospital, Capital Medical University, Beijing, China", for evaluating "respiratory fluctuations in carotid and brachial peak velocity along with other hemodynamic markers to determine response to fluid challenge. Each patient received 200ml of saline solution. Twenty-two people did not answer, while twenty-seven did. Respondents also had greater SVV,PVI,ΔIVC,ΔCDPV,andΔVpeak brach measurements. Furthermore, all of these metrics demonstrated statistically significant linear associations with changes in

CI.They concluded that ΔIVC and ΔVpeak brach ultrasound analysis, especially ΔCDPV, could predict fluid response and be proposed as a continuous, non-invasive method of monitoring functional hemodynamic" parameters in septic shock patients receiving mechanical ventilation.[21]

In a prospective observational study, "Malini Joshi, Praveen Dhakane, Shilpushp J Bhosale, Rutuja Phulambrikar, and Atul P Kulkarni" correlated the velocity time integrals of "carotid and brachial arteries and compared them with changes in pulse pressure and stroke volume to assess fluid responsiveness. They selected 27 patients that underwent supra-major abdominal operations. The hemodynamic (HR, SBP, MAP, CI, SV, PPV, SVV, VTi_TAPCarotid, VTi_TAPBrachial, VTi_flowCarotid, and VTi_flowBrachial) and respiratory (peak and plateau pressures) parameters have been evaluated at baseline, before, and after fluid bolus. Temporarily, tidal volume increased to 8mL/kg. Patients became responders if SV increased by >15%. Patients exhibited fluid responders in 29 of cases. There was a poor correlation between the carotid and brachial artery VTi_TAP and" VTi_flow, demonstrating that measures of the carotid and brachial vessels can't be utilized interchangeably. [22]

BASIC SCIENCES

VEINS :

Veins as capacitance vessels principally acting as conduit vessels , transporting blood from the body's organs and tissues back to the heart.

Veins are blood reservoirs at rest , housing two thirds of the body's blood volume.

Their high vascular compliance is owed to thin walls , large diameter and less muscle. They are thirty times more complaint than arteries .[23]

However , pulmonary veins atypically carry oxygenated blood from lungs to heart.

Embryologically , capillary plexuses give rise to the earliest veins which carry blood into the sinus venosus, the inflow end of the forming heart.

The major venous systems include the internal jugular veins (IJV) that carry blood from the head and neck, the subclavian veins (SCV) that carry blood from the upper extremities, the femoral veins which drains the lower extremities.

All these veins drain into the superior and inferior-vena cava before reaching the heart.

INFERIOR VENA CAVA : [23,24,25]

ORIGIN : Confluence of common iliac vein at the level of L5 vertebra.

COURSE: It ascends on the right side of the vertebral column from L3-L5, on the right psoas major and reaches upto the right side of aorta. IVC has a short

intrathoracic course(2.5 cm) , enters the thorax through the caval opening in the diaphragm entering the right atrium.

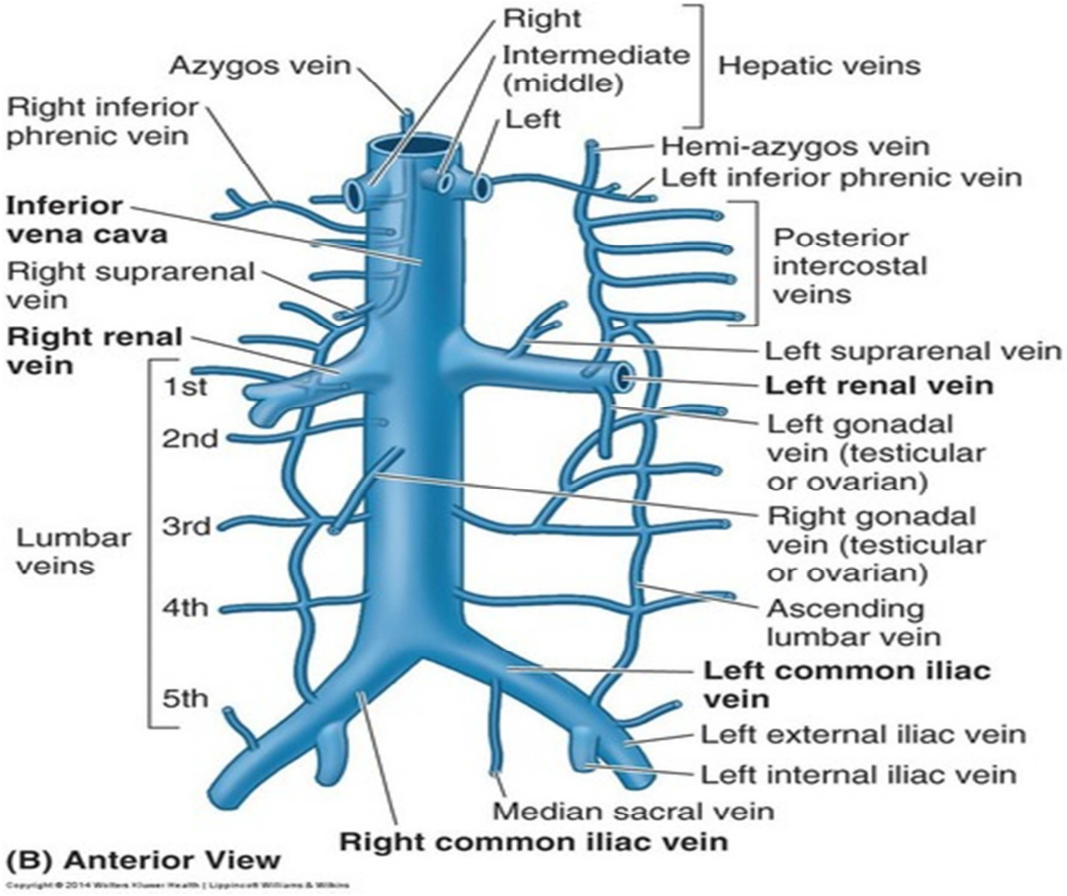

FIGURE 1 : IVC and its branches

RELATIONS :

- Anterior
  - Right common Iliac artery
  - Horizontal part of Duodenum
  - Head of Pancreas
  - Liver

- Posterior
  - Vertebrae
  - Right Psoas
  - Right crus of Diaphragm
- Right
  - Right Ureter
  - Medial border of right Kidney
  - Right lobe of Liver
- Left
  - Aorta
  - Left crus of Diaphragm

Tributaries:

- T8: Paired inferior phrenic veins.
- T8: Hepatic veins
- L1: right suprarenal vein
- L1: renal veins
- L2: right gonadal vein
- L1-L5: lumbar veins
- L5: common iliac veins (origin).

CHARACTERISTICS :

Large retroperitoneal vessel which transports deoxygenated blood from the lower extremities and abdomen back to the right atrium of the heart.

largest diameter of the venous system thin walled vessel doesn't contain one way valves and forward flow to the heart is driven by the differential pressure created by normal respiration.

A symmetric vessel

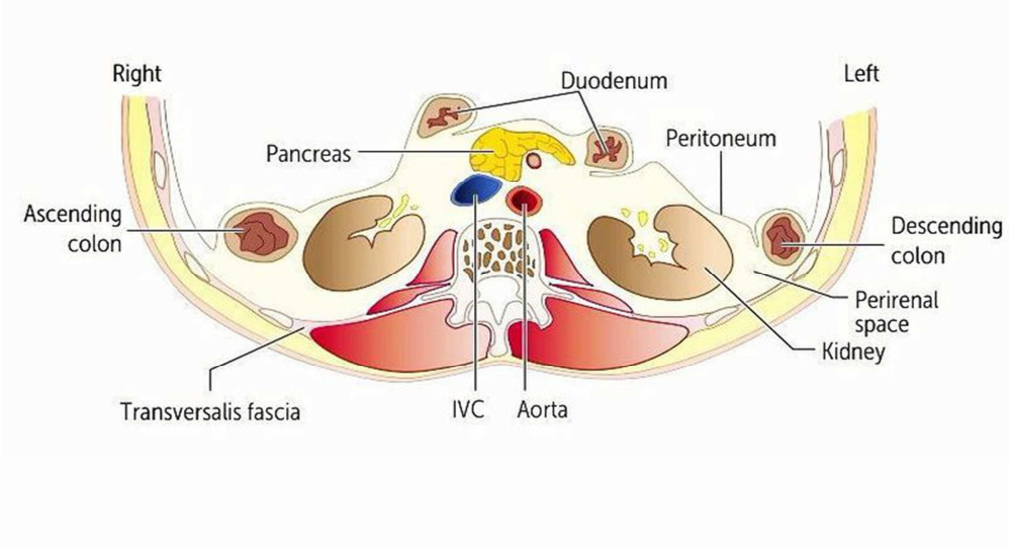

FIGURE 2 : IVC RELATIONS

BLOOD SUPPLY : deoxygenated blood and vasa vasorum

NERVE SUPPLY : Splanchnic nerves

FRANK STARLING LAW [(26)]

Otto Frank demonstrated increased ventricular contraction when the ventricle was stretched prior to contraction in the late 19th century. He stated that the heart is able to adapt the ejected blood volume to the venous return on a beat-to-beat basis.

Increased venous return ---------Increased ventricular filling pressures ------- stroke volume augmentation-------increased right atrial pressure -------- myocyte stretching---- increase in sarcomere length

The Frank-Starling curve is, therefore, also known as the cardiac function curve.

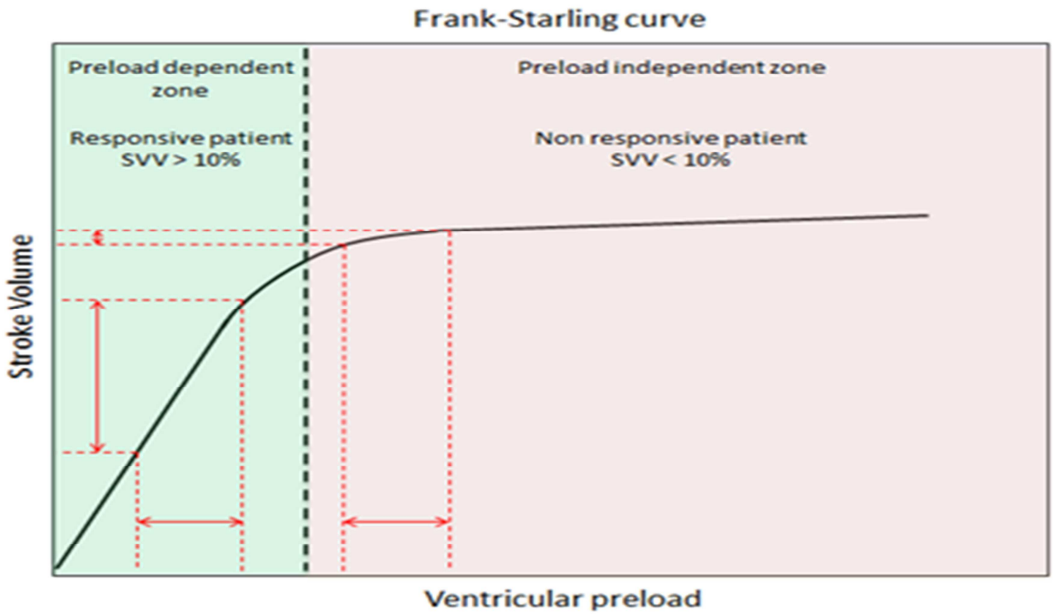

FIGURE 3 : FRANK STARLING CURVE

Since the major portion of our blood volume resides in capacitance veins, which are highly distensible, there is a substantial amount of volume not creating transmural pressure, the so-called unstressed volume.

The volume that does create a transmural pressure above zero is called the stressed volume determining the mean systemic filling pressure (MSFP)

MSFP is the driving force behind venous return, just as mean arterial pressure drives cardiac output. Similarly, venous return is driven by the pressure gradient between the MSFP and RAP limited by the resistance (Rv) venous flow encounters, hence the following equation:

Venous return = (MSFP-RAP)/Rv

It can be deduced that :

venous return can be raised by

1) Lowering RAP,
2) Decreasing Rv,
3) Increasing MSFP

The circulatory system can be described as a composite function curve consisting of input and output of the heart, as venous return and cardiac output have to be equal within a few heartbeats.

Subsequently, cardiac output cannot increase without an increase in venous return clarified by the Frank Starling principle 'the heart pumps what it receives'.

But although increasing preload by fluid loading will increase cardiac output when the patient is on the ascending portion of the cardiac function curve, fluid loading will have little effect when the heart is functioning near the flat part.

Guyton made this concept elegantly comprehensible by graphically superimposing the venous return curve on the cardiac function curve, as both are a function of RAP.

It should be noticed that both curves are in fact a function of preload and thereby represent transmural pressure, i.e. intramural (as RAP is obtained) minus extramural pressure.

Therefore a change in extramural intrathoracic pressure can significantly alter preload.

It is key to find out a patient's position on the combined venous return/ cardiac function curve to predict whether an increase in cardiac output is to be expected from fluid loading or cardiac function augmentation since achieving supra-physiological cardiac outputs through inotropics has shown to be detrimental.

On the 'flat' part of the cardiac function curve, a rise in MSFP upon fluid loading is accompanied by a similar increase in RAP negating an increase in venous return and cardiac output, indicating fluid unresponsiveness. Fluid administration in a non-fluid responsive patient will accelerate a rise in cardiac filling pressures and thus hydrostatic pressures causing pulmonary and general oedema.

Determining volume status is challenging but important since insufficient resuscitation on the other hand has been associated with organ hypoperfusion and ischaemia

PREDICTORS OF FLUID RESPONSIVENESS :

STATIC	DYNAMIC
CENTRAL VENOUS PRESSURE	PULSE PRESSURE VARIATION
PAOP	STROKE VOLUME VARIATION
IVC DIAMETER	IVC COLLAPSIBILTY INDEX
IVC DISTENSIBILITY / COLLAPSIBILITY	EXPIRATORY OCCLUSION TEST
GLOBAL END DIASTOLIC VOLUME	PASSIVE LEG RAISING (PLR)
CORRECTED FLOW TIME	Aortic velocity time integral
	ETCO2 variation

DYNAMIC parameters are more reliable and are principally governed by interactions between heart and lungs. During inspiration, there is a decrease in preloading of the right atrium due to the transmission of intrathoracic pressure, which increases at this time in the cycle.

IVC COLLAPSIBILTY INDEX :

Pressure changes in IVC :

IVC does not contain such valves, which makes the blood flow from IVC to the heart dependent on the pressure gradient created by normal respiration.

During inspiration, the diaphragm contracts, creating negative pressure inside the thorax to expand the lungs. This pressure gradient pulls the blood from the abdominal IVC into the thoracic IVC, then into the right atrium. The intra-abdominal pressure during inspiration also increases during inspiration due to the down displacement of the diaphragm.

During the breathing cycle, the inferior vena cava (IVC) can be seen to go from its most minor diameter during inspiration to its largest diameter during expiration

Factors Affecting Ivc Diameter:

Intrathoracic Pressure

Abdominal Pressures

Central Venous Pressure (Cvp)

Compliance of the Vessel.

Its caliber is altered by respiration , blood volume and right heart function.

In spontaneously breathing patients, changes in IVC diameter reflect the interaction between CVP and the range of gradient between intrathoracic and abdominal pressures.

Fluid responsiveness can be considered when the collapsibility index reaches 12–18% variation in patients subjected to mechanical ventilation and 50% in patients with spontaneous breathing

FORMULA : CI = (IVC max-IVC min)/IVC max

ARTERIES [27]

Arteries transport oxygen, nutrients, and hormones away from the heart throughout the body. However , pulmonary artery moves unoxygenated blood from the heart to the lungs to complete the gas exchange in the alveoli.

CHARACTERISTICS :

Composed of three different layers: first : innermost intima

second : media or the middle layer

third : outermost adventitia

Have nonstriated muscles encompassing the vessels to provide support and integrity to the entire artery.

Arteries are classified into three major types based on their size and morphology; these 3 types are: elastic arteries (conducting arteries), muscular arteries (distributing arteries), and arterioles.

BRACHIAL ARTERY :

main artery of the upper arm

continuation of the axillary artery

LOCATION : begins at the lower border of the teres major muscle

COURSE :It runs down the anterior aspect of the arm, traveling along the medial side of the biceps brachii muscle and is located deep to the **bicipital aponeurosis**

The artery passes along the medial side of the arm and is accompanied by the **median nerve** for much of its length.

The artery passes through the cubital fossa at the elbow, where it bifurcates into the radial and ulnar arteries opposite the neck of the radius. Throughout its course, the brachial artery is relatively superficial, lying just beneath the skin and fascia

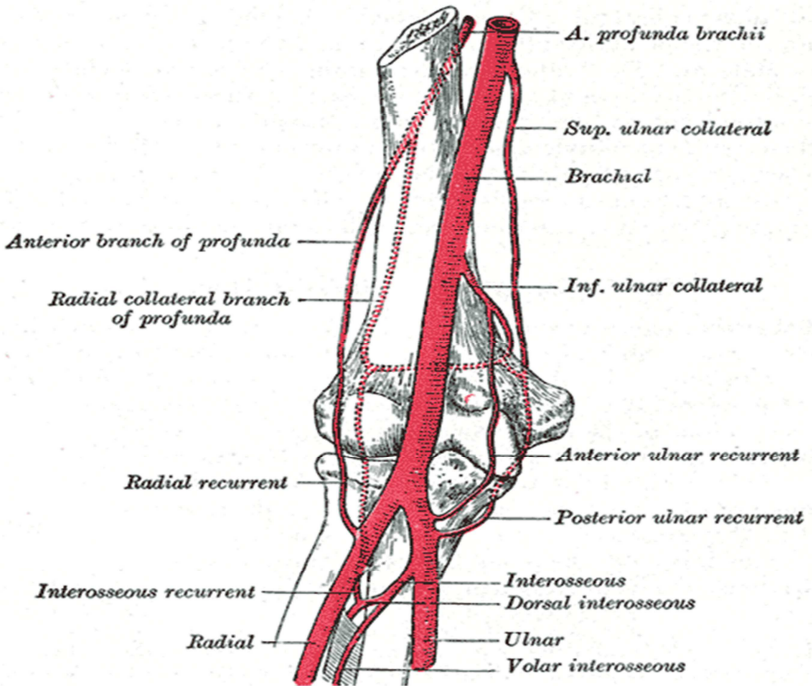

FIGURE 4 : BRACHIAL ARTERY AND ITS BRANCHES

BRANCHES : [28]

VASCULAR SUPPLY :

- Brachial artery: biceps brachii muscle, triceps brachii muscle, coracobrachialis muscle

  BRANCHES AND BLOOD SUPPLY:

- Profunda brachii artery: deltoid muscle, triceps brachii muscle, anconeus muscle
- Superior ulnar collateral artery: supplies the periarticular arterial anastomoses of the elbow and elbow joint
- Inferior ulnar collateral artery: brachialis muscle, biceps brachii muscle, coracobrachialis muscle
- Ulnar artery: elbow joint, central and medial forearm muscles, common flexor sheath
- Radial artery: elbow joint, lateral forearm muscles, carpal bones and joints, thumb and lateral index finger

ARTERIAL BIOMECHANICS AND PULSE WAVE VELOCITY:

Blood flow characteristics differ in conduit , resistance arteries and in arterioles.

The conduit arteries are elastic in nature and blood flows in a pulsatile manner based on the oscillatory ejections of the left ventricle (the ejected stroke volume is accommodated by the elastic characteristics of the central great arteries [Windkessel effect]).

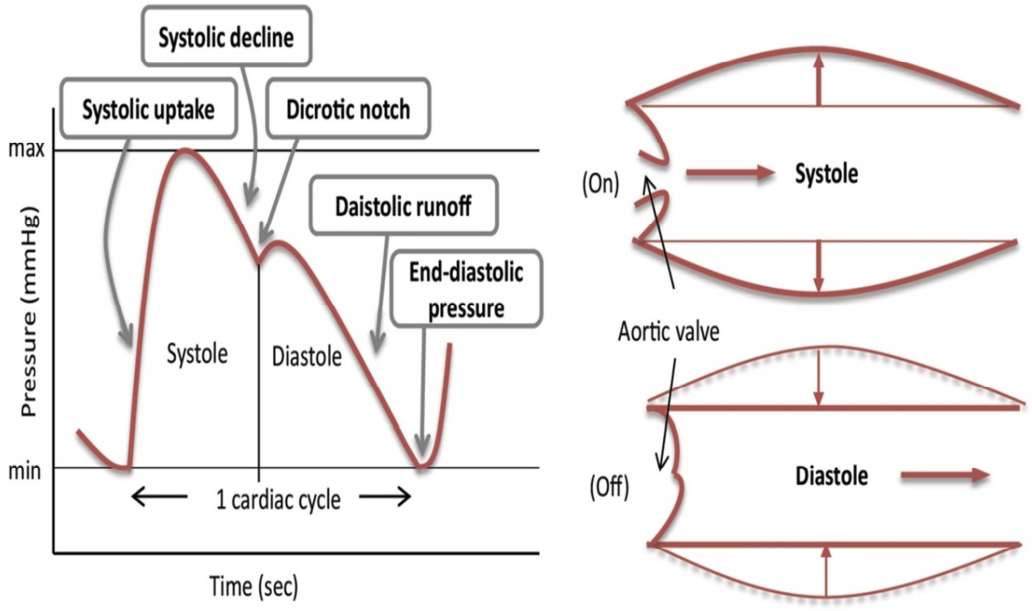

FIGURE 5 : ARTERIAL BIOMECHANICS

In conduit arteries blood flows in a “distending wave” or pressure pulsation and it is this pulsation that is felt when a pulse is palpated.

Elastin content and compliance decrease in progressively more distal arterial vessels. The net result is that one observes higher pulse pressures in more distal arteries

This pulse pressure lessens to almost no pressure variation after flowing through the resistance arteries due to their numerous branches and by extrinsically and intrinsically regulating their tone. By the time flow of a theoretical “wave” reaches the arterioles, the flow has become continuous.

Factors affecting blood flow :

- Pulse pressure
- Stroke volume
- vascular compliance
- Volume of the blood
- Viscosity of the blood
- Blood vessel length and diameter

Mathematical Approach to Factors Affecting Blood Flow:

Jean Louis Marie Poiseuille was a French physician and physiologist who devised a mathematical equation describing blood flow and its relationship to known parameters

Poiseuille's equation:

Blood flow = $\pi \Delta P r4 / 8\eta\lambda$

Where ,

- ΔP represents the difference in pressure.
- r4 is the radius (one-half of the diameter) of the vessel to the fourth power.
- η is the Greek letter eta and represents the viscosity of the blood.
- λ is the Greek letter lambda and represents the length of a blood vessel.
- Π is the Greek letter pi, used to represent the mathematical constant that is the ratio of a circle's circumference to its diameter. It may commonly be represented as 3.14

FLOW VELOCITY (41)

Working principle :

Ultrasonic measurements of blood flow velocity are based on theDoppler effect.

Piezoelectric transducers transmit ultrasound waves with a frequency of f0 into the skin. When an echo comes from a moving scatterer (such as red blood cells), the received frequency fR has a certain deviation from the transmitted frequency, that is, a Doppler shift fD

$fD = fR - f0 = 2\ f0\ V\cos\theta/c$

where c is the speed of sound, V is the flow velocity, and θ, known as the Doppler angle, is the angle between the axis of the ultrasound beam and the direction of flow, looking toward the transducer

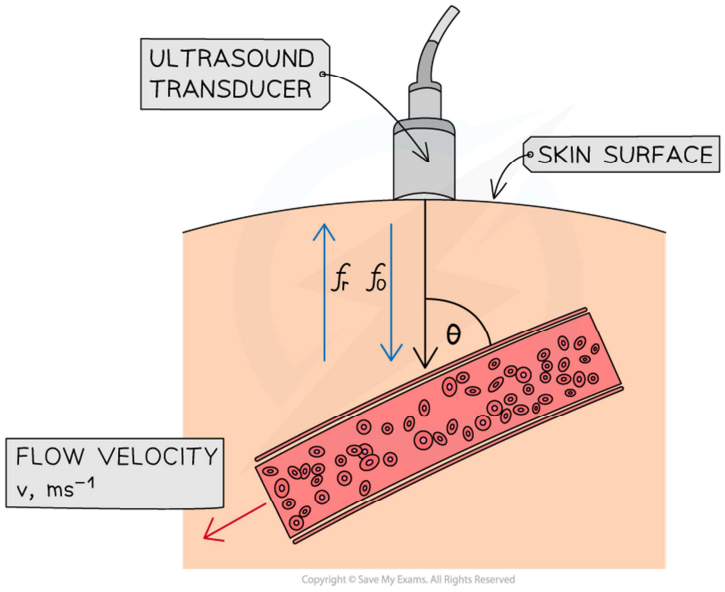

FIGURE 6 : DOPPLER EFFECT

When the scatterer moves relative to the probe (θ is not equal to90°), the received echo will exhibit a certain frequency shift. If the scatterer moves toward the probe ($0 \leq \theta < 90°$), the echo frequency will be higher than the transmitted frequency, which is called "forward"; if the scatterer moves away from the probe ($90° < \square \leq 180°$),the echo frequency will be lower than the transmitted frequency, which is called "reverse."

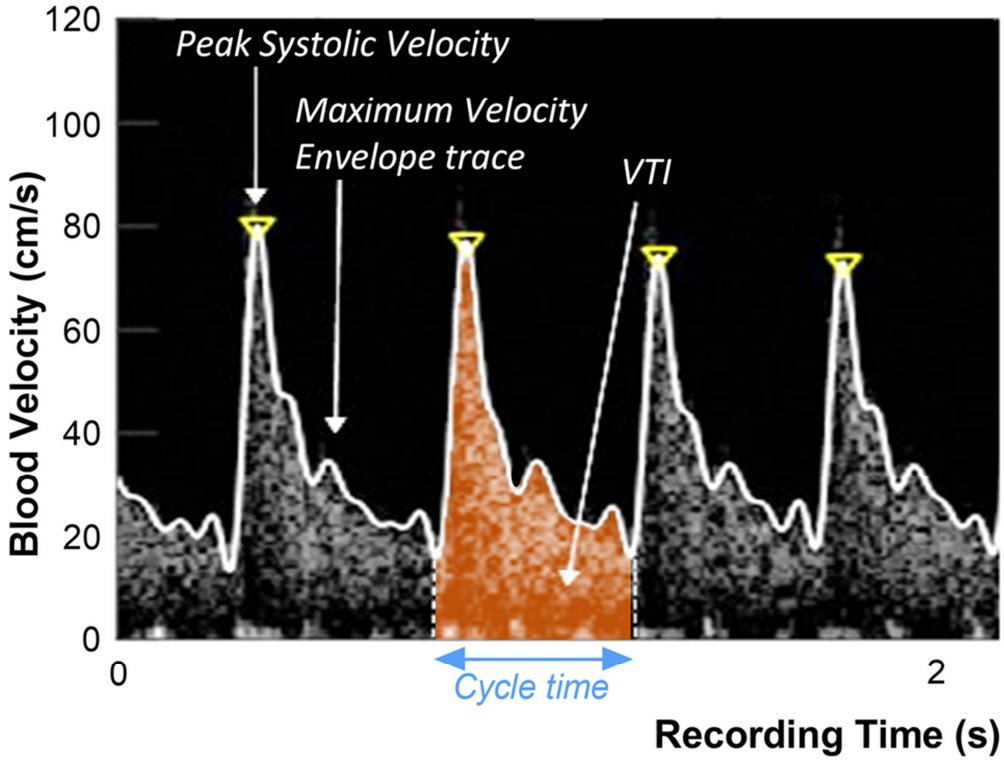

FIGURE 7 : DEPICTION OF PEAK SYSTOLIC VELOCITY

PASSIVE LEG RAISING : [29,30]

Passive leg raise is a brief and completely reversible endogenous fluid challenge. It implies lifting the legs passively from the horizontal plane in a lying subject at 45 degrees which induces a gravitational transfer of blood from the lower part of the body toward the central circulatory compartment.

It recruits a part of blood contained in the venous reservoir and converts unstressed volume to stressed volume, increasing cardiac preload, likely through an increase in the mean circulatory pressure which is the driving pressure for venous return.

If the right ventricle is preload responsive, the increase in systemic venous return results in an increase in right cardiac output and hence in the left ventricular filling.

In mechanically ventilated patients fully adapted to their ventilator PLR-induced changes in stroke volume have been found to be closely correlated with the changes in stroke volume induced by a subsequent 300ml colloid infusion.

The main advantages of this manoeuvre are the possibility of applying it to most critically ill patients, even in spontaneous breathing, low tidal volume, low lung compliance and with arrhythmias. Therefore the PLR can be still used in circumstances where heart–lung interaction indices are misleading.

It represents a preload test which consists of about 300 mL of blood.

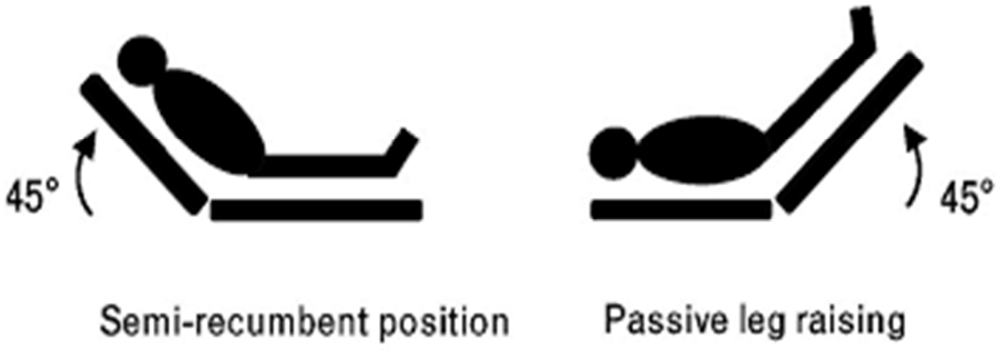

FIGURE 8 : PASSIVE LEG RAISE

ULTRASONOGRAPHY:

Ultrasound technique depends on the processing of reflected sound waves. On procreation of periodic and vibrating particles it results in a waveform motion, by which they create an image.

Soundwaves: These are the pressure waves that advances by series of compression and decompression of the medium they are travelling in.

Types:

1) Infrasound: Frequency less than 20 Hz

2) Audible sound: Frequency 20 Hz to 20000 Hz

3) Ultrasound: Frequency more than 20000Hz.

Ultrasound is nothing but sound waves in frequency range of around 2 to 15 megahertz and has a wide range of diagnostic and treatment purpose in the field of medicine. The frequency range used in vascular ultrasonography 2–10MHz. Sound waves are emitted by piezoelectric material, most often synthetic ceramic material (lead zirconate titanate [PZT]), which is contained in ultrasound transducers.

Piezoelectric effect:

When a rapidly alternating electrical voltage is applied to piezoelectric material, the material experiences corresponding oscillations in mechanical strain. As this material expands and contracts rapidly, vibrations in the adjacent material are produced and sound wave are generated.

Mechanical properties of piezoelectric material determine the range of sound wave frequencies that are generated. Sound waves propagate through media by creating compressions and rarefactions of particles.

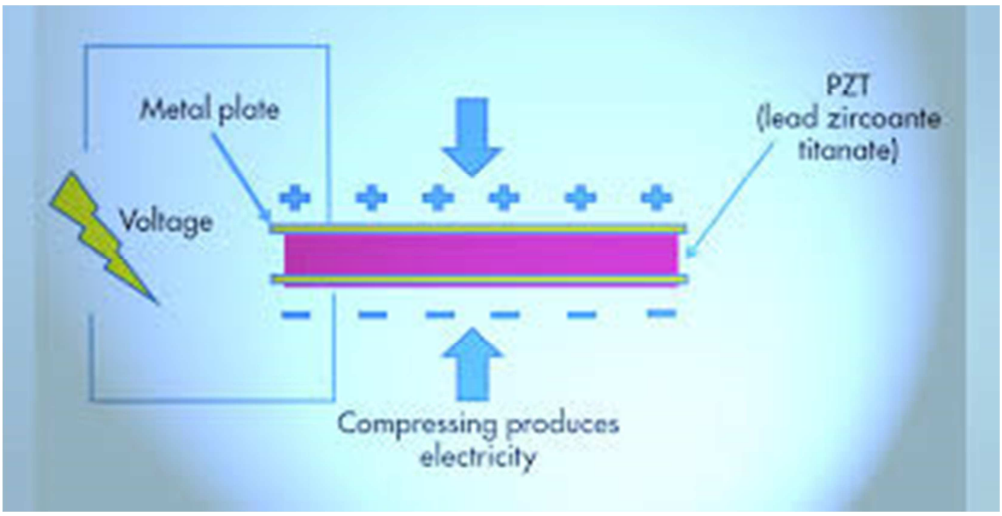

FIGURE 9 : PIEZOELECTRIC EFFECT

This process of generating mechanical strain from the application of an electrical signal to piezoelectric material is known as the "reverse piezoelectric effect". The opposite process, or generation of an electrical signal from mechanical strain of piezoelectric material, is known as the "Direct piezoelectric effect".

Transducers produce ultrasound waves by the reverse piezoelectric effect, and reflected ultrasound waves, or echoes, are received by the same transducer and converted to an electrical signal by the direct piezoelectric effect. When it lies on the surface 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 produce the acoustic shadowing. If the tissues are homogenous in their densities then echo-free images are seen (blood, urine, ascites).

TRANSDUCER:

It is one of the component of USG machine which can be handheld.

Transducer is used for optical transmission and for reception of sound wave.

It converts electric voltage into sound waves (mechanical energy) and vice versa based on piezoelectric effect.

Most common material used is lead zirconate titanate.

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: For proper transmission of sound waves to one or multiple tissues.
- Housing.

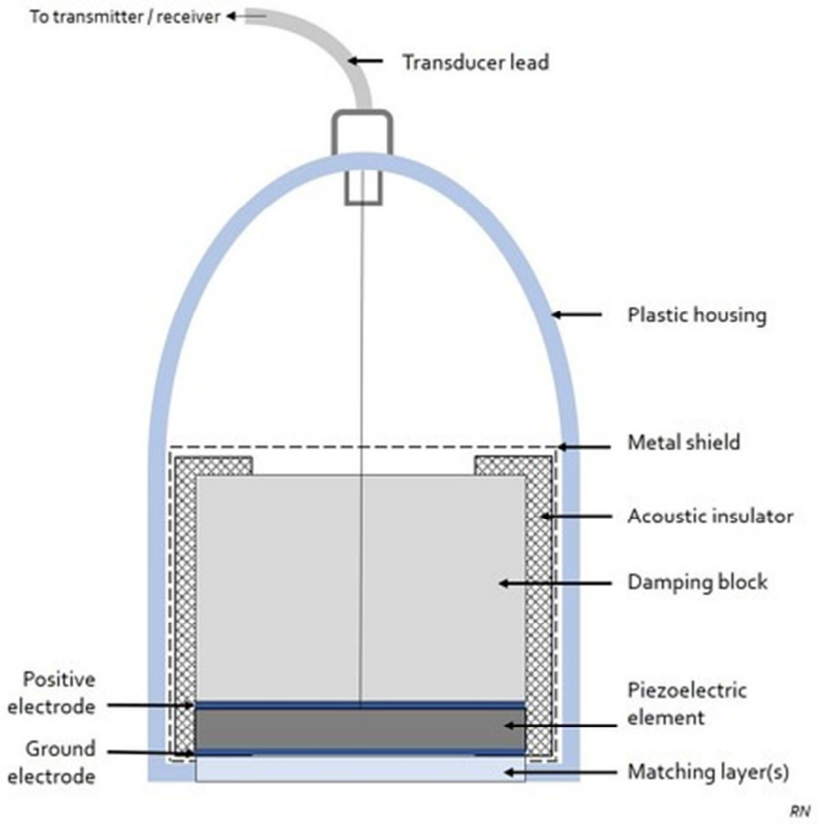

FIGURE 10 : USG – TRANSDUCER

Transducers receive and record the intensity of the returning sound waves.

TYPES OF TRANSDUCERS: There are four types of transducers:

1. Linear
2. Curvilinear
3. Phased-array.
4. Intracavitary

1.Linear Probe:

Piezoelectric crystals arranged in a flat matrix.

Produces parallel linear ultrasound beams.

Generate a rectangular image

Shorter-wavelength sound waves (axial and lateral resolution)

Visualization of superficial structures

Frequency range – 5-15 MHZ

Imaging Depth – 9 cm

Applications:

Vascular examination(Arteries/veins)

Procedures(catheterization)

Pleural examination

Skin/soft tissues

Musculoskeletal

Thyroid

Lymph Nodes

Nerves.

FIGURE 11 : USG – LINEAR PROBE

2.Curvilinear transducers:(figure 11)

Piezoelectric crystals curvilinear-convex arrangement Ultrasound beam is broad and trapezoidal It provides wide field of view lower resolution compared with the linear transducers

Used to examine deeper tissues

Uses lower frequencies (2to 5 MHz)

Longer wavelengths

Penetrate deep structures (Depth - 5 to 25 cm)

Applications:

Imaging abdominal and pelvic organs Imaging larger musculoskeletal structures

Transvaginal and transrectal examinations.

FIGURE 12 : CURVILINEAR PROBE

MODES OF IMAGING:

Two-dimensional (2D) or B-mode.

Motion mode (M-mode).

Doppler mode(D-mode).

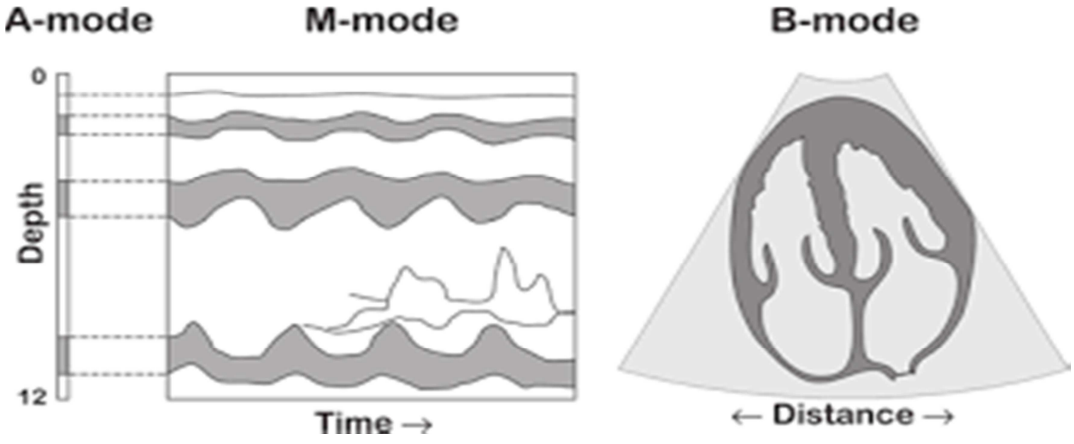

FIGURE 13 : MODES OF IMAGING

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 (Figure 8). 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 lengths and depths. It is frequently used in ophthalmology for measuring the corneal thickness and axial length measurements.

B-MODE: The majority of diagnostic ultrasound machines uses two-dimensional (2D) mode. This mode is also called B-mode, or brightness mode, because the echogenicity, or "brightness," of observed structures is regulated by the number of reflected signals and velocity. The consecutive impulses are emitted at defined intervals and encoded digitally. Only encoded echoes are used and other interfering echoes are subtracted.

Amplitude of signal is reflected by moving particles and it is processed in the interval between two pulses. The echo waves are reflected as dots. 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. Higher the amplitude (strength) of the echo wave , brighter will be the dot. When all the emitted waves reach the transducer back, the 2D ultrasound image (B mode) is formed

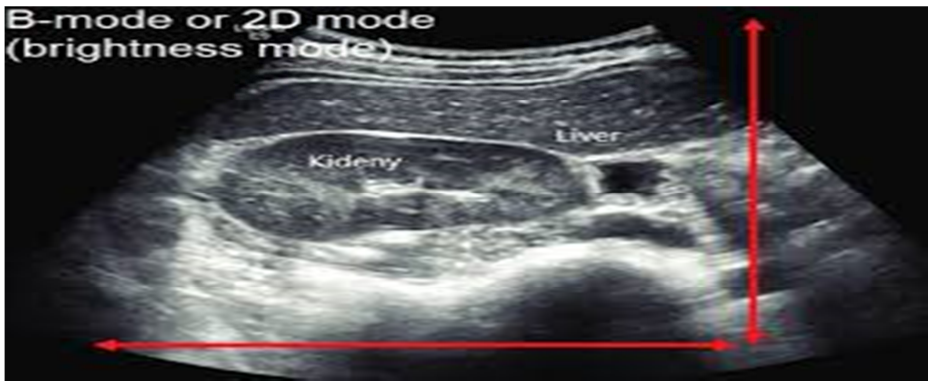

FIGURE 14 : B- MODE IMAGE

M-mode (Motion mode): It is an older imaging mode. M-mode can be applied along a single line within the 2D image. A single-axis beam is emitted along the cursor line and movements of all tissues along that line are plotted over time. . 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 often used to measure the size of cardiac chambers or movement of cardiac valves throughout the cardiac cycle. The point-of-care applications include measurement of respiratory variation of the inferior vena cava and evaluation of the lung-pleura interface in the assessment of pneumothorax

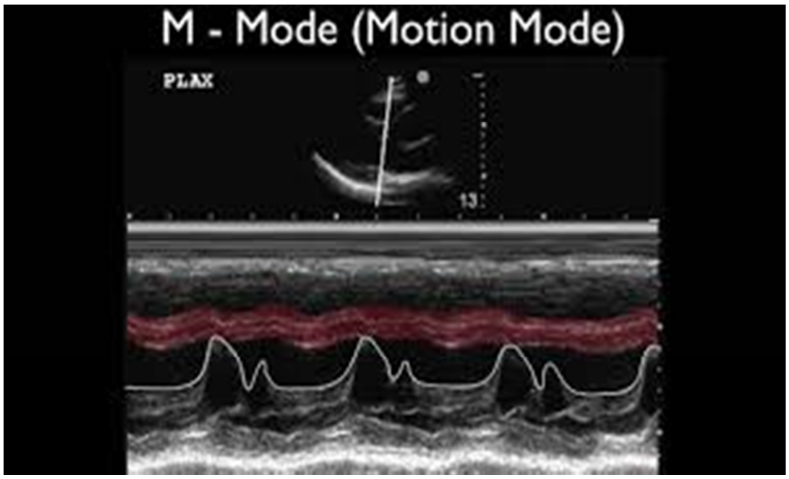

FIGURE 15 : M- MODE IMAGING

DOPPLER IMAGING:

The Doppler effect: The shift in the frequency of sound waves due to motion between the source and observer In ultrasonography, the primary source of sound waves is the transducer, and the same transducer is the observer for returning echoes. Movement of tissues,most often blood flow, produces a shift in frequency of returning sound waves. Blood flow moving toward the transducer shifts the echoes to a higher frequency, whereas blood flow moving away from the transducer shifts the echoes to a lower frequency.The change in frequency between the emitted and received sound waves is called as Doppler shift.

Variables that determine the amount of Doppler shift are:

1. Frequency of ultrasound waves

2. Velocity of blood flow

3. Angle of insonation.

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 (RBCs) 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 .

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 (≈ 1540 m/s).

α – 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 will thus be:

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

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

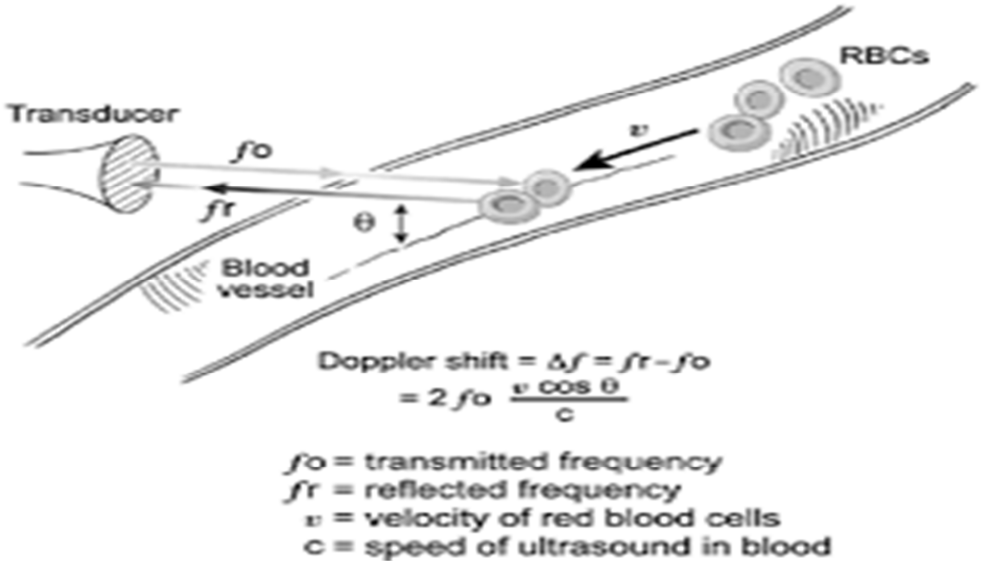

FIGURE 16 : DOPPLER EFFECT

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 travelled can be determined as we have the velocity with which it travels (≈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 targetted. Pulse repitition frequency is the number of pulses that are emitted in one second.

Thus, by decreasing the pulse repitition frequency we will be able to scan deeper structures (as the time required for the echoes to return back increases).

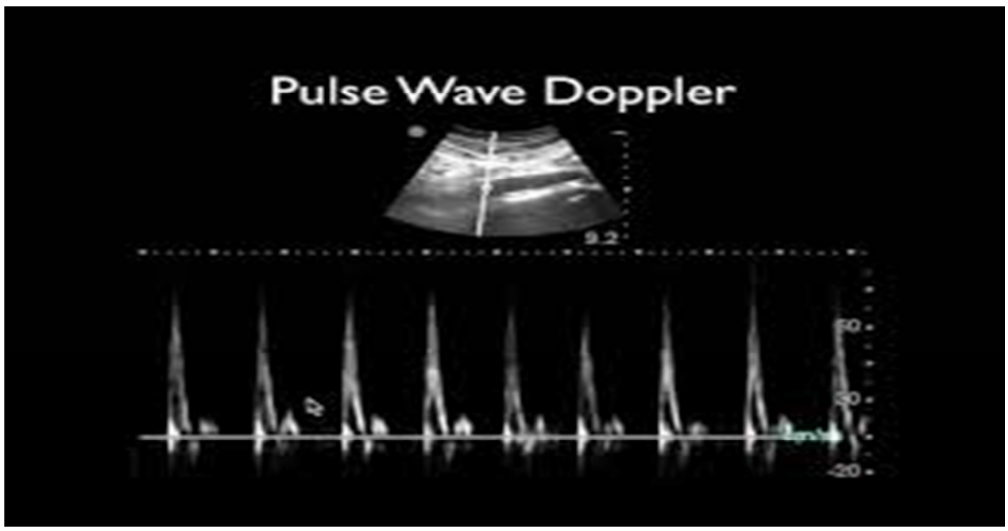

FIGURE 17 : PULSE WAVE DOPPLER IMAGING

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 pulse 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.

SONOANATOMY: The ability to distinguish arteries from veins is important. Veins are oval or triangular shaped, thin-walled, fully compressible, and change size with breathing (respiratory variation) or Valsalva.

INFERIOR VENACAVA:

Type of probe: a phased-array (frequency of 2.0–4.0 MHz) or curvilinear probe (frequency of 3.5–5.0 MHz) should be used.

Low-frequency probes provide better penetration and visualization of deep structures.

Depth: Depth of field should be adjusted to allow complete visualization of the IVC and its entrance into the right atrium. Obese patients will require an increased depth setting.

Place the probe horizontally on the subxiphoid process to do top to bottom scan and then turn to longitudinal scan, then turn the probe to 90 degree clockwise to get the image of IVC.

By gently fanning the probe up and down, one can visualize IVC and the aorta anterior to the central shadowing from the vertebral body. By fanning further up towards the chest, hepatic veins joining the IVC come into view .

For M-mode, IVC diameters were measured during quiet passive respiration . Respiratory variability with percentage collapse of the IVC was calculated as the inferior vena cava collapsibility index.

IVCCI: [(Maximum IVC diameter – Minimum IVC diameter) / Maximum IVC diameter] x 100.

Three anatomic approaches:

1) sub-xyphoid transabdominal long axis (LA) 2-3cm caudal to the right atrial (RA) junction
2) transabdominal short axis (SA) immediately inferior to the inflow of the hepatic veins
3) Right lateral transabdominal coronal long axis (CLA) (aka “rescue view”) 2-3cm caudal to the RA junction

All measurements were obtained with a 3.5-Mhz curved array ultrasound probe.

BRACHIAL ARTERY :

Type of probe: LINEAR PROBE(minimum frequency of 7 MHz)

Ultrasonography was done with patient in supine position and arm extended .

The brachial artery is imaged above the antecubital fossa in the longitudinal plane.

Initially identified in B mode , and then assessed in doppler mode in 60 degree Doppler angle.

Normal continuous-wave Doppler waveforms have a high-impedance triphasic shape, characteristic of extremity arteries (with the limb at rest). Time to peak is very short, the systolic peak is narrow, and flow is absent in late diastole.

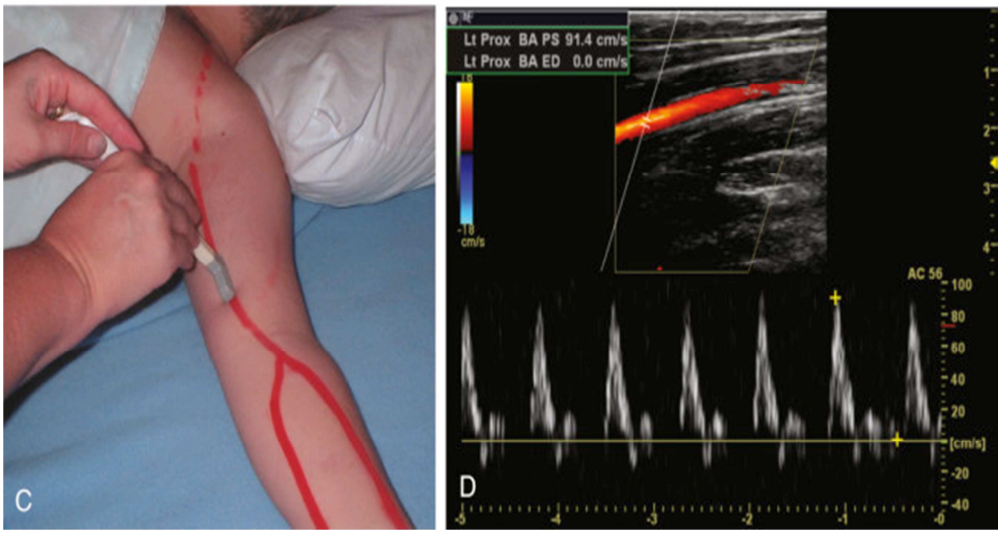

FIGURE 18 : BRACHIAL ARTERY USG ASSESSMENT

MATERIALS AND METHODS

Source of Data:

For 1year, patients between ages of 18-60 that are members of ASA I and II of either gender would undergo elective surgery in a supine position under GA at "KLE's Dr. Prabhakar Kore charitable Hospital and Medical Research Centre, Nehru Nagar, Belagavi-10."

Study Design: Observational study

Study Period: 1 year study

Sample Size: 106

Sampling technique:

Sample size at 95%confidence interval

20% tolerable error and 10% attrition

$$n = \frac{z_{1-\alpha\div 2} * SD^2}{(20\% \text{ of } SD)^2} * 100$$

$$= 105.6$$

Where $z_{1-\alpha\div 2} = 1.96$

Inclusion Criteria:

- ASA physical status I and II
- Age from 18-60y/o
- Provides consent
- Patients posted for elective surgeries under GA

Exclusion Criteria:

- All patients on vasopressor drugs to maintain MAP>65 mm Hg
- All patients who are unwilling to give consent
- All patients requiring rapid sequence intubation
- All patients undergoing emergency surgeries
- All patients experiencing extended airway instrumentation due to difficult intubation
- Presence of major peripheral vascular diseases
- All patients with increased intra-abdominal pressure
- All patients with implanted pacemaker /cardioverter
- All patients with multiple risk factors
- The institutional ethics board's approval was acquired. Written informed consent was taken.
- 106 suitable volunteers who fell into the I and II categories of the American Society of Anaesthesiologists were chosen. The research's participants underwent GA surgery and ranged in age from 18-60.
- Patients had been asked to fast day prior to surgery after meeting inclusion and exclusion criteria while providing their informed consent. BP has been monitored non-invasively pre-operatively and if baseline MAP differed by >30% compared with that of BP measurement recorded during pre-operative anesthesia visit, Inj. Midazolam 0.03mg/kg were administered and ten minutes of relaxation was granted. If the blood pressure difference was noted persistently, we excluded that patient.

- In the pre-operative waiting area, each of the study participants were subjected to ultrasonographic examination. Before performing the examination, all of the patients were awake, supine, and breathing on their own for at least five minutes.

- The inferior vena cava was observed applying low frequency curvilinear probe, a subcostal method, and paramedian long-axis view while patient remained in supine position and breathing on their own for at least 5 min. A two-dimensional image of the Inferior vena cava was obtained where it enters the right atrium. Pulse wave Doppler was utilized to distinguish between the aorta and the inferior vena cava. Scan has been conducted 2-3cm distal to right atrium, and image and breathing changes of inferior vena cava diameter have been determined with M mode. While patients were at rest, all were told to breathe normally (spontaneous breathing). During spontaneous breathing, M mode has been employed for measuring inferior vena cava's minimum and maximum diameters (dIVC min and dIVCmax), respectively. Following formula has been employed for determining collapsibility index.

- "Collapsibility Index=$(dIVCmax-dIVCmi)100dIVCmax$"

	Maximum Diameter	Minimum Diameter	Collapsibility Index
Inferior Vena cava (spontaneous breathing)			

- Brachial artery blood flow velocity was then measured via Doppler USG (4–10MHz linear array transducer). Patient had been set in supine position with transducer 5–10cm above antecubital fossa over slightly abducted arm.
- Transducer was turned to provide a transversal image of the artery after ultrasound confirmation of proper placement and arterial pulse quality. Angle Doppler was set to guarantee an angle of less than 60 degrees for accurate reading.

  Sample volume and vessel lumen has been adjusted to cover center of arterial vessel to obtain clear blood velocity trace. It was documented as the peak systolic flow velocity.
- Later the patient's legs was raised passively by an assistant for more than 45 degrees for a duration of 90 seconds and the procedure of recording brachial artery peak systolic flow velocity was repeated .
- Formula has been applied to determine percentage change in peak systolic flow velocity.
- *"Peak systolic flow velocity(passive leg raise)-peak systolic flow velocity(supine)÷peak systolic flow velocity(passiv e leg raise)*100"*
- **THE FOLLOWING OBSERVATIONS ARE NOTED :**

	PEAK SYSTOLIC FLOW VELOCITY (SUPINE)	PEAK SYSTOLIC FLOW VELOCITY (PASSIVE LEG RAISE)	% VARIATION
BRACHIAL ARTERY			

- The patients were subsequently taken to OT, where all of the regular monitors—SpO2, ECG, and NIBP were connected. The closed circle system was then used to preoxygenate the patients with 100% O2.
- Pre-medication was administered to patients using Inj. Glycopyrrolate 0.004-0.05mg/kg of midazolam, 2mcg/kg of fentanyl, and 0.006mg/kg. Inj. Thiopentone (5 mg/kg bodyweight) was used as the induction agent. Endotracheal intubation was made initiated after injecting 0.08–0.1 mg/kg of Vecuronium. Anaesthesia was sustained using 50:50 mixture of oxygen and air.
- Every 2min, non-invasive measurements of mean arterial pressure, diastolic, and systolic BP had been obtained. Crystalloid had been administered at rate of 10ml/kg/hr. Only limited stimulation in terms of skin preparation was permitted while patient had been in supine position.
- MAP less than 55mmHg or if fall in systolic/ diastolic/ MAP is more than 30% of the baseline greater than 2 minutes, despite prompt administration of fluid , was considered to have Post-induction hypotension and was managed with an IV bolus of Inj Ephedrine 5mg.
- Once the surgery started, hemodynamic data collection was stopped. Vital parameters were monitored throughout till the end of surgery.

- The following observations were noted :

TIME	SYSTOLC BP	DIASTOLIC BP	MAP
BASELINE			
INDUCTION			
2 MINUTES AFTER INDUCTION			
4 MINUTES AFTER INDUCTION			
6 MINUTES AFTER INDUCTION			
8 MINUTES AFTER INDUCTION			
INCISION			

- To maintain anaesthesia, oxygen, nitrous oxide and sevoflurane, an inhaled volatile anaesthetic, were utilized. Fluid and blood administration were done as per the requirement. Ten minutes before finishing of the procedure, application Nitrous oxide and Sevoflurane was ceased, and the patient was be ventilated using just 100% oxygen.

- After surgery, patients had been reversed with glycopyrrolate (0.01mg/kg) and neostigmine (0.05mg/kg).
- Patient have been extubated when regular spontaneous breathing pattern was observed and response to pain stimuli was garnered. The patient was then moved to the

  Recovery area.

METHODS:

Microsoft Excel and the statistical program R version 4.4.2 have been employed for analyzing data. Frequency tables representing categorical variables. Continuous variables have been represented as "Mean±SD/Median(Min,Max)". "Association in categorical variables is examined via chi square test. 'QQ plot and Shapiro-Wilk test' have been employed to validate that variable is normal. In the case that data is normally distributed, parametric testing could be employed. If otherwise, tests that aren't parametric could be employed. Whitney, 'Mann distribution of variables' over PIH is compared with U test. 'Friedman test' compares that variables are distributed across time. Post hoc analysis is performed with pairwise Wilcoxon test. The association in MAP and BA variation and CI is examined by Spearman's rank correlation test. P-value ≥0.05 denotes statistical" significance.

RESULTS

There are 106 subjects' measurements in data. Distribution of subjects based on demographic details is displayed in the table below.

Table 1: Distribution of subjects according to demographical details.

Variables	Sub Category	Number of subjects (%)
Age (years)	≤20	8 (7.55%)
	21-30	18 (16.98%)
	31-40	29 (27.36%)
	41-50	20 (18.87%)
	51-60	31 (29.25%)
	Mean ± SD Median (Min, Max)	41.08 ± 12.91 40 (18, 60)
Sex	Female	54 (50.94%)
	Male	52 (49.06%)

Participants' ages ranged from 18-60 y/o, with a mean age of 41.08±12.91 and median of 40y/o. Majority of subjects reported 51-60y/o(29.25%), followed by 31-40 (27.36%) and 41-50 (18.87%). The lowest representation was in the ≤20 years category(7.55%). In terms of sex distribution, the study included 54 (50.94%) females and 52 49.06%) males, indicating an almost equal representation of both sexes.

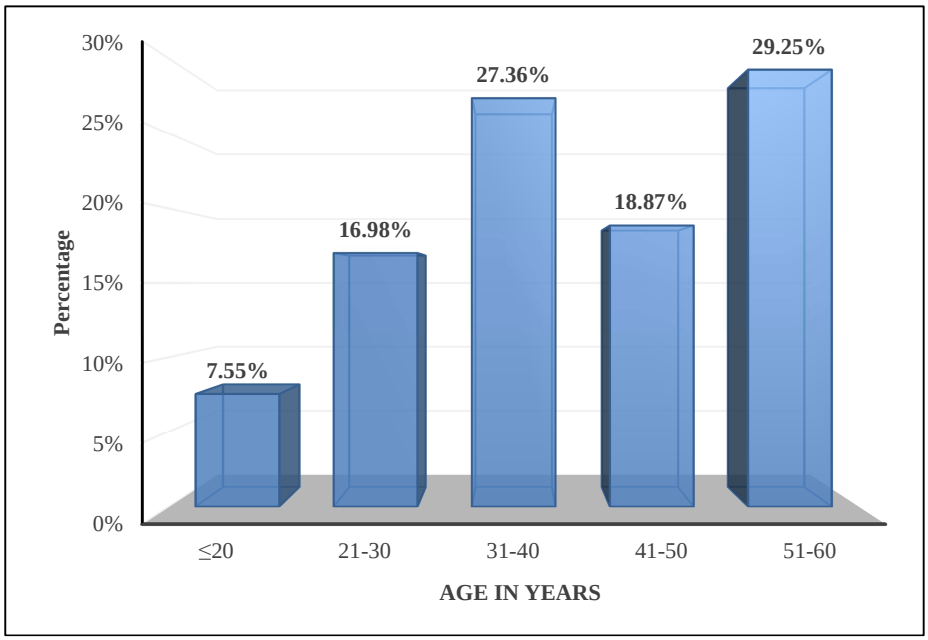

Figure 1: Distribution of patients as per age

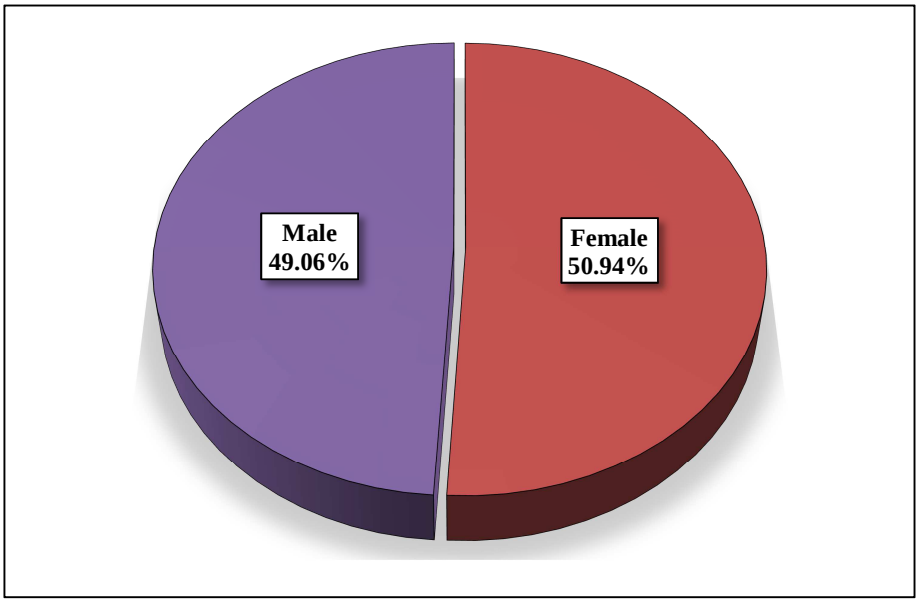

Figure 2: Distribution of patients with respect to gender

Below mentioned table gives distribution of patients as per ASA grade.

Table 2: Distribution of participants according to ASA grade.

ASA Grade	Number of subjects (%)
I	47 (44.34%)
II	59 (55.66%)

Among the participants, 47 (44.34%) were categorized as ASA Grade I and the majority, 59 (55.66%) subjects, were classified as ASA Grade II.

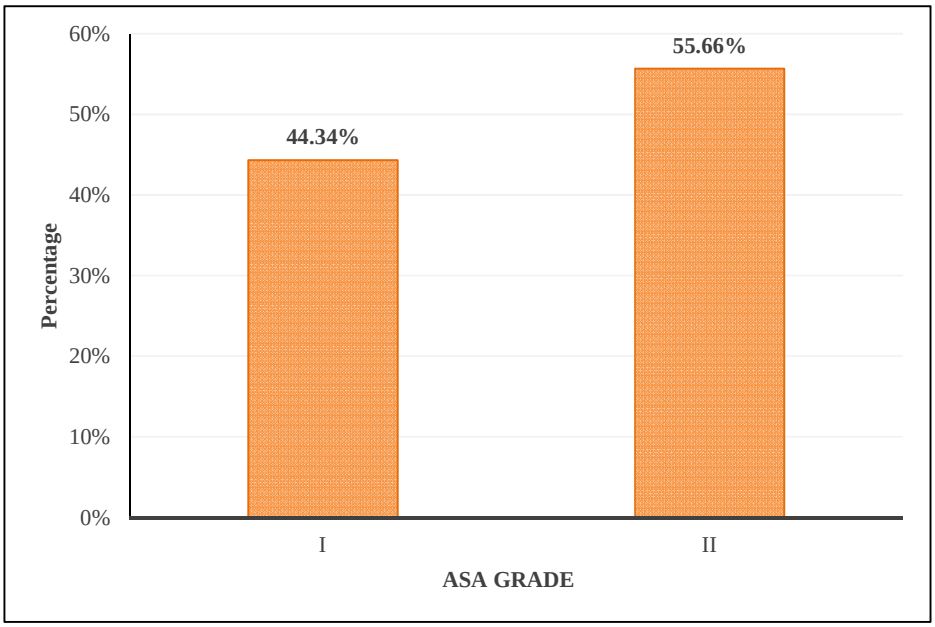

Figure 3: Distribution of subjects as per ASA grade.

Table below illustrates IVC participant distribution.

Table 3: Distribution of subjects with respect to IVC.

Variables	**Sub Category**	**IVC DIAMETER (CM)**
IVC max	Mean±SD	1.88±0.48
	Median (Min, Max)	1.92 (0.68, 2.6)
IVC min	Mean±SD	1.21±0.51
	Median (Min, Max)	1.1 (0.4, 2.22)
IVC collapsibility Index	Mean±SD	36.58 ± 18.49
	Median (Min, Max)	41.94 (2.6, 66.5)
IVC collapsibility Index	**SUB CATEGORY**	**PERCENTAGE OF SUBJECTS**
	>50%	34 (32.08%)
	≤50%	72 (67.92%)

IVC max ranging 0.68-2.6cm, with mean of 1.88±0.48cm and median of 1.92cm. IVC min ranged from 0.4-2.22cm, with mean of 1.21±0.51cm and median of 1.1cm.

The IVC collapsibility index showed a mean value of 36.58±18.49%, with a median of 41.94% (ranging from 2.6-66.5%). Based on the standard 50% threshold for assessing collapsibility, 34(32.08%) subjects had an IVC collapsibility index of more than 50%, while 72 (67.92%) subjects had a collapsibility index of 50% or less.

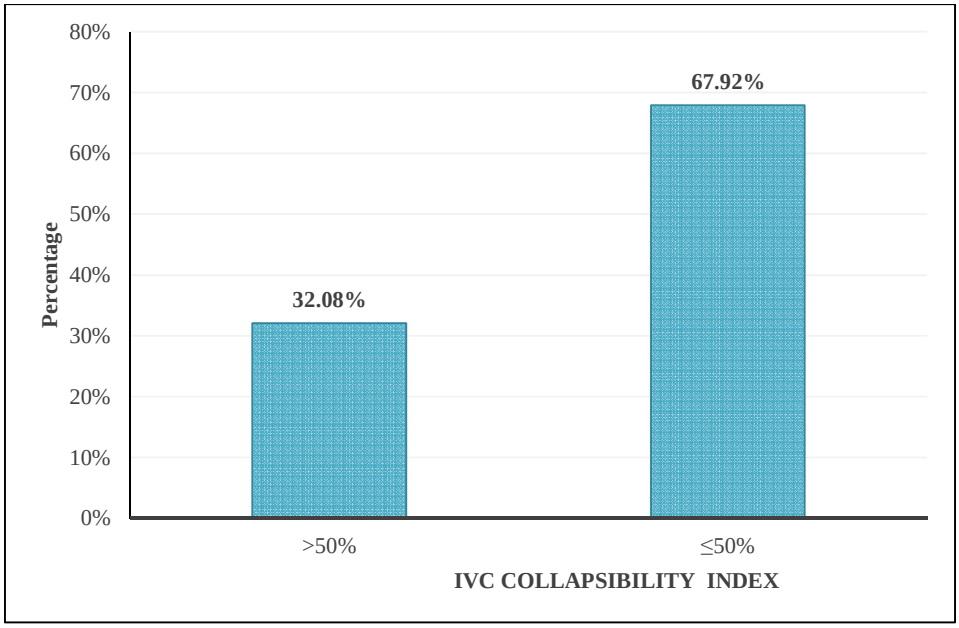

Figure 4: Distribution of participants with respect to IVC collapsibility index.

Table below displays subjects by brachial artery peak systolic flow velocity.

Table 4: Distribution of subjects according to brachial artery peak systolic flow velocity.

Variables	**Sub Category**	**Brachial artery velocity (cm/sec)**
Supine	Mean ± SD	59.8 ± 10
	Median (Min, Max)	60.2 (42.9, 83.2)
PLR	Mean ± SD	67.79 ± 9.45
	Median (Min, Max)	68.75 (47.4, 86.6)
Brachial artery velocity Variation	Mean ± SD	11.81 ± 6.95
	Median (Min, Max)	9.67 (2.7, 26.3)
Brachial artery velocity Variation	**Sub Category**	**Percentage Of Subjects**
	>10%	53 (50%)
	≤10%	53 (50%)

Mean BA in supine position has been 59.8±10, with median of 60.2(ranging from 42.9-83.2). Following PLR, mean BA increased to 67.79±9.45, with median of 68.75(ranging from 47.4-86.6).

BA variation had a mean of 11.81±6.95, with median of 9.67(ranging from 2.7-26.3).

Subjects have been evenly distributed based on 10% threshold for BA variation, with 53(50%) showing variation of more than 10%, and 53 (50%) having variation of 10% or less.

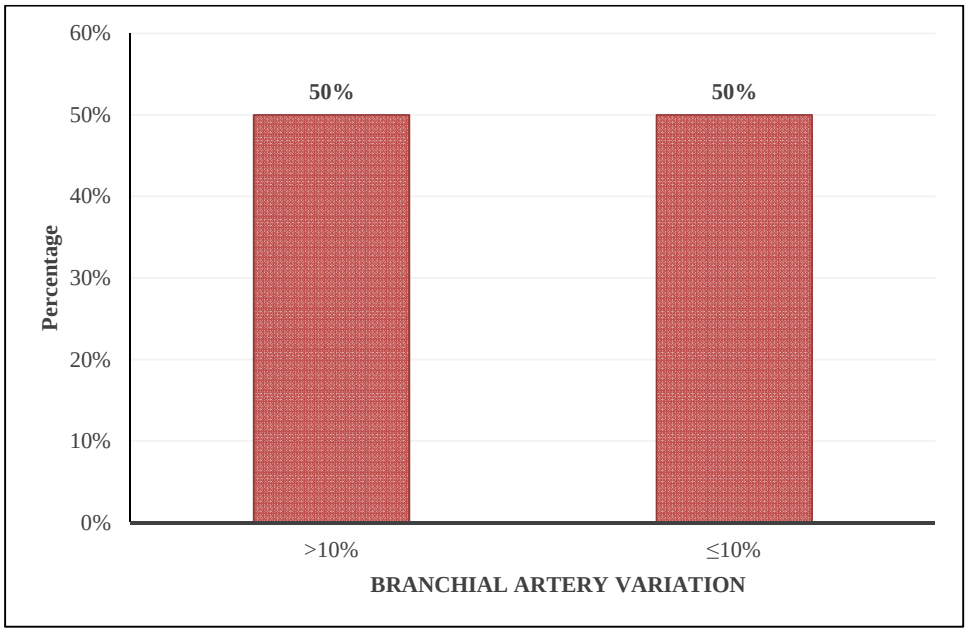

Figure 5: Distribution of participants according to Branchial Artery Variation.

Following table illustrates distribution of subjects according to PIH.

Table 5: Distribution of subjects according to PIH.

POST INDUCTION HYPOTENSION	Number of subjects (%)
No	52 (49.06%)
Yes	54 (50.94%)

Among participants, 54 (50.94%) subjects experienced PIH, while 52 (49.06%) subjects did not.

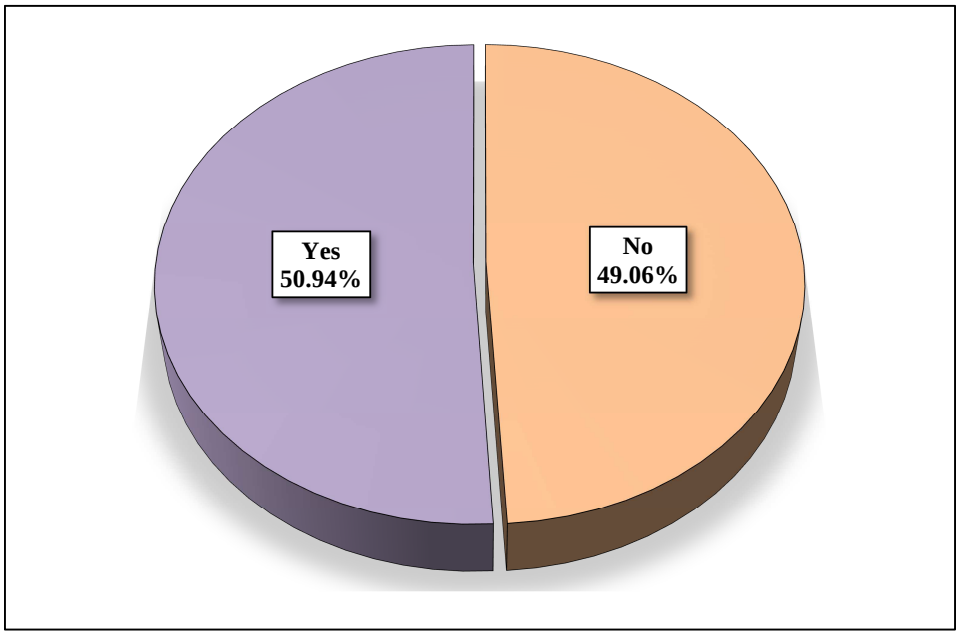

Figure 6: Distribution of subjects according to post induction hypotension.

Following table illustrates distribution of SBP at various time points.

Table 6: Distribution of SBP at time points:

Time intervals	SBP		p-value
	Mean ± SD	**Median (Min, Max)**	
Baseline	137.81±13.77	140(114, 165)	**< 0.001^{F}***
Induction	132.36±13.24	132(112, 158)	
2mins	128.5±12.27	130(112, 153)	
4mins	123.81±11.61	120(95, 149)	
6mins	118.61±13.11	115(90, 148)	
8mins	114.2±14.74	112(80, 144)	
Incision	110.07±16.2	110(77, 143)	

*Abbreviation:F–Friedman's test,*indicates statistical significance.*

Friedman's test revealed consistently significant drop in SBP upon induction, with highly significant variation in SBP (p-value<0.001) across time periods. Additionally, post hoc analysis verified that significant difference existed between baseline and every time point that followed("p-values<0.05").

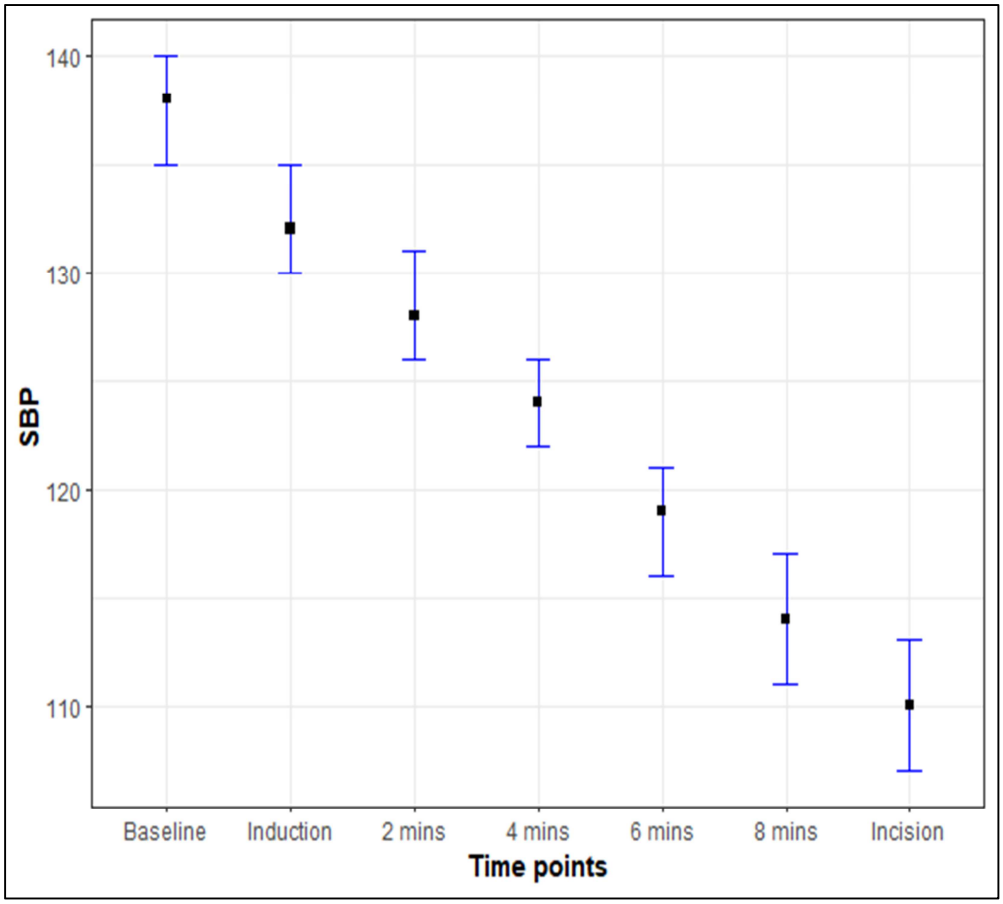

Figure 7: Mean plot of SBP over time.

Following table provides distribution of DBP over time.

Table 7: Distribution of DBP over time.

Time intervals	DBP		p-value
	Mean±SD	**Median (Min, Max)**	
Baseline	80.29±9.42	78(65, 100)	**< 0.001[F]***
Induction	78.08±9.24	76(62, 99)	
2 mins	74.49±8.68	74(60, 96)	
4 mins	72.53±8.11	74(50, 93)	
6 mins	69.29±9.51	70(50, 96)	
8 mins	66.7±10.28	68(48, 93)	
Incision	64.26 ± 10.81	62(40, 86)	

*"Abbreviation:F– Friedman's test,*indicates statistical significance".*

A constant and considerable decrease in DBP upon induction was indicated by Friedman's test, which revealed a highly significant difference in DBP (p-value < 0.001) throughout the time points. Additionally, post hoc analysis verified that there has been noteworthy distinction between baseline and each point that followed("p-values<0.05")

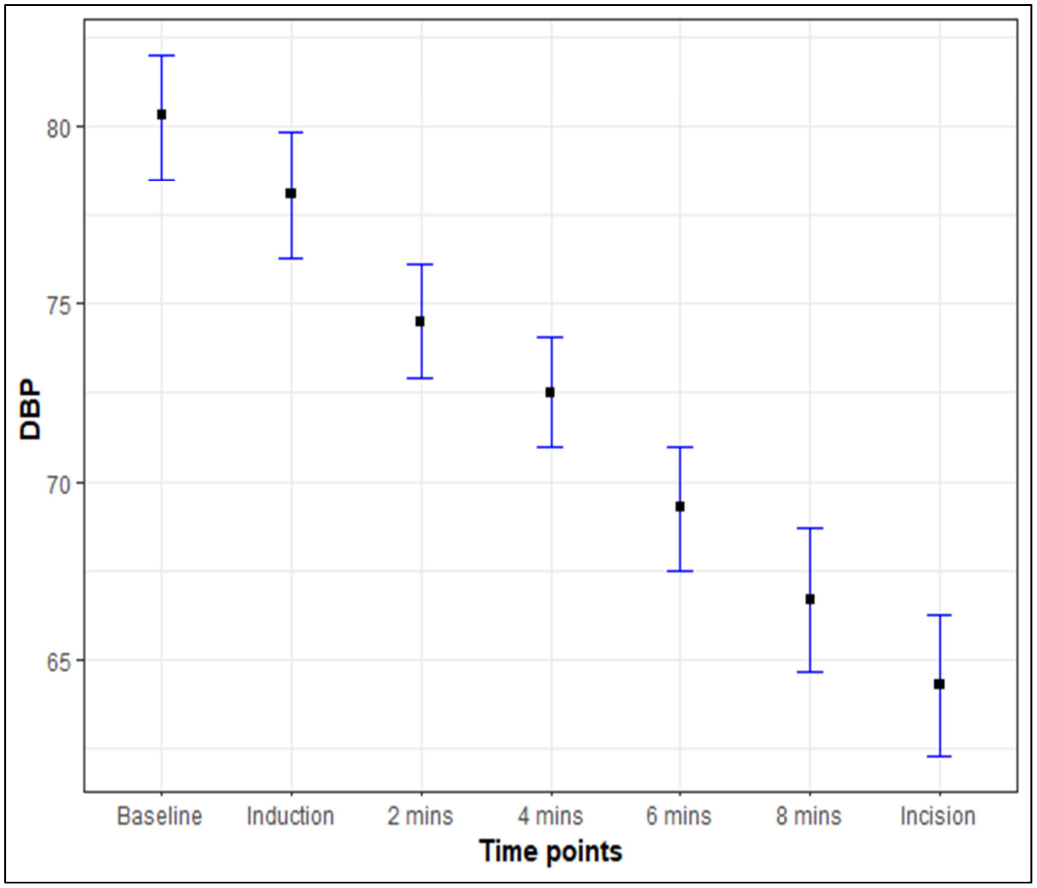

Figure 8: Mean plot of DBP over time.

Table below display distribution of MAP at different time points.

Table 8: Distribution of Mean arterial pressure over time.

Time intervals	Mean arterial pressure		p-value
	Mean ± SD	**Median (Min, Max)**	
Baseline	99.19±10.01	100(83, 121)	**< 0.001^{F}***
Induction	96.01±9.93	94(79, 118)	
2 mins	92.52±9.47	93.5(78, 113)	
4 mins	89.33±8.79	88(65, 110)	
6 mins	85.47±10.32	86(63, 113)	
8 mins	82.27±11.4	81.5(59, 110)	
Incision	79.28±12.17	78(53, 103)	

*Abbreviation: F – Friedman's test, with * denoting statistical significance..*

A constant and considerable decrease in MAP upon induction was indicated by Friedman's test, revealed significant difference in MAP ("p-value<0.001") throughout the time points. Additionally, post hoc analysis verified that there was a noteworthy distinction between the baseline and every time point in succession ("p-values<0.05").

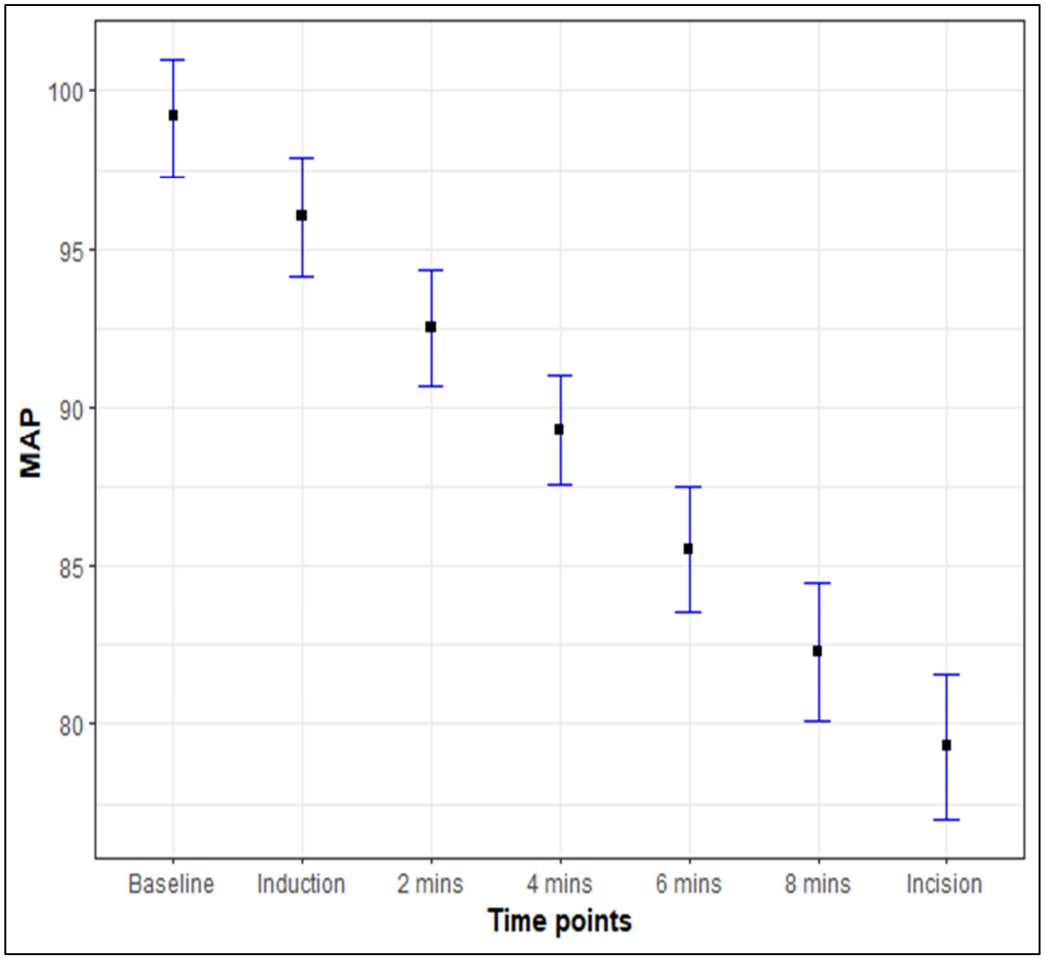

Figure 9: Mean plot of MAP at various time points

Demographic information is compared over PIH in following table.

Table 9: Comparison of demographic details over Post Induction Hypotension(PIH)

Variables	Sub Category	Post induction hypotension		p-value
		No	Yes	
Age (years)	≤20	4 (7.69%)	4 (7.41%)	0.3228[MC]
	21-30	9 (17.31%)	9 (16.67%)	
	31-40	12 (23.08%)	17 (31.48%)	
	41-50	14 (26.92%)	6 (11.11%)	
	51-60	13 (25%)	18 (33.33%)	
	Mean ± SD Median (Min, Max)	40.60 ± 12.52 42 (18, 60)	41.54 ± 13.38 39.5 (19, 60)	0.7856[MW]
Sex	Female	26 (50%)	28 (51.85%)	0.8488[C]
	Male	26 (50%)	26 (48.15%)	

"Abbreviation: C – Chi square test, MC – Chi square test with Monte Carlo simulation, MW – Mann Whitney U test".

From "Chi-square test, it is observed that age distribution between the two groups did not show a significant difference (p-value=0.3228). Further, Mann-Whitney U test revealed that overall age difference between 2 groups wasn't statistically significant (p-value=0.7856). Sex distribution nearly equal in both groups, with 50% females and 50% males in the no-PIH group, and 51.85% females and 48.15% males in PIH group, with no significant difference" (p-value=0.8488).

Following table provides comparison of ASA grade over PIH.

Table 10: Comparison of ASA grade over PIH.

ASA grade	PIH		p-value
	No	Yes	
I	22 (42.31%)	25 (46.3%)	0.6794[C]
II	30 (57.69%)	29 (53.7%)	

Abbreviation: C – Chi square test.

Chi-square test indicates that 2 groups' ASA grades didn't differ significantly (p-value=0.6794).

IVC collapsibility index is compared to PIH in the following table

Table 11: Comparison of IVC collapsibility index over PIH.

IVC collapsibility Index	PIH		p-value
	No	Yes	
>50%	0	34 (62.96%)	**< 0.001[C]***
≤50%	52 (100%)	20 (37.04%)	
Mean ± SD Median (Min, Max)	24.07 ± 13.19 21.03 (2.6, 50)	48.63 ± 14.44 52.51 (2.9, 66.5)	**< 0.001[MW]***

*"Abbreviation: C – Chi square test, MW – Mann Whitney U test, * indicates statistical significance".*

IVC collapsibility index and PIH are significantly correlated, based on Chi-square test ("p-value<0.001"). In particular, 62.96% of participants with PIH had an IVC collapsibility index exceeding 50%, but none of the subjects without PIH had an index higher than 50%. Additionally, significant difference in distribution of IVC collapsibility index between individuals with and without PIH reported by Mann-Whitney U test (p-value<0.001). Results imply that PIH incidence is substantially correlated with a greater IVC collapsibility index.

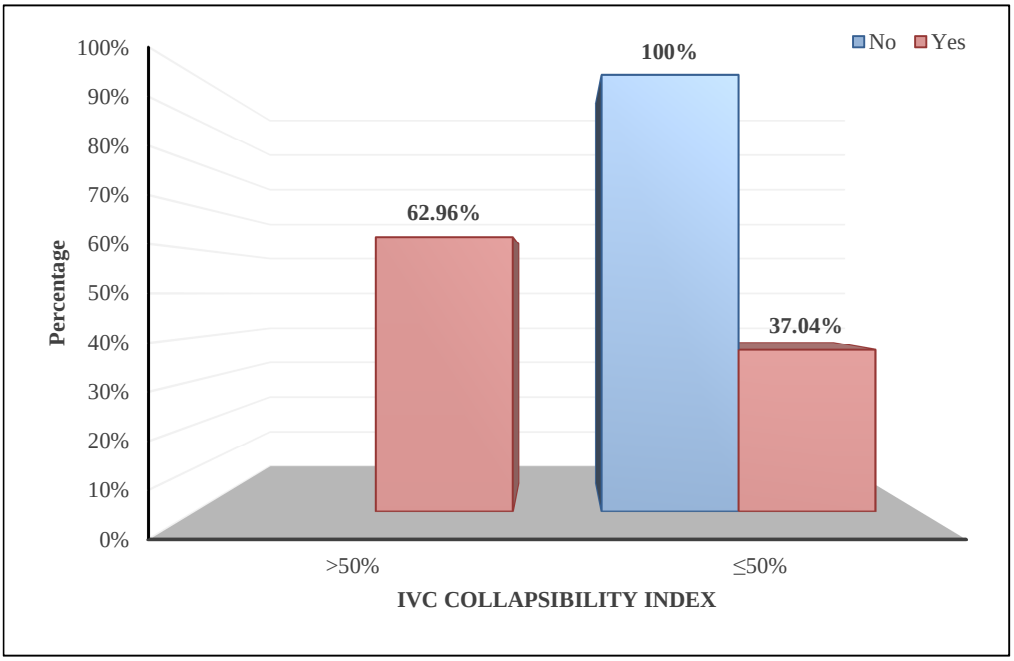

Figure 10: Distribution of IVC collapsibility index over PIH.

Following table compares Brachial artery velocity variations over PIH.

Table 12: Comparison of Brachial artery velocity variation over PIH.

Brachial artery Velocity Variation	PIH		p-value
	No	Yes	
>10%	4 (7.69%)	49 (90.74%)	**< 0.001^{C}***
≤10%	48 (92.31%)	5 (9.26%)	
Mean ± SD Median (Min, Max)	6.5 ± 2.41 6.32 (2.7, 14.4)	16.93 ± 5.98 16.7 (2.7, 26.3)	**< 0.001^{MW}***

*"Abbreviation: C – Chi square test, MW – Mann Whitney U test, * indicates statistical significance".*

Chi-square test revealed significant association between Brachial artery velocity variation and PIH (p-value<0.001). Specifically, 90.74% of subjects with PIH had Brachial artery flow velocity variation greater than 10%, compared to only 7.69% of subjects without PIH. Conversely, 92.31% of subjects without PIH had a Brachial artery flow velocity variation of 10% or less, while only 9.26% of subjects with PIH showed this lower variation.

Mann-Whitney U test further confirmed a significant difference in distribution of Brachial artery flow velocity variation in 2 groups (p-value<0.001). Mean Brachial artery flow velocity variation for those without PIH was 6.5 ± 2.41, with a median of 6.32, while the mean Brachial artery flow velocity variation for those with PIH was 16.93 ± 5.98, with a median of 16.7. These findings suggest that greater Brachial artery flow velocity variation is significantly associated with the occurrence of Post induction hypotension.

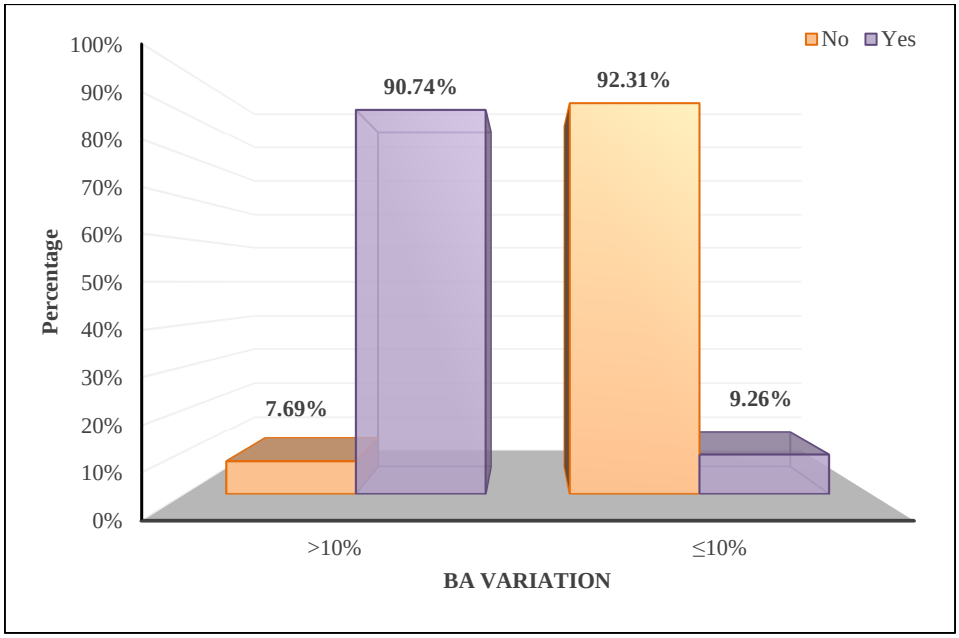

Figure 11: Distribution of Brachial artery peak systolic flow velocity variation over PIH.

Note: All subjects with an IVC collapsibility index greater than 50% had Brachial artery peak systolic flow velocity variation greater than 10%.

The following table gives the correlation of IVC collapsibility index and Brachial artery flow velocity variation with MAP at different time points.

Table 13: Correlation of IVC collapsibility index and Brachial artery (BA) flow velocity variation with MAP at different time points.

Time points	IVC collapsibility Index		BA Variation	
	Correlation coefficient	**p-value ^{SP}**	**Correlation coefficient**	**p-value ^{SP}**
Baseline	-0.2735	**0.0046***	-0.2823	**0.0034***
Induction	-0.3011	**0.0017***	-0.2951	**0.0021***
2 mins	-0.3730	**< 0.001***	-0.3987	**< 0.001***
4 mins	-0.4836	**< 0.001***	-0.4783	**< 0.001***
6 mins	-0.6110	**< 0.001***	-0.5913	**< 0.001***
8 mins	-0.6333	**< 0.001***	-0.6332	**< 0.001***
Incision	-0.6824	**< 0.001***	-0.6981	**< 0.001***

*Abbreviation: SP – Spearman's rank correlation test, * indicates statistical significance.*

IVC collapsibility index and Brachial artery peak systolic flow velocity fluctuation with MAP was found to be significantly correlated negatively at each time point , according to Spearman's rank correlation test (all p-values<0.05)

DISCUSSION

Patients undergoing general anaesthesia are prone to intraoperative hypotension that are attributed to varying causes at different stages of induction and surgery. Therefore, if ABP declines below lower limit of vascular autoregulation curve, it may result in ischaemia of essential organs. Factors implicated are lower pre-induction systolic arterial pressure, advanced age, emergency surgical procedures, spinal or epidural anaesthesia techniques, male gender, and ASA classification. [(4)]

Other factors include volatile agents and GA drugs that directly depress the myocardium which might result in post induction hypotension.

Hence, as anaesthesiologists it becomes vital to gauge the intravascular volume prior to surgery to better combat post induction hypotension.

Determining fluid responsiveness is highly essential to determine which patients will benefit from fluid loading to prevent hypoperfusion to vital organs. For predicting volume status and guide fluid management, static and dynamic parameters have developed.[(26)]

Given that they are more predictive than static measurements, dynamic parameters taking into account how respiratory changes affect BP or cardiac output have surpassed latter. [(31)]

Most dynamic parameters are however invasive in nature which has been delineated by T. Andrew Bowdle, ranging from arrhythmias, pulmonary infarction, pulmonary artery perforation from pulmonary artery catheterisation, pneumothorax, exsanguinating hemorrhage from accidental puncture of veins and arteries, catheter and air embolism, infections from central access.[(32)]

Dincer Yildizdas, Nagehan Aslan have asserted the relevance of ivc collapsibility index as a dynamic parameter in predicting hypotension as IVC "is highly sensitive to fluid changes and varies in size depending on respiratory changes under intrathoracic pressure". USG guided POCUS can easily, quickly and non-invasively assess the fluid status in a radiation-free manner at bedside. (33)

However, Matthew J. Kaptein , Elaine M. Kaptein have explained conditions where IVC diameters and indices are unreliable such as severe tricuspid regurgitation, rheumatic valvular heart disease which may increase IVC max, intra-abdominal hypertension which may lead to "abdominal pain or distention, an open chest or abdomen, postoperative surgical dressings, bowel gas, subcutaneous emphysema that may result in suboptimal visualization, IVC distension, masses causing external compression, venous thrombosis, or large extracorporeal membrane oxygenation catheters" that may change vena caval physiology and morbid obesity.(34)

We investigated IVC collapsibility index in a patient that breathed on their own and compared it with brachial artery peak systolic flow velocity variation with passive leg elevating to overcome aforementioned limitations of IVCCI and predict post-induction hypotension.

Gregory A Schmidt further substantiated the use of hand-held USG device in non-invasive monitoring of brachial artery and its peak systolic flow velocity variation which mirrored the respiratory alterations in BP measured via radial artery catheter as "radial artery pulse pressure variation quite precisely predicts fluid responsiveness, with value >10% being both sensitive and specific (95% and 95%)". Primary need for this study was to establish a new non invasive parameter since IVC

and other dynamic parameters require a regular cardiac rhythm, patient on mechanical ventilation with tidal volume higher than usual and most modalities are invasive.[35]

Garcia et al. concluded that ΔVpeakbrach is a non-invasive bedside tool that can specifically guide fluid management in emergency department or in CCU for hemodynamically unstable patients after receiving little guidance in brachial artery doppler measurement. Additionally, it could identify preload reliance in patients on passive mechanical ventilation without requirement for arterial catheterization.[10]

We initiated a one-year hospital-centered observational investigation in the anesthesiology department at KLE's Dr Prabhakar Kore Hospital and Medical Research Centre, including 106 adult patients aged 18-60.

Our research attempts to evaluate brachial artery peak systolic flow velocity and IVC collapsibility index with passive leg to predict hypotension post-GA induction.

52 of 106 patients in current research had been male, accounting for 49.06% of total population, while 54 of patients had been female, representing 50.94%.

Participants' age groups remained similar. Majority of participants have been in the 51–60 age group, with mean age being 41.08y/o, with minimum age of 19 and a maximum age of 60.

59 patients belonged to ASA II category as opposed to 47 patients in ASA I category.

During spontaneous breathing, the average inferior vena cava minimum and maximum diameters were 1.21 cm and 1.88 cm, respectively, with IVC collapsibility index showing a mean value of 36.58±18.49%, with 34(32.08%) subjects exhibiting

IVC collapsibility index of >50%.Similar study was conducted by Nadia Rose et al where IVCmin and IVCmax were 1.11cm and 1.93cm respectively and significant hypotension was observed at a cutoff of 37% for IVCCI.[13]

In the present study, we analysed brachial peak systolic flow velocity in supine position and with passive leg raising, mean values being 59.8 cm/second and 67.79 cm/second respectively. A concurrent increase in brachial artery peak systolic flow velocity was seen after passive leg raise.

Brachial artery variation had a mean of 11.81cm/second with 53 patients (50%) having velocity variation of >10%.

Our research corresponds with Garcia et al.'s prospective clinical trial of 38 mechanically ventilated patients with severe circulatory disorders in a 17-bed multidisciplinary CCU.A 500 mL colloid was utilized for volume expansion. ΔVpeakbrach has been calculated by dividing difference between greatest and lowest Vpeakbrach readings over one respiratory cycle by the mean of the two values. FloTrac/Vigileo system (ΔSVVigileo) has been employed for monitoring fluctuation in stroke volume and ΔPPrad. At baseline, responder patients had considerably greater levels of ΔVpeakbrach, ΔPPrad, and ΔSVVigileo than nonresponder patients [14vs.8%; 18vs.5%;13vs.8%;P<0.0001, respectively]. ΔPPrad, Vpeakbrach, and ΔSVVigileo all showed declines due to expansion of volume, with mean values of 8.58%, 6.95%, and 9.33%, respectively. ΔVpeakbrach value above 10% proposed fluid responsiveness with "sensitivity of 74% and specificity of 95%, with positive and negative predictive values of 93% and 78%," respectively.[10]

In current research, we didn't administer exogenous fluids . Rather, we utilised passive leg raising in our study to mimic an endogenous fluid challenge. Legs were lifted from the horizontal plane in a lying patient at 45 degrees for 90 seconds in order to induce a gravitational shift in blood flow to the central compartment from the lower body.

Jihad Mallat's prospective multicenter research, that has been conducted in 11 ICU around France with patients suffering from severe heart failure on mechanical ventilation, has validated the value of passive leg lift. Their objective had been to determine if "changes in pulse pressure caused by passive leg elevating could be employed in predicting fluid responsiveness in patients receiving mechanical ventilation. An increase in CI of >15%" with volume loading was considered as fluid responsiveness. A total of 164 patients (60.7%) were identified as fluid responders. At baseline, fluid responders had significantly larger pulse pressure variation and much lower cardiac and stroke volume indices than fluid non-responders (10%,1.9L/min/m2 and 23L/min/m2 respectively). Passive leg raising induced significant increases in CI and stroke volume index(2.3 L/min/m^2 and 28L/min/m^2) and decreased the absolute and relative pulse pressure variation(6%). ΔPPVPLR, ΔCIPLR and ΔSVIPLR values were found to be significantly correlatable ($P<0.001$). When predicting fluid responsiveness, AUC for change in SVI based on by PLR and ΔPPV remained 0.90 and 0.92, respectively. Thus, PLR was effectively demonstrated to be a non-invasive prediction method for fluid responsiveness in individuals suffering from acute circulatory failure. [20]

In the present study, 54 patients (50.94%) experienced post induction hypotension.

At the point of induction, the systolic blood pressure displayed a highly significant p value of less than 0.001, with significant difference between baseline and time intervals of 2,4,6,8min, incision. Mean SBP at baseline was calculated to be 137.81mmHg with fall in mean SBP of 110.07mmHg at the time of incision .

Similar findings were seen with diastolic BP, with significant difference in DBP across time points after induction and extremely significant p-value >0.001, with mean DBP at baseline being 80.29mmHg and lowest at incision time being 64.26mmHg .

In current research, MAP at point of induction illustrated p-value < 0.001which was highly significant as per Friedman's test, and post hoc analysis confirmed a reduction in MAP values after induction till incision across all time points, with mean baseline MAP being 99.19mmHg and maximum fall in mean value of MAP being 79.28mmHg.

From Chi Square test, it was demonstrated that there was no statistical significance over age distribution (p value=0.3228) , gender (p-value=0.8488) and ASA status (p-value=0.6794) in our research.

However, a significant association determined between IVC collapsibility index and PIH (p-value<0.001) in our research with 62.96% of subjects with PIH having an index greater than 50% suggesting that a higher IVC collapsibility index is significantly associated with PIH occurrence.

Also, 90.74% of subjects with PIH had a brachial artery velocity variation greater than 10%, has been statistically significant (p-value<0.001). Mean Brachial artery variation for those without PIH was 6.5% while mean Brachial artery variation

for those with PIH was 16.93%, confirming that greater Brachial artery variation is significantly associated with the occurrence of post induction hypotension.

In our study, All subjects with an IVC collapsibility index greater than 50% had brachial artery velocity variation of more than 10%.

According to the Spearman's rank correlation test, the IVC collapsibility index and BA fluctuation with MAP at all time points have a significant negative connection (all p-values < 0.05).

However, there are a few limitations in our study :

Our study doesn’t include ASA III and IV patients who require invasive haemodynamic monitoring and intravascular volume status monitoring is essential.

CONCLUSION

We conclude that both brachial artery peak systolic flow velocity variation with passive leg raises and IVC collapsibility index are equally effective in predicting post induction hypotension post-induction of GA.

SUMMARY

In our study , we assessed IVC collapsibility index and brachial artery peak systolic velocity variation with passive leg raise preoperatively in ASA 1 and 2 patients alongwith their baseline blood pressure readings. Intra operatively , BP monitoring was done at intervals of 2min, 4 min , 6 min , 8 min and incision.

If MAP were less than 55mmHg or if fall in systolic/ diastolic/ MAP was more than 30% of the baseline, they were deemed to have post induction hypotension.

In the present study , we encountered 34(32.08%) subjects with having an IVC collapsibility index of more than 50% and 53(50%) showing variation of more than 10% in brachial artery peak systolic velocity.

Among a total of 106 participants, 54 (50.94%) subjects experienced PIH. A constant and considerable decrease in MAP was indicated by Friedman's test upon induction. It revealed a significant difference in MAP ("p-value<0.001") throughout the time points.

Our results further revealed that 62.96% of participants with PIH had an IVC collapsibility index exceeding 50%, but none of the subjects without PIH had an index higher than 50%, with significant correlation (p value <0.001).

Additionally , 90.74% of subjects with PIH had Brachial artery flow velocity variation greater than 10% (p-value<0.001). All subjects with an IVC collapsibility index greater than 50% had Brachial artery peak systolic flow velocity variation greater than 10%.

From our study we can conclude that IVC collapsibility index and brachial artery peak systolic flow velocity fluctuation were found to be significantly correlated negatively at each time point with MAP, according to Spearman's rank correlation test (all p-values<0.05).

Hence , we can utilise both IVC collapsibility index and brachial peak systolic flow velocity variation with passive leg raise in safely predicting intra operative hypotension in a non invasive manner.

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ANNEXURES

ANNEXURE – I - INFORMED CONSENT FORM

"A comparative study of inferior vena cava collapsibility index and brachial artery peak systolic flow velocity variation with passive leg raising in predicting hypotension after induction of general anaesthesia.**"**

Name of Student/Principal Investigator:

Name of Guide/Co Investigators:

Introduction: General anaesthesia is often associated with fall in blood pressure which can cause adverse events such as MI, stroke and acute kidney injury leading to extended hospital stay

Patient's volume status prior to general anaesthesia can have an effect on intra operative hypotension.

Ultrasonography is a useful non-invasive tool to predict intravascular volume and has no complications. In this study , we will assess IVC collapsibility index and brachial artery peak systolic flow velocity and determine which of the either is a better predictor of fall in Intra operative BP .

Explanation of procedure: If you agree to participate in my study , we will perform USG on your abdomen and at your arm to assess Inferior vena cava and brachial artery respectively just prior to operation.

Later , during the operation , we will monitor your blood pressure to correlate the findings with our pre operative readings.

Withdrawal from participation in the study: Participation in this study in voluntary. You will be free to decide whether to participate in this study or continue

participation once enrolled. In case you decide to withdraw your participation, you are free to do so. However, please convey the decision to the principal investigator.

Possible benefits from participating in the study: You will/will not get any benefits by participating in this study. The data gathered will help population at large.

Possible risks from participating in the study: There are no risks involved in participating in this study .

Privacy and confidentiality: The information collected from you will be coded, to prevent any person to identify you. Your identity will never be revealed. The data collected from you will be kept confidential and only processed or aggregated data will be used for publication.

Financial incentives: You will not receive any payment for participating in this study.

Cost of investigations done during the course of study will be paid by the **principal investigator / Participant.** (Strike out which is not applicable)

Authorization for publication of aggregated data: Results obtained after processing of the aggregated data will be published for scientific purpose and or presented to scientific groups.

However, your identity will never be revealed.

Questions: In case of any questions with regard to this study, you are free to contact:

If you have any question or complaints with regard to your right as study participant you may contact Dr Harsha Hegde, Chairperson, Ethical committee of JNMC, 0831-2473777 Extension 4052.

Legal rights: By signing this consent form, we are not waiving any of your legal rights

CONSENT STATEMENT

I am making a voluntary decision to participate in the study " **A comparative study of inferior vena cava collapsibility index and brachial artery peak systolic flow velocity variation with passive leg raising in predicting hypotension after induction of general anaesthesia**.". My signature below indicates that I have decided to participate and I have read the information provided above or the information provided above has been read to me in the language that I understand best. I was given the opportunity to ask questions and that they have been answered to my satisfaction.

Name of the participant:

Signature or left thumb impression of the participant:

Name of the witness:

Signature or left thumb impression of the witness:

Name of the investigator:

Signature of the investigator:

ANNEXURE II

PROFORMA

" A comparative study of inferior vena cava collapsibility index and brachial artery peak systolic flow velocity variation with passive leg raising in predicting hypotension after induction of general anaesthesia."

Name	:	Age	:
Gender	:	Weight	:
Height	:	Date of Examination	:
Address	:	Occupation	:

Pre examination evaluation

Past History

- HTN ☐ DM ☐ IHD ☐ Arrhythmia ☐ Valvular heart diseases ☐
- H/o previous surgery/(s) where airway difficulty was encountered. Yes ☐ No ☐

General physical examination

Weight (Kg)	:	Temperature (^{0}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 ☐

The following observations will be noted:

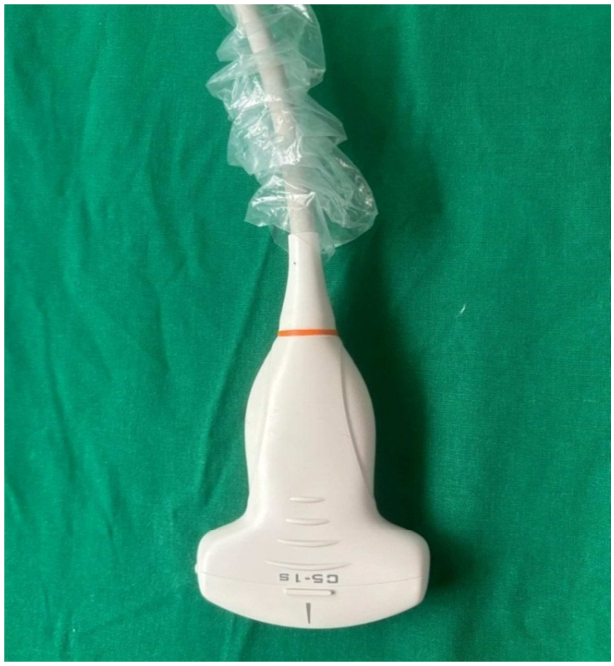
	Maximum Diameter	Minimum Diameter	Collapsibility Index
Inferior Vena cava (spontaneous breathing)			

	PEAK SYSTOLIC FLOW VELOCITY (SUPINE)	PEAK SYSTOLIC FLOW VELOCITY (PASSIVE LEG RAISE)	% VARIATION
BRACHIAL ARTERY			

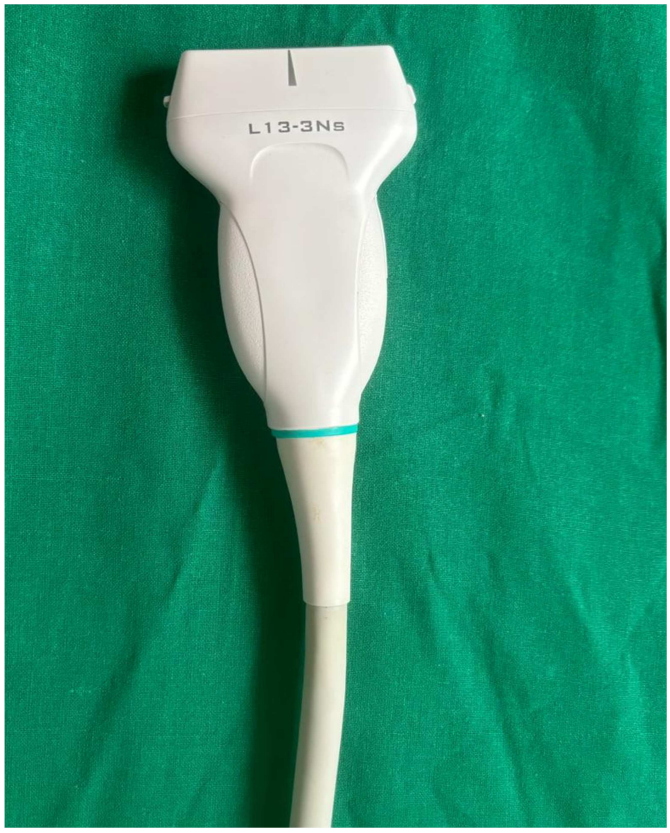
TIME	SYSTOLIC BP	DIASTOLIC BP	MAP
BASELINE			
INDUCTION			
2 MINUTES			
4 MINUTES			
6 MINUTES			
8 MINUTES			
INCISION			

ANNEXURE III PHOTOGRAPHS

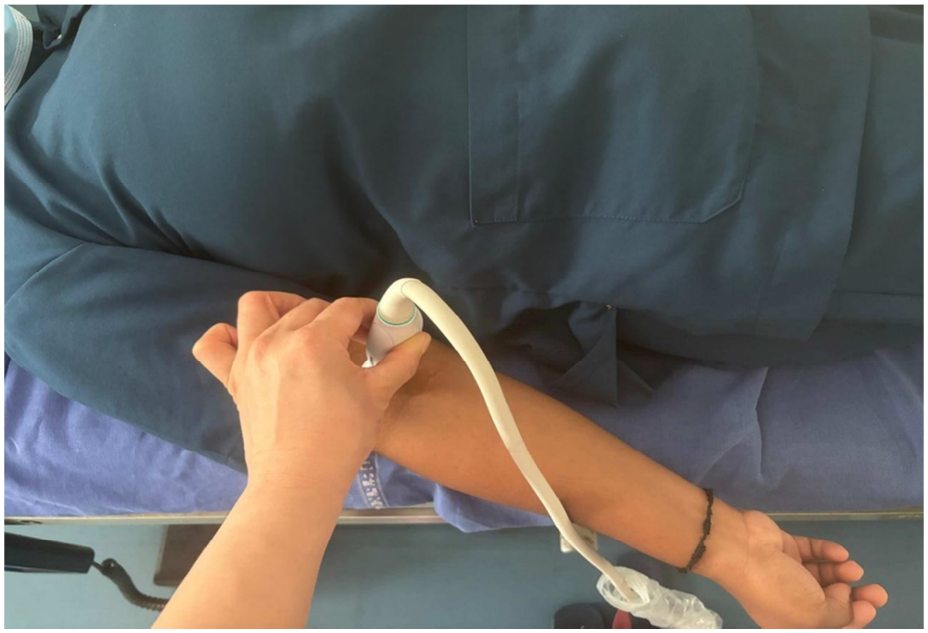
PICTURE 1 : USG MACHINE



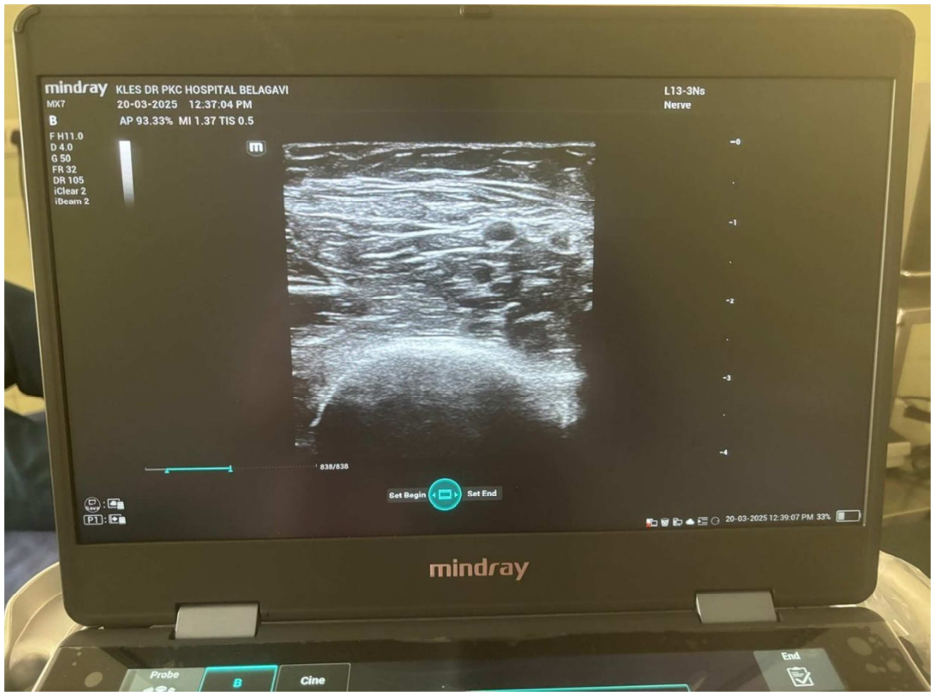
PICTURE 2 : CURVILINEAR PROBE



PICTURE 3 : LINEAR PROBE

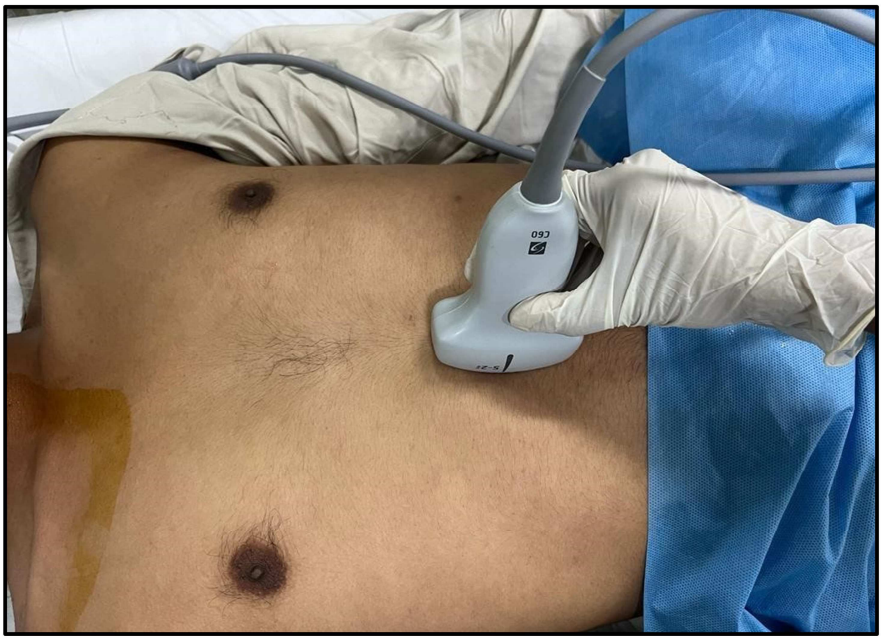


PICTURE 4 : BRACHIAL ARTERY ULTRASOUND ASSESSMENT

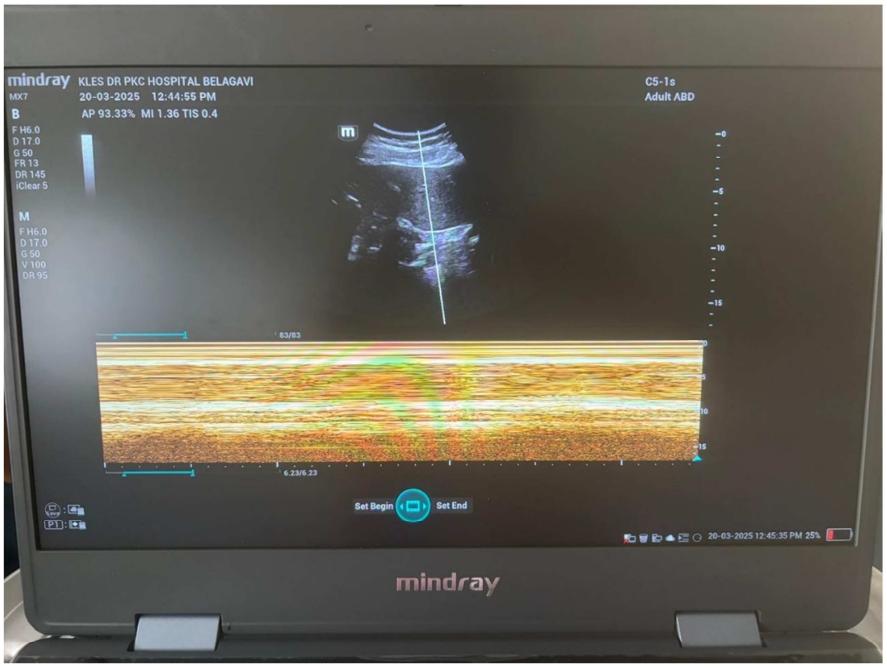


PICTURE 5 : BRACHIAL ARTERY (B MODE)

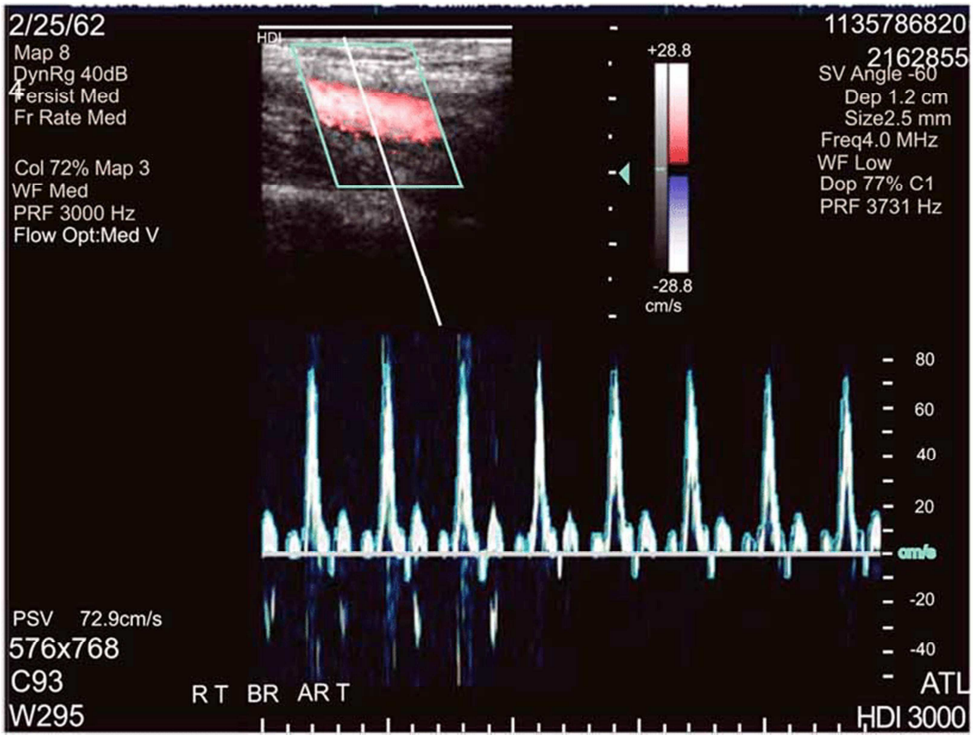
PICTURE 6 : PASSIVE LEG RAISE



PICTURE 7 : INFERIOR VENA CAVA ON SPONTANEOUS BREATHING



PICTURE 8 : INFERIOR VENA CAVA (M MODE)



PICTURE 9 : BRACHIAL ARTERY (DOPPLER MODE)

ANNEXURE IV- MASTER CHART

					IVC			BA			SYS/DIAS (MAP)						
Si No.	Age	Sex	Ip No.	ASA Grade	IVC (Max)	IVC (Min)	IVC (Index)	Supine	PLR	VARIATION	Baseline S/D(MAP)	INDUCTION	2 MIN	4 MIN	6 MIN	8 MIN	INCISION
1	60	M	10096015	II	2.5	1.3	48	65	70	7.14	128/78(95)	118/74(89)	116/74(87)	114/70(85)	112/68(82)	110/64(80)	110/62(78)
2	59	M	10096958	I	2.6	1.2	53	68	80	15	140/80(100)	136/78(97)	128/74(92)	120/70(86)	110/60(76)	100/55(70)	85/50(61)
3	49	F	10097160	II	1.7	1	41.17	55	60	8.33	120/70(86)	118/70(86)	116/68(84)	114/66(82)	114/64(80)	112/62(78)	110/62(78)
4	55	F	10096998	II	1.5	1.1	26.6	53	55	3.6	124/80(94)	120/78(92)	118/76(90)	118/74(88)	114/72(86)	112/70(84)	112/70(84)
5	42	F	10096784	I	2.5	1.1	56	60	72	16.6	146/78(100)	132/76(94)	130/74(94)	120/72(88)	110/72(84)	108/68(81)	100/60(73)
6	54	M	10095192	I	2.4	1.2	50	60	78	23.07	122/70(87)	116/68(84)	114/62(79)	110/60(76)	100/58(72)	100/55(70)	100/50(67)
7	60	M	10097249	II	2.6	1.1	57.6	62	77.6	20.1	142/80(100)	130/78(95)	124/70(88)	116/68(84)	110/64(79)	100/60(73)	96/68(77)
8	60	M	10097211	I	1.7	0.8	52.9	55	69.3	20.6	130/70(90)	120/68(85)	115/64(81)	110/60(76)	100/55(70)	95/50(65)	90/50(63)
9	19	F	10097223	I	1	0.5	50	60.2	70.5	13.19	120/65(83)	118/64(82)	116/62(80)	116/60(79)	114/60(78)	114/60(78)	112/58(76)
10	25	F	10096892	II	1.5	1.2	20	55	60	8.3	140/88(105)	138/86(103)	136/80(99)	133/78(96)	130/77(94)	128/76(93)	124/70(88)
11	60	M	10094626	II	2.02	1.05	48.01	66.3	79.6	16.7	146/78(100)	132/76(94)	130/74(94)	120/72(88)	110/72(84)	108/68(81)	100/60(73)
12	56	F	10096776	II	1.58	1.2	24.05	50	56	10.71	120/65(83)	118/64(82)	116/62(80)	116/60(79)	114/60(78)	112/58(76)	95/50(65)
13	44	F	10095160	I	2.35	2.05	12.7	74.4	80.3	7.34	120/70(86)	118/70(86)	116/68(84)	114/66(82)	114/64(80)	112/62(78)	110/62(78)
14	26	F	10096813	II	1.3	0.5	61.53	62	78.8	21.31	130/70(90)	120/68(85)	115/64(81)	110/60(76)	100/55(70)	95/50(65)	90/50(63)
15	47	F	10094599	II	2.35	2.02	14.04	60.2	64.2	6.2	124/80(94)	120/78(92)	118/76(90)	118/74(88)	114/72(86)	112/70(84)	112/70(84)
16	34	F	10098018	II	2.24	0.93	58.4	50.4	66.4	24.09	122/70(87)	116/68(84)	114/62(79)	110/60(76)	100/58(72)	100/55(70)	100/50(67)
17	54	M	10098077	I	2.41	1.9	21.16	72.6	78.2	7.16	140/88(105)	138/86(103)	136/80(99)	133/78(96)	130/77(94)	128/76(93)	124/70(88)
18	37	F	10098025	II	2.45	1.97	19.59	68.4	70.3	2.7	124/80(94)	120/78(92)	118/76(90)	118/74(88)	114/72(86)	112/70(84)	112/70(84)
19	48	F	10098053	II	1.98	1.06	46.4	60.2	70.4	14.4	120/65(83)	118/64(82)	116/62(80)	116/60(79)	114/60(78)	114/60(78)	100/60(73)

20	39	F	10098102	II	1.71	0.88	48.5	57	69.3	17.7	130/70(90)	120/68(85)	115/64(81)	110/60(76)	100/55(70)	95/50(65)	90/55(65)
21	40	F	10098149	I	2.49	2.02	18.8	77.1	80.2	3.8	124/80(94)	120/78(92)	118/76(90)	118/74(88)	110/64(79)	100/60(73)	96/68(77)
22	40	M	10098149	I	1.7	0.8	52.9	50.2	68.2	26.3	122/70(87)	116/68(84)	114/62(79)	112/68(82)	110/60(76)	100/55(70)	85/50(61)
23	25	F	10098152	II	2.35	2.02	12.7	50.4	66.4	24.09	140/88(105)	138/86(103)	136/80(99)	133/78(96)	118/74(88)	114/72(86)	112/70(84)
24	19	F	10098013	I	1	0.5	50	50	56	10.7	124/80(94)	120/78(92)	118/76(90)	118/74(88)	114/60(78)	114/60(78)	100/60(73)
25	49	F	10098006	II	1.5	1.2	20	60.2	64.2	6.2	140/88(105)	132/76(94)	130/74(94)	124/80(94)	122/70(87)	122/70(87)	120/65(83)
26	32	F	10097824	I	2.24	0.93	58.4	62	78.8	21.31	140/88(105)	138/86(103)	130/74(94)	116/68(84)	110/64(79)	100/60(73)	100/60(73)
27	19	M	10098110	II	1.98	1.06	46.4	50.2	68.2	26.3	146/78(100)	138/86(103)	133/78(96)	128/76(93)	118/74(88)	112/70(84)	110/62(78)
28	37	M	10098469	I	2.49	2.02	18.8	68.4	70.3	2.7	140/88(105)	132/76(94)	120/72(88)	118/74(88)	115/64(81)	114/62(79)	114/60(78)
29	56	F	10098422	I	2.06	2	2.9	68	70.3	3.2	146/78(100)	132/76(94)	124/70(88)	122/70(87)	116/68(84)	114/62(79)	114/62(79)
30	34	F	10098018	II	1.84	1.66	9.7	77.1	80.2	3.8	140/88(105)	138/86(103)	136/80(99)	133/78(96)	130/77(94)	128/76(93)	124/70(88)
31	48	F	10098119	II	2.23	2.01	9.8	60.2	64.2	6.2	124/80(94)	120/78(92)	118/76(90)	118/74(88)	114/72(86)	112/70(84)	112/70(84)
32	35	M	10098421	II	2.37	1.57	33.7	74.4	80.3	7.34	122/70(87)	116/68(84)	114/62(79)	114/60(78)	112/58(76)	110/64(79)	110/60(76)
33	46	F	10098450	II	1.84	1.15	37.5	62.2	66.3	6.1	124/80(94)	120/78(92)	118/76(90)	114/72(86)	112/70(84)	112/70(84)	110/60(76)
34	35	F	10098155	I	1.72	0.8	53.4	60.2	70.4	14.4	130/70(90)	120/68(85)	116/60(79)	114/60(78)	100/55(70)	95/50(65)	90/50(63)
35	28	F	10098461	II	2.48	2.11	14.9	60.2	64.2	6.2	124/80(94)	120/78(92)	118/76(90)	118/74(88)	110/64(79)	100/60(73)	96/68(77)
36	42	F	10098150	I	0.97	0.5	48.4	50	56	10.7	120/65(83)	118/64(82)	116/62(80)	116/60(79)	114/60(78)	100/55(70)	100/50(67)
37	40	F	10098014	I	1.79	1.62	9.49	74.4	80.3	7.34	154/76(102)	148/76(100)	140/74(96)	137/70(92)	135/70(91)	130/68(87)	128/64(85)
38	51	F	10099301	II	1.4	1	28.57	60.2	64.2	6.2	140/74(96)	137/70(92)	136/80(99)	133/78(96)	130/77(94)	128/76(93)	124/80(94)
39	35	F	10098865	II	2.11	1.03	51.18	50.4	66.4	24.09	155/90(112)	146/88(107)	140/86(104)	135/80(98)	124/77(92)	120/70(87)	116/67(83)
40	60	M	10099305	II	1.94	1.55	20.1	77.1	80.2	3.8	140/88(105)	138/86(103)	136/80(99)	133/78(96)	122/70(87)	124/77(92)	120/70(87)
41	38	M	10099276	II	1.8	1.01	43.88	60.2	70.4	14.4	124/80(94)	120/78(92)	118/76(90)	118/74(88)	114/60(78)	114/60(78)	100/60(73)
42	34	F	10098967	II	2.43	1.02	58.02	50.2	68.2	26.3	146/78(100)	132/76(94)	124/70(88)	118/74(88)	112/68(82)	110/60(76)	100/55(70)
43	30	M	10099073	II	1	0.5	50	50	56	10.71	124/80(94)	120/78(92)	128/76(93)	124/80(94)	100/60(73)	100/55(70)	85/50(61)
44	19	F	10099012	II	1.72	0.8	53.4	60	78	23.07	154/76(102)	148/76(100)	140/74(96)	133/78(96)	118/74(88)	114/72(86)	114/60(78)
45	40	M	10099967	II	2.6	1.1	57.6	50.3	68.2	26.3	140/88(105)	132/76(94)	120/72(88)	110/64(79)	100/60(73)	100/55(70)	100/55(70)
46	24	M	10099930	I	1.52	1.02	32.89	77.1	80.1	3.8	150/96(114)	149/96(114)	143/94(110)	140/90(107)	135/90(105)	128/86(100)	126/85(99)

47	20	M	10100043	I	2.4	1.8	25	65	70	7.14	132/76(94)	124/70(88)	122/70(87)	120/70(87)	120/70(87)	114/60(78)	112/60(77)
48	27	F	10100029	I	1.14	0.4	64.91	60.2	70.5	13.19	147/96(113)	144/93(110)	148/76(100)	120/78(92)	118/64(82)	116/62(80)	112/70(84)
49	60	M	10100015	II	1.58	0.97	38.6	74.4	80.3	7.34	154/76(102)	148/76(100)	138/86(103)	136/80(99)	135/83(100)	130/80(96)	128/86(100)
50	43	M	10098652	I	2.01	1.01	49.7	50	56	10.71	120/65(83)	118/64(82)	116/62(80)	118/74(88)	114/72(86)	112/70(84)	110/60(76)
51	31	M	10100003	II	1.66	1.2	27.7	74.4	80.3	7.34	140/88(105)	138/86(103)	136/80(99)	133/78(96)	130/77(94)	128/76(93)	124/70(88)
52	40	F	10100005	I	1.94	1.82	6.18	60.2	64.2	6.2	140/88(105)	138/86(103)	136/80(99)	133/78(96)	132/77(94)	128/76(93)	124/70(88)
53	28	M	10100033	II	1.82	1.4	23.07	55.3	60	7.83	154/76(102)	148/76(100)	140/74(96)	133/78(96)	130/77(94)	128/76(93)	124/80(94)
54	34	M	10098705	I	2.12	1.1	48.11	44.6	55	18.9	140/88(105)	138/86(103)	136/80(99)	133/78(96)	118/74(88)	114/72(86)	112/70(84)
55	25	F	10099052	I	1.88	0.9	52.12	48.2	55.01	12.3	147/96(113)	144/93(110)	128/76(93)	124/80(94)	118/74(88)	112/68(82)	110/60(76)
56	45	M	10103840	II	1.6	1.22	23.7	56.6	60.5	6.44	118/70(86)	116/68(84)	114/66(82)	112/70(84)	112/70(84)	110/60(76)	110/64(79)
57	18	M	10103561	I	2.5	1.67	33.2	66.8	70.4	5.11	140/88(105)	132/76(94)	130/74(94)	128/76(93)	124/80(94)	123/82(95)	122/80(94)
58	34	F	10103795	I	2.06	0.69	66.5	43.7	54	19.07	122/70(87)	116/68(84)	114/62(79)	100/60(73)	100/55(70)	80/55(63)	77/55(62)
59	23	M	10103801	I	1.59	1.36	14.4	77.1	80.02	3.64	165/100(121)	158/99(118)	153/90(111)	147/88(107)	145/80 (101)	142/80(100)	140/77 (98)
60	24	M	10103824	I	0.86	0.68	20.9	69.5	75	7.33	154/76(102)	148/76(100)	140/74(96)	137/70(92)	136/80(99)	135/83(100)	130/80(96)
61	51	F	10103203	I	2.48	2	19.3	72.8	77	5.45	140/88(105)	136/80(99)	133/78(96)	128/76(93)	124/80(94)	120/65(83)	118/64(82)
62	30	M	10103874	II	2.42	1.1	54.54	60.2	70.5	13.19	124/80(94)	120/78(92)	118/76(90)	118/74(88)	114/60(78)	107/55(72)	100/48(65)
63	52	M	10102840	I	1.92	1.1	42.7	58.8	64	8.12	148/76(100)	140/88(105)	136/80(99)	132/76(94)	130/74(94)	132/76(94)	123/82(95)
64	42	M	10103958	II	1.21	1	17.35	77.3	80.4	3.8	165/100(121)	158/99(118)	153/90(111)	148/76(100)	148/76(100)	138/86(103)	136/80(99)
65	31	F	10103170	II	2.45	1.97	19.59	65	70	7.14	150/96(114)	149/96(114)	146/78(100)	148/76(100)	147/96(113)	138/86(103)	136/80(99)
66	48	M	10102816	I	1	0.5	50	50	56	10.71	154/76(102)	148/76(100)	140/74(96)	124/80(94)	118/74(88)	110/60(76)	110/64(79)
67	31	F	10102845	I	2.23	2.01	9.8	60.2	64.2	6.2	133/78(96)	130/74(94)	122/70(87)	123/82(95)	114/72(86)	112/68(82)	110/64(79)
68	46	F	10102506	II	1.5	1.2	20	64.2	70.2	8.5	132/76(94)	124/70(88)	122/70(87)	120/70(87)	118/74(88)	114/72(86)	114/60(78)
69	26	F	10102761	II	1.5	1.1	26.6	70.2	76.4	8.11	165/100(121)	155/92(113)	153/90(111)	149/86(107)	145/80 (101)	140/77 (98)	136/80(99)
70	40	F	10102877	I	1.88	0.9	52.12	62	78.8	21.31	122/70(87)	116/68(84)	114/62(79)	112/68(82)	110/60(76)	100/55(70)	85/50(61)
71	37	F	10102806	II	1.4	1	28.57	58.5	66.2	11.6	138/86(103)	130/74(94)	133/78(96)	118/74(88)	112/70(84)	110/64(79)	110/60(76)
72	44	M	10103142	II	1.94	1.55	20.1	60.9	64.4	8.5	155/92(113)	151/90(110)	149/86(107)	143/84(103)	140/79(99)	139/77 (97)	136/75(95)

73	38	F	10102810	I	1.88	0.9	52.12	50.4	66.4	24.09	130/70(90)	120/68(85)	115/64(81)	110/60(76)	100/55(70)	80/55(63)	77/55(62)
74	60	M	10102641	II	2.02	1.05	48.01	60.2	70.4	14.4	130/70(90)	120/68(85)	114/60(78)	112/70(84)	100/55(70)	95/50(65)	90/50(63)
75	40	M	10103110	I	2.35	2.02	14.04	65.7	70.7	7.07	154/76(102)	148/76(100)	147/96(113)	144/93(110)	138/86(103)	136/80(99)	133/78(96)
76	58	F	10102769	II	1.92	1.1	42.7	47.3	50.9	7.07	124/80(94)	120/78(92)	118/76(90)	118/74(88)	122/70(87)	118/74(88)	114/60(78)
77	59	F	10103179	II	2.5	1.1	56	55.5	64.4	13.8	116/68(84)	114/62(79)	112/70(84)	110/64(79)	100/55(70)	95/50(65)	77/55(62)
78	36	M	10102602	II	1.4	1	28.57	66.4	70.3	5.54	155/92(113)	153/90(111)	151/90(110)	149/86(107)	148/76(100)	140/79(99)	138/86(103)
79	30	M	10103151	I	2.14	2.02	5.6	51.76	53.5	3.25	154/76(102)	148/76(100)	149/86(107)	143/84(103)	140/79(99)	136/80(99)	133/78(96)
80	51	M	10103154	II	2.27	2.11	7.04	48.2	51.2	5.8	165/100(121)	158/99(118)	153/90(111)	148/76(100)	147/96(113)	144/93(110)	143/84(103)
81	43	F	10100117	II	1	0.5	50	60	72	16.6	154/76(102)	148/76(100)	140/74(96)	123/82(95)	118/74(88)	115/64(81)	110/60(76)
82	60	M	10102093	I	2.15	0.92	57.2	50.4	66.4	24.09	130/74(94)	122/70(87)	115/64(81)	110/60(76)	100/55(70)	80/55(63)	77/55(62)
83	60	F	10103269	II	1.47	1.11	24.48	59.03	62.2	5.09	148/76(100)	140/88(105)	136/80(99)	132/76(94)	130/74(94)	128/76(93)	124/80(94)
84	60	M	10102908	II	2.5	1.3	48	50.45	56.6	10.8	149/86(107)	145/80 (101)	132/76(94)	130/74(94)	122/70(87)	112/68(82)	110/60(76)
85	56	F	10109883	I	0.68	0.4	41.1	56.35	58.2	3.17	155/92(113)	151/90(110)	146/78(100)	137/70(92)	136/80(99)	135/83(100)	135/83(100)
86	59	M	10109503	II	1.75	1.5	14.28	83.2	86.6	4.15	140/88(105)	138/86(103)	136/80(99)	133/78(96)	130/77(94)	128/76(93)	124/70(88)
87	20	F	10107263	II	2.26	1.01	55.3	48.2	55.01	12.3	147/88(107)	145/80 (101)	130/70(90)	122/70(87)	115/64(81)	112/68(82)	110/60(76)
88	45	M	10109803	I	1.74	1.32	24.13	59.76	63.2	5.44	140/74(96)	137/70(92)	136/80(99)	133/78(96)	130/77(94)	128/76(93)	124/80(94)
89	44	F	10109850	I	1.66	1.07	35.54	78.3	83.3	6	154/76(102)	148/76(100)	138/86(103)	136/80(99)	135/83(100)	130/80(96)	128/86(100)
90	53	F	10108600	II	1.43	0.53	62.93	43.7	54.02	19.07	163/100(121)	154/97(116)	150/94(112)	143/90(107)	130/77(94)	126/74(91)	124/73(90)
91	20	M	10109351	I	2.48	2.03	18.14	53.29	58.1	8.2	120/70(86)	118/70(86)	116/68(84)	114/66(82)	114/64(80)	112/62(78)	110/62(78)
92	60	M	10109644	II	1.25	0.51	59.2	42.9	54	21.34	122/70(87)	116/68(84)	114/62(79)	110/60(76)	100/58(72)	100/55(70)	100/50(67)
93	56	F	10110144	I	2.29	2.09	8.73	43.3	47.4	8.64	140/88(105)	136/80(99)	133/78(96)	128/76(93)	124/80(94)	120/65(83)	118/64(82)
94	53	M	10110069	I	1.54	0.64	58.44	43.6	53.3	18.19	150/96(114)	149/96(114)	143/94(110)	130/74(94)	122/70(87)	115/64(81)	110/60(76)
95	58	M	10110045	II	2.24	2.18	2.6	74.4	80.3	7.34	154/97(116)	150/94(112)	140/74(96)	137/70(92)	136/80(99)	135/83(100)	133/78(96)
96	21	F	10110489	I	1.83	0.81	55.7	43.9	52.3	16.06	124/80(94)	120/78(92)	118/76(90)	118/74(88)	114/60(78)	107/55(72)	100/48(65)
97	25	M	10110476	I	2.4	2.22	7.5	68.4	70.3	2.7	140/88(105)	138/86(103)	136/80(99)	133/78(96)	130/77(94)	128/76(93)	124/70(88)
98	30	M	10121989	II	1.88	0.9	52.12	60.2	70.5	13.19	146/78(100)	132/76(94)	130/74(94)	120/72(88)	114/62(79)	110/60(76)	95/50(65)

99	44	M	10122122	I	2.11	1.03	51.18	66.3	79.6	16.7	155/90(112)	146/88(107)	140/86(104)	122/70(87)	115/64(81)	112/68(82)	110/60(76)
100	60	M	10121831	II	2.15	0.92	57.2	43.7	54	19.07	118/76(90)	118/74(88)	114/60(78)	107/55(72)	100/55(70)	95/50(65)	77/55(62)
101	44	M	10121929	II	1.92	0.76	60.41	50.4	62.6	19.48	120/65(83)	118/64(82)	116/62(80)	116/68(84)	114/62(79)	100/60(73)	95/50(65)
102	26	F	10121276	II	0.95	0.67	58.5	44.8	53.4	16.1	114/72(86)	112/70(84)	112/70(84)	110/60(76)	100/55(70)	80/55(63)	77/55(62)
103	39	F	10120849	II	2.1	2.02	3.8	83.1	86.6	4.15	154/76(102)	148/76(100)	140/74(96)	137/70(92)	136/80(99)	135/83(100)	130/80(96)
104	39	F M	10120802	II	0.99	0.45	54.54	53.8	66.3	18.85	146/78(100)	132/76(94)	130/74(94)	120/72(88)	110/72(84)	108/68(81)	100/60(73)
105	59	M	10121136	I	1.2	0.55	54.16	60.02	78	23.07	122/70(87)	116/68(84)	114/62(79)	95/50(65)	90/50(63)	82/48(59)	80/40(53)
106	34	M	10122160	I	1.76	0.87	50.56	60.2	72.3	16.7	155/92(113)	151/90(110)	146/78(100)	124/80(94)	122/70(87)	114/62(79)	110/60(76)