

MEASUREMENT OF INFERIOR VENA CAVA PARAMETERS IN THE NORMAL ADULT INDIAN POPULATION USING TRANSABDOMINAL ULTRASOUND: A STANDARDISATION STUDY

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ABSTRACT

BACKGROUND

The study was undertaken with a view to determine various inferior vena cava (IVC) parameters such as diameter in inspiration, in expiration, the mean diameter, and the collapsibility index using transabdominal ultrasound (TAS), and thus define the normal range of values for Indian population and derive nomogram values. The study was also undertaken to highlight the variations in the IVC parameters in accordance with various determinants such as age, gender, height, weight, body surface area and body mass index in the study group.

METHODS

105 patients comprising of healthy Indian subjects were included in the study. The hepatic portion of the IVC was scanned with ultrasound in axial cross section. The anteroposterior diameter was measured in maximum inspiration and expiration placing the callipers from "inner to inner" wall. The mean diameter and the collapsibility index were then calculated. The resultant data was analysed using student's t test, t test and ANOVA. A 'p value' of less than 0.05 was considered significant.

RESULTS

Males had significantly higher collapsibility index than the females. Maximal IVC diameters were found in males in the age group of 21 to 30 years, and this was statistically significant with respect to mean IVC diameter and IVC diameter on expiration. In general, across all age groups, the IVC diameter in males was found to be higher. IVC parameters did not show any statistically significant variations with changes in the body surface area or body mass index.

CONCLUSIONS

TAS is a reliable, cost effective modality to monitor and measure IVC parameters. Variations in IVC parameters across age, gender, height, weight, etc. have been documented. "Nomogram chart of IVC parameters" has been derived for the Indian population and may serve as a standing reference.

KEYWORDS

IVC Diameter, Ultrasound, IVC Doppler, IVC nomogram, Collapsibility Index, IVC Nomogram.

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INTRODUCTION: The inferior vena cava (IVC) is a dynamic vascular structure that changes its calibre in accordance with the respiratory cycle of the subject reflecting the increase and decrease in the intrathoracic pressure associated with normal respiration. IVC also reflects the haemodynamic status of the subject and undergoes changes in calibre with respect to the hydration/intravascular volume status of the patient.

IVC can be visualised satisfactorily by various imaging modalities like Magnetic Resonance Imaging (MRI), Computed Tomography (CT), Ultrasonography (USG) and

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Colour Doppler Imaging, Digital subtraction venography (DSV) and Nuclear Scintigraphy. Transabdominal ultrasound is the most cost effective, dynamic, relatively accurate, and easily performed study to measure diameter and the collapsibility index of IVC.

The measurement of IVC diameters (IVCD) by transabdominal ultrasound is commonly undertaken for various reasons. Assessment of haemodynamic status in trauma patients who present with blood loss and hypotension is possible by observing the IVC diameter and a decision to start intravascular volume replacement can be made.^(1,2) Hypovolaemic shock, especially in the paediatric population secondary to acute diarrhoea or sepsis is evidenced by the significantly smaller diameter of the IVC at rest. The ratios of IVC to aorta diameters are lower in patients with dehydration.⁽³⁾ IVC measurements serve as an indirect measure of right atrial pressure^(4,5,6) and central venous pressure.⁽⁶⁾

Respiratory variation of IVC diameter is less in patients with congestive cardiac failure compared to patients with euvolaemic dyspnoea.⁽⁷⁾ Ultrasonography of the inferior vena cava (IVC) represents a cost effective and a valid clinical tool to assess the effectiveness of diuretic therapy in patients with chronic congestive heart failure.⁽⁸⁾

Respiratory change in IVC diameter is an accurate predictor of fluid responsiveness in septic patients.⁽⁹⁾ IVC parameters can accurately predict eccentric left ventricular hypertrophy in Continuous Ambulatory Peritoneal Dialysis (CAPD) patients.

Patients with cirrhotic livers are found to have rigid IVCs that are less prone to calibre change during the normal phases of respiration.⁽¹⁰⁾ Studies have been undertaken that have taken in to account the non-variability of IVC calibre during respiration to diagnose cirrhosis of the liver in chronic alcoholics. Thus, cirrhosis induced stiffness of the hepatic parenchyma and the resultant reduction in collapsibility of the hepatic portion of IVC could possibly be used as a sonographic sign for the diagnosis of cirrhosis.

IVC normally increases in size significantly during pregnancy secondary to hormonal influence and plasma expansion.⁽¹¹⁾ Failure of the IVC to enlarge has been linked with foetal compromise and studies have been undertaken to prove this association.⁽¹²⁾

IVC measurements are used in monitoring of dialysis patients and help prevent over hydration in continuous ambulatory peritoneal dialysis patients.⁽¹³⁾ IVC serial measurements also prevent IV volume overload in patients on prolonged IV fluids.

IVC measurements are important in interventional vascular radiology for placement of an appropriate IVC filter and for the liver transplant surgeon.

Despite multiple studies that demonstrate the clinical utility of IVC measurements, values for the diameter/collapsibility index etc. of the IVC have not been standardised for any particular population/racial sub-group. This has created a big lacuna in clinical decisions which incorporate IVC measurements in them.

Krause et al of the Tel Aviv University, Israel⁽¹³⁾ in the course of their study of the IVC diameters as a useful method of fluid estimation in children on haemodialysis, rightly observe that "One of the major obstacles is a lack of normal values for IVCD in adults and in children. In a study of 86 healthy adults, the diameter of IVC varied widely (range 1.3–2.8 cm) and did not correlate with height, weight or body surface area".

To the best of our knowledge, only three studies have been undertaken to delineate the parameters of IVC in normal population. Some of those studies have been performed on cadavers and not on a living population.⁽¹⁴⁾ This study has been undertaken to define the nomogram values of IVC parameters in the normal Indian population.

AIM AND OBJECTIVES: To assess TAS as a modality to monitor and measure IVC parameters. To document/highlight variations in IVC parameters across age, gender, height, weight, body surface area, body mass index,

etc. To derive the "Nomogram chart of IVC parameters" for Indian population.

MATERIALS AND METHODS: The number of people included in the study group were 105. The study period was from May 2008 to August 2009, spanning a time interval of 1 year and 3 months. Informed consent was obtained from all the patients participating in the study and permission for the study was obtained by the hospital ethics committee. The study was designed to arrive at the normal parameters of IVC measurement values in the Indian population and to highlight the variations in the parameters if any, and hence strict inclusion and exclusion criteria were enforced.

Inclusion Criteria: The study group was drawn predominantly from normal, asymptomatic patients who presented for the purposes of routine general health checkup. The study was performed at Sri Ramachandra Medial College and Research Institute, Sri Ramachandra University, Porur, Chennai. The study group was drawn from both the sexes and encompassed a wide socioeconomic range. IVC varies in diameter and parameters in various pathological states. Thus, extensive history taking and scrutiny of the old clinical records of the patient was resorted to identify potentially abnormal patients and to exclude them from the study. The overall hydration of the patient was also taken into consideration. The patients included in the study were the ones who had refrained from drinking water or other liquids, since two hours prior to their ultrasonic examination.

Exclusion Criteria: Patients who were excluded were those who were below 18 years of age, non-Indian nationals, pregnant females, hypertensives, recent blood donors and patient who had pre-existing cardiac illness, medical renal disease, liver cirrhosis/hepatic failure, a recent bout of acute diarrhoeal illness/vomiting due to gastroenteritis and hypovolaemia due to trauma. Patients on prolonged IV fluids, on diuretic therapy for cardiac failure/hypertension or on Haemodialysis or Continuous Ambulatory Peritoneal Dialysis were also excluded. Dilated IVC was a common echocardiographic finding in top level elite athletes⁽¹⁵⁾ probably due to adaptation of an extra-cardiac structure to chronic strenuous exercise. Hence, exclusion of such patients was done through careful history taking.

A commercial ultrasound machine (Aloka Prosound 5500) with a curvilinear probe of 3.5 MHz frequency was used to scan all the study subjects. The subjects were placed in the supine position with the couch being horizontal, and the hepatic portion of the IVC was scanned in the subxiphoidal view. This view is employed in all the patients so as to ensure that the portion of the hepatic IVC measured in all the patients remains the same. This view gives us the axial cross section of the IVC. The anteroposterior diameter of the IVC is measured (Fig. 1) in maximum inspiration (IVCDi) and expiration (IVCDe). The calliper placement for measuring the diameter is placed from "inner to inner" wall.

Long axis views of the IVC are not employed for lack of reproducibility. The mean diameter of the IVC (IVCDm) was calculated as the average of IVCDi and IVCDe.

Collapsibility index (CI) was calculated using the formula:

$$\text{Collapsibility Index} = \frac{\{IVCDe - IVCDi\} \times 100}{IVCDe}$$



Fig. 1: Transabdominal Ultrasound of the Intrahepatic Portion of Inferior Vena Cava in Inspiration and Expiration

Collected data were analysed using Statistical Packages for Social Sciences (SPSS) program 11.0 version for Windows. Analysis tests used in this study were student's t test, t test and ANOVA (Analysis of Variance). A p value of less than 0.05 was considered significant. The t test was used to evaluate the changes of parameters' values after inspiration and expiration. Student's t test was used to evaluate the differences of parameters' values between genders. ANOVA was used to evaluate the differences of parameters' values between age groups. Statistical analysis revealed that there was no significant association between the age and sex of the patients (p = 0.204). Hence, it is clear that the study has not drawn more of the study sample from any particular age group or gender, thus rendering the study as statistically viable.

RESULTS AND OBSERVATION: We scrutinised the demographic details of the study group chosen for this study and moved further to examine the observations and trends made in the study population with reference to the IVC parameters. We then tried to ascertain whether these trends were statistically significant enough to suggest a global prevalence in the general population. Variations which were not statistically significant were also highlighted and the reasons behind them were hypothesised. Thus, the entire study was analysed from physiological, clinical, and statistical points of view and conclusions were drawn.

A total number of 105 patients were included in this study (Fig. 2). The total males in the study comprised of some 42 patients (40%). The total females of the study

group comprised of some 63 patients (60%). The maximum percentage of the study group belonged to the 21 to 30-year age group interval (30.5%), followed by 31 to 40-year and 41 to 50-year age group intervals (21.0% each respectively). Thus, the majority of the study group comprised of a predominantly young and middle aged populace with just over 79% of the study population being under the age of 50. The females were more than the males in all the age group intervals except below 20 years and above 60 years.

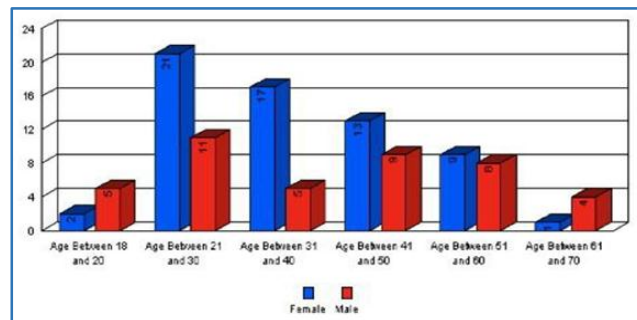


Fig. 2: Age Group and Gender wise Distribution of Total Study Population

In the height wise break-up of the demographics, the bulk of the study group (42.9%) fell under the height interval of 151 to 160 centimetres with over 69% falling under the height interval of 151 to 170 centimetres (Fig. 3A). This emphasised that the height of the average Indian hovers around the 160 cm mark. In the weight wise demographic break-up, over 82% of the study group fell under the weight interval of 41 to 70 Kg (Fig. 3B).

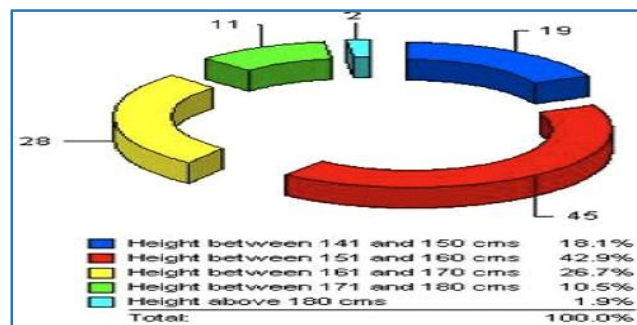


Fig. 3A: Height Interval wise Distribution of Total Study Population

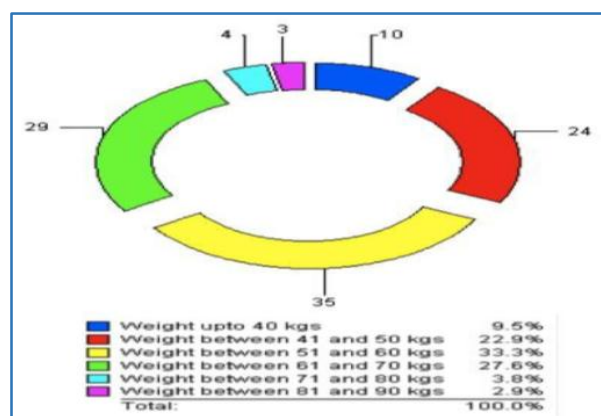


Fig. 3B: Weight wise Distribution of Total Study Population

Analysing the population break-up for factors like Body surface area (BSA) and Body mass index (BMI) which take both the height and weight into consideration, all the subjects with a BSA of greater than 2.000 were males and all the subjects with a BSA of less than 1.400 were females probably reflecting the height and the weight differences prevalent between the genders (Fig. 4A).

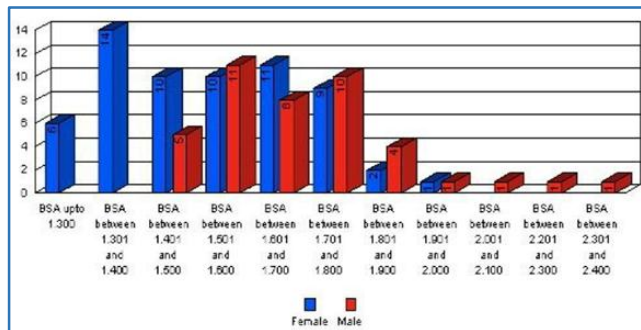


Fig. 4A: BSA (in M2) and Gender wise Distribution of Total Study Population

Taking into consideration the BMI wise study population break-up, we find that up to 8% of the subjects were grossly obese with a BMI of greater than 29.00 (6 females and 2 males). The study population with a significantly lower BMI (less than 17.00), comprised of 10.5% of the total study group, quite a remarkable chunk of the entire study population, and in this low BMI group, the females were more (8 in number) as compared to the males (3 in number) reflecting that a lower BMI is prevalent more in females (Fig. 4B).

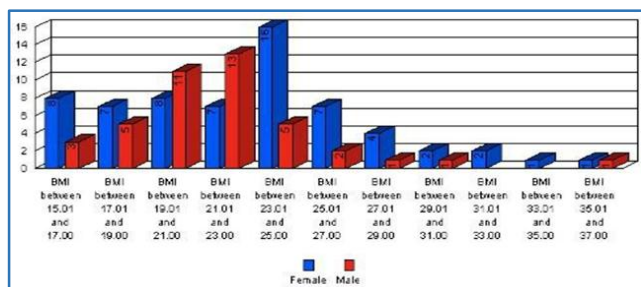


Fig. 4B: BMI and Gender wise Distribution of Total Study Population

The nomogram charts of IVC parameters (IVCDi, IVCDe, IVCDm and Collapsibility Index) were tabulated separately for males and females in accordance with the age group intervals (Table 3 and 4).

The collapsibility index was averaged for different age group intervals with gender break-up and the trends were noted (Fig 5A). In all the age group intervals barring the 41 to 50 years age group, the males had a collapsibility index that was markedly higher than the females. This finding was found to be statistically significant ($p = 0.036$) and could be explained by the fact that males on the whole have larger total lung capacities than the female and their ability to generate differences in intrathoracic pressure with each inspiration and expiration, is larger than that of the females.

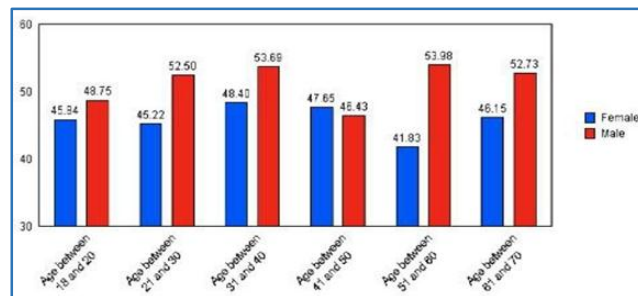


Fig. 5A: Age Group and Gender wise Averaged Collapsibility Index (%)

The absence of this trend in the 41 to 50 years age group could at least partially be explained by the prevalence of chronic obstructive pulmonary disease in the males of this population. It is to be noted that emphysema/ obstructive airway disease, was not used as a criterion for exclusion. There was no significant difference (males $p = 0.583$, females $p = 0.935$) between the collapsibility index and the age group intervals of the study population. The collapsibility index did not show any significant trend when distributed according to the BSA or BMI of the study population (Fig. 5B and 5C).

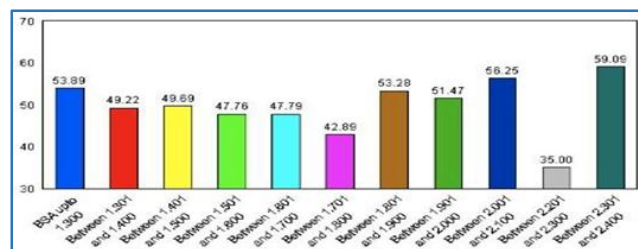


Fig. 5B: BSA (in m2) wise Averaged Collapsibility Index (%)

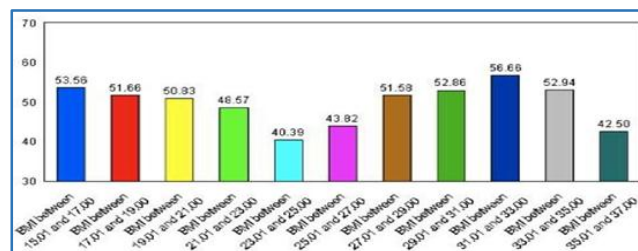


Fig. 5C: BMI wise Averaged Collapsibility Index (%)

When the IVCDi, IVCDe and IVCDm were averaged for the respective age group intervals, it was found that the maximal values for all the three parameters were found in the 21 to 30 years age group interval (Fig 6A). However, this difference was found to be statistically significant only for IVCDe and IVCDm of males with p values of 0.004 and 0.016 ($p < 0.05$) respectively (Table 1 and 2).

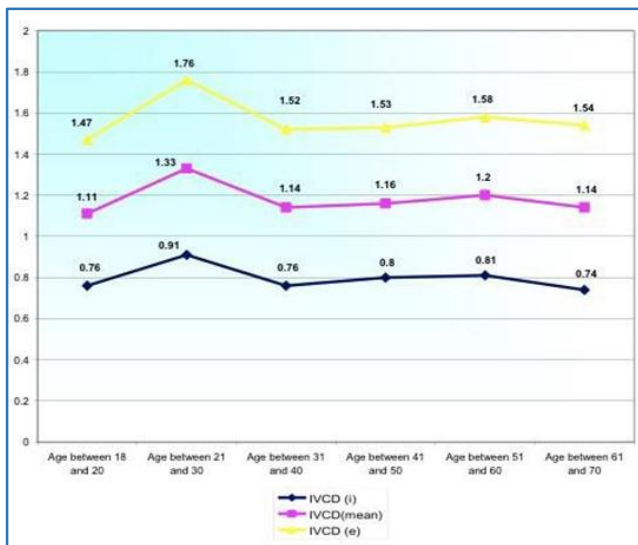


Fig. 6A: Averaged IVC Diameters Trend by Age Group

This finding can be explained by the fact that young males in this sub-group are the most physically active and hence have the highest venous return when compared to the other age groups. The IVCD_e and IVCD_m on further analysis were found to be significantly higher ($p < 0.005$) in males than in females for all the age groups except 41 to 50 years age group interval (Fig. 6B, 6C and 6D).

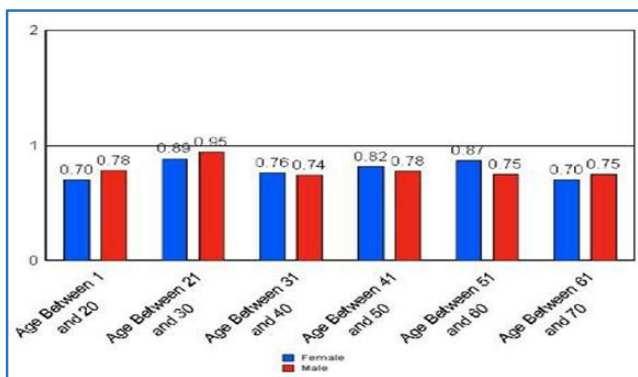


Fig. 6B: Age Group wise Average of IVCD(i) (in cm) Break-up by Gender

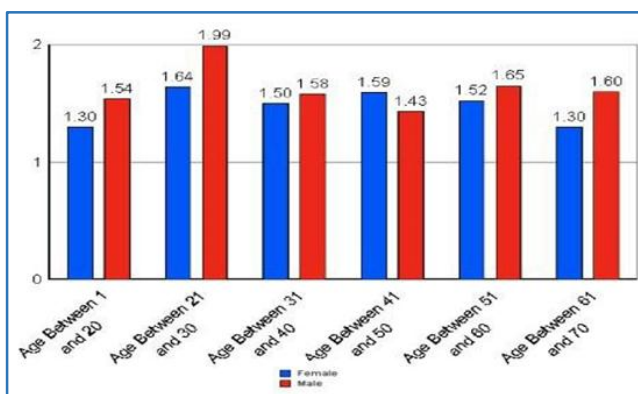


Fig. 6C: Age Group wise Average of IVCD(e) (in cm) Break-up by Gender

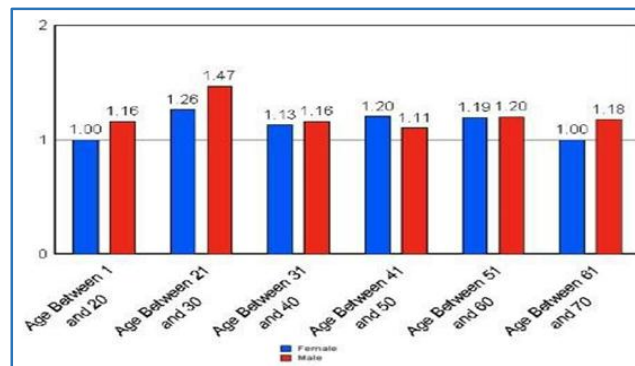


Fig. 6D: Age Group Wise Average of IVCD(m) (in cm) Break-up by Gender

The IVCD diameters were also tabulated according to the BSA and BMI intervals of the study population. By and large, IVCD_e uniformly increased with increasing surface area, after a BSA value of 1.600. The only variation in this trend was found in the BSA interval of 2.000 to 2.100 where a noticeable dip in the values was observed (Fig. 7A). The IVCD_i, IVCD_e and IVCD_m all three showed a uniform increasing trend with increasing BMI after the value of 31.00. Thus, the highest IVCD values were found in the BMI range of 35.00 to 37.00 (Fig 7B). These findings can partly be explained by the total increase in the venous return that is prevalent in the populace with a larger body habitus. However, the changes in IVCD parameters with increasing BSA and BMI were not found to statistically significant, and thus cannot be applied to the general population with any degree of confidence.

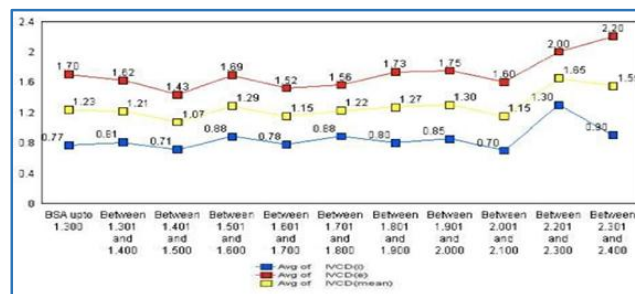


Fig. 7A: BSA (in m2) wise Averaged IVC Diameters (cm) – trend

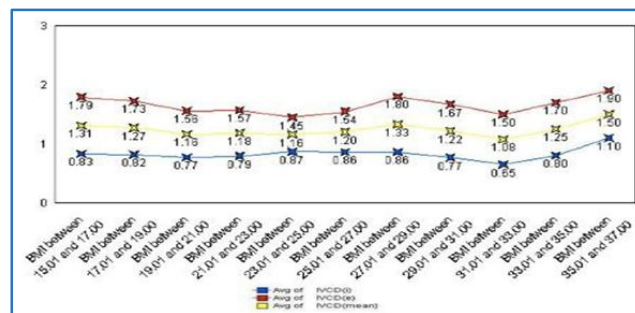


Fig. 7B: BMI wise Averaged IVC Diameters (cm) – trend

	Age Group	N	Mean	Standard Deviation	F Value	Significance
IVCDi (cm)	18 - 20	5	0.78	0.179	1.234	0.313
	21 - 30	11	0.95	0.225		
	31 - 40	5	0.74	0.230		
	41 - 50	9	0.78	0.273		
	51 - 60	8	0.75	0.151		
	61 - 70	4	0.75	0.129		
	Total	42	0.81	0.217		
IVCDe (cm)	18 - 20	5	1.54	0.422	4.298	0.004
	21 - 30	11	1.99	0.230		
	31 - 40	5	1.58	0.327		
	41 - 50	9	1.43	0.229		
	51 - 60	8	1.65	0.293		
	61 - 70	4	1.60	0.316		
	Total	42	1.67	0.341		
IVCDm (cm)	18 - 20	5	1.16	0.297	3.252	0.016
	21 - 30	11	1.47	0.194		
	31 - 40	5	1.16	0.270		
	41 - 50	9	1.11	0.230		
	51 - 60	8	1.20	0.193		
	61 - 70	4	1.17	0.210		
	Total	42	1.24	0.255		
Collapsibility Index (%)	18 - 20	5	48.75	4.878	0.762	0.583
	21 - 30	11	52.50	9.802		
	31 - 40	5	53.69	6.705		
	41 - 50	9	46.43	13.664		
	51 - 60	8	53.98	8.786		
	61 - 70	4	52.73	5.589		
	Total	42	51.20	9.525		

Table 1: Statistical Analysis – Male Patients

	Age Group	N	Mean	Standard Deviation	F Value	Significance
IVCDi (cm)	18 - 20	2	0.70	0.000	0.679	0.641
	21 - 30	21	0.89	0.282		
	31 - 40	17	0.76	0.229		
	41 - 50	13	0.82	0.223		
	51 - 60	9	0.87	0.218		
	61 - 70	1	0.70			
	Total	63	0.83	0.241		
IVCDe (cm)	18 - 20	2	1.30	0.141	0.904	0.485
	21 - 30	21	1.64	0.358		
	31 - 40	17	1.50	0.272		
	41 - 50	13	1.59	0.233		
	51 - 60	9	1.52	0.327		
	61 - 70	1	1.30			
	Total	63	1.56	0.303		

IVCDm (cm)	18 - 20	2	1.00	0.071	0.976	0.440
	21 - 30	21	1.26	0.280		
	31 - 40	17	1.13	0.211		
	41 - 50	13	1.20	0.163		
	51 - 60	9	1.19	0.240		
	61 - 70	1	1.00			
	Total	63	1.19	0.231		
Collapsibility Index (%)	18 - 20	2	45.84	5.890	0.257	0.935
	21 - 30	21	45.22	16.248		
	31 - 40	17	48.40	13.988		
	41 - 50	13	47.65	16.158		
	51 - 60	9	41.83	15.058		
	61 - 70	1	46.15			
	Total	63	46.13	14.862		

Table 2: Statistical Analysis – Female Patients

Age group (years)	IVCD (cm)			Collapsibility Index (%)
	Inspiration	Expiration	Mean	
18-20	0.78±0.179	1.54±0.422	1.16±0.297	48.75±4.878
21-30	0.95±0.225	1.99±0.230	1.47±0.194	52.50±9.802
31-40	0.74±0.230	1.58±0.327	1.16±0.270	53.69±6.705
41-50	0.78±0.273	1.43±0.229	1.11±0.230	46.43±13.664
51-60	0.75±0.151	1.65±0.293	1.20±0.193	53.98±8.766
61-70	0.75±0.129	1.60±0.316	1.17±0.210	52.73±5.589

Table 3: Nomogram Chart of IVC Parameters - Male Patients

Age group (years)	IVCD (cm)			Collapsibility Index (%)
	Inspiration	Expiration	Mean	
18-20	0.70±0.000	1.30±0.141	1.00±0.071	45.84±5.890
21-30	0.89±0.282	1.64±0.358	1.26±0.280	45.22±16.248
31-40	0.76±0.229	1.50±0.272	1.13±0.211	48.40±13.988
41-50	0.82±0.223	1.59±0.233	1.20±0.163	47.65±16.158
51-60	0.87±0.218	1.52±0.327	1.19±0.240	41.83±15.058
61-70	0.70	1.30	1.00	46.15

Table 4: Nomogram Chart of IVC Parameters - Female Patients

DISCUSSION: Numerous studies have been undertaken to highlight the usefulness of various modalities in the measurement of IVC diameter and other IVC parameters. Dewald et al found that CO2 cavograms underestimated the size of the IVC compared with iodinated contrast-enhanced cavography.⁽¹⁶⁾ Kranis et al concluded that there was no significant difference in the measured diameter of the IVC with CO2 versus iodinated contrast material after correction for magnification and pin-cushion distortion.⁽¹⁷⁾

Brown et al found that Gadolinium and CO2 for inferior vena cavography before inferior vena cava (IVC) filter placement were not significantly different from one another in measuring caval diameter.⁽¹⁸⁾

Many studies have also incorporated the IVC measurements in the diagnosis and prediction of various diseases and pathological states.^(5,8,9,13) The large amount of literature available emphasises and drives home the message that IVC diameter and other IVC parameters are of considerable importance in predicting changes in various pathologic conditions.

Nomograms of IVC parameters have to be derived from large scale trials for comparison and to delineate normal from abnormal. Currently, though normal ranges of IVC diameters are available from a few trials that have been conducted, there is lack of IVC parameters standardised in accordance with age group intervals/gender/height/weight/body surface area or body mass index.

A number of clinical scenarios in medical practice require nomograms for IVC parameters against which IVC measurements of patients can be compared. Some of such clinical situations include:

- Assessment of haemodynamic status in trauma in patients who present with blood loss and hypotension.
- Hypovolaemic shock secondary to acute diarrhoea or sepsis.
- As an indirect measure of Right Atrial Pressure & Central Venous Pressure.
- In Congestive Cardiac Failure to assess severity and guide diuretic therapy.
- As a predictor of eccentric Left Ventricular Hypertrophy in CAPD patients.
- As an indirect measure of the degree of cirrhosis in Alcoholic Liver Disease.
- Monitoring Haemodynamic status in Dialysis and CAPD patients.
- To prevent IV overload on patients with prolonged IV fluids.
- For accurate placement of appropriate sized IVC filter.
- For accurate planning of surgery and anastomosis in Liver transplant patients.
- In haemodynamic assessment of venous return in young adults and elite athletes.

The few studies that have been undertaken worldwide have either included too small sample volume to be statistically accurate or have been conducted upon people of Caucasian or Malay origin. Chuo et al have concluded that IVC has shown variations in calibre between people belonging to different races.⁽¹⁹⁾

This study has attempted to fill that lacuna by deriving a nomogram of normal IVC values and parameters for the Adult Indian population. Variations across demographics and age groups have also been documented as a part of the study.

CONCLUSIONS: Transabdominal ultrasound is a reliable, cost efficient, dynamic, effective and relatively easy modality to monitor and measure the IVC parameters. The "Nomogram chart of IVC parameters" has been derived separately for males and females in accordance with the age group intervals. The males have a collapsibility index that is markedly higher than the females. This finding is found to be statistically significant. The maximal IVC diameters are found in the 21 to 30 years age group interval. This finding is statistically significant only for IVCD_e and IVCD_m of males. The IVCD_e and IVCD_m values are observed to be significantly higher in males than females.

The IVCD parameters do not show any statistically significant variations with changes in the BSA or BMI.

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