Original Article

Ultrasound reference values for Inferior Vena Cava diameter and Collapsibility Index among adult Nigerians

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Abstract

Background: Correct estimation of intravascular volume is crucial in critically ill and traumatized patients. Measurement of the central venous pressure (CVP) is invasive and time consuming. Studies have shown that inferior vena cava diameter (IVCD) correlates with CVP. Sonographic assessment of IVCD and its respirophasic changes (collapsibility index; CI) is a non-invasive, quick and reliable means of estimating CVP and hence, intravascular fluid volume. Data on such studies are scanty among adult Nigerians.

Aim: To establish normograms of IVCD and CI for healthy adults in Benin City, Nigeria as well as determine the relationship of IVCD and CI with height, weight, body mass index (BMI), age and gender.

Method: Four hundred apparently healthy adult volunteers were prospectively studied by means of ultrasound. Demographic data and BMI were obtained. The IVCD was measured during inspiration, expiration and sniff. The CI was subsequently calculated for each subject. Statistical Package for the Social Sciences (SPSS) version 17.0 was used for data analysis including tests of significance. Probability values less than or equal to 0.05 were considered significant.

Results: The mean IVCD in this study was 6.1±2.2mm and 13.0±4.0 mm for inspiration and expiration respectively. The mean CI was 49.7±0.5%. There was no statistically significant correlation between IVCD and CI with height and BMI.

Conclusion: This study has determined normal IVCD and CI reference range for healthy Nigerian adults. The CI is independent of height, weight, BMI and gender. Since the CI is not dependent on physical attributes and gender, it may serve as an objective tool for monitoring the fluid status of patient

Keywords: Collapsibility, inferior vena cava, Nigerians, ultrasound

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INTRODUCTION

In severely ill patients and emergencies, the accurate estimation of intravascular volume is vital for guiding fluid therapy in these patients. Clinically this can be extremely difficult and traditionally central venous pressure (CVP) is used as a guide in fluid management[1,2] since it serves as a physiologic estimate of the intravascular fluid volume and the mean right atrial pressure.[3] However, its direct measurement is risky and time-consuming requiring the use of invasive catheters by skilled personnel. It is also fraught with complications, such as infection, arrhythmias, and catheter-induced thrombosis, among others. However, ultrasonography is a quick, noninvasive, portable, easy, and safe procedure in the examination of the inferior vena cava (IVC). The IVC is a large, compliant vein that

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carries deoxygenated blood into the right atrium. Its size and shape correlate strongly with the CVP.[4] As it is highly compliant, the size of the IVC varies with intravascular pressure; it collapses during inspiration and dilates during expiration. Thus, there are ranges of accepted diameters for both phases of respiration (0–14 mm in inspiration and 15–20 mm in expiration). When the IVC fails to collapse on sudden inspiration or sniff, a tamponade is suspected.[5]

Hypovolemia of any etiology is usually accompanied by a decrease in the diameter of the IVC, and acute blood loss has been found to cause changes in both inspiration and expiratory diameters of the IVC.[6] Serial measurements of IVC diameter maybe used to monitor ongoing, sometimes occult blood loss, and can also be a marker to prevent overhydration.[6,7]

Many studies have confirmed the association between the size of the IVC and collapsibility index (CI) with the right-sided cardiac hemodynamics and pressure.[8,9] The efficiency of CI, CI as a simple guide to right review hence atria pressure has also been investigated and found to be reliable.[10,11] Current methods of estimating CI are invasive and associated with possible complications such as infection, thrombosis, and arrhythmias. The use of procedures as computed tomography (CT) and magnetic resonance imaging (MRI) is associated with problems of exposure to ionizing radiation and cost, respectively. They are also impracticable at the bedside.

The dimensions and respirophasic changes of the IVC can easily be studied by ultrasound, being a safe, nonionizing, noninvasive, portable, and accessible imaging modality. This study aimed to assess the diameter and CI of the IVC among adult Nigerians.

MATERIALS AND METHODS

This was a prospective cross-sectional study of 400 apparently healthy volunteers among medical students, student nurses, and members of staff of the University of Benin Teaching Hospital (UBTH), Benin City. The study duration was 6 months. Participants with <2 weeks' history of severe gastroenteritis and blood donation, as well as pregnant women, were excluded from the study. Approval to conduct the study was granted by the Ethics and Research Committee of the UBTH.

Following informed consent, selected participants were made to lie supine with the head slightly elevated. A curvilinear probe of a SONOACE X4 machine with a transducer frequency of 3.5 MHz (Medison Inc.; Korea) was used for the scans. Measurements were obtained by the senior registrar under the supervision of consultant radiologists.

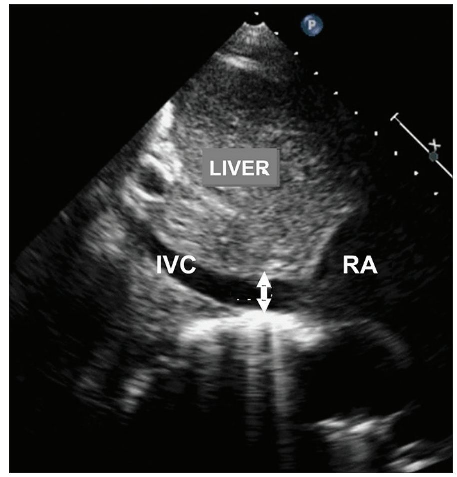

Figure 1: Longitudinal sonogram of inferior vena cava draining into the right atrium. Double arrow depict sites of measurement

Longitudinal scans were done in the right hypochondrium, using the liver as the acoustic window. The IVC was visualized longitudinally, adjacent to the liver, and crossing the diaphragm. The vessel was then followed longitudinally along its course, until it enters the right atrium, and confirming it as the IVC [Figure 1]. The IVC diameter (IVCD) was then measured at a point 2 cm from its entry into the right atrium, where its walls are most parallel. Measurements were taken at end inspiration and expiration (while the participant was instructed to slowly inhale and exhale) and with sniff. Each measurement was made thrice and the average value recorded. The CI was calculated with the formula:

$$CI = \frac{\text{IVCD exp} - \text{IVCD insp}}{\text{IVCD exp}} \times 100.^{[5,8,12]}$$

The diameters of the IVC in both phases of the respiratory cycle, the collapsibility index, and biophysical parameters, including demographic data, were entered to a spreadsheet (Microsoft Excel 2007, Microsoft Inc. USA). Data analysis was done using the Statistical Package for the Social Sciences version 17 (SPSS Inc. Chicago, IL, USA). Frequency and contingency tables were drawn. Statistical tests of significance were done using the Student's *t*-test and Pearson's correlation coefficient where appropriate. Tests were considered statistically significant at $P \leq 0.05$.

RESULTS

A total of 400 volunteers were recruited for this study. Participants' ages ranged from 18 to 76 years. The mean age of the participants was 38.7 ± 14.5 years, and the median age

Table 1: Socio demographic and anthropometric characteristics of study population

Age group	Frequency (*n*=400)	Percentage
<20 years	16	4.0
21-30 years	140	35.0
31-40 years	71	17.8
41-50 years	74	18.5
51-60 years	57	14.2
61 years and above	42	10.5
Gender		
Female	183	45.8
Male	217	54.2
Weight group (kg)		
41-60	77	19.2
61-80	257	64.2
81-100	64	16.0
101 and above	2	0.5
Height group (m)		
<1.70	297	74.2
>1.70	103	25.8
BMI group (kg/m²)		
<20	29	7.2
21-30	343	85.8
31 and above	28	7.0

Table 2: Descriptive statistics of the study population and ivc size/collapsibility index

	Minimum	Maximum	Mean±Std. Dev.
Gender			
Age of subjects	18	72	37.50±14.23
Female (*n*-183)			
Weight	49.0	107.0	67.50±10.69
Height	1.32	1.85	1.60±0.09
BMI	17.43	38.83	26.37±3.99
Av_ivcd_insp	1.70	12.40	6.62±2.15
Av_ivcd_exp	5.40	23.50	13.06±4.05
Ivcdsniff	1.50	12.80	6.25±2.12
Collapsibility_index	42.52	59.79	49.34±5.18
Male (*n*-217)			
Age of subjects	18	76	39.75±14.75
Weight	52.0	102.0	73.12±9.48
Height	1.42	1.90	1.67±0.10
Bmi	17.90	35.25	26.13±3.04
Av_ivcd_insp	2.90	13.00	6.49±2.13
Av_ivcd_exp	6.00	24.00	13.00±4.10
Ivcdsniff	2.66	12.60	6.12±2.09
Collapsibility_index	47.27	56.00	50.10±4.92

$P<0.05$. AV_IVCD_insp: Average Inferior Vena Cava Diameter (Inspiration), AV_IVCD_exp: Average Inferior Vena Cava Diameter (Expiration), AV_IVCD_sniff: Average Inferior Vena Cava Diameter (Sniff), COLLASIBILITY_INDEX: Collasibility Index

group was 21–30 years. There were 217 males (54.0%) and 183 females (46.0%). The mean height of the participants was 1.6 ± 0.1 m (range: 1.3–1.9 m); mean weight was 70.5 ± 10.4 kg while body mass index ranged from 17.4 kg/m² to 38.8 kg (mean: 26.2 ± 3.5 kg/m²) [Table 1].

The mean IVCD inspiration for all participants was 6.5 ± 2.1 mm. Males had a mean IVCD inspiration of 6.5 ± 2.1 mm and females had 6.6 ± 2.1 mm. The mean IVCD expiration for the study population was 13.3 ± 4.0; the values for males and females were 13.0 ± 4.1 and 13.0 ± 4.0mm, respectively. The overall mean IVCD sniff was 6.2 ± 2.1 mm with mean values of 6.1 ± 2.1 mm and 6.2 ± 2.1 mm for males and females, respectively [Table 2].

Table 3: Relationship between Gender AV_IVCD_insp, AV_IVCD_exp and COLLASIBILITY_INDEX

Parameter	Gender	*n*	Mean	Std. deviation	*t*-test	*P*
AV_IVCD_insp	Female	183	6.6158	2.15195	0.598	0.638
	Male	217	6.4874	2.13068		
AV_IVCD_exp	Female	183	13.0613	4.04654	0.142	0.547
	Male	217	13.0032	4.09825		
Collasibility_Index	Female	183	49.3381	5.17868	-1.510	0.125
	Male	217	50.1015	4.91655		

Correlation is significant at $P<0.05$. AV_IVCD_insp: Average Inferior Vena Cava Diameter (Inspiration), AV_IVCD_exp: Average Inferior Vena Cava Diameter (Expiration), AV_IVCD_sniff: Average Inferior Vena Cava Diameter (Sniff), COLLASIBILITY_INDEX: Collasibility Index

Table 4: Correlation between dimensions of the IVC/C.I and weight, height and body mass index

	Weight	Height	BMI	AV_IVCD_insp	AV_IVCD_exp
AV_IVCD_insp					
Pearson correlation	0.046	0.128	-0.053	1	0.953
Sig. (2-tailed)	0.356	0.010	0.294		0.000
AV_IVCD_exp					
Pearson correlation	0.083	0.145	-0.029	0.953	1
Sig. (2-tailed)	0.097	0.004	0.557	0.000	
Collasibility_index					
Pearson correlation	0.086	0.050	0.041	-0.284	0.005
Sig. (2-tailed)	0.085	0.321	0.419	0.000	0.920
IVCDsniff					
Pearson correlation	0.052	0.151	-0.068	0.979	0.935
Sig. (2-tailed)	0.298	0.002	0.176	0.000	0.000

There was no statistically significant difference in IVCD between the genders: P =0.638 and P = 0.547 for IVCD inspiration and IVCD expiration, respectively [Table 3].

The overall mean CI was 49.7% ± 0.5% (range = 49.2%–50.2%). The mean value for males was 50.1% and females was 49.3% ± 5.2%. Pearson's analysis found no correlation between weight and IVCD insp (r = 0.046; P = 0.356), IVCD expiration (r = 0.083; P = 0.097), IVCD sniff (r = 0.052; P = 0.298), and CI (r = 0.085; P = 0.085). Furthermore, there was no correlation between BMI and IVCD inspiration (r = 0.053; P = 0.294), IVCD expiration (r = 0.029; P = 0.557), IVCD sniff (r = 0.068; P = 0.176), and CI (r = 0.041; P = 0.419) [Table 4].

Participants' height showed weak correlation with IVCD inspiration (r = 0.128; P = 0.01), IVCD expiration (r = 0.151; P = 0.004), and IVCD sniff (r = 0.151; P = 0.002) There was no correlation between height and CI (r = 0.05; P = 0.321) [Table 4]. There was strong positive correlation between IVCD sniff and IVCD inspiration: r = 0.979;

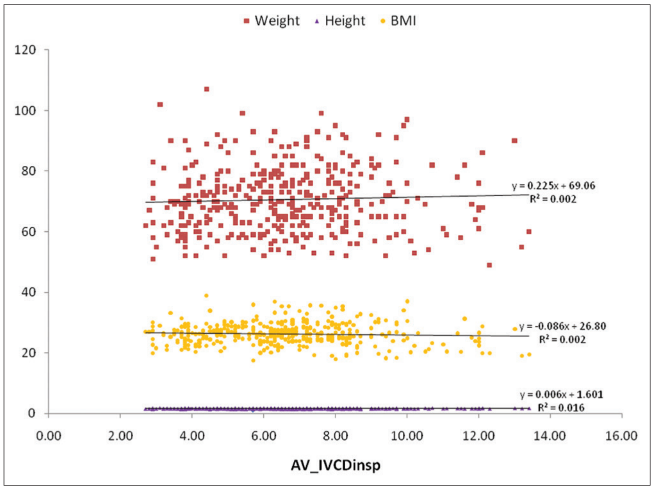

Figure 2: Scatter plot of Average_inferior vena cava diameter inspiration and anthropometric parameters

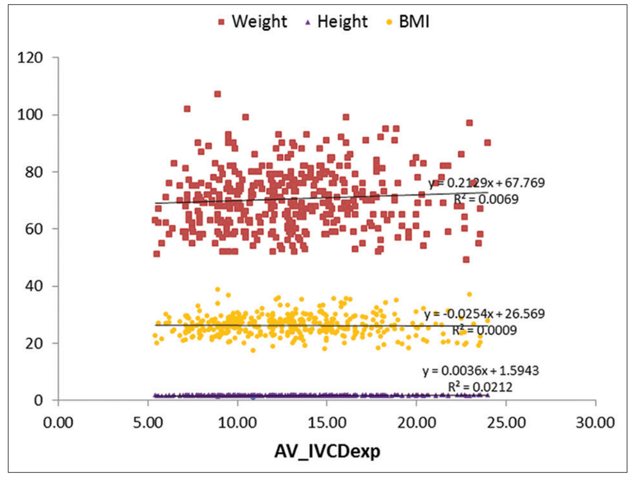

Figure 3: Scatter plot of AV_inferior vena cava diameter expiration and anthropometric parameters

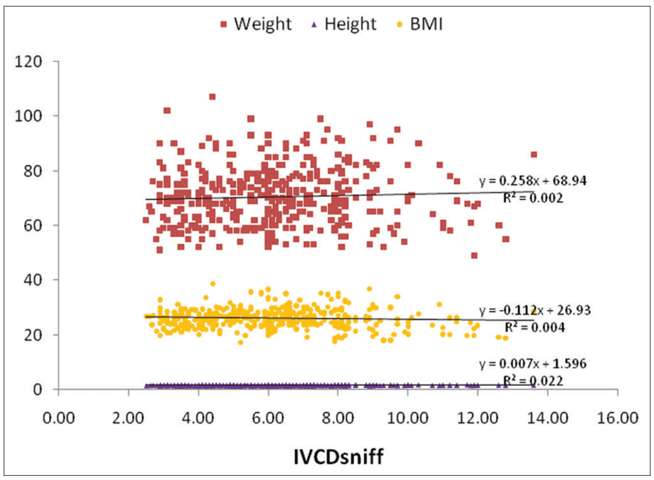

Figure 4: Scatter plot of inferior vena cava diameter sniff anthropometric parameters

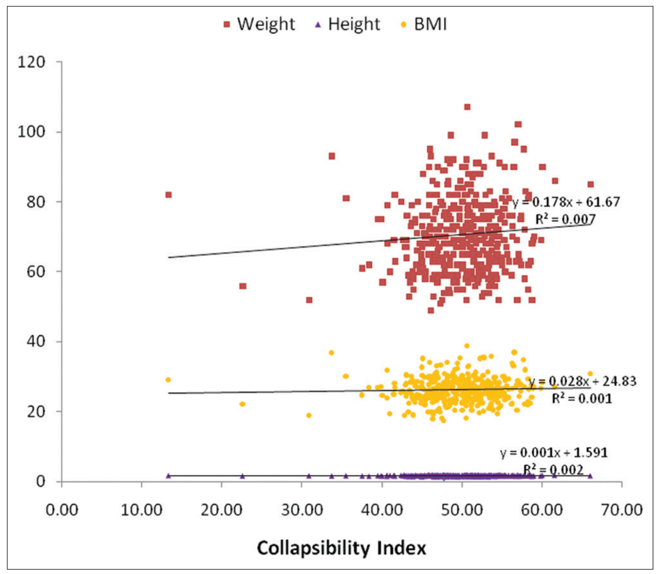

Figure 5: Scatter plot of collapsibility index and anthropometric parameters

P = 0.001. However, the Student's t-test showed no statistically significant difference between these two parameters; $t = -2.448$; $P = 0.678$).

Scatter diagrams as the graphic representation of results are depicted in Figures 2-5. Although the mean IVC parameters did not change across the age groups, a slight decrease in CI was noticed in the age group of 31–40 years, and again above age 51 years.

DISCUSSION

Sonographic assessment of the IVCD and CI has recently emerged as an important, noninvasive part of fluid management for critically ill or traumatized patients in the developed world.[13,14] On the contrary, the literature on this subject is scantly in the Nigerian or African environment, and hence reference values are few.

In this study, there was no significant difference in IVCD values between males and females. A previous study by Mandelbaum and Ritz[15] on IVCD measurement in dialysis patient also did not find any significant difference in values between the genders. The mean IVCD in this study was 6.5 ± 2.1 mm and 13.0 ± 4.1 mm for inspiration and expiration, respectively, these values are statistically different ($P = 0.001$). A marked decrease in caliber (collapse) was observed at end inspiration or following a sniff. This observation was similarly reported by Mintz *et al*.[9] and Grant *et al*.[16] when they studied IVC caliber changes by ultrasound in normal volunteers in USA and Denmark respectively. It can thus be inferred that respirophasic changes in IVCD inspiration and IVCD sniff correlated strongly ($r = 0.979$); however, the difference between these values was not statistically significant ($P = 0.678$). Lyon *et al*.[6] sonographically studied IVCD and CI in blood donors and controls in the US and made a similar observation. Their study concluded that participants do not have to be instructed to breathe to get reliable results and in addition recommended the sniff test as being sensitive in suspected cases of cardiac tamponade and pericardial effusion.

The present study found no significant association between BMI and IVCD or CI, similar to the reports by Mandelbaum and Ritz[15] when ultrasound was used to access both parameters in 125 participants. The authors also reported no correlation with height ($r = 0.321$). The mean IVCD in this study was 6.5 ± 2.1 mm which was similar to the value of 6.9 ± 0.1 mm reported by Yanagawa *et al*.[17] in Japanese adults. Sefidbakht *et al*.[18] reported similar figures in a case–control study of the IVCD in trauma patients in Iran. These findings further reinforce the probable lack of racial variation in IVCD values.

The wide range of IVCD found in this study (1.7–13.0 mm for inspiration and 5.4–24.0 mm for expiration) is in agreement with the previous reports by foreign workers.[5,19] This makes a single or absolute reading of the IVCD for assessment of fluid status unreliable. Since the CI has a narrow reference range, (49.2%–50.2%) it may serve as a better tool for evaluation the fluid status of patients.[5,8,19] The mean CI in this study was $49.8 \pm 0.5\%$, which is similar to CI of 50% obtained by Feissel *et al*.[20] among Americans. A recent Nigerian study at Aminu Kano Teaching Hospital reported a wide range of normal IVCD values (4.8–18.8 mm in inspiration, and 10.9–25.4 mm in expiration).[21] This wide range of IVCD values is similar to the findings of the present study.

Other imaging modalities have been used to evaluate the IVC with regard to fluid volume status including computerized tomographic venography (CTV) and magnetic resonance venography (MRV). While CT has the disadvantage of ionizing radiation and the use of intravenous contrast, MRV is expensive and inaccessible for most patients in the Nigerian/Sub-Saharan environment. MRV is also not ideal in trauma cases because of long imaging time. Moreover, Glockner and Lee[22] compared the different modalities used in assessing IVCD and concluded that sonography remains the modality of choice because it is convenient, fast, accurate, and relatively cheaper than CTV or MRV.

CONCLUSION

A wide range of normal values of IVCD was reported; this limits its usefulness in assessing patients with severe trauma or shock. CI is a better guide for the determination of fluid status of patients. Therefore, the sonographic evaluation of the CI of the IVC should be adopted as a non-invasive procedure by the physicians for rapid diagnosis, and prompt results, in the management of critically ill or traumatized patients for the assessment of their fluid status.

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Conflicts of interest

There are no conflicts of interest.

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