ORIGINAL ARTICLE

Measuring Variation of IVC Diameter in Bangladeshi Population in BIRDEM – A Prospective Observational Study

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ABSTRACT
Background: *Echocardiographic assessment of inferior vena cava (IVC) diameter and its respiratory variation helps to measure right atrial pressure (RAP). While IVC distends RAP rises. Phases of respiratory cycle has significant variation of inferior vena cava diameter in normal individual. There may be other factors that also influence IVC diameter.* ***Aim****: The present study aimed to see the size and dynamics of IVC, its respiratory variation and other factors influencing IVC diameter..* ***Methods & Materials:*** *This prospective observational study was conducted at BIRDEM over six months in 2024, involving 1200 adult patients. Demographic data were recorded. BMI was calculated and categorized for analysis. Echocardiographic assessments of IVC maximum (IVC Max) and minimum (IVC Min) diameters, collapsibility index (CI), left ventricular ejection fraction (EF), and diastolic dysfunction (DD) were measured. Variation of IVC diameter with age, sex, BMI, EF, DD, and DM were assessed, with $p < 0.05$ considered significant.* ***Results:*** *The mean age of participants was 53.04 ± 10.95 years, and mean BMI was 26.00 ± 4.46 kg/m^2. Mean IVC Max and Min diameters were 18.44 ± 1.84 mm and 13.28 ± 2.00 mm, with a mean CI of 0.292 ± 0.115. IVC size correlated positively with age, male sex, and BMI ($p < 0.01$) but not with diabetes ($p > 0.05$). Larger IVC diameters and lower CI were observed in participants with reduced EF and advanced diastolic dysfunction ($p < 0.001$).* ***Conclusion:*** *IVC diameter and collapsibility index are significantly related to cardiac function and demographic factors, serving as useful non-invasive indicators of right atrial pressure and cardiac filling status.*

Keywords: *Inferior vena cava (IVC), echocardiography, ejection fraction (EF), diastolic dysfunction (DD), diabetes mellitus (DM), Body mass index (BMI)*

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INTRODUCTION

Echocardiographic measurement of the inferior vena cava (IVC) diameter and its respiratory variation is commonly performed worldwide. It is a simple and noninvasive method and is recommended by the current guidelines of the American Society of Echocardiography, in conjunction with the European Association of Echocardiography [1,2]. Echocardiography allows comprehensive evaluation of cardiac function, and the inferior vena cava (IVC) can be clearly visualized using the transthoracic subcostal approach [3]. In healthy individuals with spontaneous respiration, cyclic changes in pleural pressure led to variations in IVC diameter. Echocardiography serves as a dependable method to assess these changes [4], utilizing parameters such as IVC diameter and the collapsibility index. As a highly collapsible vein, the IVC diameter is closely associated with right-sided cardiac function [5]. The normal range of IVC diameter varies widely. As the combination of IVC diameter and its collapsibility index offers a more precise and non-invasive estimation of right atrial pressure, determining standard reference values is essential [6-8].

However, there may be multiple factors influencing IVC measurements. It is critical to recognize the factors that influence IVC diameter and its respiratory variation. Patil et al. (2016) conducted a prospective observational study to establish normal reference values for inferior vena cava (IVC) size and its respiratory variations using M-mode echocardiography. That Indian study measured IVC diameter during inspiration and expiration in the subcostal view and found significant correlations between IVC diameter and anthropometric parameters such as height, weight, and BMI [9]. Studies assessing IVC diameter in healthy individuals are limited. Early identification of hemodynamic alterations through accessible, cost-effective methods such as echocardiographic IVC assessment can enhance clinical decision-making and improve patient outcomes. Therefore, this study aims to address this knowledge by measuring the IVC diameter and its relation with age, sex, BMI, diabetes mellitus, ejection fraction, and diastolic dysfunction among adult Bangladeshi patients. The findings are expected to contribute to a better understanding of cardiovascular physiology in the Bangladeshi population and support more individualized, evidence-based patient care.

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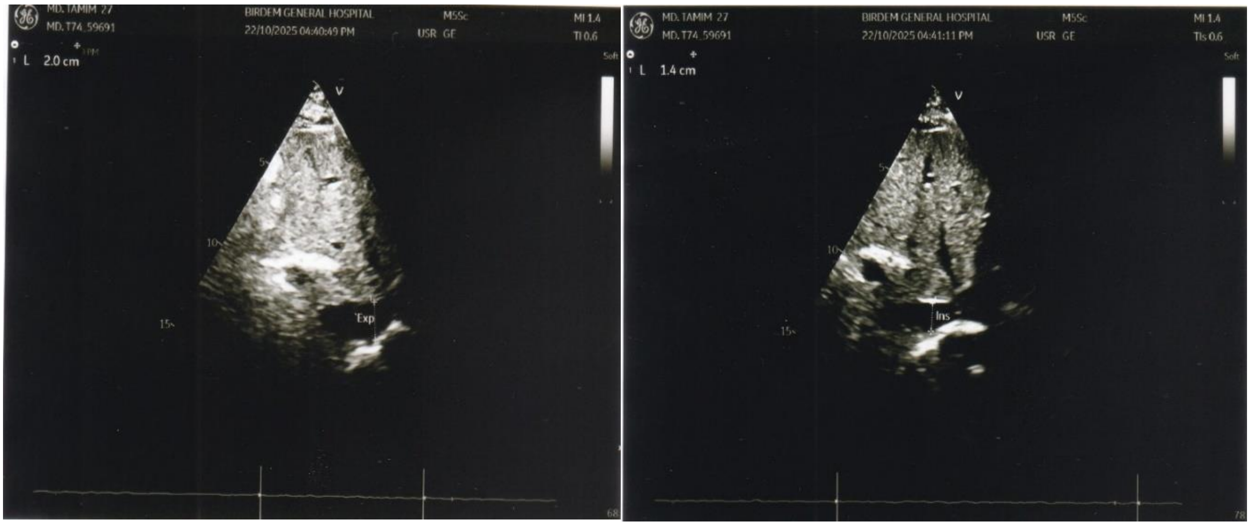
METHODS & MATERIALS

Study design and population

This prospective observational study was conducted over six months, from July to December 2024, at the Bangladesh Institute of Research and Rehabilitation in Diabetes, Endocrine and Metabolic Disorders (BIRDEM). A total of 1,200 adult patients (≥18 years) of both sexes, attending for clinical evaluation, were consecutively enrolled and both diabetic and non-diabetic patients were included. Cases having either congenital heart disease, severe valvular disease or significant respiratory illness that could interfere with IVC measurement were excluded from this study. Demographic data such as age, sex, height, and weight were recorded, and Body Mass Index (BMI) was calculated.

Echocardiographic Assessment:

Echocardiography was done and the IVC measurement was performed based on current guidelines [10,11] using a commercially available system (Vivid E, 95 GE Healthcare, Herten, Norway). Patients were examined and all measurements were taken in the supine position. The Infrahepatic segment of the IVC was visualized in a subcostal longitudinal view as it entered the right atrium. IVC dimensions were measured 1–2 cm caudal to the right atrial junction, perpendicular to the vessel's long axis, throughout the respiratory cycle. The images were recorded in a standard subcostal longitudinal view (Fig. 1).



Expiration Inspiration

The maximum IVC diameter was recorded at end-expiration, and the minimum diameter during inspiration to ensure full inspiratory collapse. The IVC collapsibility index (IVCCI) was computed as: [(maximum IVC diameter – minimum IVC diameter) / maximum IVC diameter] × 100. Each reported value represented the average of three consecutive measurements [12].

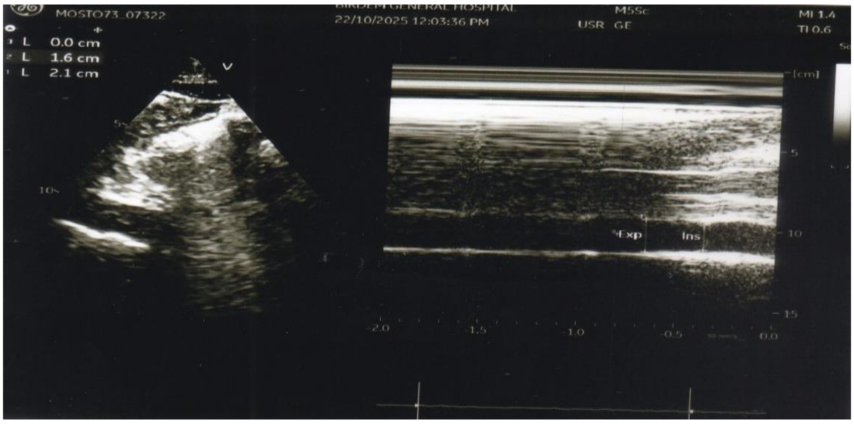


Figure – 2: M-Mode Echocardiography image showing changes in IVC diameter during expiration and inspiration

A 2–4 MHz transducer was positioned immediately below the xiphisternum, 1–2 cm to the right of the midline, directed toward the sternal notch. Once an optimal 2D image was obtained, M-mode tracing was recorded 1 cm caudal to the hepatic vein junction during short sniffs to capture maximum and minimum diameters.

Data Analysis:

Continuous variables were summarized as mean ± standard deviation (SD) or median (interquartile range), and categorical variables as frequencies and percentages. Associations between IVC parameters and variables such as age, sex, BMI, diabetes mellitus, ejection fraction (EF), and diastolic dysfunction (DD) were analyzed using appropriate statistical tests. A p-value < 0.05 was considered statistically significant.

Ethical Considerations:
Ethical approval was obtained from the Institutional Review Board of BIRDEM, and written informed consent was collected from all participants, ensuring confidentiality and adherence to ethical research standards.

RESULTS

In this study mean age of study population was found 53.04 ± 10.95 years. Mean BMI was calculated as 26.00 ± 4.46 kg/m^2, indicating that a considerable proportion of patients were overweight. After measuring IVC diameter, mean inferior vena cava (IVC) maximum and minimum diameters were found 18.44 ± 1.84 mm and 13.28 ± 2.00 mm, respectively. The collapsibility index (CI), an important marker of volume status, had a mean value of 0.292 ± 0.115.

Table – I: Baseline Characteristics of the Study Participants (*n*=1200)

Variable	Mean ± SD	Range	Minimum	Maximum
Age (years)	53.04 ± 10.95	48.00	27.00	75.00
Height (m)	1.58 ± 0.10	0.40	1.40	1.80
Weight (kg)	64.83 ± 10.26	60.00	36.00	96.00
BMI (kg/m^2)	26.00 ± 4.46	24.70	17.96	42.66
IVC Max (mm)	18.44 ± 1.84	11.00	11.00	22.00
IVC Min (mm)	13.28 ± 2.00	10.00	9.00	19.00
Collapsibility Index (CI)	0.292 ± 0.115	0.69	0.11	0.80

Table I shows the baseline characteristics of the study participants: mean age (53.04 ± 10.95 years), height, weight and BMI. Also showing variation of IVC Max, IVC Min and collapsibility index (CI).

Table – II: Associations between IVC diameter and demographic variables

Variable	IVC Max (r or β ± SE)	p-value	IVC Min (r or β ± SE)	p-value
Age (years)	0.15 ± 0.03 (r)	0.001	0.12 ± 0.04 (r)	0.003
Sex (Male vs Female)	1.48 ± 0.10 (β)	<0.001	0.94 ± 0.09 (β)	<0.001
BMI (kg/m^2)	0.07 ± 0.02 (r)	0.005	0.06 ± 0.02 (r)	0.008

Here, r=Pearson correlation coefficient (for continuous variables like Age, BMI); β±SE= Regression coefficient± standard error (for categorical variable Sex)

Table II shows the associations between inferior vena cava (IVC) diameters and demographic variables. A significant positive correlation was observed between age and both IVC Max (r = 0.15, p = 0.001) and IVC Min (r = 0.12, p = 0.003), indicating that IVC diameter tends to increase slightly as age advances. Regarding sex, male participants had significantly larger IVC diameters compared to females, with regression coefficients of 1.48 ± 0.10 mm for IVC Max and 0.94 ± 0.09 mm for IVC Min (both p < 0.001). Body mass index (BMI) also showed a modest but statistically significant positive correlation with IVC diameters: IVC Max (r = 0.07, p = 0.005) and IVC Min (r = 0.06, p = 0.008). This implies that higher BMI is associated with slightly larger IVC diameters.

Table – III: Distribution of Diastolic Dysfunction (DD) and Diabetes Mellitus (DM) Among Study Participants (*n*=1200)

Variable	Category	Frequency (n)	Percent (%)
Diastolic Dysfunction (DD)	Present	981	81.8
Diastolic Dysfunction (DD)	Absent	219	18.3
Diabetes Mellitus (DM)	Present	1069	89.1
Diabetes Mellitus (DM)	Absent	131	10.9

Among the 1200 participants, 81.8% had diastolic dysfunction. Diabetes mellitus was highly prevalent, affecting 89.1% of participants (Table-III).

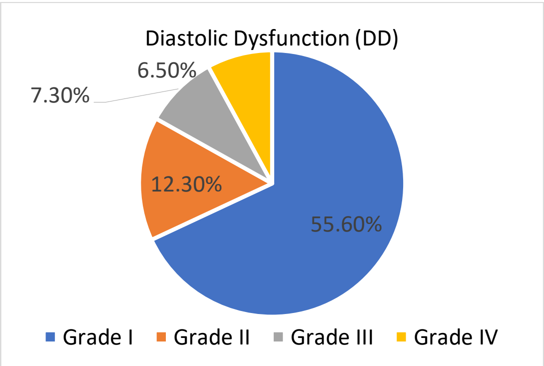


Figure – 3: Distribution of Diastolic Dysfunction (DD)

Figure 3 shows the distribution of Diastolic Dysfunction (DD). Most participants (81.8%) had diastolic dysfunction, predominantly Grade I (55.6%), followed by Grades II (12.3%), III (7.3%), and IV (6.5%).

Table – IV: Comparison of IVC Max and IVC Min by EF Group

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EF Group	N	IVC Max (Mean ± SD)	IVC Min (Mean ± SD)	p-value (t-test)
HFrEF (≤40%)	201	19.9184 ± 0.78626	15.0204 ± 0.82890	<0.001
HFmrEF (41–49%)	688	18.6131 ± 1.81123	14.0298 ± 2.57679	<0.001
HFpEF (≥50%)	311	18.3337 ± 1.84991	13.0671 ± 1.84908	<0.001

Table IV presents the comparison of IVC Max and IVC Min by EF Group among the 1200 participants. IVC maximum and minimum diameters differed significantly between EF groups ($p < 0.001$). Patients with HFrEF had the largest mean IVC Max (19.92 mm) and IVC Min (15.02 mm), followed by HFmrEF and HFpEF. This indicates that lower EF is associated with larger IVC diameters, reflecting increased central venous pressure or volume overload in reduced systolic function.

Table – V: Comparison of IVC Max and Min by DM Status

DM Status	N	IVC Max (Mean ± SD)	IVC Min (Mean ± SD)	p-value (t-test)
Present	1069	18.50 ± 1.80	13.20 ± 1.95	0.412
Absent	131	18.45 ± 1.85	13.18 ± 1.92	0.412

Table V shows the comparison of IVC Max and Min by DM Status. Participants with and without diabetes mellitus had comparable mean IVC Max and IVC Min values, with differences that were not statistically significant ($p > 0.05$). This indicates no measurable association between diabetes status and IVC diameter in the present study population.

Table – VI: Association Between Ejection Fraction (EF) Categories and Collapsibility Index (CI)

EF Category	Paired Variable	Mean Difference (CI – IVC)	SD	t-value	df	p-value
HFrEF (n=49)	CI – IVC Max	-19.63	0.82	-167.27	48	<0.001
	CI – IVC Min	-14.73	0.83	-123.72	48	<0.001
HFmrEF (n=168)	CI – IVC Max	-18.32	1.82	-130.44	167	<0.001
	CI – IVC Min	-13.74	2.59	-68.71	167	<0.001
HFpEF (n=983)	CI – IVC Max	-18.04	1.86	-304.74	982	<0.001
	CI – IVC Min	-12.78	1.85	-216.29	982	<0.001

Note: Paired t-test was used

In table VI, a strong and statistically significant negative association was observed between the Collapsibility Index (CI) and IVC diameters (both Max and Min) across all Ejection Fraction (EF) categories ($p < 0.001$). This finding indicates that a decrease in CI is associated with an increase in IVC diameter, suggesting reduced venous collapsibility and elevated right atrial pressure among patients with lower EF values.

Table – VII: Comparison of IVC Max and IVC Min by Diastolic dysfunction (DD) status

Variable	Category	Frequency (n)	Percent (%)	IVC Max (Mean±SD)	IVC Min (Mean ± SD)	p-value (t-test)
Diastolic Dysfunction (DD)	Present	981	81.8			
	Grade I	667	55.6	18.10±1.80	12.90±1.90	<0.001
	Grade II	147	12.3	18.33±1.85	13.07±1.85	<0.001
	Grade III	88	7.3	18.61±1.81	14.03±2.58	<0.001
	Grade IV	78	6.5	19.92±0.79	15.02±0.83	<0.001
Diastolic Dysfunction (DD)	Absent	219	18.3	18.09±1.91	13.17±1.95	<0.001

Note: Independent t-test and one-way ANOVA were used

Table VII presents the comparison of IVC Max and IVC Min by Diastolic dysfunction (DD) status. IVC diameters (Max and Min) varied across diastolic dysfunction (DD) grades, with the smallest diameters observed in early DD (Grade I–II) and progressively larger diameters in higher DD grades (Grade III–IV). Participants without DD had the smallest IVC diameters. All differences were statistically significant ($p < 0.001$), indicating that IVC size increases proportionally with the severity of diastolic dysfunction.

DISCUSSION

This prospective study evaluated the variation of inferior vena cava (IVC) diameter with demographic factors (age, sex, and BMI) and key clinical variables, including diastolic dysfunction (DD), diabetes mellitus (DM), and ejection fraction (EF), among patients at BIRDEM. The findings support the clinical utility of IVC measurements as non-invasive markers of volume status and cardiac function. Diastolic dysfunction (DD) is associated with an increase in inferior vena cava (IVC) diameter and a reduction in its respiratory variation. Consequently, DD leads to a decreased collapsibility index (CI), and higher grades of diastolic dysfunction are correlated with elevated right atrial pressure (RAP).

Age and sex showed significant associations with IVC diameter in this study. Consistent with Franco et al. (2022), the diameter of the IVC decreased with advancing age in both sexes, and males had larger diameter than females in certain age groups, which may reflect sex-based anatomic or haemodynamic differences [13]. Moreover, Cain et al. (2009) highlighted that age and sex significantly influence cardiovascular structures, including ventricular dimensions, which may parallel the observed demographic variations in IVC size due to systemic hemodynamic changes [14]. Chang et al. reported that males typically have wider IVCs due to increased circulating blood volume and body surface area [15]. Patil et al. (2016) reported that BMI has a significant influence on inferior vena cava (IVC) diameter, with individuals having higher BMI generally exhibiting larger IVC dimensions, likely due to increased intravascular volume and altered hemodynamics associated with greater body mass [9]. These findings underscore the necessity of considering demographic factors such as age, sex, and body habitus when assessing IVC measurements for clinical decision-making.

A strong association was observed between IVC dimensions and EF categories. Participants with heart failure with reduced ejection fraction (HFrEF) had the highest mean IVC Max and Min diameters, suggesting elevated right atrial pressure and central venous congestion. This supports findings from Gerges et al., who demonstrated that patients with HFrEF often have non-collapsible, dilated IVCs due to impaired right heart drainage and volume overload.[16] Likewise,
Blehari et al. and Pellicoridentified IVC diameter as a sensitive marker for stratifying heart failure severity and right-sided pressures.[17,18] In our study, a strong and statistically significant negative association was observed between the Collapsibility Index (CI) and IVC diameters (both Max and Min) across all Ejection Fraction (EF) categories ($p < 0.001$), demonstrating that reduced IVC collapsibility is associated with venous congestion and heart failure — conditions typically characterized by lower ejection fraction and elevated right atrial pressures [17,18].

In this study, no significant difference was observed in the maximum and minimum inferior vena cava (IVC) diameters between participants with and without diabetes mellitus (DM). These findings suggest that, within this population, the presence of diabetes does not appear to have a measurable impact on IVC size. This aligns with limited existing literature, as direct associations between DM and IVC diameter remain underexplored. While diabetes is known to cause vascular dysfunction and remodeling in arterial beds [19], its influence on large venous structures like the IVC may be less pronounced or require more sensitive measures to detect.

The present study demonstrated a significant association between diastolic dysfunction (DD) severity and inferior vena cava (IVC) diameters Participants having DD has larger IVC diameter and reduced CI than those not having DD. All differences were statistically significant ($p < 0.001$), indicating a meaningful association between DD severity and IVC size. These findings align with the pathophysiological insights discussed by Litwin and Zile (2020), who emphasized that diastolic dysfunction impairs ventricular relaxation and compliance, leading to elevated filling pressures and consequent venous congestion, which can manifest as increased IVC diameter [20]. Similarly, Schumacher et al., (2008) highlighted that echocardiographic parameter reflecting elevated left ventricular filling pressures correlate with venous dilation, supporting the use of IVC measurements as an indirect marker of diastolic function severity [21]. The gradual Increase in IVC diameter with worsening DD grades observed in this study may reflect compensatory hemodynamic adjustments or progressive reduction in preload status as cardiac function deteriorates. Nagueh et al. (2009) recommend using echocardiographic parameters—including IVC diameter and its respiratory variation—as valuable non-invasive measures to estimate right atrial pressure and assess left ventricular diastolic dysfunction severity [22], underscoring the clinical utility of IVC measurement as an adjunct in evaluating diastolic function and monitoring disease progression. These results of the study highlight the potential of IVC measurement as a non-invasive echocardiographic parameter that reflects underlying hemodynamic and structural cardiovascular changes in diverse patient subgroups.

LIMITATIONS

This study has several important limitations. First this study was conducted in a single tertiary care hospital (BIRDEM), the findings may not be fully generalizable to the broader Bangladeshi population. Second. The number of patients in this study is relatively small. Larger sample size is needed to validate our findings. Third, inter-observer variation and unmeasured factors such as hydration status or comorbidities could have influenced IVC measurements. Causal relationships could not be established. Finally, we used the sniff maneuver to assess the respiratory change of IVC diameter but the manner and degree of sniff respiration vary by individual and cannot be standardized. So, there might be some variations in collapsibility index. Future multicenter and longitudinal studies are needed to confirm these findings and develop population-specific reference values.

CONCLUSION

This prospective study demonstrated that inferior vena cava (IVC) diameter is significantly influenced by demographic factors such as age and sex, BMI as well as by key cardiac parameters including ejection fraction and diastolic dysfunction severity. Larger IVC dimensions were observed in males, individuals with higher BMI. Inferior vena cava (IVC) diameter and collapsibility index (CI) are significantly associated with cardiac function parameters, particularly ejection fraction (EF) and diastolic dysfunction (DD). Larger IVC diameters and lower CI values were consistently observed in patients with reduced EF and more advanced grades of DD, reflecting increased central venous pressure and diminished venous collapsibility. No significant association was found between IVC size and diabetes mellitus status. These findings support the role of IVC measurement as a simple, non-invasive echocardiographic marker. Incorporating IVC assessment into routine echocardiography may enhance the evaluation and monitoring of patients with varying cardiovascular profiles.

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