RESEARCH ARTICLE

A morphological study comparing heart size measurement on chest radiograph with echocardiography in local population

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Abstract

Objective: To investigate heart size on chest X-ray via cardiothoracic ratio, and to correlate it with echocardiographic measurements.

Method: The comparative analytical, cross-sectional study was conducted at the Pakistan Navy Station Shifa Hospital, Karachi, between January 2021 and July 2021. The radiological parameters were measured on chest X-rays posterior-anterior view, and the echocardiographic parameters were measured using 2-dimensional transthoracic echocardiography. The absence or presence of cardiomegaly on both imaging modalities was modelled as a binary categorical variable and compared. Data was analysed using SPSS 23.

Results: Of the 79 participants, 44(55.7%) were males and 35(44.3%) were females. The mean age of the sample was 52.71±14.54 years. There were 28(35.44%) enlarged hearts on chest X-ray and 46(58.22%) on echocardiography. The sensitivity and specificity of chest X-ray were 54.35% and 90.90%, respectively. The positive and negative predictive values were 89.28% and 58.82%, respectively. The accuracy of chest X-ray in identifying an enlarged heart was 69.62%.

Conclusion: The cardiac silhouette on a chest X-ray could demonstrate heart size through simple measurements with high specificity and reasonable accuracy. However, a normal heart size on chest X-ray may not have a normal function.

Keywords: Heart size, Cardiomegaly, Cardiothoracic ratio, Chest X-ray, PA view, Transthoracic echocardiography.

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Introduction

Heart size is an important index in clinical medicine and forensic science. It remains a subject of research due to its variability resulting from a range of factors, such as height, weight, gender and age.[1] The parameters measured or the imaging modality used also contributes to the variations. An enlarged heart shadow on a chest X-ray in posterior-anterior (PA) view is usually pathognomonic of a heart disease, although it can be due to physiological reasons as well.[2] A small heart shadow may also be observed in a condition called small heart syndrome (SHS), often associated with chronic fatigue syndrome (CFS) and conditions such as asthmatic paroxysm with emphysema or adrenal insufficiency.[3]

Convenient tools at disposal for measuring heart size are chest radiography and two-dimensional (2D) transthoracic echocardiography (TTE), the latter being the gold standard. Chest radiography uses ionizing radiation which limits its use, but the ease of operability and cost-effectiveness makes it more practical. A PA view is preferred over the anterior-posterior (AP) view because the heart appears artificially enlarged in the latter.[4] On the other hand, echocardiography uses high-pitch sound waves to produce an image of the heart, allowing detailed structural and functional assessment. It is considered safe, but the technical expertise, time and cost required makes it reserved as an advanced investigation.

Echocardiography allows the dimensions of the heart and its function to be determined via a set of measurements. The guidelines and standard reference values used for these measurements are set by organisations like the American Society of Echocardiography (ASE) and the European Association of Cardiovascular Imaging (EACVI).[5,6]

Considering the expenses involved with an advanced imaging technique, investigating the findings obtained from any such technique that may be translatable to a simpler one will help in better utilisation of resources. For this purpose, routine echocardiographic parameters used by clinicians in Pakistan can be compared with radiographic parameters measured on a chest radiograph. The findings will serve useful for clinicians working in limited resource settings to make the best of what is available to them, and prevent unnecessary or delayed referrals to higher level of healthcare.

The current study was planned to investigate heart size on CXR PA view via cardiothoracic ratio (CTR), and to correlate it with echocardiographic measurements.

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Patients and Methods

The comparative analytical, cross-sectional study was conducted at the Department of Cardiology, Pakistan Navy Station (PNS) Shifa Hospital, Karachi, from January 18, 2021 to July 19, 2021. After approval from the ethics review committee (ERC) of Bahria University Medical and Dental College (BUMDC), Karachi, the sample size was calculated using OpenEpi calculator[7] with 95% confidence level and 5% margin of error in the light of literature.[8] The sample was raised using consecutive non-probability sampling technique from among in-patients of either gender admitted through out-patient department (OPD) or emergency department (ED) with signs and symptoms or complaints related to cardiac disease. They had either investigation or both done at the time of admission, or within three days post-admission. Those with abnormality related to thoracic cage or the cervical and thoracic spine, any past intervention performed on the heart, severe respiratory diseases resulting in pleural effusion or occluding a clear view of lung fields for taking measurements and a missing study parameter on echocardiography were excluded.

CXR were taken in PA view (Toshiba X-ray Machine, KXO-15R). Measurements recorded using Fiji ImageJ software included transverse right cardiac diameter (TRD), which is the distance between the right lateral most margin of the heart and the midline passing through the spinous processes of the vertebral bodies; transverse left cardiac diameter (TLD), which is the distance between the left lateral most margin of the heart to the midline passing through the spinous processes of the vertebral bodies; transverse cardiac diameter (TCD), which is the maximum horizontal distance between the most lateral margins of the cardiac silhouette (TCD = TRD + TLD); transverse thoracic diameter (TTD), which is the widest internal transverse diameter of the thoracic cavity (measured between the inner surfaces of the ribs); and CTR, which is calculated as a ratio of TTD and TCD, with a value ≤0.5 indicating a normal heart size, and >0.5 indicating the presence of cardiomegaly.

All echocardiograms were reported by an experienced consultant echocardiologist (Canon Aplio i600). The measurements related to chamber size, heart function and great arteries were defined, and conducted according to the internationally agreed guidelines of ASE.[5] The echocardiographic parameters included right atrium (RA) minor-axis (or transverse) diameter (RAD) measured in apical four-chamber (A4C) view; left atrium (LA) anterior-posterior (AP) diameter (LAD) measured in the parasternal long-axis (PLAX) view; right ventricle (RV) linear diameter (RVD) measured in PLAX view, and total annular plane systolic excursion (TAPSE) obtained from M-mode tracing in A4C view; left ventricle (LV) internal diameter in diastole (LVIDd) and systole (LVIDs), interventricular septal diameter in diastole (IVSd), and posterior wall diameter in diastole (PWd) measured in PLAX view, while LV ejection fraction (EF) was measured using Biplane Simpson's Method;[9] aortic diameter, measured at the level of aortic annulus in PLAX view; pulmonary artery systolic pressure (PASP), determined by the modified Bernoulli equation[10] and right atrial pressure (RAP),[5] for which tricuspid regurgitant jet or maximum velocity (Vmax)[5] was obtained using continuous-wave tissue Doppler in PLAX view and the inferior vena cava (IVC) diameter and collapsibility[5] measured in the subcostal IVC (SIVC) view; LV mass, calculated using Devereux and Reichek 'cube' formula[9] and relative wall thickness (RWT), calculated using the formula, RWT = (2 x PWd)/ LVIDd.[9]

Cardiomegaly was considered to be present if any of the study parameters related to chamber size measured more than their respective normal reference values.[5]

The study population was divided into four groups after comparing the results of CXR and echocardiography: Group A comprised enlarged heart on both CXR and echocardiography; Group B had enlarged heart on CXR, but a normal heart size on echocardiography; Group C had normal heart size on CXR, but an enlarged heart on echocardiography; and Group D had normal heart size on both CXR and echocardiography.

LV dysfunction was reported as diastolic or systolic dysfunction, or both. Right ventricular dysfunction was reported as a depressed function or systolic dysfunction.

Data was analysed using SPSS 23. Categorical variables were expressed as frequencies and percentages, and were analysed using chi-square test. Shapiro-Wilk's test ($p>0.05$) and histograms were used to check for normal distribution of continuous variables, which were analysed using Student's t test for normally distributed variables and Mann–Whitney U test for variables not normally distributed. Correlations were analysed using Pearson's correlation coefficient (r) and Spearman's rank correlation coefficient (ρ) tests, respectively. $P<0.05$ was considered statistically significant, and $p<0.01$ was considered highly significant.

Results

Of the 79 participants, 44(55.7%) were males and 35(44.3%) were females. The mean age of the sample was 52.71±14.54 years (Table 1).

The most common diagnosis was Acute Coronary Syndrome 44(56%) (Table 2). There were 28(35.44%) enlarged hearts on CXR (Table 3) and 46(58.22%) on echocardiography (Table 4).

Table-1: Baseline physical characteristics of the participants.

Variable	Gender	Mean±SD	Minimum	Maximum	*p*-value
Age (years)	Male	55.11±14.34	19.00	75.00	0.075
	Female	49.69±14.42	20.00	73.00	
Weight (kg)	Male	69.27±7.99	50.00	85.00	0.000
	Female	60.86±5.41	45.00	78.00	
Height (m)	Male	1.67±0.07	1.52	1.88	0.000
	Female	1.53±0.04	1.42	1.60	
BMI (kg/m^2)	Male	24.98±2.94	18.12	31.18	0.107
	Female	26.03±2.73	18.62	33.39	
BSA (m^2)	Male	1.77±0.12	1.51	1.98	0.000
	Female	1.58±0.07	1.41	1.77	

SD: Standard deviation, BMI: Body mass index, BSA: Body Surface Area (Dubois & Dubois formula)

Table-2: Diagnoses among the participants.

Diagnosis	n (%)	Diagnosis	n (%)
Acute Coronary Syndrome (NSTEMI)	29 (36.71)	Decompensated Heart Failure	8 (10.13)
Acute Coronary Syndrome (STEMI)	13 (16.46)	Dilated Cardiomyopathy	5 (6.33)
Acute Coronary Syndrome (Unstable Angina)	2 (2.53)	Dissection of Aorta	1 (1.27)
Chronic Thromboembolic Pulmonary Hypertension (CTEPH)	1 (1.27)	Peripartum Cardiomyopathy	1 (1.27)
Congenital Heart Disease (Atrial Septal Defect)	1 (1.27)	Rheumatic Heart Disease	3 (3.80)
Constrictive Pericarditis	2 (2.53)	Valvular Heart Disease	13 (16.46)

NSTEMI: Non-ST elevation myocardial infarction, STEMI: ST elevation myocardial infarction.

Table-3: Distribution of radiological parameters.

Parameter	Normal Heart Size (n=51)		Cardiomegaly (n=28)	
	Male (n=26)	Female (n=25)	Male (n=18)	Female (n=10)
TTD (cm)	0.792	†0.012	0.155	0.168
TRD (cm)	0.202	0.282	0.398	0.094
TLD (cm)	0.072	0.065	0.217	0.419
TCD (cm)	0.896	0.047	0.502	0.484
CTR	0.123	0.107	†0.002	0.808

TTD: Transverse thoracic diameter, TRD: Transverse right cardiac diameter,
TLD: Transverse left cardiac diameter, TCD: Transverse cardiac diameter, CTR: Cardiothoracic ratio.

Table-4: Distribution of echocardiographic parameters.

Parameter	Normal Heart Size (n=33)		Cardiomegaly (n=46)	
	Male (n=18)	Female (n=15)	Male (n=26)	Female (n=20)
TRAD (mm)	†0.038	0.212	0.931	0.599
LAD (mm)	†0.012	0.147	0.405	0.550
RVD (mm)	†0.000	†0.000	†0.007	†0.022
TAPSE (mm)	0.076	0.299	0.175	0.337
LVIDd (mm)	0.542	0.660	†0.012	0.347
LVIDs (mm)	0.562	0.223	0.203	0.151
IVSd (mm)	†0.000	0.168	0.282	†0.041
PWT (mm)	†0.012	†0.018	†0.011	0.168
EF (%)	†0.019	†0.009	†0.001	0.578
LV Mass (g/m2)	†0.007	0.239	0.929	†0.015
RWT (mm)	0.892	0.512	0.087	0.162
Aorta (mm)	0.776	0.637	0.623	0.103
PASP (mm Hg)	†0.000	†0.008	0.205	†0.047

RAD: Right atrium diameter, LAD: Left atrium diameter, RVD: Right ventricle diameter, TAPSE: Total annular plane systolic excursion, LVIDd: Left ventricle internal diameter in diastole, LVIDs: Left ventricle internal diameter in systole, PWT: Posterior wall thickness, IVSd: Interventricular septum thickness in diastole, EF: Ejection fraction, LV: Left ventricle, RWT: Relative wall thickness, PASP: Pulmonary artery systolic pressure.

Table-5: Comparison of radiological and echocardiographic findings related to heart size.

		Echocardiography Result: Enlarged Heart	Echocardiography Result: Normal Heart Size	Total
Chest X-ray (PA View) Results	CTR > 0.5 (Enlarged Heart)	25 (31.6%) **[Group A] True Positive**	3 (3.8%) **[Group B] False Positive**	28 (35.4%)
	CTR ≤ 0.5 (Normal Heart Size)	21 (26.6%) **[Group C] False Negative**	30 (38.0%) **[Group D] True Negative**	51 (64.6%)
Total	46 (58.2%)	33 (41.8%)	79 (100.0%)	

PA: Posterior-anterior, CTR: Cardiothoracic ratio.

The sensitivity and specificity of CXR were 54.35% and 90.90%, respectively. The positive predictive value (PPV) and negative predictive value (NPV) were 89.28% and 58.82%, respectively. The accuracy of CXR in identifying an enlarged heart was 69.62% (Table 5).

Correlations were observed for TTD and TCD in groups A, B and D. TLD showed correlations in all the four groups. The only correlation observed for TRD was in Group B, and for CTR in Group A (Table 6).

Discussion

The sensitivity and specificity of CXR-PA in determining an enlarged heart in the current study compared favourably with several studies,[11-13] although there are studies[14,15] that reported a better sensitivity and poor-to-moderate specificity. These differences are attributed to the echocardiographic parameters used, as they differed from one study to another. It was observed that not all chambers were considered in most of the aforementioned studies.[11-15] The differences could also be attributed to the study population, which in the current study consisted of patients with heart-related complaints or disorders, and the time interval between echocardiography and CXR-PA. The high PPV in the current study means that an enlarged cardiac silhouette has a high probability of being associated with a truly enlarged heart on echocardiography. While a moderate NPV concurs that a normal silhouette cannot exclude individual chamber enlargement. The positive likelihood ratio (LR) confirms that when an enlarged heart is reported on CXR-PA, the actual chance of having an enlarged heart on echocardiography increased six-fold.

In the current study, the mean radiological parameters for normal heart size in males were comparable to earlier studies[16-18] that investigated CTR, whereas the female heart size was smaller. Most of the mean echocardiographic parameters in the current sample with normal heart size were greater compared to studies in India.[19,20] These

Table-6: Correlation of radiological and echocardiographic parameters.

	Group A (True Positive)	Group B (False Positive)	Group C (False Negative)	Group D (True Negative)
TTD	**i. LVIDs** (*r*= 0.421, *p*=0.036*) ii. **Aorta** (*r*= 0.484, *p*=0.014*)	**i. LVIDd** (*r*= 0.997, *p*=0.045*) ii. **PWd** (*r*= -1.000, *p*=0.007**) iii. RWT (*r*= -1.000, *p*=0.015*)	Not significant	**i. RAD** (*r*= 0.553, *p*=0.002**) ii. **LAD** (*r*= 0.436, *p*=0.016*)
TRD	Not significant	i. **LVIDd** (*r*= 0.997, *p*=0.049*) ii. **PWd** (*r*= -1.000, *p*=0.004**) iii. RWT (*r*= -0.997, *p*=0.048*)	Not significant	Not significant
TLD	i. **LVIDd** (*r*= 0.396, *p*=0.050*) ii. **LVIDs** (*r*= 0.542, *p*=0.005**) iii. **IVSd** (*r*= -0.478, *p*=0.016*) iv. **EF** (*r*= -0.594, *p*=0.002**) v. **RWT** (*r*= -0.485, *p*=0.014*)	i. **LVIDd** (*r*= 1.000, *p*=0.012*) ii. **PWd** (*r*= -0.998, *p*=0.040*) iii. **RWT** (*r*= -0.997, *p*=0.048*)	i. **EF** (*r*= -0.543, *p*=0.011*)	i. **RAD** (*r*= 0.428, *p*=0.018*) ii. **AORTA** (*r*= 0.372, *p*=0.043*)
TCD	i. **LVIDs** (*r*=0.457, *p*=0.022*) ii. **EF** (*r*= -0.464, *p*=0.020*)	i. **LVIDd** (*r*= 1.000, *p*=0.020*) ii. **PWd** (*r*= -0.999, *p*=0.032*) iii. **RWT** (*r*= -0.998, *p*=0.041*)	Not significant	i. **RAD** (*r*=0.462, *p*=0.010*) ii. **LAD** (*r*=0.367, *p*=0.046*)
CTR	i. **RVD** (*r*= 0.493, *p*=0.012*) ii. **PASP** (*r*= 0.537, *p*=0.012*)	Not significant	Not significant	Not significant

TTD: Transverse thoracic diameter, TRD: Transverse right cardiac diameter, TLD: Transverse left cardiac diameter, TCD: Transverse cardiac diameter, CTR: Cardiothoracic ratio, RAD: Right atrium diameter, LAD: Left atrium diameter, RVD: Right ventricle diameter, LVIDd: Left ventricle internal diameter in diastole, RWT: Relative wall thickness PWd: Posterior wall diameter, IVSd: Interventricular septum thickness in diastole, EF: Ejection fraction, RWT: Relative wall thickness, PASP: Pulmonary artery systolic pressure.

measurements were smaller for males and greater for females when compared to a study in Turkey.[21] An Egyptian study reported mean values greater than the current findings except for RV which was smaller.[22] A study in Japan reported mean values for most parameters greater in males, but smaller in females compared to the current study.[23] Thus, regional differences do exist.[24] The mean LV EF was suboptimum in the current study because the participants were in-patients admitted with heart-related disorders.

For a true enlarged heart, the CTR correlated with an increase in RVD and PASP, the latter reflecting an increase in pulmonary vascular pressure.[25] The TCD correlated with an increase in LVIDs and a decrease in LV EF. The TLD correlated to an increase in both LVIDd and LVIDs, and a decrease in LV EF. Several studies have established that EF decreases as the LV size increases, as seen in dilated cardiomyopathy.[26] A study reported correlation of CTR, TLD and TRD with LVIDd in participants with LV enlargement.[27]

For a false enlarged heart, the CTR did not correlate with any of the echocardiographic parameters. In contrast, TCD, TLD, TRD and TTD did correlate to an increase in LVIDd, and a decrease in PWd and RWT. For a true normal-sized heart, TCD and TLD correlated to an increase in RAD. TLD also correlated to an increase in LAD and aortic diameter. For a false normal-sized heart, TLD correlated to a decrease in LV EF. In contrast, a study reported correlation of CTR with LV EF in participants with depressed LV EF, but none in those with preserved LV EF.[28]

Thus, it can be inferred that for a heart with normal size on echocardiography, the cardiac silhouette on CXR-PA will correlate strongly with the size of both the atria and aortic diameter. And when the heart is enlarged on echocardiography, the silhouette will correlate strongly with LV diameters and EF. Regarding heart function, the LV dysfunction was more common than RV dysfunction in the total study participants, and females frequently had a normal LV function. A high number of participants in Group D with a compromised ventricular function reaffirms that even though the heart size may appear normal on CXR-PA, the heart function may not be normal.

In terms of limitations of the current study, a single CXR-PA view was used to minimize radiation exposure. The echocardiographic parameters used are commonly measured in routine practice by cardiologists in Pakistan. The sample size was small due to limited time frame of the study. There was a slight disparity in the gender distribution.

It is recommended that further studies investigating other imaging modalities be explored with a larger sample size for findings that may be useful for better utilisation of simple investigations, and thus resources.

Conclusion

The cardiac silhouette on a CXR-PA could demonstrate heart size through simple measurements with high specificity and reasonable accuracy. However, a normal heart size on CXR-PA may not have a normal function. For estimation of heart size, measuring CTR and TCD on a CXR-PA can serve as very useful tools.

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