Pak Heart J

TRANSTHORACIC ECHOCARDIOGRAPHIC CHAMBER QUANTIFICATION IN THE LIGHT OF CURRENT GUIDELINES

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Contribution

IH conceived the idea, designed the study, reviewed litrature and did final manuscript drafting.

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ABSTRACT

Echocardiography, since its introduction by Edler, has greatly revolutionized cardiac practice and helps in the diagnoses of diseases. It involves multiple modalities for a complete study but the most fundamental part is chamber quantification by M-mode and 2D scanning. Guidelines have been proposed for these regularly by various agencies especially American Society of Echocardiography with timely updates. These updates show changes in these parameters which are at times quite marked. To keep abreast with the evolving knowledge in this field, most recent guidelines have been reviewed and it is attempted to present it in an easy format for all those involved with cardiology practice especially echocardiography.

Key Words: Echocardiography, Chamber quantification, Recommendations, Guidelines.

INTRODUCTION

Echocardiography since its introduction by Edler has greatly revolutionized cardiac practice and helps in the diagnoses of diseases remarkably.[1] It involves multiple modalities like M-mode, 2D, color and spectral Doppler etc. for a complete study but the most fundamental part is chamber quantification by M-mode and 2D.This is an obligatory part of any echocardiographic study. An accuracy of these measurements determines the diagnostic yield. Since long, many guidelines have been issued by various agencies with regular up-gradation. In this regard American Society of Echocardiography took the lead and presented the first such guideline in 19892).These measurements not only indicate the sizes of chambers but also have prognostic values. Various methods of chamber quantification like M-mode, 2D, 3D and Speckle tracking are now available. The primary purpose of this writing is to make the reader fully conversant with this basic step of echocardiography. The importance of being updated in this regard can be ascertained by the fact that drastic changes in these measurements' cut-off values have been noted in serial guidelines. Examples of Left Atrial volume and LV ejection fraction can be cited in this regard. Two different normal values from the two guidelines of ASE in 2015 and 2005 can be seen in the following table.[3,4] These changes have been made as time showed better prognostic values for the later (2015) measurements.

To define the cut-off values for normal and abnormal measurements (to classify them into the categories of mild, moderate and severely abnormal) was a point of debate. However, the following methods for delineating these values and recommending them in the guidelines were considered:

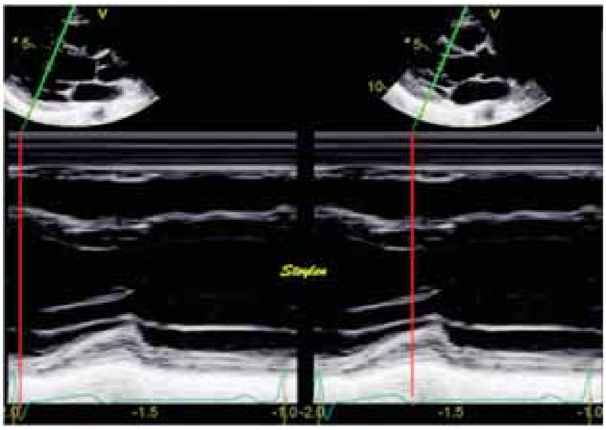
- SDs above and below the reference limit (healthy people)
- Percentile value (from a group of healthy people and with disease)
- On the basis of outcome or prognosis
- Experience based consensus of expert opinion

After looking into the pros and cons of each method it has been recommended that LV volumes, EF, LV mass and LA volume should be reported on the basis of experience based consensus of expert opinion whereas for the rest of the measurements mean value and SDs of gender, age and body surface area (BSA)-normalized cutoff of upper and lower limits are to be reported.

Quantification of cardiac chambers needs linear measurements and in some cases volumetric measurements. For linear measurements the old method of M-mode only is not recommended any more, however, measurements from a 2D directed M-mode can be obtained, but the best method is to obtain the linear measurements directly from a 2D frozen image. Volume assessment from linear measurements by geometric formulae (Teicholz or Quinones) is no longer recommended. For this purpose Modified Simpson's biplane method or Area length method should be adopted as narrated below.

Heart shows translational movement during systole and diastole, hence the M-mode cursor transecting the heart during the two phases of cardiac cycle may not be crossing the same points and there is usually some variation in this regard which results in some difference in measurements as shown in figure 1.

Figure 1: Translational movement of heart cuts LV at different points in systole and diastole"



This means that measurements in fact are taken from different part of the ventricle in end diastole and end systole. For this reason, direct 2-D measurement from a frozen image is a better option, figure 2. When taking linear measurements, leading edge to leading edge methods should be applied except when measuring aortic or any valve's annulus size where inner edge to inner edge method is used. M-mode measurements are 2-D directed which ensures greater accuracy. While measuring the calipers should be placed on the interface of cavity and myocardial wall, and wall and the pericardium.

Table 1: Comparative Normal Values of Left Atrial Volume in the two Guidelines of ASE (2015 AND 2005)

LA VOL./BSA	Normal	Mildly Enlarged	Moderately Enlarged	Severley Enlarged
2015	16-34	35-41	42-48	>48
2005	16-28	29-33	34-39	>40

Table 2: Comparative Normal Values of LV Ejection Fraction In the Two Guidelines of ASE (2015 And 2005)

	Normal	Mildly Enlarged	Moderately Enlarged	Severley Enlarged
2015	>52	51-41	40-30	>30
2005	>55	54-45	44-30	>30

This means that measurements in fact are taken from different part of the ventricle in end diastole and end systole. For this reason, direct 2-D measurement from a frozen image is a better option, figure 2. When taking linear measurements, leading edge to leading edge methods should be applied except when measuring aortic or any valve's annulus size where inner edge to inner edge method is used. M-mode measurements are 2-D directed which ensures greater accuracy. While measuring the calipers should be placed on the interface of cavity and myocardial wall, and wall and the pericardium.

Figure 2: Direct 2D Measurements of Left Ventricle

The timing of measurementsis usually either at end-diastole (peak of R wave) and end-systole (end of T wave) but diastolic measurements of left ventricle can be taken at the maximum cavity size or one frame after mitral valve has fully opened. For systole, least cavity size can be taken or one frame after mitral valve has closed.

Many of the parameters are affected by obesity, body size and various other factors. For this reason, the measurements are indexed. In this regard, body surface area (BSA), serves the purpose most of the time but other allometric parameters like height 2.7etc are also utilized as narrated below.

LITERATURE SEARCH:

A literature search throughgoogle and PUB-MED with the words "echocardiography" and "chamber quantification" and "guidelines" yielded eleven articles from which the main material has been extracted for this review.

TEXT:

As a routine, the following measurements must be obtained in every study

I. LEFT VENTRICLE
- Cavity size
- Inter ventricular septum and posterior wall thicknesses
- Mass

II. RIGHT VENTRICLE
- Cavity size
- Wall thickness

III. LEFT ATRIUM

IV. RIGHT ATRIUM

V. AORTIC ROOT
- Annulus
- Sinus portion
- Sino-tubular junction
- Ascending aorta

VI. INFERIOR VENA CAVA

VII. PULMONARY ARTERY (main and branches)

VIII. OUTFLOW TRACTS

The measurements involve linear dimensions and volumetric assessments. From these basic measurements, various other parameters (especially the functional activity of left and right ventricle like LVEF, LVFS, RV FAC etc.) can be drawn.

For descriptive purpose chamber quantification has been described in four sections in this document:

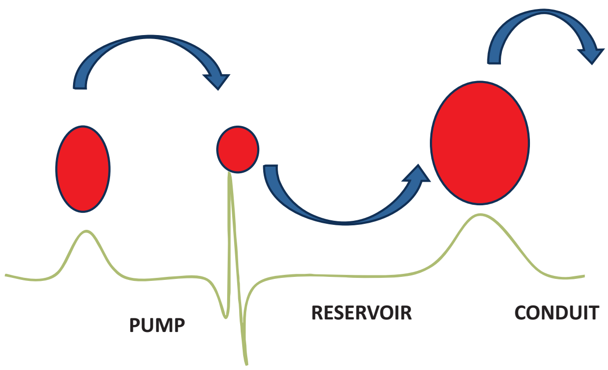
- Section I – Linear measurements
- Section II- Volumetric measurements
- Section III- LV mass measurement
- Section IV- Ventricular function assessment

SECTION 1- LINEAR MEASUREMENTS

LEFT ATRIUM:

Being a very important chamber of heart it performs various functions so as to maintain adequate cardiac output. The functions performed by it can be gauged from figure 3 which shows that it acts as a reservoir, conduit and booster pump during cardiac cycle. Left atrial size has great prognostic value with regard to morbidity and mortality in different disease states as has been demonstrated in numerous studies.[5-7]

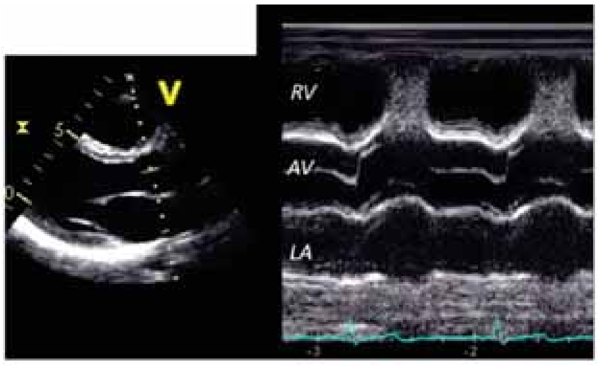
Figure 3: Three Functions of Left Atrium



Left atrium is quantified for linear dimension and volume. Linear dimension is taken from 2D directed M-mode image or directly from a 2D image in Parasternal long axis view.

For measurement of left atrium, M-mode cursor should transect the sinus portion of aorta with the transducer placed in a parasternal long axis position. LA size is measured at the end of T wave (end-systole) to ensure measurement at the time of maximum LA filling as shown in figure .4

Figure 4: 2D Directed M Mode Measurement of Left Atrium



However, it is better to measure the left atrium size directly from a frozen 2D image from anterior surface of posterior aortic wall to anterior surface of posterior LA wall in a leading edge to leading edge method as shown in figure 5. However, this also may not tell the correct left atrial size as detailed in the section of volumetric assessment of Left atrium.

Figure 5: 2D Linear Measurement of Left Atrium

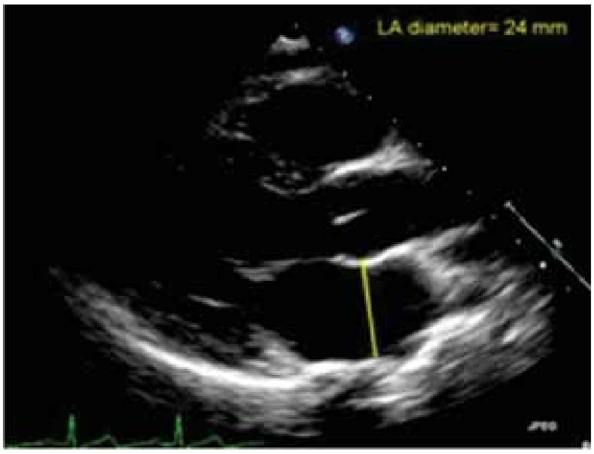


Table 3: Left Atrium - Normal Ranges and Cut Off Values For Severity Assessment By Linear Method

	Male				Female			
	Normal Range	Mildly Abnormal	Moderately Abnormal	Severly Abnormal	Normal Range	Mildly Abnormal	Moderately Abnormal	Severly Abnormal
Diameter	3.0-4.0	4.1-4.6	4.7-5.2	≥ 5.2	2.7-3.8	3.9-4.2	4.3-4.6	≥ 4.7
Diameter/BSA	1.5-2.3	2.4-2.6	2.7-2.9	≥ 3.0	1.5-2.3	2.4-2.6	2.7-2.9	≥ 3.0

LEFT VENTRICLE

The linear dimensions obtained for left ventricle are: Septal thickness, posterior wall thickness, LV cavity size—all in both phases of cardiac cycle i.e. systole and diastole. For measurements of Left ventricle, 2-D directed M-mode view is obtained again from parasternal long axis position with the patient in left lateral position and respiration held briefly at end expiration. The M-mode cursor should transect the left ventricle just below the tips of mitral valve leaflets. The transducer should be exactly perpendicular to the surface so that no trabecula on either side of septum or along the left ventricle posterior wall should interfere with the measurement.

Interventricularseptal thickness is measured from the endocardium on right to left side of septum both at end systole and diastole in a leading edge to leading edge method as shown in figure 6, the measurements could be taken either in M-mode or directly from a 2D frozen image (later method is preferred).

It has been shown that LV diameter assessment adds prognostic value to ejection fraction estimate in risk stratification for sudden cardiac death[8] (Table 4,5).

Figure 6: 2D Directed f M-Mode Measurements of LV Cavity, IVS And Posterior Wall

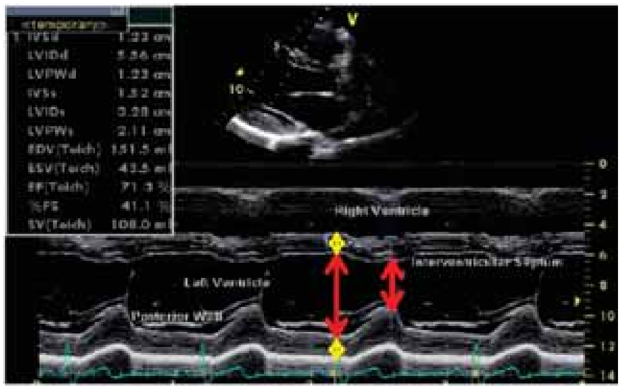


Table 4: Normal Ranges and Cut Off Values of Septum and LV Posterior Wall For Severity Assessment By Linear Method

	Male				Female			
	Normal Range	Mildly Abnormal	Moderately Abnormal	Severly Abnormal	Normal Range	Mildly Abnormal	Moderately Abnormal	Severly Abnormal
Septal Thickness	0.6-1.0	1.1-1.3	1.4-1.6	> 1.6	0.6-0.9	1.0-1.2	1.3-1.5	> 1.5
Post. Wall Thickness	0.6-1.0	1.1-1.3	1.4-1.6	> 1.6	0.6-0.9	1.0-1.2	1.3-1.5	> 1.5

Table 5: Normal Ranges and Cut-Off Values For LV Measurements

	Male				Female			
	Normal	Mild	Mod	Severe	Normal	Mild	Mod	Severe
Diastolic Diameter	4.2-5.8	5.9-6.3	6.4-6.8	>6.8	3.8-5.2	5.3-5.6	5.7-6.1	>6.1
DD/BSA (cm/m^2)	2.2-3.0	3.1-3.3	3.4-3.6	>3.6	2.3-3.1	3.2-3.4	3.5-3.7	>3.7
Systolic Diameter	2.5-4.0	4.1-4.3	4.4-4.5	>4.5	2.2-3.5	3.6-3.8	3.9-4.1	>4.1
SD/BSA (cm/m^2)	1.3-2.1	2.2-2.3	2.4-2.5	>2.5	1.3-2.1	2.2-2.3	2.4-2.6	>2.6

RIGHT VENTRICLE

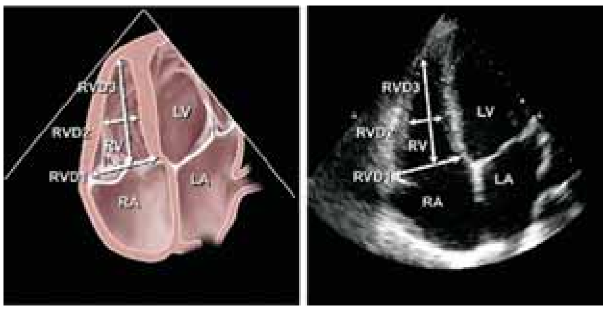
Right ventricle because of its unique crescentic shape is very difficult to measure, but due to its enormous prognostic value in cardio-pulmonary diseases, guidelines have been forwarded to estimate its size and function.[9,10] Normal RV values are shown in table 6.

Right ventricle measurements include linear measurements of RV cavity, wall thickness and two functional parameters, viz; Tricuspid annular plane systolic excursion and Fractional area change.

Linear measurements require an apical four chamber view and these are taken on a 2-D frozen image at end-diastole. An RV directed four chamber view gives better results but make sure that LV apex forms the tip of this image and maximum RV size is obtained. Three measurements are taken for this purpose as shown in figure 7.

- Basal RV level
- Mid RV level
- RV long axis

Figure 7: 2d Measurements of Right Ventricle From Apical 4C Position



Thickness of RV wall is obtained either from a parasternal long-axis view or sub costal four-chamber view either in M-mode at end-diastole below the tricuspid annulus equal to the length of fully open anterior leaflet of tricuspid valve as shown in Fig 8 and 8a.

Figure 8: 2D Measurement of RV Thickness From Sub-Costal View

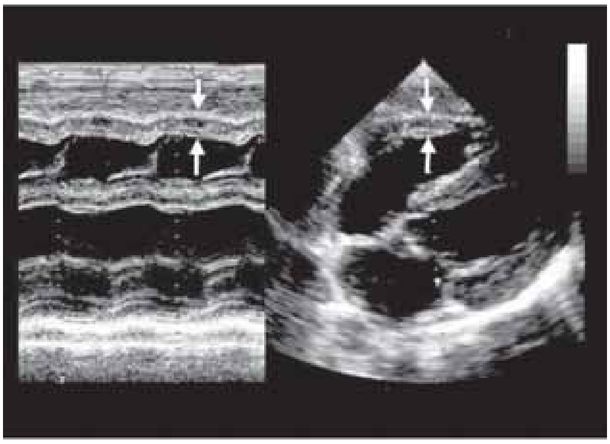
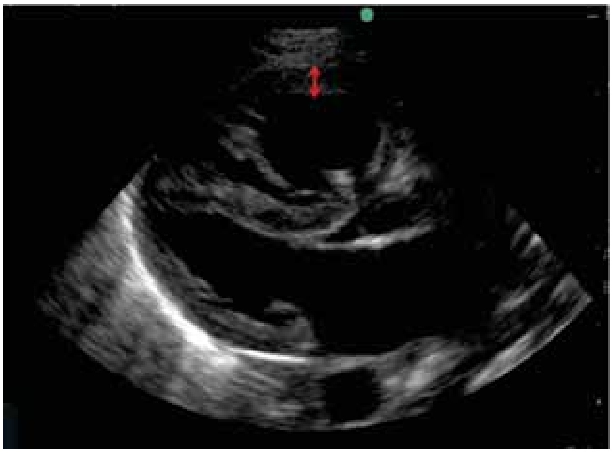
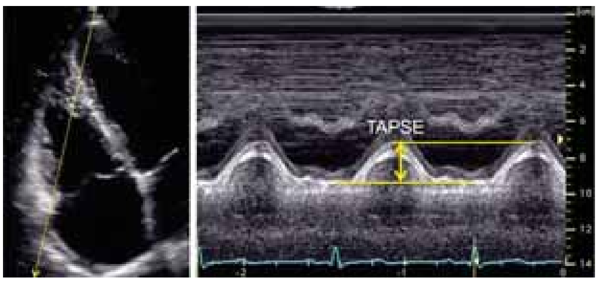


Figure 8a: RV Wall Thickness From PS Lax View



Functional parameters of Right ventricle can also be derived from M-mode and 2D linear measurements.[11-13] One of this is the extent of movement of Tricuspid valve annulus during systole from apical 4 chamber view known as TAPSE (Tricuspid annular plane systolic excursion) which shows its longitudinal function. Normally this plane moves more than 16 mm towards apex and can be measured by passing an M-mode cursor through the tricuspid annulus as shown in figure 9.

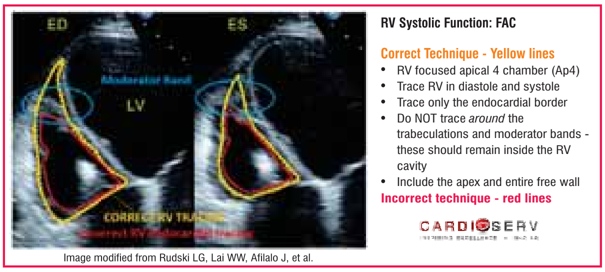
Figure 9: Measurement of Tricuspid Annular Plane Systolic Excursion From Apical 4c View



Fractional area change is another parameter of global RV function. It is derived from apical 4 chamber view by tracing the contours of Right ventricle during diastole and systole to derive the area, figure. 10 and then applying the formula as follows

Fractional Area Change = RVarea (diast.) - RVarea (syst.) X100/ RVarea (diast.)

Figure 10: 2D Measurement of RV Fractional Area Change From Apical 4c View



For **RV outflow tract** measurements, parasternal long axis (measuredfrom the anterior RV wall to the inter-ventricular septal-aorticjunction) and short axis views at aortic root level are utilized as shown in figure 11. RV measured from Parasternal Long axis view is actually the RV outflow tract.

Proximal RVOT is measured from parasternal short axis view with the cursor traversing the mid of aorta whereas distal RVOT is measured proximal to pulmonic valve

Figure 11: Linear 2d Measurements of Proximal and Distal RV Outflow Tracts From PS Sax View

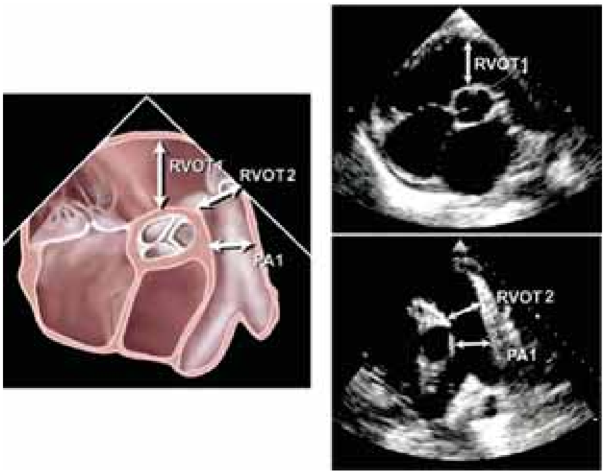


Table 6: Normal Values For RV Chamber Size

Parameter	MEAN ± SD (in mm)	Normal Range (in mm)
RV Basal diameter	33 ± 4	25-41
RV mid diameter	27 ± 4	19-35
RV longitudinal diameter	71 ± 6	59-83
RVOT PLAX diameter	25 ±2.5	20-30
RVOT proximal diameter	28 ± 3.5	21-35
RVOT distal diameter	22 ± 2.5	17-27
RV wall thickness	3 ± 1	1-5

RIGHT ATRIUM

Linear measurements of Right atrium are minor axis and major axis measurements which are obtained from apical four chamber view. Minor axis is obtained as a linear line drawn from its midpoint joining inter-atrial septum to RA free wall whereas, the major axis is measured in the same view by drawing a line from midpoint of Tricuspid annular plane to the superior wall of right atrium, figure. 12.

PULMONARY ARTERIES

The diameter of main pulmonary artery can be measured above the pulmonic valve at its mid-level in a Parasternal short axis view whereas the two pulmonary artery branches are measured at their ostia as show in figure 13.

Table 7: Normal Ranges and Cut-Off Values For RA Measurements

	Male				Female			
	Normal	Mild	Mod	Severe	Normal	Mild	Mod	Severe
Minor Axis Dimension	2.9-4.5	4.6-4.9	5.0-5.4	≥ 5.5	2.9-4.5	4.6-4.9	5.0-5.4	≥ 5.5
Minor Axis Dimension/BSA	1.7-2.5	2.6-2.8	2.9-3.1	≥ 3.2	1.7-2.5	2.6-2.8	2.9-3.1	≥ 3.2
Major Axis Dimension/BSA	2.4±0.3				2.5±0.3			

Figure 12: Linear 2D Measurement of Minor and Major Axis of Right Atrium From Apical 4c View

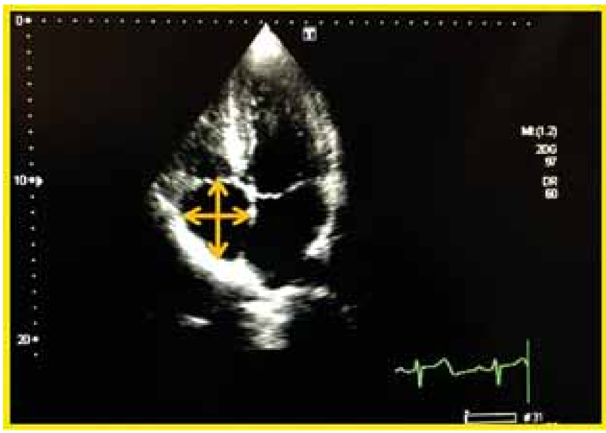


Figure 13: Linear 2D Measurements of Main and Branch Pulmonary Arteries From PS Sax View at the Level of

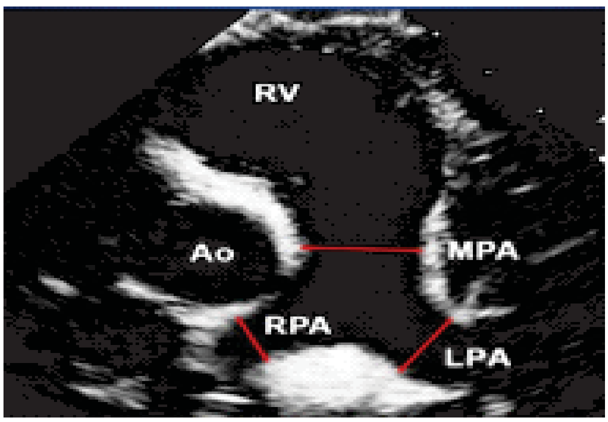


Table 8a: Pulmonary Artery Measurements

	Normal Range	Mildly Abnormal	Moderaterly Abnormal	Severly Abnormal
Pa Diameter	1.5-2.1	2.2-2.5	2.6-2.9	≥ 3.0

AORTIC ROOT

Aortic root extends from the annulus to its junction with ascending aorta at Sino-tubular junction.[14,15] It includes:

- Aortic annulus, the hinge point of attachment of the bases of three aortic leaflets, the narrowest part of aortic root
- Sinus portion, the most curved part of aortic root formed by right and non-coronary sinuses.
- Sino-tubular junction is the junction of the curved part with tubular ascending aorta.

M-mode measurement is obtained in parasternal long axis view with the cursor crossing the sinus portion of aortic root. However, for aortic root assessment, 2-D method is better and utilized in a leading edge to leading edge principle except for aortic annulus as shown in figure 14. Aortic annulus should be measured in mid-systole Fig.14 a, as by this time the orifice gets a more spherical shape[16] whereas the sinus portion and Sino-tubular junction should be measured in diastole as shown in figure.

Figure14: Linear 2D Measurements of Aortic Root From PS Lax View

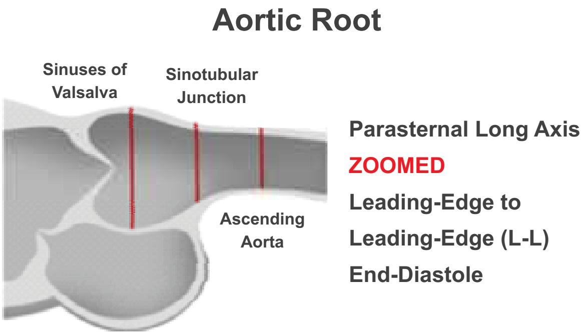
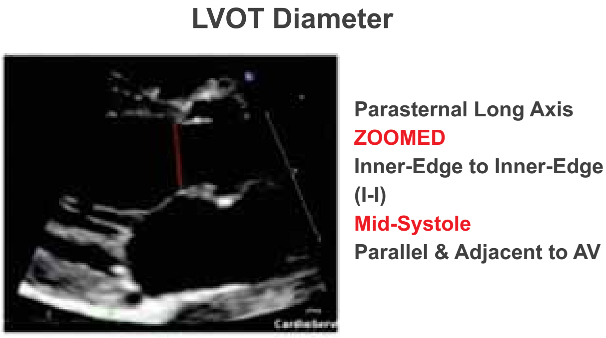


Figure 14 a: Measurement of Aortic Annulus in Mid-Systole



With the increasing use of TAVR (Trans-cutaneous Aortic Valve Replacement) immaculate assessment of all components of aortic root by echocardiography is of paramount importance in modern days of interventional cardiology. It is recommended to assess the aortic root by 2D method as translational movement of heart may under estimate its size by 2mm. Normal ranges and cutt off for aortic rote are shown in table 9.

Table 9: Normal Ranges and Cut-Off Values For Aortic Root Measurements[17]

	Male	Female
Annulus	2.3-2.9	2.1-2.5
Sinus of valsalva	3.1-3.7	2.7-3.3
Sinotubular Junct.	2.6-3.2	2.3-2.9
Prox. Ascend Aorta	2.6-3.4	2.3-3.1

INFERIOR VENA CAVA

Assessment of inferior vena cava size is important as it indicates not only the volume status of the patient but also the right ventricular/pulmonary artery pressure. For this, a 2-D sagittal view of IVC from sub costal location is obtained and the vessel is measured 1 to 2 cm distal to the point where it enters the right atrium, once in quiet breathing and once after sniffing, to assess not only the actual size but also the collapsibility which is then incorporated into RV pressure assessment 18 as shown in the table 10.

Figure 15: Linear 2D Measurement of Inferior Vena Cava From Sub-Costal Sagittal Plane

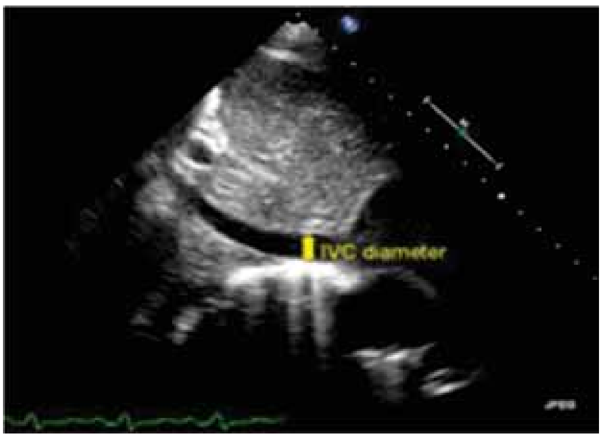


Table 10: Inferior Vena Cava And Right Atrial Pressure Estimation (Measured in Sub-Costal view 1-2 Cm from RA Junction)

Size	Collapsibility	Estimated Ra Pressure
< 1.7 CMS	< 50 %	0-5 mmHg
> 1.7 CMS	> 50 %	6-10 mmHg
> 1.7 CMS	< 50 %	10-15 mmHg
> 1.7 CMS	NO COLLAPSE	15+mmHg

The assessment of cardiac chambers by linear measurements has many advantages and limitations are shown in table 10.

Table 11: Advantages and Limitations of Chamber Assessment By Linear Measurement

Advantages	Limitations
Simple and reproducible	Mostly single dimensional measurements
	Beam orientation frequently off axis
High temporal resolution	RV dimensions and function may be erroneously measured
Enormous research data with demonstrated	due to its crescent shape and angle-dependence
prognostic value especially for	LV mass measurement maybe overestimated as linear
LV mass measurement	measurements are cubed.

Areas of the two atria can be measured in apical 4 and 2 chamber views, but this measurement is not recommended as the more robust volumetric measurements are easily obtainable with much wealth of prognostic data in support.

SECTION II---VOLUMETRIC MEASUREMENTS

Linear measurements although still done for chamber quantification but are not recommended for derivation of volume as different cardiac chambers don't conform to a particular geometrical shape (for which specific formulae are available) even in normal people and the distortion of shape has no limit in diseased states.

Simple measurement of Left atrium along its antero-posterior axis can't be used to calculate its volume because for this LA is assumed to be a sphere and all its three dimensions as equal, as a matter of fact LA is constrained by bony structures anteriorly and posteriorly and enlarges more in side to side and supero-inferior directions. Left ventricle is assumed to be a truncated prolate ellipse (very difficult for any geometrical formula to fit this shape) and when diseased (e.g. affected by aneurysm formation, dyskinesia or akinesia) no formula can fill in. Right ventricle is a crescent shaped structure wrapped around left ventricle and its volume can't be quantitated by a single linear measurement.

For all the above mentioned reasons volume of any chamber is measured by:

1. Biplane Modified Simpson's Disk summation method, preferred and recommended method.
2. Area length method.

All the rest like Teicholz or Quninone'smethod are not recommended to be used anymore.

The above mentioned two methods have been validated very well in laboratory studies with Simpson's method showing the best correlation.[19]

Firstly, an explanation of these methods is given and then how they are applied in clinical practice would be described.

MODIFIED SIMPSON'S BIPLANE METHOD OF DISKS

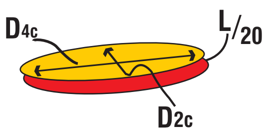
This is the preferred and recommended method for estimation of volume especially Left ventricle and Left atrium. The basis of this method is that volume of any chamber can be measured by dividing it into cylinders (coin shaped) of equal size, measuring the volume of individual coins and adding them all will give the volume of the chamber.

For this purpose first two views viz., apical 4 chamber and 2 chamber are obtained and endocardial border of the chamber is traced once in diastole and in systole, then a line is drawn along the long axis of the chamber, the soft-ware in the machine will automatically divide the traced area into 20 coins of equal height (h), the other two diameters (a and b) can be easily measured by the machine's in-built soft-ware.

Volume of a single cylinder (coin) is obtained by measuring its diameters in two orthogonal planes and applying the following formula (as shown in figure 16, 17and 17a)

$$\text{Volume (mL)} = \pi\,(D_1/2) \times (D_2/2) \times h$$

Figure 16: Estimation of Volume of A Single Disc
Volume of each ellipitical disk:

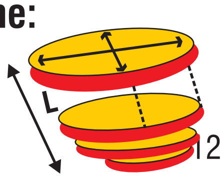


$$\frac{\pi\,(D4c \times D2c)\,L}{4n}$$

Figure 17: Estimation of Volume of All 20 Discs By Disc Summation Method

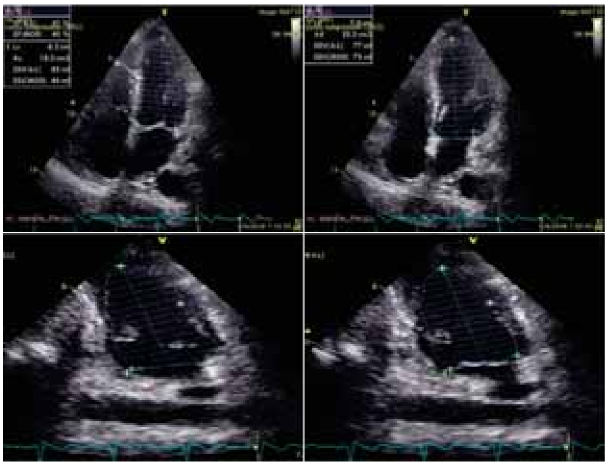
Total Ventricular Volume:

$$\frac{\pi}{4}\sum^{20} D_{4C} \times D_{4C} \times L / 20$$



The only caveat this method has is correct definition of endocardial border especially when tracing the LV apical region, for this extrapolation should be kept minimal. In difficult to assess cases help may be taken by injecting contrast which delineates the borders better.[20] Papillary muscles are included in volume assessment of left ventricle.

Figure 17a: LV Volume Estimation Biplane Simpson's Method Apical 4 And 2c Views



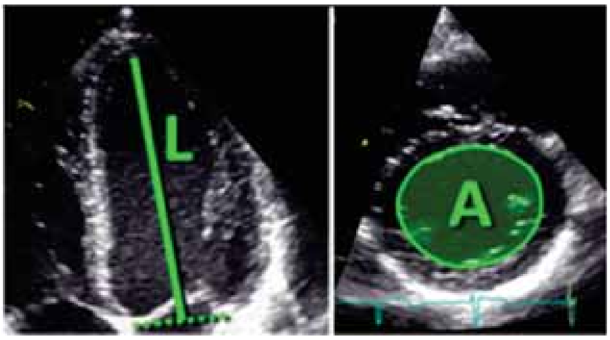
AREA LENGTH METHOD

Used when the previous method is difficult to apply because of technical reasons. In this method it is assumed that LV is a bullet shaped or hemi-ellipsoid structure and the followingformula is used:

Volume = 5/6 AL Where A= area at mid ventricular level and L is the length of ventricle from Mitral annular plane to LV apex.

Two views of LV are needed for this purpose, one an apical four chamber view to measure the length of LV (this gives L) and another a short axis view at mid-papillary muscle level in which the inner area is traced along the endocardial border excluding the papillary muscles (this gives A), figure 18.

Figure 18: The measurements are taken at end-diastolic and at end-systolic to



The measurements are taken at end diastole and at end systole to get End diastolic volume and End systolic volume and then the formula for EF issued.

Table 12: Normal Ranges and Cut-Off Values For LV Volumetric Measurements

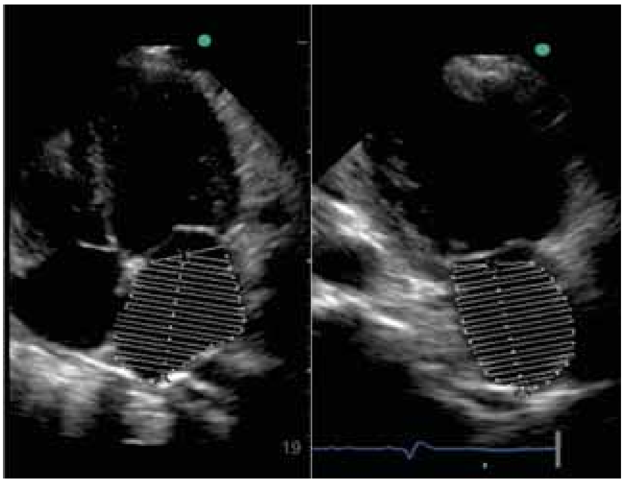
	Male				Female			
	Normal	Mild	Mod	Severe	Normal	Mild	Mod	Severe
Diastolic Vol.	62-150	151-174	175-200	> 200	46-106	107-120	121-130	> 130
Diastolic Vol. /BSA	34-74	75-89	90-100	> 100	29-61	62-70	71-80	> 80
Systolic Volume	21-61	62-73	74-85	> 85	14-42	43-55	56-67	> 67
Systolic Vol. /BSA	11-31	32-38	39-45	> 45	8-24	25-32	33-40	> 40

LEFT ATRIUM

Left atrium is said to be pillow shaped with no natural long or short axis and its dimensions are affected by dilatation and tortuosity of ascending and descending aorta especially in elderly, hence, it is very important to measure its volume for correct estimation of its size.[21-23] LAVI is prognostically better associated with onset of atrial fibrillation CHF, stroke, TIA, coronary revascularization and CV death than any other parameter measured for it.[24] Volume assessment has greater prognostic value for survival after MI and first CV event in elderly.[25]

Left atrial volume can be obtained by obtaining two orthogonal views (apical 4 and 2 chambers), and applying the Biplane modified Simpson's method. While Left atrial volume is assessed by this method Pulmonary veins and left atrial appendage should be excluded and the length of left atrium should be similar in the two planes (Figure 19).

Figure 19: Estimation of Left Atrial Volume By Modified Simpson's Method



It can be appreciated with practice that the long axis of LV and LA are not in line and LA should be measured when maximum volume of it can be seen, as shown below,(Figure 20).

As an alternate to this Biplane Area-length method can be used in which in each view the endocardial border is traced to get the two areasand the length of LA is taken from plane of Mitral valve annulus to its superior wall as shown in figure 21.

Figure 20: Orientation of The Long Axes of Left Ventricle and Left Atrium

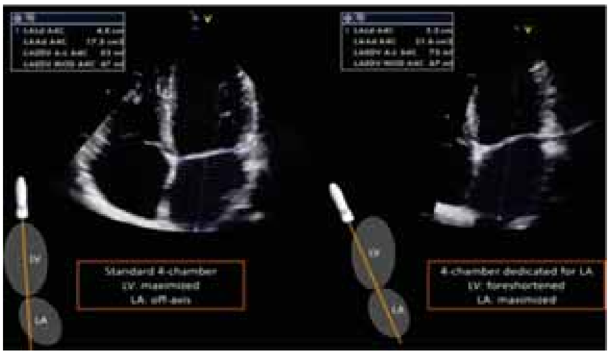


Figure 21: Estimation of Left Atrial Volume By Area Length Method from Apical 2 and 4 Chamber Views.

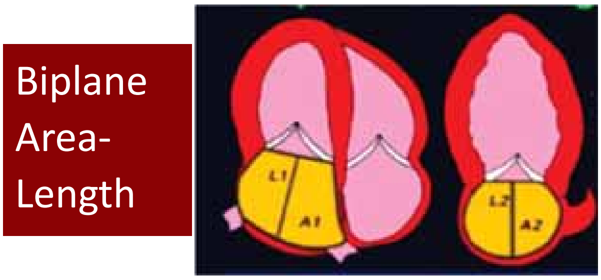


Table 13: Normal Ranges and Cut-Off Values For LV Volumetric Measurements

	Male				Female			
	Normal	Mild	Mod	Severe	Normal	Mild	Mod	Severe
VOLUME	18-58	59-68	69-78	$\geq$ 79	22-52	53-62	63-72	$\geq$ 73
VOL./BSA	22 ± 6	29-33	34-39	$\geq$ 40	22 ± 6	29-33	34-39	$\geq$ 40

Right ventricular volume measurement by this method can only estimate the volume of RV body and results in gross under-estimation of its size hence 2D RV volumes are not recommended to be measured by this method. However, right atrial volume measurements can be done by these methods, as two orthogonal views cannot be obtained so RA volume assessment can be done by single plane apical 4 chamber view.

The advantages and limitations of volume measurement can be gauged from the table below (Table 14).

Table 14: Volumetric Measurements- Advantages and Limitations

ADVANTAGES	LIMITATIONS
It corrects shape distortion of the chamber.	In case of LV assessment, apex may be foreshortened
	There may be endocardial dropout
There are less geometrical assumptions about asymmetric remodeling, especially of LA and LV	LV distortions in planes other than 2D and 4D views may not be accounted for
It enables accurate assessment of asymmetric remodeling	Data with regard to LA and RA assessment is not much

SECTION III -- LV MASS ASSESSMENT

Assessment of LV mass has great prognostic value especially in hypertensive patientsand in patients with coronary artery disease and hence should routinely be done in every case.[26,27] For this purpose both linear methods and 2D methods are available, the later is quite cumbersome and the former has huge data in clinical trials and research based on it and is therefore widely used.[28-31] However, for interested readers both methods are described here:

1. LINEAR METHOD: for this purpose Devereux formula is used which is as follows:

LV MASS = $0.8 \times 1.4 \times [(IVS + LVID + PWT)3 – LVID3] + 0.6g^3$

For this purpose end diastolic measurements of septum (IVS), posterior LV wall (PWT) and left ventricular internal dimensions are measured either by M-mode which is 2D guided and taken either in parasternal long axis or short axis view keeping it perpendicular to long axis of left ventricle. The same measurements can also be obtained by 2D parasternal long axis view which avoids the problem of angle between ultrasound beam and the perpendicular axis of LV in this view (Table 15).

Table 15: Normal ranges and cut-off values for lv mass (by linear method)

	Male				Female			
LV Mass (G)	88-224	225-258	259-292	> 292	67-162	163-186	187-210	> 210
LV Mass/BSA (G/M^2)	49-115	116-131	132-148	> 148	43-95	96-108	109-121	> 121

1. **2D BASED METHODS**: these are slightly cumbersome. For this purpose 2 formulae are used, Truncated ellipsoid and Area-length method. Mean wall thickness is calculated from epicardial (A1) and endocardial (A2) cross sectional areas in short axis view at the level of papillary muscle considered part of LV cavity Fig 22. The short axis radius is calculated as: b= under root $A2/\pi$, then mean wall thickness t is calculated as t = (under root of $A1/\pi$) – b and the cross sectional area of the myocardium (Am) in short axis view is :

Am = A1 – A2. LV mass is calculated from these measurements plus the LV length measured from the level of the short axis plane to the base (d) and to the apex (a) (Figure 22).

$$\text{LV MASS (AL)} = 1.05 \{[\tfrac{5}{6}\, A1(A+d+t)] - (5/6\, A2\, (a + d)]\}$$

$$\text{LV MASS (TE)} = 1.05 \times \{(b + t)^2\, [2/3\, (a + 1) + d - d^3/3(a+t)^2] - b^2[2/3\, a+d - d^3/3a^2]\}$$

Figure 22: 2D Area Length and Truncated Ellipsoid Methods for LV Mass Assessment

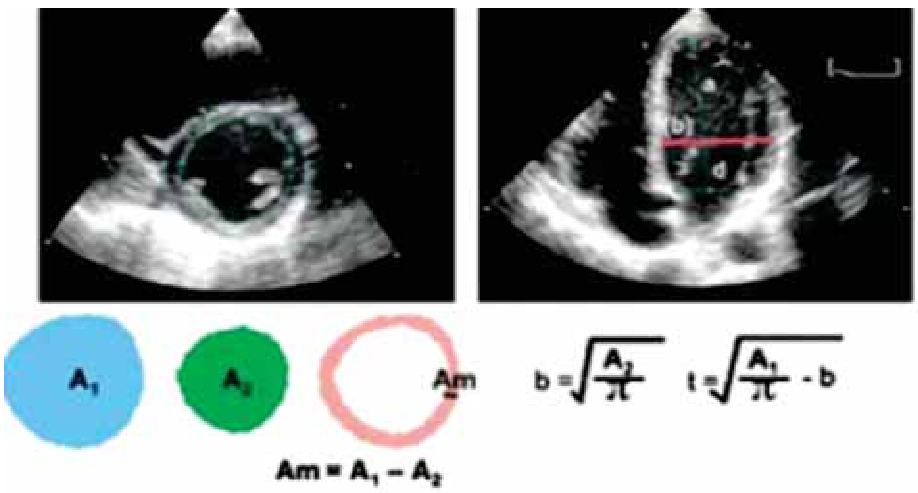


Table 16: LV Mass Assessment By 2d Method

	Male				Female			
	Normal	Mild LVH	Moderate LVH	Severe LVH	Normal	Mild LVH	Moderate LVH	Severe LVH
LV Mg	66-150	151-171	172-182	> 182	96-200	201-227	228-254	> 254
LVM/BSA g/m^2	44-88	89-100	101-112	> 113	50-102	103-116	117-130	> 130

REGIONAL WALL THICKNESS

This is another parameter of great significance derived from the same measurements. A ratio of wall to cavity size is derived and four types of geometrical patterns emerge, each of which has different prognostic value. Regional wall thickness is determined by the formula:

RWT = 2 X PW /LVEDD

Normal upper limit of regional wall thickness is 0.42 (Figure 23) (Table 17)[33].

Figure 23: Patterns of Left Ventricular Geometry According to Mass and RWT

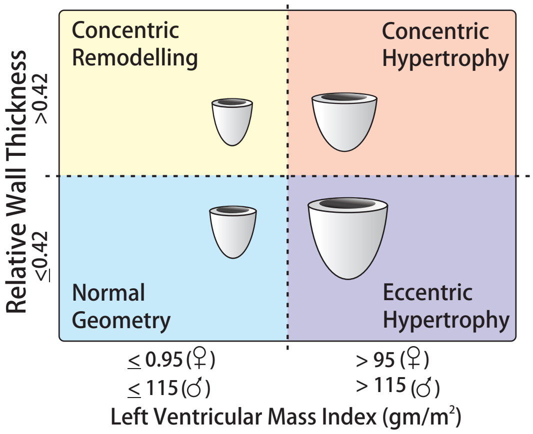


Table 17: Normal Ranges and Cut-Off Values for Relative Wall Thickness Measurements

	Male				Female			
	Normal	Mild	MOD	Severe	Normal	Mild	Moderate	Severe
Relative Wall	0.22-0.42	0.43-0.46	0.47- 0.51	$\geq$ 0.52	0.22-0.42	0.43-0.47	0.48- 0.52	$\geq$ 0.53

SECTION IV: SYSTOLIC VENTRICULAR FUNCTION ASSESSMENT

LEFT VENTRICULAR FUNCTION: GLOBAL

Global LV function is assessed either by calculating Ejection Fraction or estimating the Fractional shortening%. Once the ventricular volumes have been obtained from 2D derived methods of either Bi-plane modified Simpson's method or Area length method as detailed above assessment of global LV function is easy. Ejection fraction is the percentage of LV end diastolic volume ejected in one beat and is calculated by the following formula:

$$EF(\%) = \frac{EDV - ESV}{EDV} X100$$

Where EDV and ESV stand for end diastolic and end systolic ventricular volume respectively.

Fractional shortening is the percentage of LV diameters which shortens during systole as a ratio of end diastolic diameter. For this purpose LV diameters in diastole and systole as obtained either by 2D directed M-mode imaging or directly from 2D frozen image. This is not applied in cases of regional dysfunction but is a very useful measurement in hypertension, valvular heart disease and obesity. The formula for this measurement is as follows:

"FRACTIONALSHORTENING = LVED - LVES/LVED".

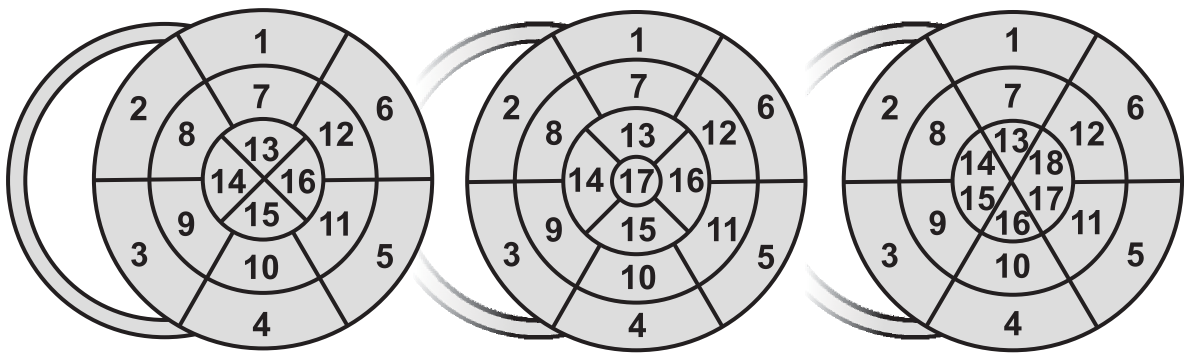
Table 18: Left Ventricular Ejection Fraction and Fractional Shortening

	Male				Female			
	Normal	**Mild**	**Moderate**	**Severe**	**Normal**	**Mild**	**Moderate**	**Severe**
Lv Ejection Fraction %	52-72	41-51	30-40	< 30	54-74	41-53	30-40	< 30
Lv Fract. Shortening %	25-43	20-24	15-19	$\leq$ 14	27-45	22-26	17-21	$\leq$ 16

REGIONAL ASSESSMENT

For this purpose LV is divided into segments varying from 16-18. Basal and mid third of LV are divided into six segments each with numbering done from basal anterior segment being one and rotating counter-clockwise as shown in fig. previously apex was divided into 4 segments as anterior, septal, inferior and lateral, in later schemes an apical cap was introduced as 17th segment (this however, does not contribute to LV contractility). In another model apex was also divided into six segments as base and mid regions, but this results in an over-expression of apex of apical contractility, so for practical purposes it is recommended to use 16 segment model in routine cases.

Figure 24: Segments of Left Ventricle[3]



<u>all models</u>

1. basal anterior
2. basal anteroseptal
3. basal inferoseptal
4. basal inferior
5. basal inferolateral
6. basal anterolateral
7. mid anterior
8. mid anteroseptal
9. mid inferoseptal
10. mid inferior
11. mid inferolateral
12. mid anterolateral

<u>16 and 17 segment model</u>

13. apical anterior
14. apical septal
15. apical inferior
16. apical lateral

<u>17 segment model only</u>

17. apex

<u>18 segment model only</u>

13. apical anterior
14. apical anteroseptal
15. apical inferoseptal
16. apical inferior
17. apical inferolateral
18. apical anterolateral

The degree of contractility is assessed by eye-balling as thickening of segments, however, the effect of tethering and translational movements must be kept in mind. A scoring system has been proposed to assess the degree of contractility as shown in figure 24 (Table 19).

Table 19: LV Wall Motion Scoring Based on Eye Balling

Movement	Score
Normal or Hyperkinetic	1
Hypokinetic (Reduced Thickening)	2
Akinetic (Absent or Negligible Thickening	3
Dyskinetic (Systolic Thinning or Stretching	4

Besides, ischemic heart disease abnormal regional motion could be caused by bundle branch block, pacing, abnormal activation sequence of LV myocardium, myocarditis etc., all of these should be reported. Similarly, abnormal motions like paradoxic septum, septal bounce etc. should also be reported.

Summary is shown in table 20 of different methods used for measurement

Table 20: Summary of Individual Measurement and the Recommended Method

S.No.	Parameter	Recommended Method	Alternate Method
1.	LEFT ATRIUM LINEAR DIMENSION	DIR ECT FROM 2D IMAGE PS LAX VIEW WITH CURSOR CROSSING SINUS PORTION OF AORTA	2D DIRECTED MODE AT SAME POSITION.
2.	LEFT VENTRICLE LINEAR DIMENSION	DIRECT FROM 2D IMAGE PS LAX VIEW WITH CURSOR CROSSING THE TIPS OF MITRAL VALVE LEAFLETS	2D DIRECTED MODE AT SAME POSITION.
3.	RIGHT VENTRICLE	2D APICAL 4C VIEW	
4.	RVOT-PROXIMAL	2D PS SAX VIEW OR PS LAX VIEW	
5.	RVOT-DISTAL	2D PS SAX VIEW AT GREAT VESSEL LEVEL	
6.	PULMONARY ARTERIES	2D SAX VIEW AT PA LEVEL	
7.	AORTA	2D PSLAX VIEW	
8.	INFERIOR VENA CAVA	SUBCOSTAL SAGITAL VIEW	
9.	LEFT ATRIAL VOLUME	SIMPSON'S METHOD IN APICAL 4C AND 2C BIPLANE MODIFIED VIEWS.	AREA LENGTH METHOD APICAL 4C VIEW.
10.	LEFT VENTRICULAR VOLUME	BIPLANE MODIFIED SIMPSON'S METHOD IN APICAL 4C AND 2C VIEWS.	AREA LENGTH METHOD APICAL 4C AND PS SAX VIEW AT MID VENTRICULAR LEVEL.
11.	LEFT VENTRICLE MASS	M-MODE AT PS LAX VIEW BY DEVEREUX FORMULA.	2D AREA LENGTH AND TRUNCATED ELLIPSOID METHODS.

CONCLUSION

Guidelines on trans-thoracic echocardiography have shown great changes over the years and a thorough knowledge of these as detailed in this text is a pre-requisite for any study.

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