

THE AMERICAN SOCIETY OF ECHOCARDIOGRAPHY RECOMMENDATIONS FOR CARDIAC CHAMBER QUANTIFICATION IN ADULTS: A QUICK REFERENCE GUIDE FROM THE ASE WORKFLOW AND LAB MANAGEMENT TASK FORCE

Accurate and reproducible assessment of cardiac chamber size and function is essential for clinical care. A standardized methodology creates a common approach to the assessment of cardiac structure and function both within and between echocardiography labs. This facilitates better communication and improves the ability to compare results between studies as well as differentiate normal from abnormal findings in an individual patient. This document summarizes key points from the 2015 ASE Chamber Quantification Guideline and is meant to serve as quick reference for sonographers and interpreting physicians. It is designed to provide guidance on chamber quantification for adult patients; a separate ASE Guidelines document that details recommended quantification methods in the pediatric age group has also been published and should be used for patients ≤ 18 years of age (3). (1) For details of the methodology and the rationale for current recommendations, the interested reader is referred to the complete Guideline statement. Figures and tables are reproduced from ASE Guidelines. (1,2)

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References:

1. Lang RM, Badano LP, Mor-Avi V, et al. [Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging](#). J Am Soc Echocardiogr 2015;28:1-39.e14.
2. Rudski LG, Lai WW, Afilato J, et al. [Guidelines for the echocardiographic assessment of the right heart in adults: a report from the American Society of Echocardiography](#). J Am Soc Echocardiogr 2010;23:685-713.
3. Lopez L, Colan SD, Frommelt PC, Ensing GJ, Kendall K, Younoszai AK, Lai WW, Geva T. [Recommendations for quantification methods during the performance of a pediatric echocardiogram: a report from the Pediatric Measurements Writing Group of the American Society of Echocardiography Pediatric and Congenital Heart Disease Council](#). J Am Soc Echocardiogr 2010 May;23(5):465-95.

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ASE Workflow & Lab Management Taskforce: David A. Orsinelli, MD, FASE (Chair), Alicia Armour, BS, MA, RDCS, FASE, Jeanne De Cara, MD, FASE, Brian Fey, RDCS, ACS, FASE, Peter Frommelt, MD, FASE, Juan Lopez-Mattei, MD, FASE, Jane Marshall, BS, RDCS, FASE, Athena Poppas, MD, FASE, Vandana Sachdev, MD, FASE, Liza Sanchez, RCS, FASE, and Timothy Woods, MD, FASE, *Columbus, Ohio; Durham, North Carolina; Chicago, Illinois; Milwaukee, Wisconsin; Houston, Texas; Boston, Massachusetts; Providence, Rhode Island; Bethesda, Maryland; Memphis, Tennessee.*

LEFT VENTRICLE (LV) SIZE AND FUNCTION

(For full recommendation refer to the [Chamber Quantification Guideline](#) p. 3-16)

LV Size

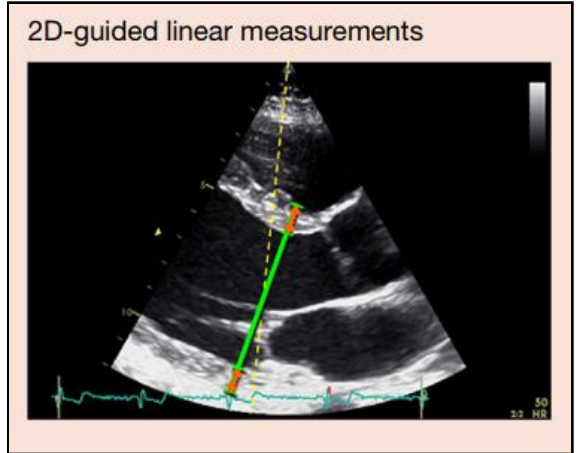
Linear Measurements

LVID Diastole (LVIDD)

- Inner edge to inner edge, perpendicular to the long axis of the LV, at or immediately below the level of the mitral valve leaflet tips.
- Perform at end-diastole (defined as the first frame after mitral valve closure or the frame with the largest LV dimensions/volume.) Each laboratory should choose one method for consistency.

LVID Systole (LVIDS)

- Inner edge to inner edge, perpendicular to the long axis of the LV, at or immediately below the level of the mitral valve leaflet tips.
- Perform at end-systole (defined as either as the frame after aortic valve closure or the smallest LV dimension/volume.) Each laboratory should choose one method for consistency.

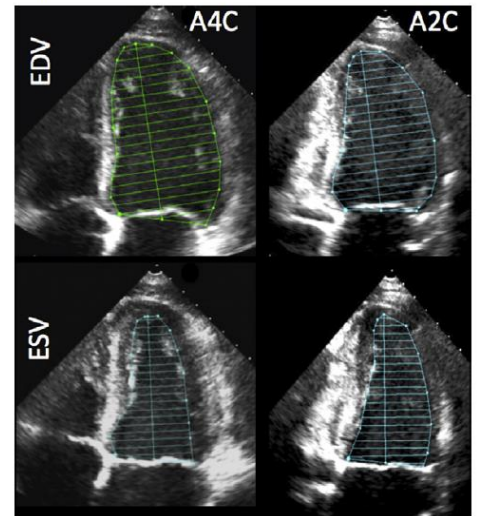


LV Volume Measurement

2D Methods

- Preferred technique is Biplane Method of Discs (modified Simpson's rule). See ASE 2015 chamber quantification document for the alternative area-length technique.
- Measured from the apical 4- and 2-chamber views (preferably an LV focused view) tracing the endocardial – blood pool interface (between the compacted myocardium and the cavity) at end-diastole and end-systole on images with clear endocardial border definition.
- Papillary muscles should be excluded from the cavity tracing.
- Maximize LV area and avoid foreshortening.
- When approaching the MV plane, the contour is closed by connecting the two opposite sections of the MV ring with a straight line.
- The LV length is the bisector between this line and the apical point of the LV contour distant from it.

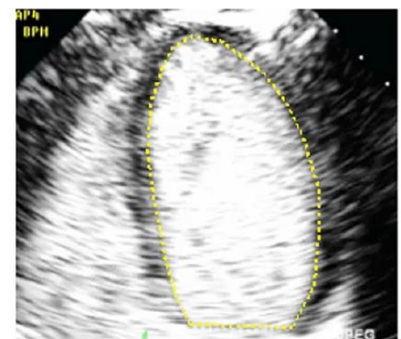
Biplane disk summation



Endocardial Border Enhancement

- When ≥ 2 contiguous endocardial segments cannot be visualized in the apical views, contrast should be used. If employed, the contrast-enhanced images should be used for Biplane tracing
 - Avoid acoustic shadowing in the basal segments of the LV when contrast concentration is high.
 - Note: Normal reference values for contrast enhanced LV volumes are not well established, however contrast enhanced images have been demonstrated to provide more reproducible volumetric and therefore ejection fraction data that correlate better with CMR.

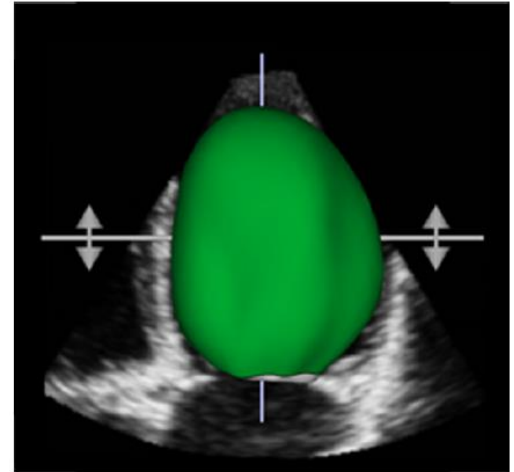
Endocardial border enhancement



3D Methods (Specific methodology varies by vendor / software versions)

- Familiarize staff with platforms in lab.
- LV volumes are calculated from a “full volume” data set (raw data).
- Perform on an LV focused volume (atria are not important).
 - Focus on including the entire LV in the pyramidal dataset and obtaining good endocardial border definition.
- On most systems, the volume/frame rate should be 15Hz or higher.
- Semi-automated software algorithm is then employed to detect endocardial borders in three orthogonal imaging planes. Once borders are reviewed and approved by the operator, volume is computed.
- Self-checks:
 - Volumes should be feasible in ED and ES.
 - Borders should track the endocardium, similar to a bi-plane. Contours / tracking may need to be manually adjusted.
- Record and store the “report page”. This will contain the full analysis data vs. the biplane volumes and EF.

3D data sets



LV Mass Calculations

Linear Method

LVID, IVS, PW Diastole

- Electronic calipers should be positioned on the interface between myocardial wall and cavity, and the interface between wall and pericardium.
- Perform at end-diastole (previously defined) perpendicular to the long axis of the LV, at or immediately below the level of the mitral valve leaflet tips.

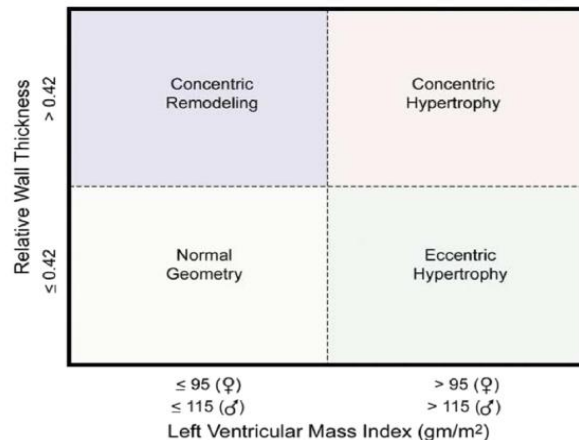
$$\text{LV mass} = 0.8 \times (1.04 \times [(IVS + LVID + PWT)^3 - LVID^3]) + 0.6 \text{ grams}$$

2D-based formulas

- Infrequently used in most clinical labs, see full Guideline statement for details.

Relative Wall Thickness (RWT)

- $RWT = (2 \times \text{posterior wall thickness}) / (LVIDD)$.
- Useful to categorize LV mass and pattern of remodeling.



Left Ventricular Function Assessment

(For full recommendation refer to the [Chamber Quantification Guideline](#) p. 6-13)

LV Global Systolic Function Parameters

- Fractional Shortening (use is discouraged)
 - $FS = LVIDD - LVIDS / LVIDD$ (normal $\geq 25\%$)
 - Derived from M-mode or linear 2D measurements
- Ejection Fraction (EF) (see below) is the predominant method for assessing global systolic function (see below) and is derived from the LV end-diastolic volume (LVEDV) and LV end-systolic volume (LVESV).
- Global Longitudinal Strain is a new parameter to assess LV systolic function.

LV Volumes used to calculate EF

- Volumes can be derived from 2DE or 3DE (see section on LV size for methodology).
 - The biplane method of disks is the preferred 2DE method.
 - In laboratories with 3D experience, three-dimensional volumes should be utilized.
- Volumes derived from linear measurements should **NOT** be used.
- Use of contrast is encouraged as detailed in LV Volumetric Measurement (Cannot use contrast with 3D data acquisitions).

LVEF by Biplane Method of Disks (modified Simpson's rule) or 3DE

- See prior section for methodology of volume measurements.
- $LVEF = LVEDV - LVESV / LVEDV$

Normal Ranges for LV Size and Function

- Normal values for LV chamber dimensions (linear), volumes and ejection fraction vary by gender.
- A normal ejection fraction is 53-73% (52-72% for men, 54-74% for women).
Refer to Table 2 (normal values for non-contrast images) and Table 4 (recommendations for the normal range, mildly, moderately and severely abnormal ejection fraction).

Global Longitudinal Strain (GLS)

- Defined as the change in length of an object within a certain direction relative to its baseline length.
- A measurement of deformation that is used to assess LV systolic function.
- $Strain (\%) = (L_t - L_0) / L_0$
 - L_t is the length at time t, L_0 is the length at time 0.
- GLS is assessed by speckle tracking, the specific methodology varies by vendor.
- Peak GLS describes the relative length change between end-diastole and end-systole.

$$GLS (\%) = (MLs - MLd) / MLd$$

(MLs = myocardial length end-systole, MLd = myocardial length end-diastole)

- Since MLs is smaller than MLd peak GLS is a negative number.
- CW of the aortic valve or PW of the LVOT should be obtained for timing of aortic valve opening and closure.
- The three standard apical views should be acquired in succession as LV focused views optimizing endocardial borders at a frame rate of 60Hz-90Hz. Heart rate should not vary more than 5bpm.
- Follow the system software prompts for analysis (specific method varies by vendor).
- GLS should be measured in the 3 standard apical views (apical 4 chamber, 2 chamber and long axis) and the average GLS should be reported.

- Normal values depend on several factors including the vendor and version of software. As a general guide, a peak GLS of -20% can be considered normal. The smaller the absolute number, the more abnormal is the strain.

LV Regional Function

Segmentation of the LV

- Segmentation schemes should reflect coronary perfusion territories and allow standardized communication within echocardiography and with other imaging modalities.
- When using this 17-segment model to assess wall motion or regional strain, the 17th segment (the apical cap) should not be included.
- Although certain variability exists in the coronary artery blood supply to myocardial segments, segments are usually attributed to the three major coronary arteries.

17 Segment Model

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
13. Apical Anterior
14. Apical Septal
15. Apical Inferior
16. Apical Lateral
17. Apex

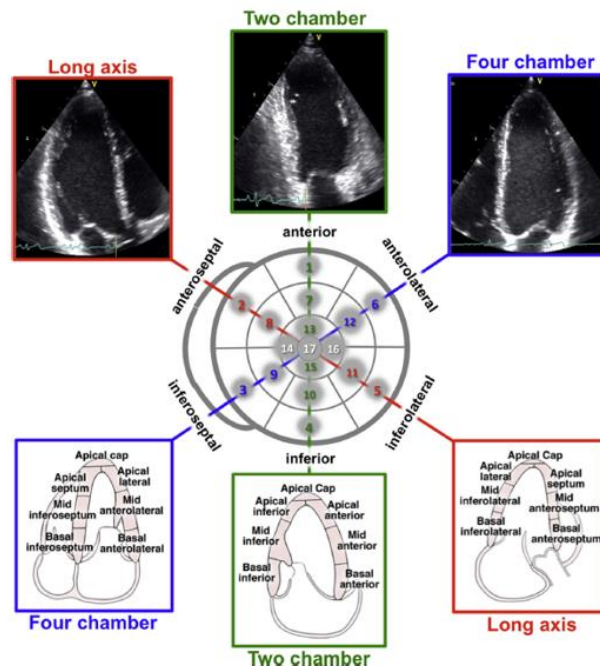


Figure 4 Orientation of apical four-chamber (A4C), apical two-chamber (A2C), and apical long-axis (ALX) views in relation to the bull's-eye display of the LV segments (center). Top panels show actual images, and bottom panels schematically depict the LV wall segments in each view.

The following scoring system is recommended:

1 = Normal or Hyperkinetic

2 = Hypokinetic (reduced thickening)

3 = Akinetic (absent or negligible thickening, i.e. scar)

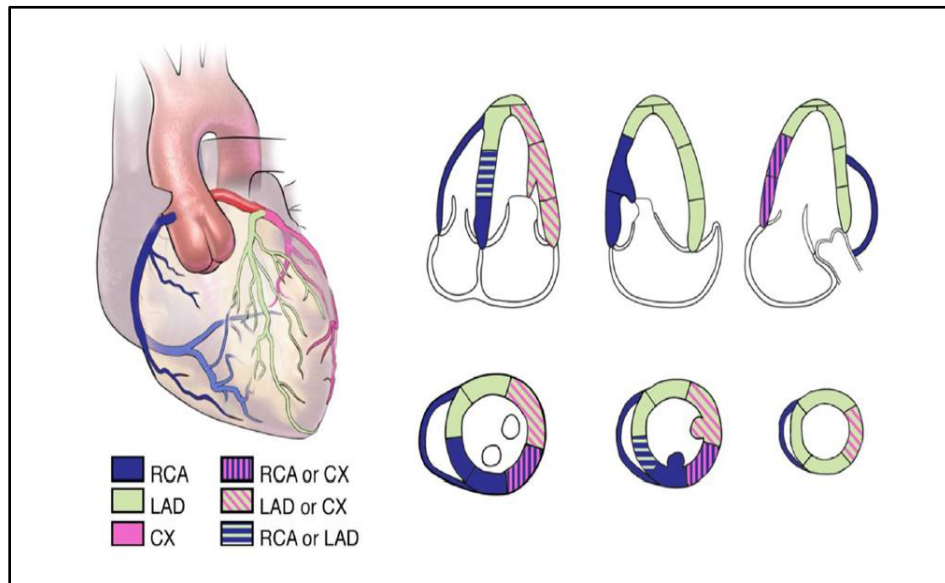
4 = Dyskinetic (systolic thinning or stretching, i.e. aneurysm)

Visual Assessment

- Semi quantitative wall motion score (1-4) can be assigned to each segment to calculate the LV wall motion score index (sum score of all segments assessed / # segments assessed).

Regional Wall Motion during Infarction and Ischemia

- Coronary artery distribution varies among patients. Some segments have variable coronary perfusion.
- Echocardiography may over or underestimate the amount of ischemic or infarcted myocardium, depending on the function of adjacent regions, regional loading conditions, and stunning.



Regional Abnormalities in the Absence of Coronary Artery Disease

- Regional wall motion abnormalities may also occur in the absence of coronary artery disease (examples: myocarditis, sarcoidosis and takotsubo cardiomyopathy).
- Interventricular septal wall motion abnormalities may be found in:
 - Left bundle branch block
 - RV pacing
 - RV pressure/volume overload
 - Post op septal motion
- Wall motion patterns due to conduction delays (abnormal sequence of myocardial activation):
 - Septal bounce (“beaking”, “flash”)
 - Lateral apical motion during systole (“apical rocking”).

RIGHT VENTRICLE (RV) SIZE AND FUNCTION

(For full recommendation refer to the [Chamber Quantification Guideline](#) p. 16-20)

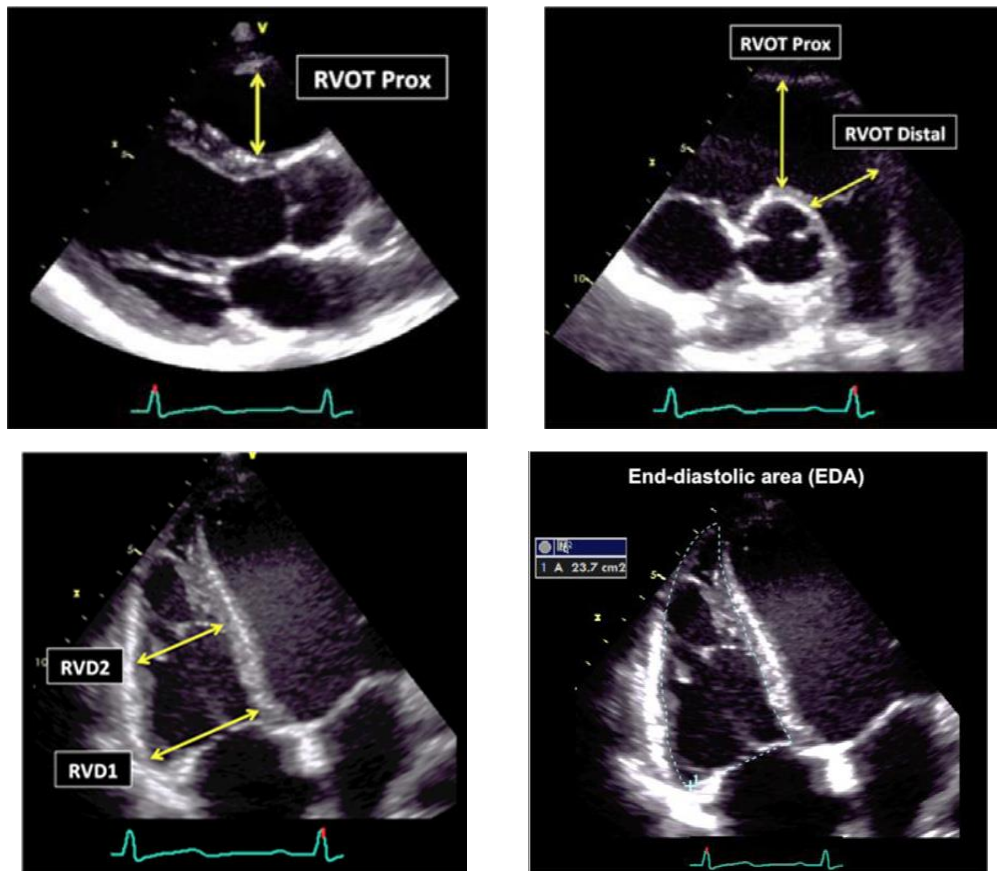
In order to assess RV size and function it is important to use **all available views**. Each view adds complementary information, permitting a more complete assessment of the different segments of the RV.

The essential views for imaging and assessment of the RV are:

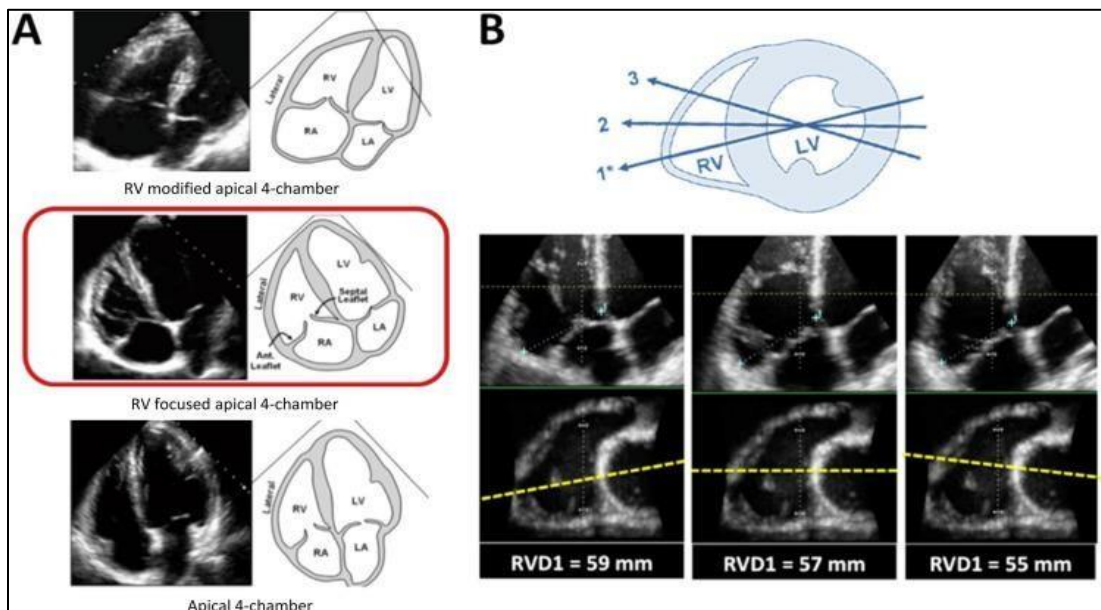
- Left parasternal long-axis view (PLAX)
- Left parasternal short-axis view (PSAX)
- Left parasternal RV inflow view
- Apical 4-chamber view
- Focused apical 4-chamber RV view
- Modified apical 4-chamber view
- Subcostal views

RV Size

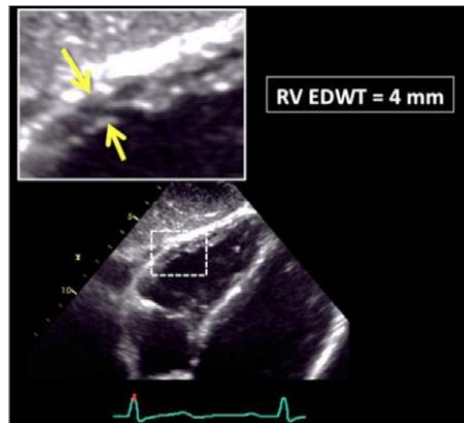
RV size should be routinely assessed by conventional 2DE using multiple acoustic windows. All chamber measurements should be made inner-edge to inner-edge. The report should **include both qualitative and quantitative parameters**. Most of the values are **not indexed** to gender, BSA, or height.



To measure the RV diameter, the **RV focused apical 4-chamber view** (a dedicated view which keeps the LV apex in the center and displays the largest basal RV diameter as shown below) should be used. Since RV linear dimensions are dependent on probe rotation and different RV views, the echocardiographic report should **state the window** from which the measurement was obtained. A single measurement may not reflect global RV size. An RV diameter of **>41mm** at the base and **>35mm** at the mid-level is abnormal.



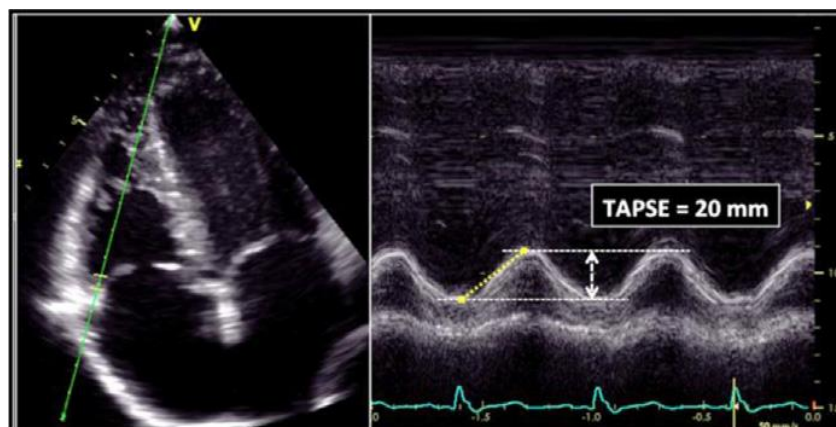
RV wall thickness should be measured by 2DE or M-mode at end-diastole, zoomed on the RV mid-wall (preferably from the **subcostal view**). A thickness of **>5mm** is abnormal.



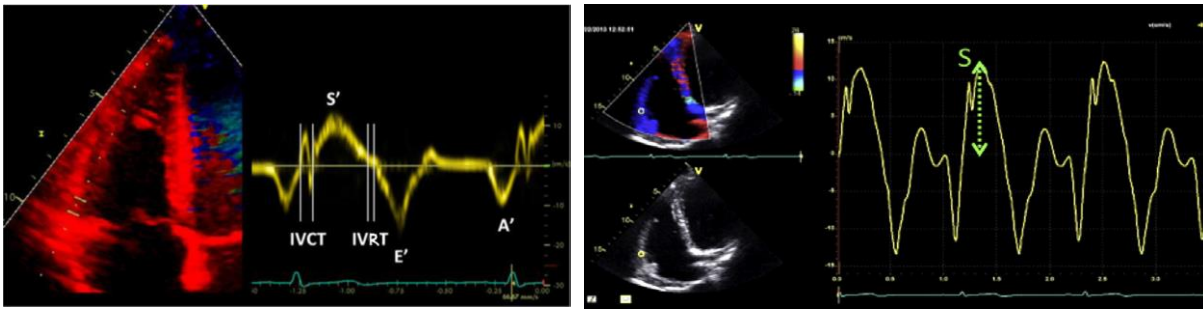
RV Function

RV systolic function should be assessed by **at least one or a combination** of the following **recommended parameters**:

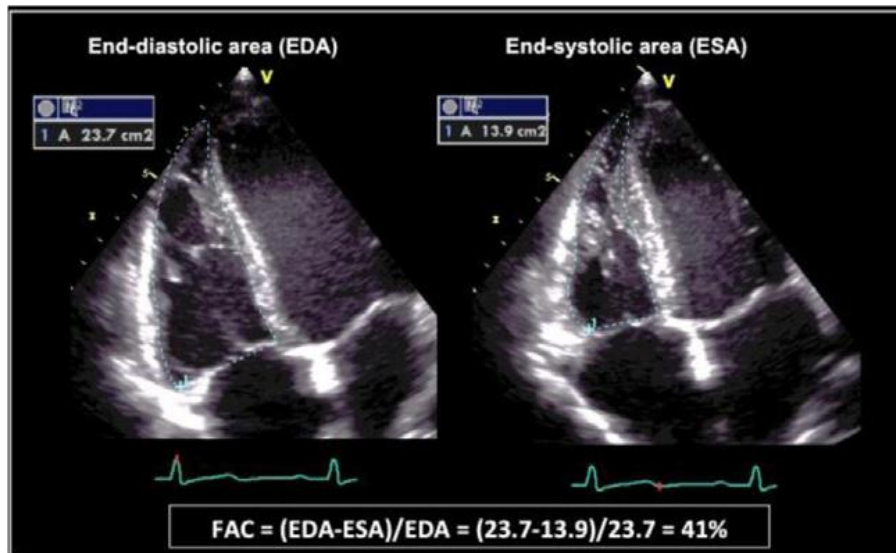
1. TAPSE (Tricuspid Annular Plane Systolic Excursion)
 2. DTI-Derived Tricuspid Lateral Annular Systolic Velocity S'
 3. FAC (fractional area change)
 4. RV longitudinal strain
 5. 3D EF
 6. Right Index of Myocardial Performance (RIMP or MPI)
- 1) TAPSE predominantly reflects RV **longitudinal function**, but it has shown good correlation with parameters estimating RV global systolic function. TAPSE may over- or underestimate RV function because of **cardiac translation**.



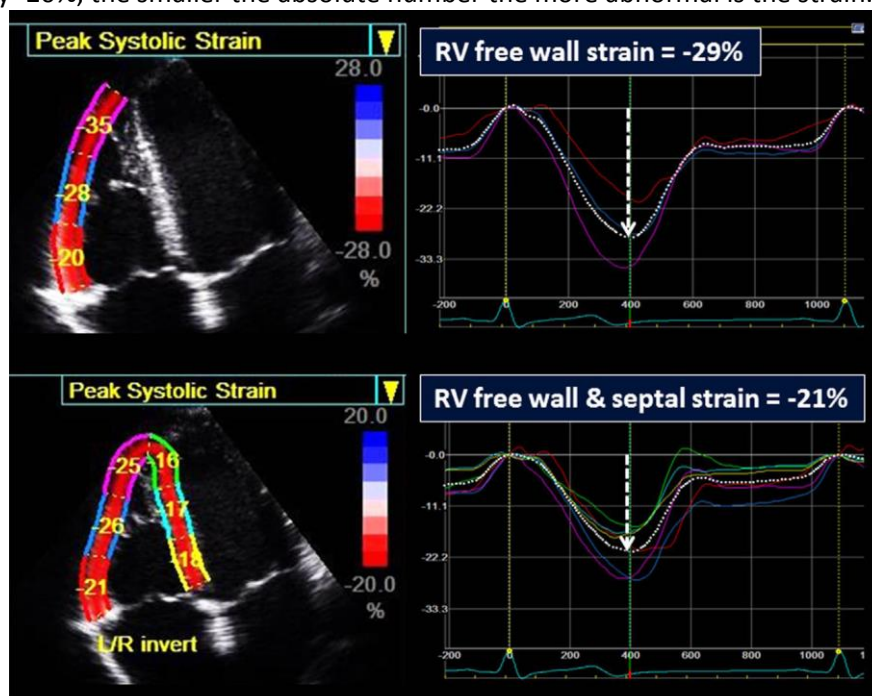
- 2) DTI -derived tricuspid lateral annular systolic velocity S' represents basal systolic function, not global RV function. The velocity may not be accurate in patients who are post thoracotomy, pulmonary thromboendarterectomy or heart transplantation. It is also **angle dependent**.



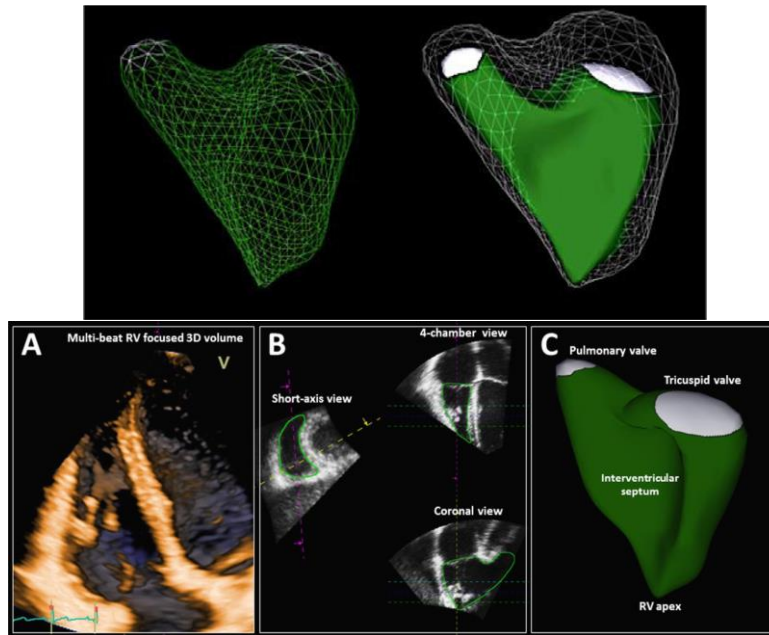
- 3) FAC reflects **both longitudinal and radial components** of RV contraction. It does not include the contribution of **RV outflow tract** to overall systolic function.



- 4) RV longitudinal strain is less confounded by overall heart motion, but depends on RV loading conditions as well as RV size and shape. RV longitudinal strain should be measured in the RV-focused view. A normal value is approximately -20%, the smaller the absolute number the more abnormal is the strain.

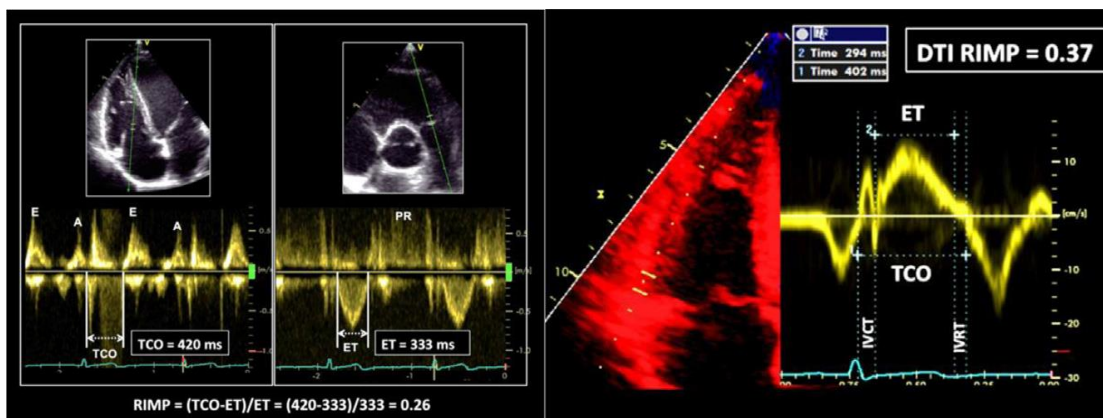


- 5) RV 3D EF does not directly reflect RV contractile function, but provides an integrated view of the interaction between RV contractility and load. The limitations of 3D assessment of RV EF are load dependency, interventricular changes affecting septal motion, poor acoustic windows, and irregular rhythms.



- 6) RIMP (Right Index of Myocardial performance) assesses global RV function. The measurement requires beats with similar RR intervals and is unreliable when RA pressure is elevated. The IVCT, IVRT and ET intervals used in the calculation can be obtained from PW Doppler of the TV inflow and RVOT outflow or from tissue Doppler of the lateral TV annulus (see figure). Normal values differ depending on the method used.

- a. $RIMP = (TCO - ET)/ET$ where TCO is the TV closure to opening time (and equals the IVRT + IVCT).



ATRIA

(For full recommendation refer to the [Chamber Quantification Guideline](#) p. 20-29)

Left Atrium (LA) Area and Volume Measurements

- Should be measured at end-systole when the LA chamber is at its greatest dimension (prior to MV opening).

- Avoid foreshortening.
- Dedicated acquisition of LA from the apical approach should be obtained to maximize LA length and alignment of the true long axis of the LA for area and volume measures.
- For LA tracings (area or volume) the confluences of the pulmonary veins and LA appendage should be excluded.
- The atrioventricular interface should be represented by the mitral annulus plane.

LA Anterior-Posterior (AP) dimension

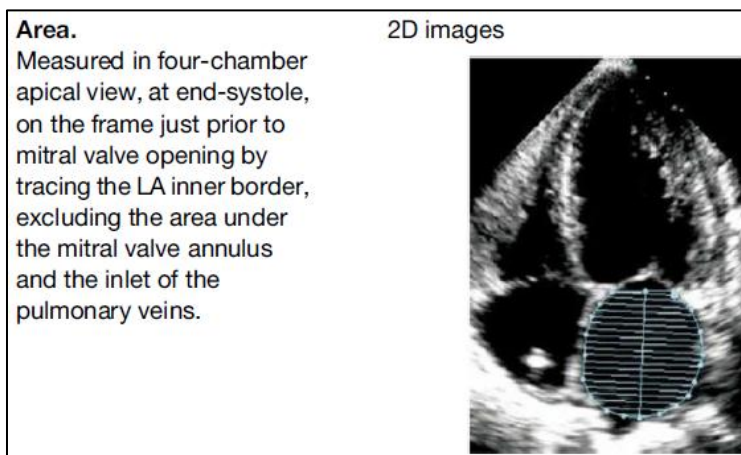
- Should not be used as sole LA measurement (does not represent accurate LA size).
- 2D measure is preferred over M-mode.
- Perpendicular to the long axis of the LA posterior wall, leading edge to leading edge (M-mode) or inner edge to inner edge (2DE).
- Measured at the level of the aortic sinuses.



LA Area and Volumes (Apical 4 and 2 chambers)

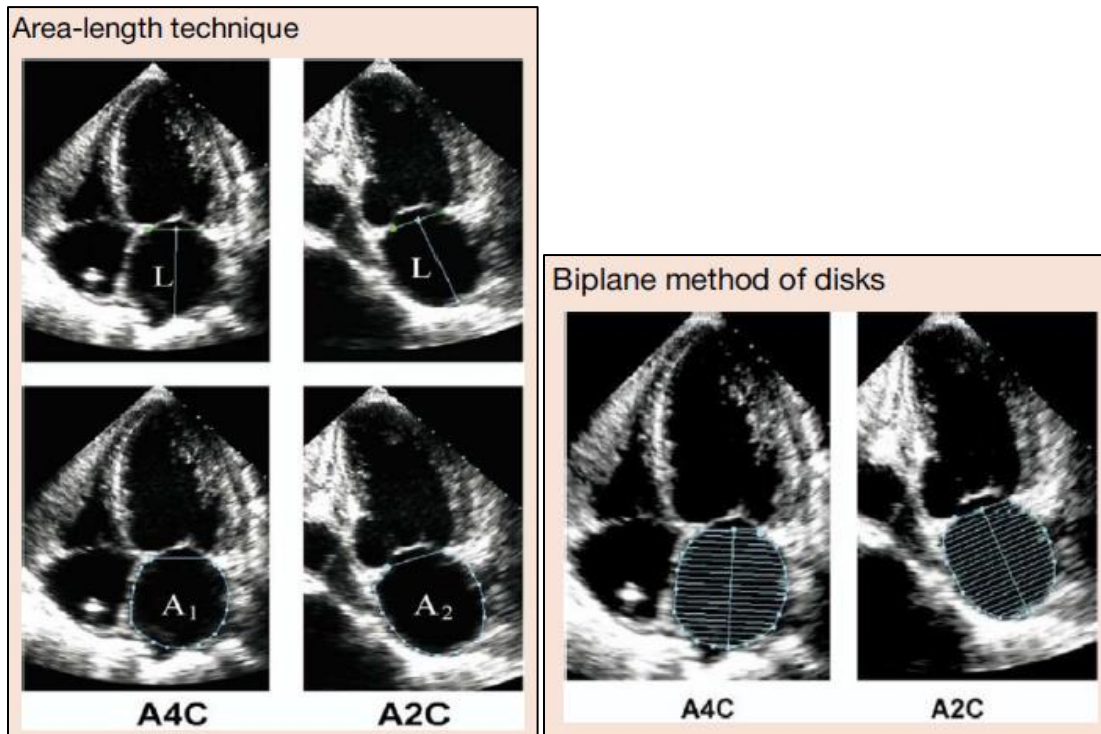
LA Area

- The base of the LA should be at its largest size.
- Trace the LA inner border, excluding the area under the MV annulus, pulmonary veins, and LA appendage.



LA Volume (Preferred over linear or area measurements)

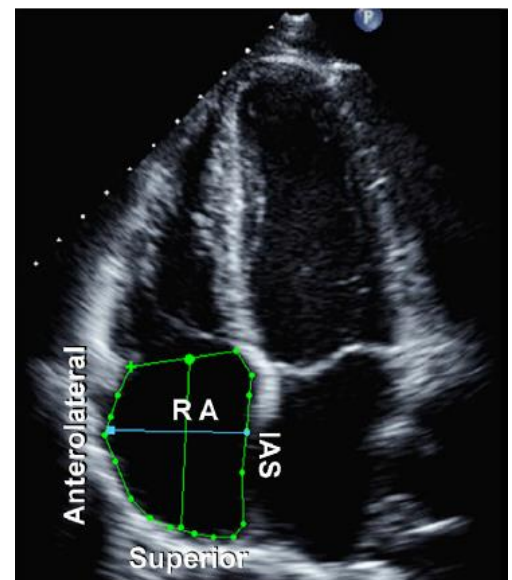
- Volume can be calculated by the Area-length method or disk summation technique (modified biplane) which is preferred.
- Trace the LA inner border, excluding the area under the MV annulus, pulmonary veins, and LA appendage from the apical 4 and 2 chamber views.
- Area-length technique: the length (L) should be measured from the shorter of the two long axes in the 4C and 2C views



Right Atrium (RA) Area & Volume Measurements

RA area

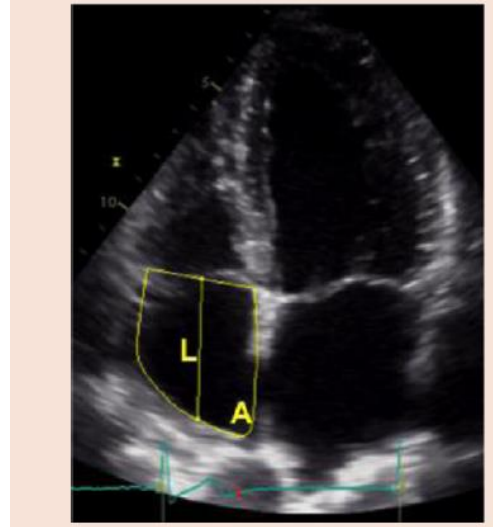
- The RA should be measured at end-ventricular systole when the RA chamber is at its greatest dimension, prior to TV opening.
- A dedicated right heart view (from an Apical 4 chamber view that includes the entire RA and is not foreshortened) should be used for acquisition to ensure the RA is not foreshortened.
- The RA length should also be maximized ensuring alignment along the true long axis of the RA.
- The base of the RA should be at its largest size indicating that the imaging plane passes through the maximal short-axis area.
- When performing planimetry of the RA, trace the RA inner border excluding the area under the TV annulus and the confluences of the RA appendage.



RA Volume (single plane)

- More robust and accurate when compared with linear measurements.
- Should be performed from an Apical 4 chamber view that includes the entire RA and is not foreshortened (dedicated right heart view), tracing the RA inner border excluding the area under the TV annulus.
- No standard orthogonal RA view to use for biplane so a single-view area-length and/or disk summation technique should be used.
- Area-length method: the length should be performed at the center of the area under the TV annulus to the superior RA wall.

2D view



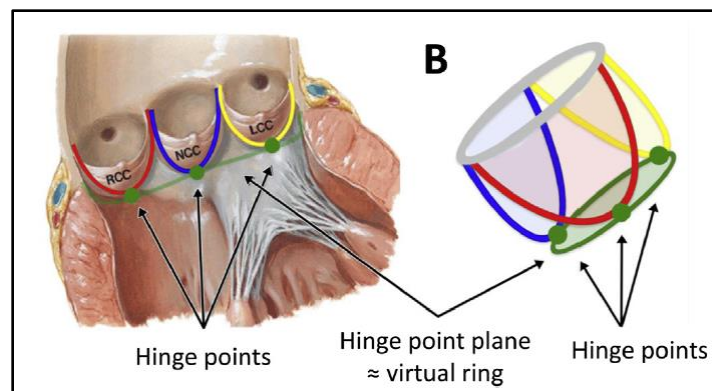
AORTA

(For full recommendation refer to the [Chamber Quantification Guideline](#) p. 28-32)

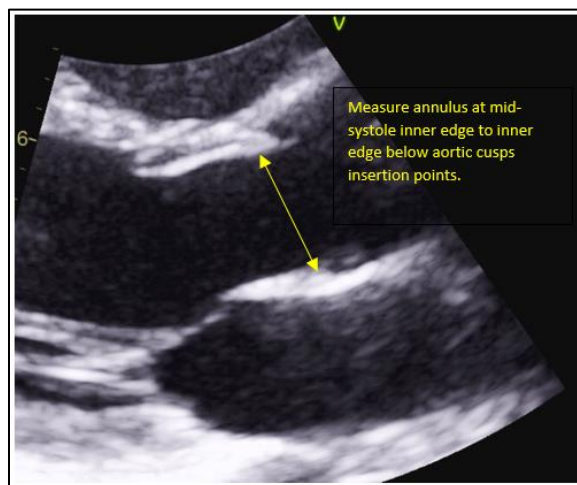
Aortic Annulus and Aortic Root

Aortic annulus

- Not a true or distinct anatomic structure but is a virtual ring that may be defined by joining the basal attachments, or nadirs, of the three aortic leaflets.
- The distal (uppermost) attachments of the leaflets, in the shape of a crown, form a true anatomic ring.

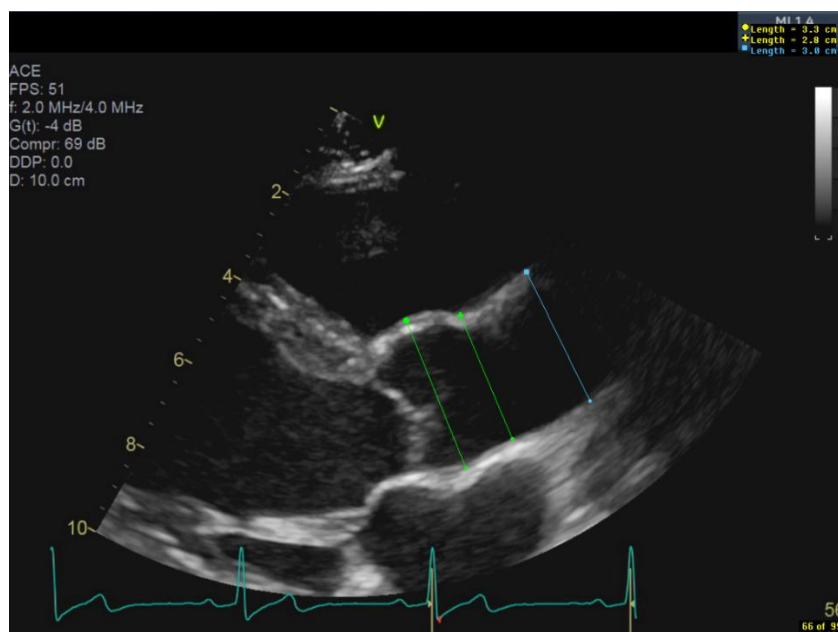


- Measurements of the aortic annulus should be made in the zoom mode using standard electronic calipers in mid-systole, when the annulus is slightly larger and rounder than in diastole.
- Measurement should be performed between the hinge points of the aortic valve leaflets (usually between the hinge point of the right coronary cusp and the edge of the sinus at the side of the commissures between the left coronary cusp and the non-coronary cusp) from inner edge to inner edge.
- As a general rule, calcium protuberances should be considered as part of the lumen, not of the aortic wall, and therefore excluded from the diameter measurement.



Aortic Root

- The diameter of the aortic root (at the maximal diameter of the sinuses of Valsalva) should be obtained from the parasternal long-axis view, which depicts the aortic root and the proximal ascending aorta.
- The tubular ascending aorta is often not adequately visualized from a standard parasternal window. In these instances, moving the transducer closer to the sternum and/ or to a higher intercostal space may allow visualization of a longer portion of the ascending aorta.
- Measurements should be made in the view that depicts the maximum aortic diameter perpendicular to the long axis of the aorta and at end-diastole.
- An asymmetric closure line, in which the tips of the closed leaflets are closer to one of the hinge points, is an indication that the cross-section is not encompassing the largest root diameter.
- The leading edge to leading edge convention for measurements of the aortic root and aorta is recommended.
- Two-dimensional echocardiographic aortic diameter measurements are preferable to M-mode measurements, because cardiac motion may result in changes in the position of the M-mode cursor relative to the maximum diameter of the sinuses of Valsalva.



INFERIOR VENA CAVA

(For full recommendation refer to the [Chamber Quantification Guideline](#) p. 32-33)

- The diameter of the IVC should be measured in the subcostal view with the patient in the supine, using the long-axis view. For accuracy, this measurement should be made perpendicular to the IVC long axis.
- For simplicity and uniformity of reporting, specific values of RA pressure, rather than ranges, should be used in the determination of systolic pulmonary artery pressure.
- IVC diameter < 2.1 cm that collapses >50% with a sniff suggests normal RA pressure of 3 mm Hg.
- IVC diameter > 2.1 cm that collapses < 50% with a sniff suggests high RA pressure of 15 mm Hg.
- In indeterminate cases in which the IVC diameter and collapse do not fit this paradigm, an intermediate value of 8 mm Hg (range, 5-10 mm Hg) may be used, or, preferably, secondary indices of elevated RA pressure should be integrated.

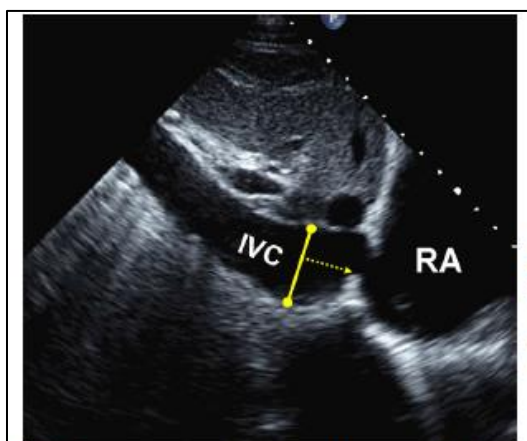


Figure 4 Inferior vena cava (IVC) view. Measurement of the IVC. The diameter (*solid line*) is measured perpendicular to the long axis of the IVC at end-expiration, just proximal to the junction of the hepatic veins that lie approximately 0.5 to 3.0 cm proximal to the ostium of the right atrium (RA).

APPENDIX – Normative Values

Left Ventricle (LV) Size and Function p. 2

Standard LV Measurement Parameters

	Male				Female			
	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal
LV dimension								
LV diastolic diameter (cm)	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
LV diastolic diameter/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
LV systolic diameter (cm)	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
LV systolic diameter/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

Normal Ranges and Severity Cutoff Values for 2D-derived LV Volumes

	Male				Female			
	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal
LV volume								
LV diastolic volume (mL)	62–150	151–174	175–200	>200	46–106	107–120	121–130	>130
LV diastolic volume/BSA (mL/m ²)	34–74	75–89	90–100	>100	29–61	62–70	71–80	>80
LV systolic volume (mL)	21–61	62–73	74–85	>85	14–42	43–55	56–67	>67
LV systolic volume/BSA (mL/m ²)	11–31	32–38	39–45	>45	8–24	25–32	33–40	>40

Normal Reference Values for Indexed LV Volumes by 3DE

	Aune <i>et al.</i> (2010)	Fukuda <i>et al.</i> (2012)	Chahal <i>et al.</i> (2012)	Muraru <i>et al.</i> (2013)
Number of subjects	166	410	978	226
Ethnic makeup of population	Scandinavian	Japanese	51% European white, 49% Asian Indian	White European
EDVi (mL/m ²)				
Men, mean (LLN, ULN)	66 (46, 86)	50 (26, 74)	White: 49 (31, 67); Indian: 41 (23, 59)	63 (41, 85)
Women, mean (LLN, ULN)	58 (42, 74)	46 (28, 64)	White: 42 (26, 58); Indian: 39 (23, 55)	56 (40, 78)
ESVi (mL/m ²)				
Men, mean (LLN, ULN)	29 (17, 41)	19 (9, 29)	White: 19 (9, 29); Indian: 16 (6, 26)	24 (14, 34)
Women, mean (LLN, ULN)	23 (13, 33)	17 (9, 25)	White: 16 (8, 24); Indian: 15 (7, 23)	20 (12, 28)

Normal Ranges and Severity Cutoff Values for LV Wall Thickness and Mass Using Linear Method

	Male				Female			
	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal
LV mass by linear method								
Septal wall thickness (cm)	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
Posterior wall thickness (cm)	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
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

	Male				Female			
	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal
LV EF (%)	52–72	41–51	30–40	<30	54–74	41–53	30–40	<30

Right Ventricle (RV) Size and Function *p. 6*

Parameter	Mean \pm SD	Normal range
RV basal diameter (mm)	33 \pm 4	25–41
RV mid diameter (mm)	27 \pm 4	19–35
RV longitudinal diameter (mm)	71 \pm 6	59–83
RVOT PLAX diameter (mm)	25 \pm 2.5	20–30
RVOT proximal diameter (mm)	28 \pm 3.5	21–35
RVOT distal diameter (mm)	22 \pm 2.5	17–27
RV wall thickness (mm)	3 \pm 1	1–5
RVOT EDA (cm ²)		
Men	17 \pm 3.5	10–24
Women	14 \pm 3	8–20
RV EDA indexed to BSA (cm ² /m ²)		
Men	8.8 \pm 1.9	5–12.6
Women	8.0 \pm 1.75	4.5–11.5
RV ESA (cm ²)		
Men	9 \pm 3	3–15
Women	7 \pm 2	3–11
RV ESA indexed to BSA (cm ² /m ²)		
Men	4.7 \pm 1.35	2.0–7.4
Women	4.0 \pm 1.2	1.6–6.4
RV EDV indexed to BSA (mL/m ²)		
Men	61 \pm 13	35–87
Women	53 \pm 10.5	32–74
RV ESV indexed to BSA (mL/m ²)		
Men	27 \pm 8.5	10–44
Women	22 \pm 7	8–36

EDA, end-diastolic area; *ESA*, end-systolic area; *PLAX*, parasternal long-axis view; *RVOT*, RV outflow tract.

Parameter	Mean \pm SD	Abnormality threshold
TAPSE (mm)	24 \pm 3.5	<17
Pulsed Doppler S wave (cm/sec)	14.1 \pm 2.3	<9.5
Color Doppler S wave (cm/sec)	9.7 \pm 1.85	<6.0
RV fractional area change (%)	49 \pm 7	<35
RV free wall 2D strain* (%)	–29 \pm 4.5	>–20 (<20 in magnitude with the negative sign)
RV 3D EF (%)	58 \pm 6.5	<45
Pulsed Doppler MPI	0.26 \pm 0.085	>0.43
Tissue Doppler MPI	0.38 \pm 0.08	>0.54

Atria p. 10

Standard LA Anterior-Posterior Dimensions		
Parameter	Male	Female
LAd (cm)	3.0-4.0	2.7-3.8
LAd indexed by BSA (cm/m ²)	1.5-2.3	1.5-2.3
LAd, left atrium diameter; BSA, body surface area		

Normal ranges and severity cutoff values for LA Area and LA Volume				
Parameter	Normal	Mildly enlarged	Moderately enlarged	Severely enlarged
LA Area (cm ²)	≤ 20	21-30	31-40	≥41
LA Volume indexed by BSA (mL/m ²)	16-34	35-41	42-48	>48
LA, left atrium; BSA, body surface area				

RA Measurement Standards from JASE 2010 Right Heart Guidelines (2)

Normal ranges and severity cutoff values for RA Area		
Parameter	Normal	Enlarged
RA (cm ²)	≤18	>18
RA, right atrium		

Table 13 Normal RA size obtained from 2D echocardiographic studies		
	Women	Men
RA minor axis dimension (cm/m ²)	1.9 ± 0.3	1.9 ± 0.3
RA major axis dimension (cm/m ²)	2.5 ± 0.3	2.4 ± 0.3
2D echocardiographic RA volume (mL/m ²)	21 ± 6	25 ± 7
Data are expressed as mean ± SD.		

Aorta p. 13

Table 14 Aortic root dimensions in normal adults				
Aortic Root	Absolute values (cm)		Indexed values (cm/m ²)	
	Men	Women	Men	Women
Annulus	2.6 ± 0.3	2.3 ± 0.2	1.3 ± 0.1	1.3 ± 0.1
Sinuses of Valsalva	3.4 ± 0.3	3.0 ± 0.3	1.7 ± 0.2	1.8 ± 0.2
Sinotubular junction	2.9 ± 0.3	2.6 ± 0.3	1.5 ± 0.2	1.5 ± 0.2
Proximal ascending aorta	3.0 ± 0.4	2.7 ± 0.4	1.5 ± 0.2	1.6 ± 0.3