A. PARASTERNAL WINDOW

LAX LV

TRANSDUCER

Place the transducer at the left parasternal window with the indicator toward the patient's right shoulder to acquire the parasternal long axis left ventricle (LAX LV).

TIP: start superior/medial along the sternum and slowly work inferior/lateral until the heart is located, then fine-tune the location and angle of the transducer.

PROTOCOL

1) Initially, increase the depth and acquire the entire cardiac structure and surroundings.

- Rule out extracardiac abnormalities such as pericardial effusion, pleural effusion, and mass.

2) Decrease the depth so the heart fills the screen. Assess chamber size, wall thickness, global function, and valvular function.

- Rule out abnormalities such as chamber dilatation, hypertrophy, decreased global function, wall motion abnormality (WMA), and valvular abnormality.

INCREASE DEPTH

DECREASE DEPTH, DIASTOLE

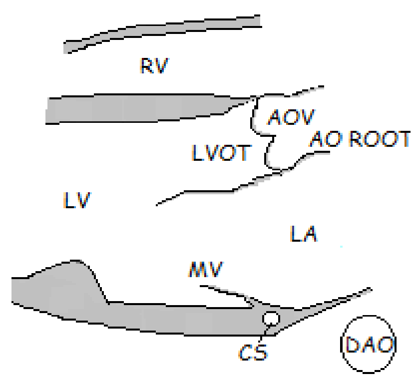
SYSTOLE

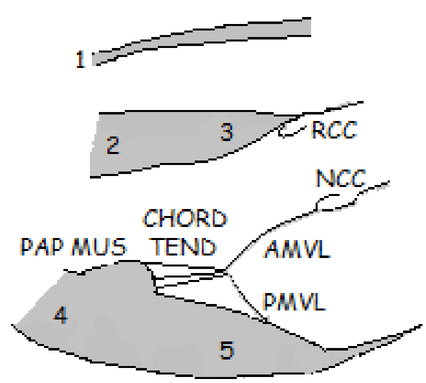
LV HYPERTROPHY

ABBREVIATIONS

AMVL = ANTERIOR MV LEAFLET
AO ROOT = AORTIC ROOT
AOV = AORTIC VALVE
CHORD TEND = CHORDAE TENDINEAE
CS = CORONARY SINUS
DAO = DESCENDING AORTA
LA = LEFT ATRIUM
LV = LEFT VENTRICLE
LVOT = LV OUTFLOW TRACT
MV = MITRAL VALVE
NCC = NON-CORONARY CUSP (AOV)
PAP MUS = PAPILLARY MUSCLE
PMVL = POSTERIOR MV LEAFLET
RCC = RIGHT CORONARY CUSP (AOV)
RV = RIGHT VENTRICLE

1 = RV FREE WALL
2 = MID ANTEROSEPTAL WALL
3 = BASAL ANTEROSEPTAL WALL
(aka IVS = INTERVENTRICULAR SEPTUM)
4 = MID INFEROLATERAL WALL
5 = BASAL INFEROLATERAL WALL
(aka LVPW = LV POSTERIOR WALL)





LAX LV

PROTOCOL

3) Acquire the 2D linear dimensions (details to follow).

MEASUREMENTS

The 2019 Guidelines for Performing a Comprehensive TTE Examination in Adults: Recommendations from the American Society of Echocardiography (ASE) and the 2015 Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the ASE and the European Association of Cardiovascular Imaging recommend 2D echo linear measurements over M-mode measurements to avoid capturing oblique angles of the ventricle. Dimensions are summarized below and discussed in more detail throughout chapter.

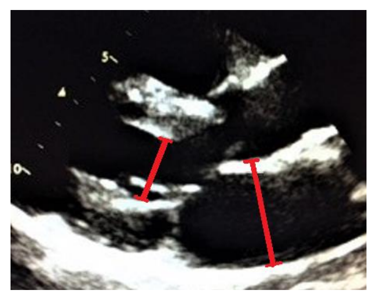
Timing is essential! Cardiac beats are saved as cine loops that give us the ability to walk through the frames of the cardiac cycle in order to correctly acquire the dimensions. Cine loop is usually controlled with the track ball or the arrow keys. The EKG, valves, and chamber size help determine the timing of the cardiac cycle.

- End diastole—mitral valve just snapped shut and left ventricle is at its largest dimension/volume.
- Early systole—aortic valve just opened and left ventricle is decreasing in size.
- End systole—aortic valve just snapped shut, or is about to, and left ventricle is at its smallest dimension/volume.

LAX LV, END DIASTOLE
RV wall (1 - 5 mm)
RVOTprox (20 - 30 mm)

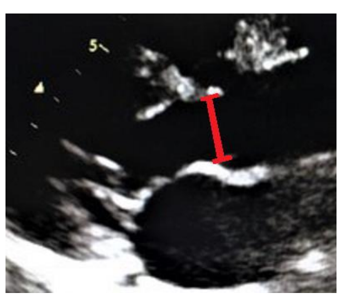
LAX LV, END DIASTOLE
IVS (female 6 - 9 mm, male 6 - 10 mm)
LVIDd (female 38 - 52 mm, male 42 - 58 mm)
PWT (female 6 - 9 mm, male 6 - 10 mm)

LAX LV, END SYSTOLE
LVIDs (female 22 - 35 mm, male 25 - 40 mm)
LA (female 27 - 38 mm, male 30 - 40 mm)

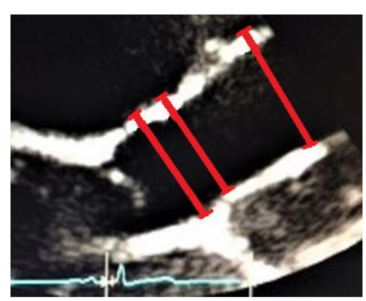


LAX LV, MID-SYSTOLE
LVOT (18 - 22 mm)

LAX AO, PEAK SYSTOLE
AOV annulus (female 23 ± 2 mm, male 26 ± 3 mm)



LAX AO, END DIASTOLE
Sinuses of Valsalva (female 30 ± 3 mm, male 34 ± 3 mm)
Sinotubular junction (female 26 ± 3 mm, male 29 ± 3 mm)
Proximal AAO (female 27 ± 4 mm, male 30 ± 4 mm)



NOTES: LVEF

LEFT VENTRICULAR EJECTION FRACTION (LVEF)
LVEF is a measurement of how much blood is pumped out of the LV chamber per contraction or heartbeat.

FRACTIONAL SHORTENING (FS)
FS is a percentage of the LV size reduction from diastole to systole as measured from the basal segments via M-mode or 2D linear measurements. FS does not provide the best assessment of LVEF because it *assumes:* normal LV geometry, symmetrical function, no WMA, no dyssynchrony/left bundle branch block (LBBB), excellent quality images, and perfect orientation—and all of these assumptions directly impact the FS. This method is discouraged by the ASE.

TEICHOLTZ METHOD
Similar to FS, the dimensions are acquired from the basal segments; however, they are cubed to acquire the chamber volumes and then the EF is calculated. Unfortunately, this method shares the same assumptions and pitfalls as the FS method. The Teicholtz (and Quinones) linear methods are no longer recommended.

Back in the 90s, *if* the ultrasound unit was programmed, we measured the M-mode on the screen during the echo and the machine calculated the LVEF via the Teicholtz linear method. If the machine was older/not programmed, we printed the M-mode on a strip chart, acquired the dimensions with hand calipers and a ruler, and used a calculator to determine the LVEF.

EYEBALL IT
It is very common to visually estimate the LVEF by eyeballing it—assess the walls from every view and then mentally compile the information and make an educated guess.

3DE IMAGING
LV size, LV volume, and LVEF are best measured via 3D echo (3DE) techniques and have become widely available. Using the apical 4C view with focus on the LV, optimize the image (adjust focus, gain, compression, TGC), maximize temporal and spatial resolution by using the smallest field of view possible, confirm good endocardial tissue definition, ask the patient to suspend respiration (to decrease motion), and activate the 3DE software to trace the endocardial borders for volume acquisition.

BIPLANE METHOD OF DISK SUMMATION
If 3DE analysis is not available, the next best method to acquire the LV volume and LVEF is the 2D biplane method of disk summation (details to follow).

STRAIN IMAGING
In 2018, the Journal of the American College of Cardiology (JACC) announced that strain echo was proven to add information about global function, regional function, and timing of the myocardial contraction; however, reproducibility was a big concern.

According to the 2019 ASE Guidelines, ventricular strain imaging is increasing in popularity and there are different types of deformation (strain) imaging available. For example, longitudinal strain is acquired by 2D speckle-tracking from the apical views—one must acquire the apical images, calculate the peak systolic strain of the LV segments (16, 17, or 18 model), display the bullseye map, and calculate global longitudinal strain indices. If utilized, labs need to develop a protocol, practice precision and expert timing (end diastole/end systole capture), and repeat studies on the same machine in order to decrease variability.

FS

- Acquire the linear LV internal dimension diastole (LVIDd)
- Acquire the linear LV internal dimension systole (LVIDs)
- $FS\% = \frac{(LVIDd - LVIDs)}{LVIDd} \times 100$
- Normal FS% > 25%

EXAMPLE:

If LVIDd = 5.0 cm and LVIDs = 3.2 cm, then…

$$FS\% = \frac{(LVIDd - LVIDs)}{LVIDd} \times 100$$

$$FS\% = \frac{(5\ \cancel{cm} - 3.2\ \cancel{cm})}{5\ \cancel{cm}} \times 100 = 36\%$$

TEICHOLTZ METHOD

- Acquire the linear LV internal dimension diastole (LVIDd)
- Acquire the linear LV internal dimension systole (LVIDs)
- LVIDd cubed equals the LV internal diastolic volume [$LVIDd^3 = LVIDV$]
- LVIDs cubed equals the LV internal systolic volume [$LVIDs^3 = LVISV$]
- $LVEF\% = \frac{(LVIDV - LVISV)}{LVIDV} \times 100$
- Normal LVEF% (20+ years old) = 53 – 73%

EXAMPLE:

If LVIDd = 5.0 cm and LVIDs = 3.2 cm, then…

$$LVIDV = LVIDd^3 = (5.0\ cm)^3 = 125\ cm^3$$

$$LVISV = LVIDs^3 = (3.2\ cm)^3 = 32.8\ cm^3$$

$$LVEF\% = \frac{(125\ \cancel{cm^3} - 32.8\ \cancel{cm^3})}{125\ \cancel{cm^3}} \times 100 = 74\%$$

LAX LV

PROTOCOL

4) Anterior wall of the right ventricle (RV) is thin and squeezes concentrically during systole.

- Rule out abnormalities such as RV hypertrophy (RVH).
- Acquire the end-diastolic RV wall thickness (normal range 1 - 5 mm).
- TIP: RV wall is often best measured from the subcostal window.

5) RV is the most anterior chamber, smaller but more trabeculated than the left ventricle, and has a complex crescent (triangular) shape—making it tricky to measure. The moderator band is used to distinguish the morphologic RV and is sometimes prominent; however, it is unusual to visualize it from the LAX LV as seen in this example.

- Rule out abnormalities such as RV dilatation and decreased RV function (RVFX)/WMA.
- Acquire the end-diastolic RV outflow tract (RVOT) proximal diameter (RVOTprox normal range 20 - 30 mm) from the anterior RV wall to the interventricular septal-aortic junction.
- TIP: RVOTprox can also be measured from the SAX BASE.

RV, END DIASTOLE

MODERATOR BAND

LAX LV

PROTOCOL

According to the 2015/2019 ASE Guidelines, acquire the left ventricular linear dimensions perpendicular to the cardiac structures, in a straight line, just beyond the tips of the mitral valve leaflets, with the calipers placed at the myocardial wall/cavity interface and the wall/pericardium interface.

6) Interventricular septum (IVS) and left ventricular posterior wall (LVPW) are ~ the same thickness (1:1 ratio), thicker than the RV walls, and squeeze concentrically during systole. A sigmoid-shaped septum is a prominent thickening or bulge of the basal septum and considered a normal variant in the older heart.

- Rule out abnormalities such as LV hypertrophy (LVH, severity scale below) and ventricular septal defect (VSD).
- Acquire the end-diastolic IVS dimension (normal range female 6 - 9 mm, male 6 - 10 mm).
- Acquire the end-diastolic posterior wall thickness (PWT, normal range female 6 - 9 mm, male 6 - 10 mm)—avoid mitral valve apparatus/pericardial effusion if present.
- If a sigmoid-shaped septum is present, report the finding and acquire the dimensions just beyond the bulge (toward the apex).

7) Left ventricle (LV) is the largest chamber located posterior and lateral to the RV. It is ellipsoid in shape, longer/more conical/less trabeculated than the RV, and may possess a false tendon—a normal variant.

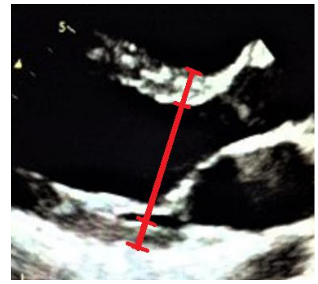
- Rule out abnormalities such as LV dilatation and decreased LVFX/WMA.
- Acquire the end-diastolic LV dimension (aka LV internal dimension diastole, LVIDd, normal range female 38 - 52 mm, male 42 - 58 mm).
- Acquire the end-systolic LV dimension (aka LV internal dimension systole, LVIDs, normal range female 22 - 35 mm, male 25 - 40 mm).

8) LV outflow tract (LVOT) is unobstructed and allows laminar flow from the LV out to the aorta.

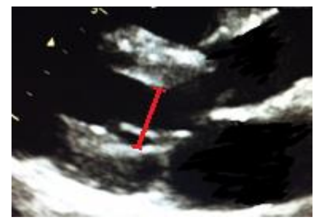
- Rule out abnormalities such as LVOT obstruction (LVOTO).
- Zoom in and adjust the gains to optimize the blood tissue interface.
- Acquire the mid-systolic LVOT diameter (normal range 18 - 22 mm) proximal and parallel to the plane of the aortic valve, from the inner edge of the septal endocardium to the inner edge of the anterior mitral valve leaflet, within 5 - 10 mm of the aortic orifice.

LVH SEVERITY SCALE

	NORMAL (mm)	MILD LVH (mm)	MODERATE LVH (mm)	SEVERE LVH (mm)
FEMALE	6 - 9	10 - 12	13 - 15	≥ 16
MALE	6 - 10	11 - 13	14 - 16	≥ 17



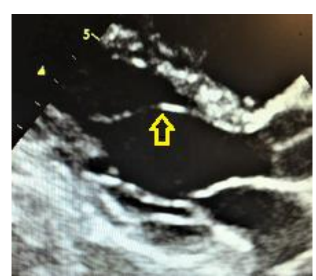
LV & WALLS, END DIASTOLE



LV, END SYSTOLE

LVOT, MID-SYSTOLE

SIGMOID-SHAPED SEPTUM



LV FALSE TENDON

LAX LV

PROTOCOL

9) Anterior mitral valve leaflet (AMVL) and posterior mitral valve leaflet (PMVL) are thin and pliable with unrestricted opening. The AMVL is continuous with the posterior wall of the aorta and more mobile than the PMVL. The mitral valve (MV) closes prior to the annular plane and does not prolapse/buckle back beyond the annular plane into the left atrium. The annulus is free of calcification and does not restrict leaflet motion.

- Rule out abnormalities such as MV prolapse (MVP); mitral annular calcification (MAC); dilated MV annulus; elongation/myxomatous changes/thickening/calcification of the MV leaflet(s) without vs with decreased excursion; and flail MV leaflet/chordae tendineae/papillary muscle.

10) Left atrium (LA) is the most posterior chamber, a reservoir that receives pulmonary venous return, a passageway to the LV, and a contractile pump (atrial systole/kick delivers 15 – 30% of LV filling). LA size is gender dependent, typically indexed to body surface area (BSA), and smaller than the LV.

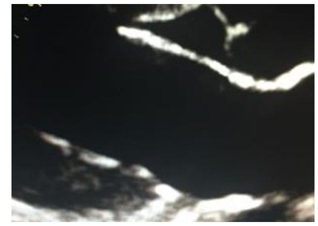
- Rule out abnormalities such as LA enlargement (LAE), clot, and mass.
- LAE correlates with negative CV outcomes. In the absence of MV disease, LAE reveals increased wall tension due to increased LA pressure (LAP), and is an indicator of LAP severity and chronicity, as well as impaired LA function. LAE is a marker for severe and chronic diastolic dysfunction, and has a clear relationship with atrial fibrillation (Afib) and stroke.
- Acquire the end-systolic (maximal) anteroposterior LA linear dimension (normal range female 27 - 38 mm, male 30 - 40 mm) perpendicular to the aortic root, at the level of the aortic sinuses, with the leading edge-to-leading edge (L - L) technique.
- LA linear dimension does not provide the most accurate assessment of LA size and should be combined with another method, such as the LA volume index (LAVi, details to follow).

11) SAX of the coronary sinus (CS, normal range 4 - 10 mm) is within the myocardium—posterior to the left atrioventricular junction (LA-LV junction). In normal sinus rhythm, the CS diameter narrows during atrial contraction.

- Rule out abnormalities such as CS dilatation that may indicate RV dysfunction, increased right atrial pressure, and anomalous venous drainage into the CS (either directly into the CS or via a persistent left superior vena cava).
- TIP: LAX of the CS can be visualized from the apical 4C and 2C.

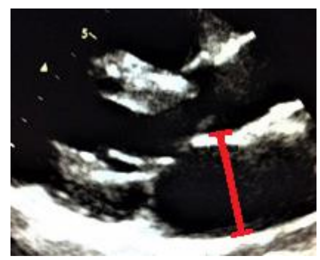
12) SAX of the descending aorta (DAO) is a separate structure—posterior to the LA.

- Rule out abnormalities such as DAO dilatation and dissection (tear of the intimal lining).

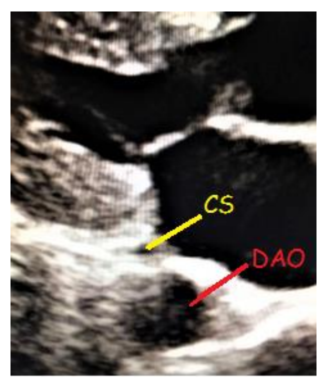


ZOOM MV

MV ANNULAR PLANE



LA, END SYSTOLE



CS & DAO (SAX)

DILATED CS