**INTRODUCTION**

Over the past four decades, echocardiography has evolved into an extremely useful diagnostic modality, which is regularly utilized for the assessment of cardiac structure and function in a wide variety of clinical settings. Its noninvasive nature, safety, easy availability, portability, and the ability to provide vast amount of diagnostic information are some of the reasons underlying its popularity as a diagnostic tool. However, echocardiography is an operator-dependent technique which can lead to considerable measurement variability, misdiagnoses, and even missed diagnoses. While adequate training is the most effective means to overcome this challenge, a standard protocol for image acquisition will improve diagnostic accuracy and maximize reproducibility of the technique.[1]

**AIMS AND OBJECTIVES**

1. To ensure that no significant pathology is missed by a beginner or a veteran in a hurry. This is especially true if the study being interpreted has been performed by someone else. A complete study will also guard against missing a rare or relevant second pathology if a primary disease is very evident, for example, organic tricuspid valve (TV) disease in the presence of significant mitral stenosis (MS).
2. To enable accurate comparison, qualitative or quantitative, of interval studies from the same patient performed by the same or different echocardiographers. Serial comparison is possible only if all the studies are complete and consist of similar views.
3. To permit extra, nonroutine measurements or verification of reported measurements on stored studies for clinical or research purposes. For example, measuring stroke volume at left ventricular (LV) outflow tract (LVOT) in a case of aortic stenosis (AS) with discrepant gradients to rule out low-flow, low-gradient situation or for applying newer measurement algorithms as they become available.
4. To afford medicolegal protection against potential negligence resulting from missing a pathology due to incomplete study. The study documentation conforming to the standards laid down by a professional society will serve as a major safeguard.

**SCOPE OF THE DOCUMENT**

1. The present document provides a set of mandatory transthoracic echocardiographic views and Doppler tracings that are required to permit comprehensive evaluation of each cardiac chamber, all valves, all coronary territories, septal intactness, great arteries and veins, major cardiac structures, and intracardiac hemodynamics. Any study done in emergency or unfavorable settings, not conforming to the recommended protocol, should be labeled a “focused” echocardiographic study.
2. All views and Doppler recordings have been devised for postprocessing and for routine or elaborate offline measurements for clinical or research requirements. Focused views are meant for drawing echocardiographer’s attention to a particular region in the zoomed image.
3. Only minimum basic measurements are recommended to be
made. Additional measurements as per the requirements of a particular pathology or institutional or research protocol can be added.

4. These recommendations in no way limit the study to conventional views only. Echocardiographers are encouraged to obtain additional nonconventional and creative views in addition to (and not excluding) the protocol to improve the diagnostic accuracy and the quality of the study.

5. These recommendations do not cover training and credentialing requirements for the echocardiographers.

**THE RECOMMENDED VIEWS AND MEASUREMENTS**

Tables 1 and 2 list the recommended views and measurements, respectively, required for performing a complete adult transthoracic echocardiographic study. However, as mentioned above, additional views and measurements may be needed depending on the underlying pathology and the requirements of local institutional or research protocol.

When performing any echocardiographic study, it is recommended to:

1. Store electrocardiogram (ECG) synchronized, minimum 3 beat loops for each two-dimensional (2D) or color Doppler image and minimum 3 Doppler spectral beats for the still images in case of pulsed-wave (PW) or continuous-wave (CW) Doppler. For patients in atrial fibrillation or any other ongoing arrhythmia, a minimum of 5 beats are recommended.

2. For offline postprocessing and measurements, archive the study in DICOM format. Other formats such as AVI/lossless JPEG or MPEG should be used for qualitative viewing only.

**The scanning technique for obtaining each specific view**

This section describes the basic technique involved in obtaining each specific view, various cardiac structures that are seen in that view, and the measurements that can be obtained. However, it must be remembered that these are only the basic guidelines aimed at helping relatively new echocardiographers in navigating through the challenges of obtaining different views. Keeping with the individual variations in body habitus and in cardiac size, shape, and orientation, constant modifications in scanning technique are required in each individual patient to obtain the best possible images. With increasing experience, the echocardiographers develop the skill required to maneuver the transducer according to the imaging requirements.

When performing an echocardiogram, it is strongly recommended to first complete the recording of the entire sequence of images for all patients with any pathology to improve the quality of the diagnostic study. The individual pathology should then be delineated in greater detail, at the end of the protocol, using various nonconventional imaging planes and Doppler recordings.

The sequence of recording the mandatory views is designed to minimize abrupt changes in the probe and the patient’s positions and to maintain a seamless workflow through various echocardiographic windows to reduce recording time. However, the sequence can be changed as per the clinical situation or the availability of access to different echocardiographic windows.

The following nomenclature is used in the present document for describing the transducer manipulations (Figure STR maneuver):

- **Sliding:** The transducer is moved in the direction parallel to its broader side, along the imaginary line passing through the orientation marker (X axis). This will move the image along the ultrasound scan plane.

- **Tilting or angling:** The transducer is tilted parallel to its shorter side or perpendicular to the ultrasound scan plane (Y axis). This maneuver will provide radial tomographic sections.

- **Rotation or twisting:** This refers to turning the index marker clockwise or counterclockwise around a fixed pivot, i.e., the long axis of the transducer (Z axis). This maneuver will rotate the ultrasound scan plane.

For each view, constant fine tuning of the transducer position and orientation is required using a combination of sliding, tilting or angling, and rotating maneuvers to obtain the optimal views as described below.

**Description of views**

**Parasternal long-axis view**

*Purpose*

Overview of LV inflow inflow, outflow, aortic root, and LV dimensions; also helpful in the assessment of perimembranous ventricular septal defect (VSD).

*Measurements*

- Mandatory: LV systolic and diastolic diameters; interventricular septal and posterior wall thickness
- Optional: LV fractional shortening.

**Technical description**

The transthoracic adult echocardiographic examination begins with a parasternal long-axis (PLAX) view that profiles the left heart and the proximal right ventricular (RV) outflow tract (RVOT) in the sagittal plane (Figure 1 and Video 1). The patient is placed in the left lateral decubitus position with the left arm raised. The transducer is positioned adjacent to the sternum in the left third or fourth intercostal space. The orientation marker is directed toward the patient’s right shoulder, and probe angled slightly to avoid foreshortening the LV.

Depth is adjusted to include the echogenic pericardium posterior to the inferolateral wall. One cine loop is acquired at a greater depth to rule out pericardial and pleural effusions. Sector width is adjusted to include the aortic root to the right and mid segments of the anterior septum and inferolateral wall to the left. One ECG-gated loop with three (normal sinus) or five (atrial fibrillation) beats is recorded.
Moving from LV inflow to outflow, the anteroposterior cross-section of the left atrium (LA), mitral valve, chordae tendineae, LV cavity in long axis, LVOT, aortic valve (AoV), and proximal ascending aorta can be appreciated in this view. The longer anterior mitral leaflet (above) and short posterior mitral leaflet (below) are visualized. The basal and mid segments of the anterior septum (above) and inferolateral wall (below) are observed in parallel orientation. Sliding the probe one rib space inferiorly brings the distal segments into view, and it is useful when profiling the LV during stress echocardiography studies. The apex is not visualized in this view. The tubular LVOT is visualized in long axis. Of the three aortic cusps, the right coronary cusp (above) and noncoronary cusp (below) are seen. The corresponding aortic sinuses, sino-tubular junction, and proximal segment of the ascending aorta are also visualized. The proximal RVOT is visualized in its short to oblique axis.

**Two-dimensional left ventricle end-diastolic and end-systolic linear measurements**

The end-diastolic frame is identified by the frame in which LV cavity is largest (the most preferred method) or the frame just after mitral valve closure. The end-systolic frame is

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**Table 1: Recommended views for a complete transthoracic adult echocardiographic study**

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<td>2D</td>
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<tr>
<td>2D</td>
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<td>Color Doppler</td>
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<tr>
<td>Color Doppler</td>
<td>Color Doppler</td>
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<td>Zoomed LA 2-chamber view</td>
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<tr>
<td>2D</td>
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<td>PLAX RV inflow view with color Doppler</td>
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<td>TR jet CW spectral Doppler</td>
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<tr>
<td></td>
<td>Tricuspid flow PW/CW spectral Doppler</td>
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</tbody>
</table>

*Additional views will be needed depending on the underlying pathology, †All views are 2D views, unless specifically mentioned, ‡All 2D and color Doppler views refer to video clips. 2D: two-dimensional, SAX: short-axis, LV: left ventricle, PR: pulmonary regurgitation, CW: continuous-wave, PSAX: parasternal short-axis, PLAX: parasternal long-axis, LA: left atrium, TR: tricuspid regurgitation, PW: pulsed-wave, RA: right atrium, LVOT: left ventricular outflow tract, MR: mitral regurgitation, MS: mitral stenosis, IVC: inferior vena cava

**Table 2: Recommended gray-scale and color measurements**

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*Additional measurements will be needed depending on the underlying pathology. IVC: inferior vena cava, RVSP: right ventricular systolic pressure, PASP: pulmonary artery systolic pressure, RA: right atrium, TAPSE: tricuspid annular plane systolic excursion, LV: left ventricle, RV: right ventricle, RVOT: right ventricular outflow tract, MPA: main pulmonary artery, LA: left atrium, IVS: intact ventricular septum, LVOT: left ventricular outflow tract, VTI: velocity time integral, TR: tricuspid regurgitation, PR: pulmonary regurgitation*
identified when the LV is smallest or the frame just before the mitral valve opens. Linear dimensions are to be taken at the level of the mitral chordae, perpendicular to the LV cavity. Measurements are made between the inner edge of the anterior septum and inner edge of the inferolateral wall using 2D echocardiography (preferred) or anatomical M-mode.\(^2\)

**Parasternal long-axis mitral valve zoom two-dimensional and color Doppler**

**Purpose**
- 2D: Mitral leaflet motion and pathology
- Color Doppler: Detection of mitral regurgitation (MR), measurement of MR jet vena contracta.

**Measurements**
- 2D: Mandatory: Nil
- Optional: Mitral annulus anteroposterior diameter
- Color Doppler: Mandatory: Nil
- Optional: Vena contracta, proximal isovelocity surface area (PISA)
- Doppler data: Qualitative.

**Technical description**
From the PLAX 2D view, a finer appreciation of the mitral valve can be obtained by magnifying the mitral apparatus using the zoom function [Figure 2a and Video 2a]. In this view, the mitral annulus, anterior and posterior mitral leaflets, and the attached chordae are well visualized. A lateral and medial angulation of the probe provides finer delineation of both anterolateral and posteromedial commissures and papillary muscles, respectively. This view is recommended when studying mitral leaflet motion and pathology. Mitral annulus anteroposterior diameter is to be measured at end-systole and end-diastole.

Placing a color window over the mitral valve in this view permits a qualitative evaluation of MR severity [Figure 2b and Video 2b]. Patients with significant jets demonstrate a well-defined area of flow convergence proximal to the jet, a vena contracta at the point of coaptation, and regurgitant jet in the L.A. Sector width is to be adjusted to cover the full extent of the regurgitant jet in the posterior L.A.

**Parasternal long-axis aortic valve zoom two-dimensional and color Doppler**

**Purpose**
- 2D: AoV and root pathology, LVOT size, subaortic membrane
- Color Doppler: Detection of AS or aortic regurgitation (AR), measurement of AR jet vena contracta.

**Measurements**
- 2D: Mandatory – aortic annulus, aortic root at sinuses, sinotubular junction
- Color Doppler: Mandatory – Nil
- Optional: Jet height, vena contracta
- Doppler data: Qualitative.

**Technical description**
Acquiring a magnified view of the AoV provides vital information on the structure and pathologies of the LVOT, annulus, aortic cusps with corresponding sinuses, the sinotubular junction, and proximal ascending aorta [Figure 3a and Video 3a]. This is of particular relevance when measuring the LVOT diameter and cross-sectional area to calculate stroke volume, or studying structural abnormalities associated with the LVOT. LVOT diameter is measured during mid systole (with the cusp maximally opened), around 0.5–1 cm from the aortic annulus, from inner edge to inner edge. The aortic annulus itself is measured between the hinge points of aortic cusps, during mid-systole and from inner edge to inner edge.\(^2\)
Applying color Doppler to this view provides qualitative information on the severity and extent of valvular regurgitation and/or valve stenosis [Figure 3b and Video 3b].

**Parasternal long-axis ascending aorta two-dimensional and color Doppler**

**Purpose**
- 2D: Ascending aorta dilatation, ascending aorta aneurysm, dissection flap, etc.
- Color Doppler: False lumen flow in case of dissection, AS jets.

**Measurements**
- 2D: Mandatory - Ascending aorta size
- 2D: Mandatory - Nil
- Doppler data: Qualitative.

**Technical description**
From the 2D PLAX view, the ascending aorta can be profiled by sliding the transducer one intercostal space higher [Figure 4a and Video 4a]. With fine angulation, the long axis of the ascending aorta is profiled. Measurements made in this view include the diameter of the aortic annulus, sinus of Valsalva, sinotubular junction, and ascending aorta. Measurements other than aortic annulus are performed at end-diastole, using the leading edge to leading edge method. This view is recommended in the setting of ascending aorta dilatation, aneurysm, and dissection. Placing a color Doppler sector over this image provides qualitative information on flow profile in the ascending aorta, localizing false lumen and dissections confined to this region [Figure 4b and Video 4b].

**Parasternal short axis at the level of semilunar valves: Two-dimensional and color Doppler**

**Purpose**
- 2D: AoV, RVOT, and pulmonary valve pathology may also be helpful in the assessment of atrial septal defect (ASD).
- Color: To detect perimembranous/supracristal VSD, RVOT stenosis, TR.

**Measurements**
- 2D: Mandatory - Pulmonary valve annulus size
- Color: Mandatory - Nil
- Doppler data: Qualitative.

**Technical description**
The parasternal short-axis (SAX) view is obtained from the PLAX view by rotating the transducer orientation mark by 90° in the clockwise direction, such that it points to the patient’s left shoulder. Moving the transducer superiorly with a slight cranial angulation provides a cross-section of the aortic root [Figure 6a and Video 6a]. The commonly referred to “circle and sausage” view profiles the aortic root (circle) surrounded by the RVOT (sausage). In addition, this view profiles the RA, the anterior and septal leaflets of the TV, the RV, RVOT, PV, and main pulmonary artery (MPA). With slight angulation, the bifurcation of the pulmonary artery into the right and left branches can be visualized. Angulating the probe posteriorly brings the LA appendage into view. A shift in rib interspace may occasionally be necessary to optimize the view. Applying color Doppler to this view [Figure 6b and Video 6b] provides a qualitative assessment of stenosis or regurgitation related to the aortic, tricuspid, or pulmonic valves. In addition, VSDs can be characterized based on location as either peri-membranous (9–12 o’clock position) or outlet/supracristal/subpulmonic (12–3 o’clock position).
Parasternal short-axis aortic valve zoom two-dimensional and color Doppler

Purpose
- 2D: Aortic leaflet pathology, coronary ostia
- Color Doppler: Detection and assessment of AR jet origin and severity.

Measurements
- 2D: Mandatory – AoV planimetry in patients with AS in patients with adequate visualization of the aortic cusps
- Color Doppler: Mandatory – Nil
- Optional - AR jet area
- Doppler data: Qualitative.

Technical description
A magnified view of the aortic root provides a clear demonstration of aortic cusp morphology and motion [Figure 7a and Video 7a]. With a slight superior angulation, the proximal right coronary artery and left coronary artery can be visualized arising from the anterior (right sinus) and posterior (left sinus) sinuses, respectively. The noncoronary sinus (right and posterior) is identified by the attachment of interatrial septum. Coronary arteries are best visualized using a higher transducer frequency with careful adjustment of the focus. The left coronary artery arises at the 4 o’clock position at the level of the pulmonary valve, and the right coronary artery is seen at the 11 o’clock position coursing between the RA and the RV. Fine angulation permits the visualization of the bifurcation of the left coronary artery into the left anterior descending artery and the left circumflex in selected patients. Placing a color Doppler window in this view [Figure 7b and Video 7b] permits qualitative estimation of AR severity by comparing AR jet area to the aortic root area. With a reduction of the Nyquist limit, diastolic flow in the proximal coronary arteries can be visualized in selected patients.

Main pulmonary artery and bifurcation with color and spectral Doppler (optional pulmonary regurgitation jet continuous-wave)

Purpose
- Color Doppler: To detect pulmonic stenosis (PS), pulmonary regurgitation (PR), or ductal flow
- PW/CW: PS, high pulmonary vascular resistance (PVR) pattern, etc.

Measurements
- Mandatory - Peak pulmonary velocity, peak PS gradient when present, end-diastolic PR gradient when present, peak and trough gradient across patent ductus arteriosus when present
- Optional - Pulmonary velocity time integral (VTI), pulmonary acceleration time, etc.
- Doppler data - Quantitative for shunt, PVR calculation.

Technical description
A fine anterior angulation of the probe from this position brings the RVOT, MPA, the left pulmonary artery, and the right pulmonary artery into view. Color Doppler provides a qualitative assessment of PR and localizes a region of turbulence in the setting of infundibular, valvular, or branch stenosis [Figure 8a and Video 8]. In patients with congenital heart disease, this view is also employed to visualize a patent ductus arteriosus flowing from the descending aorta into the...
left pulmonary artery. A PW Doppler sample volume placed in the RVOT at the level of pulmonary annulus provides information on the peak flow velocity [Figure 8b]. Additionally, the spectral tracing also provides the assessment of pulmonary hypertension from PR and calculation of PVR. In the setting of an increased velocity, PW can be used to map the area to locate the specific region of flow increase, and a subsequent switch to CW Doppler allows for quantification of the jet velocity and corresponding pressure gradient.

**Left ventricle short axis at mitral valve level two-dimensional (optional mitral color Doppler)**

**Purpose**  
Regional wall motion abnormality (RWMA), mitral valve end-on view for the assessment of mitral valve pathologies such as prolapse and MS (planimetry, commissures, etc.).

**Measurements**  
- Mandatory: Nil; mitral valve area in those with MS.
- Optional: 2D circumferential and radial strain, basal rotation.
- Doppler data: Qualitative for regurgitant orifice.

**Technical description**  
From the parasternal SAX at the level of the semilunar valves, an inferior sweep by sliding the probe caudal and leftward provides option for imaging the LV from base to apex in SAX. A change in intercostal space is necessary to ensure a perpendicular orientation of the short-axis planes. The LV SAX at the mitral valve level is characterized by a “fish mouth” appearance of the anterior and posterior mitral leaflets [Figure 9 and Video 9]. Alternatively, an M-mode performed across the valve with a sweep speed of 100 mm/s provides details of leaflet motion during the cardiac cycle. Pathologies such as mitral valve prolapse can be further characterized using high temporal frame capture on M-mode. In the setting of MS, a careful sweep starting from the papillary muscles till the LVOT SAX permits accurate planimetry of the mitral valve area at the level of the leaflet edges and also allows assessment of the extent and morphology of commissural and chordal fusion. Mitral annular and leaflet calcium can also be demonstrated using a careful upward and downward sweep of the transducer. The basal six segments of the LV can be identified in this view in keeping with the current 17-segment nomenclature. Starting from the basal anterior septum adjacent to the RV, moving in a clockwise direction, the basal anterior wall, basal inferolateral wall, basal inferior wall, and basal inferior septum are visualized.[2]

**Left ventricle short axis at papillary muscle level**

**Purpose**  
Assessment of LV ejection fraction (LVEF), RWMA; LV mass estimation; papillary muscle geometry and morphology.

**Measurements**  
- Mandatory - Nil
- Optional - LV mass calculation, 2D circumferential and radial strain.

**Technical description**  
From the LV SAX at the base of the heart, an inferior sweep and slide provides an assessment at the level of the papillary muscles [Figure 10 and Video 10]. An optimal transducer position demonstrates a circular LV cross-section with the anterolateral papillary muscle at the 4 o’clock position and posteromedial papillary muscle at 8 o’clock position. Care needs to be taken to avoid a nonperpendicular cut plane that distorts internal dimensions and overestimates LV size and contractility.

The papillary muscle level clip provides a convenient eye-ball of LV systolic function and assessment of RWMA in the six segments at the mid-LV cavity plane. Starting from the mid-anterior septum adjacent to the RV, moving clockwise, the mid-anterior wall, mid inferolateral wall, mid inferior wall, and mid inferior septum are visualized. Asymmetric wall thickness, if observed, can be measured using corresponding M-mode measurements of the septal and inferior wall. This view also provides information on papillary muscle morphology and geometry.

**Left ventricle short axis at apex two-dimensional**

**Purpose**  
Assessment of RWMA; detection of LV apical clot; assessment of pathologies such as noncompaction.

**Measurements**  
- Mandatory - Nil
- Optional - 2D circumferential and radial strain, apical rotation.

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**Figure 8:** Parasternal short-axis view showing right ventricular outflow tract, main pulmonary artery and its bifurcation; (a) with color, (b) right ventricular outflow tract flow spectral signal on pulsed-wave

**Figure 9:** Left ventricle short-axis view at the level of the mitral valve
Technical description
From the previous view, by angling and sliding the transducer even more inferiorly, a uniform tapering and reduction in cavity size is observed with the LV apex coming into view [Figure 11 and Video 11]. The apico-anterior wall, apico-lateral wall, apico-inferior wall, and apical septum are visualized. The apical 4-segment view provides information on RWMA, pathologies such as LV noncompaction, apical aneurysms and thrombus.

Apical 4-chamber view with pericardial space
Purpose
Overview of chambers, pericardial or extracardiac pathology, ASD.
Measurements
- Mandatory - LA, RA, RV diameters; LA area
- Optional - RA area, RV fractional shortening; LV length.

Technical description
The apical 4-chamber view is acquired with the patient positioned in the left lateral decubitus position. A bed with a cut out section that allows convenient access to the region under the left breast tissue is recommended for optimal imaging. The apical pulse is palpated and the probe is positioned slightly lateral to this position. The orientation marker is positioned at the 5 o’clock position to image the four chambers of the heart. The patient may be requested to suspend respiration at the end of expiration during image acquisition to reduce translational disturbances.

The apical 4-chamber view showcases the ventricles above and atria below [Figure 12 and Video 12]. The insertion of the septal TV leaflet is seen slightly apical to the mitral valve leaflet. The smooth-walled, ellipsoidal LV forms the true apex of the heart, while the thin-walled, trabeculated, wedge-shaped RV is observed to the right (left of the display). To ensure that the LV is not foreshortened, the lowest possible apical window is suggested, and the apex should be seen triangular and thickening in systole (in a normal heart). In general, the length of the LV is 2–3 times that of the major linear axis of the LA. Once in the correct position, fine adjustments to transducer frequency, focus, time gain compensation, and overall gain are made to ensure optimal delineation of the endocardium across all segments of the LV. Use of tissue harmonics is recommended to improve tissue–blood pool demarcation.

Focused left ventricle 4-chamber view
Purpose
RWMA in lateral wall and septum, LV volume estimation, high frame rate images for 2D strain, etc.
Measurements
- Mandatory - LV volume and EF by Simpson’s method
- Optional - 2D longitudinal strain.

Technical description
A magnified view of the LV provides a more detailed evaluation of LV volumes and function. In the focused LV 4-chamber view, the septum is vertically positioned in the center of the screen and divides the two ventricles [Figure 13 and Video 13]. A rightward orientation of the septum can be corrected by moving the probe laterally and a leftward deviation by moving the probe medially. The focal point should be adjusted at the midcavity level. For accurate assessment of LV volumes and RWMA, an optimal delineation of the endocardium is essential. Selective enhancement of the anterolateral and septal segments is possible on certain equipment employing lateral gain compensation. In the eventuality of an inability to track the endocardial surface in two or more segments, use of contrast is recommended.\(^1\)

To obtain LV volumes and EF using Simpson’s method of discs, first ensure optimal endocardial definition in the focused LV 4-chamber view and then trace the endocardial border in the end-diastolic frame (the frame showing the largest LV cavity size, usually the frame immediately after mitral valve closure) and the end-systolic frame (the frame showing the smallest LV cavity size, usually the frame just before mitral valve opening). The endocardial border is traced from the
point of insertion of anterior mitral leaflet into the septum in the clockwise direction till the insertion of the posterior leaflet into the lateral wall. The system then calculates a volume based on the summation of 2D-generated discs. These steps are repeated in the end-systolic frame. When both end-diastolic and end-systolic measurements are repeated in the focused 2-chamber view, the system generates an automated biplane 2D EF based on these volumetric measurements.

**Focused left ventricle 2-chamber view**

*Purpose*

RWMA in anterior and inferior wall, high frame rate images for 2D strain, etc.

*Measurements*

- Mandatory - LV volume and EF by Simpson’s method
- Optional - 2D longitudinal strain.

**Technical description**

The focused LV 2-chamber view can be obtained from the focused 4-chamber view by rotating the transducer counterclockwise by approximately 60° [Figure 14 and Video 14]. This view provides a complete visualization of the anterior wall to the right of the display and the inferior wall to the left of the display. Asking the patient to take a shallow inspiration can often help improve visualization of the anterior wall. The LA appendage is seen to the right of the display. The RV should not be visible in this view. Showcasing papillary muscles should be avoided. However, by tilting the transducer, one should be able to image both the papillary muscles from their origins to insertions into the mitral valve. Descending thoracic aorta can be visualized beneath the aorta.

**Focused left ventricle apical long-axis view**

*Purpose*

RWMA in anterior septum, inferolateral or posterior wall; high frame rate images for 2D strain, etc.

*Measurements*

- Mandatory - Nil
- Optional - 2D longitudinal strain.

**Technical description**

A further 60° counterclockwise rotation with a slight anterior angulation reveals the apical long-axis view, also called the apical 3-chamber view [Figure 15 and Video 15]. This view is analogous to the PLAX view, except that distal LV segments and apex are also seen in this view. The inferolateral wall is seen to the left of the display and anterior septum to the right of the display. The apical 3-chamber view is recommended to visualize systolic anterior motion (SAM) of the mitral leaflets, LVOT dynamic obstruction, and AoV stenosis or regurgitation.

**Zoomed left ventricle inflow and outflow view**

*two-dimensional and color Doppler*

*Purpose*

- 2D: LVOT dynamic narrowing, SAM of mitral leaflets/ chordae, mitral valve pathology, etc.
- Color Doppler: LVOT dynamic obstruction, MR/AR jet delineation, etc.

*Measurements*

- 2D: Mandatory - Nil
- Color Doppler: Mandatory - Nil
- Doppler data: Qualitative, quantitative for MR effective regurgitant orifice area by PISA method.

**Zoomed left atrium 2-chamber and 4-chamber views**

*two-dimensional*

*Purpose*

LA intra-cavity pathology, LA volume estimation.

*Measurements*

- Mandatory - LA area for volume estimation
- Optional - 2D LA strain.
Technical description

The LA is best assessed employing a magnified view of the LA, as seen in the apical 2-chamber [Figure 17 and Video 17] and 4-chamber views [Figure 18 and Video 18]. The zoom function is employed after identifying the LA as the region of interest. For optimal penetration, a lower transmit frequency is recommended, with the focal plane adjusted at the level of the LA cavity. LA area and volume are measured when the LA is maximally dilated during the end-systolic frame. The pulmonary veins and LA appendage are excluded while tracing the LA borders..LA length is measured as the distance between the LA roof and the level of the mitral annulus. The shorter of the two lengths measured in the 4-chamber and 2-chamber views is employed to calculate LA volume by the area-length method. All measurements should be indexed to body surface area.

Pulmonary vein flow pulsed-wave spectral Doppler

Purpose
Assessment of LV diastolic function.

Measurements
• Mandatory - Pulmonary vein flow systolic, diastolic, and atrial reversal velocities
• Optional - Duration of atrial reversal wave
• Doppler data - Qualitative.

Technical description

In the apical 4-chamber view, an assessment of pulmonary venous flow provides complimentary information on LV diastolic function [Figure 19 and Video 19]. Lower transmit frequencies are recommended and the focal point is adjusted at the plane of the LA roof. To obtain an optimal spectral flow pattern, the probe is angled slightly posterior from the apical position to image the right lower pulmonary vein breaking into the LA. A 2–3 mm sample volume is placed >0.5 cm into the vein, and the velocity scale decreased to accommodate low velocity flow. Certain equipment provide a low pulse repetition frequency function that can be activated to profile pulmonary venous flow. Wall filters may need to be adjusted to minimize noise. Sweep speed is adjusted between 50 and 100 mm/s at end expiration, and an average of three consecutive cardiac cycles are obtained.

Focused (left atrium-left ventricle) mitral flow color and pulsed-wave spectral Doppler (optional continuous-wave for mitral regurgitation and mitral stenosis)

Purpose
• Detection and evaluation of MR
• LV diastolic function assessment, MS severity.

Measurements
• Mandatory - Mitral inflow early and late diastolic velocities, deceleration time of early diastolic wave.

Figure 14: Focused left ventricle apical 2-chamber view

Figure 15: Focused left ventricle apical long-axis view. LV- left ventricle

Figure 16: Magnified view of the left ventricle inflow and outflow; (a) two-dimensional image, (b) with color. LV- left ventricle, LVOT- left ventricular outflow tract

Figure 17: Magnified view of the left atrium seen in the apical 2-chamber view. LA- left atrium
• Optional - LV inflow propagation velocity, PISA for MR, isovolumic relaxation time, MS severity assessment (pressure gradients, valve area by pressure half-time), MR dP/dt.
• Doppler data - Color image: Qualitative for MR, quantitative for PISA. PW: Quantitative for LV diastolic function, MS and MR, transvalvar diastolic forward flow measured at mitral annulus.

Technical description
Applying color flow across the mitral valve in the focused LA-LV view provides information on the hemodynamic severity of MR, in addition to studying mitral inflow [Figure 20a and Video 20]. Care needs to be taken to ensure a color window as narrow as possible that covers the mitral valve to avoid a drop in frame rate and maintain a Nyquist velocity of approximately 50–60 cm/s.

A PW Doppler interrogation of mitral inflow lends significant information to the assessment of LV filling [Figure 20b]. A 1–3 mm sample volume is placed at the tips of the mitral leaflets in the LV and positioned slightly closer to the lateral wall in keeping with flow direction across the valve. Color flow imaging may assist in the optimal alignment of the Doppler beam. Spectral mitral inflow velocities are initially obtained at a sweep speed of 25–50 mm/s to evaluate respiratory inflow variation. In the setting of no respiratory variation, the sweep speed is adjusted to 100 cm/s, averaged over three cardiac cycles and captured at the end of expiration.

Spectral gain and reject are adjusted to display a crisp diastolic profile across the valve. The resultant spectral pattern should demonstrate a well-defined E-wave generated by early filling and A-wave generated by atrial contraction (in normal sinus rhythm).

Mitral annular tissue Doppler (medial and lateral)

Purpose
LV systolic longitudinal function, diastolic function.

Measurements
• Mandatory - Mitral annular early diastolic velocity (E’), mitral annular systolic velocity (S’)
• Optional - Late diastolic velocity (A’)
• Doppler data - Quantitative for LV diastolic function.

Technical description
Mitrail annular tissue Doppler is obtained from the apical 4-chamber view by placing the PW sample volume on the medial and lateral annular junctions [Figures 21a, b and Video 21]. All tissue Doppler presets on equipment are set to filter out high velocity, low amplitude signals and amplify low velocity, high amplitude signals generated by the myocardium, hence no gross manual adjustments may be required. By narrowing the color tissue Doppler sector to cover the medial annulus and lateral annulus separately, an optimal frame rate of 100–120 frames/s can be acquired.

A 5–10 mm sample volume is placed at or within 1 cm of the insertion sites of the mitral leaflets on septal or lateral walls and adjusted to cover the longitudinal excursion of the annulus in both systole and diastole. Care is to be taken to ensure an angulation of <20° between the ultrasound beam and plane of annular motion. The velocity scale is adjusted to 20 cm/s to profile myocardial velocities above and below the baseline. The tracing is recorded at a sweep speed of 100 cm/s at the end of expiration. 2D reference frame is frozen to improve delineation of the spectral waveform, and an average of three consecutive cardiac cycles is considered. The S’, E’, and A’ are measured in this view. In conjunction with the early mitral inflow velocity (E), acquired using PW Doppler, a noninvasive assessment of LV filling pressures (E/E’) is possible. Myocardial performance index can also be measured from these images, considering mitral closure to opening time and ejection time.

Zoomed 5-chamber left ventricular outflow tract-two-dimensional, color, pulsed-wave spectral Doppler

Purpose
• 2D: LVOT dynamic or fixed stenosis, perimembranous VSD, etc.
• Color: LVOT dynamic or fixed stenosis, perimembranous VSD, etc.
• PW: LV stroke volume, LVOT dynamic or fixed stenosis, etc.

Measurements
• 2D: Nil
• Color Doppler: Nil
• PW: Quantitative for stroke volume, continuity equation.

Technical description
A more detailed evaluation of the LVOT is essential to assess dynamic or fixed obstruction, in addition to providing a view for accurate PW/CW measurements [Figure 22a and Video 22a]. Color flow across the LVOT provides a qualitative assessment of AR and localization of the site of obstruction, if present [Figure 22b and Video 22b]. SAM of the mitral valve is well visualized in this view. To assess LVOT flow or measure stroke volume using PW Doppler, a sample volume is placed just proximal to the AoV in the center of the LVOT [Figure 22c and Video 22c]. In calcified, degenerative AS, care should be taken to avoid placing the sample volume too close to the aortic cusps, as this can cause an artifactual increase in LVOT velocities. The sample volume position should also correspond to the location used to assess LVOT cross-section in the 2D PLAX view. In the event of an aliasing spectral pattern, the sample volume can be moved toward the LV to localize the site of obstruction. In a normal heart, the peak velocity should rapidly decline with this maneuver.

Aortic valve flow continuous-wave Doppler

Purpose
Quantification of AS severity.

Measurements
• Mandatory - AS peak and mean gradients, aortic flow VTI
• Doppler data - quantitative for AoV area estimation by continuity equation.

Technical description
Switching to CW Doppler in the previous view provides an assessment of the maximum flow across the AoV [Figure 23 and Video 23]. A peak velocity and VTI obtained from CW can be used in conjunction with the corresponding values obtained in the LVOT to assess AoV area using the continuity equation. All spectral Doppler tracings are to be recorded at 100 mm/s, adjusting baseline and velocity scale to ensure optimal measurement. Like all Doppler evaluations, care is to be taken to ensure the beam is as parallel as possible to blood flow.

Focused right atrium-right ventricle view two-dimensional, tricuspid flow color Doppler, continuous-wave and pulsed-wave

Purpose
• 2D: RV size and function, interventricular septal motion, intracavity clot, mass, etc.
• Color: Detection of TR
• CW: RV/PA systolic pressure
• PW: RV diastolic function, tricuspid stenosis, etc.

Measurements
2D
• Mandatory – RA, RV dimensions
• Optional – Tricuspid annular plane systolic excursion (TAPSE), TV annular size

Color
• Mandatory – Nil
• Optional – TR jet PISA
• Doppler data: Qualitative

CW
• Mandatory – TR jet peak gradient
• Doppler data: Quantitative for PASP, RV dP/dt, etc.

PW
• Mandatory – Tricuspid inflow early diastolic velocity
• Optional – Tricuspid inflow late diastolic velocity, deceleration time of early diastolic wave, pressure half-time
• Doppler data: Quantitative.

Technical description
To perform a focused evaluation of the RV, one would need to begin with the apical 4-chamber view and align the RV with the center of the screen [4]. This view is obtained by moving the transducer slightly medially and reducing the sector width to encompass the RA and RV. In a normal heart, the RV is less than two-thirds the size of the LV [Figure 24a and Video 24]. RV size is assessed by measuring diameters at the base and mid-cavity region at end-diastole, when the chamber size is largest. The length of the RV is assessed from the plane of the TV annulus till the RV apex in this view. TAPSE is an evaluation of the systolic longitudinal excursion of the TV annulus and is representative of RV systolic function. This is performed by placing an M-mode cursor through the annulus and measuring the displacement at peak systole.
Placing a color Doppler window across the TV in this view allows one to qualitatively assess the severity of TR, or turbulence across the TV [Figure 24b and Video 24]. An approximation of RV systolic pressure can be obtained by assessing the TR jet with CW Doppler [Figure 24c] and adding the resultant peak pressure gradient to RA mean pressure as assessed by IVC size and collapsibility. The cursor is aligned as parallel to the flow as possible. Once the spectral Doppler is obtained, the baseline and velocity scale are adjusted to measure the peak velocity. Spectral gain can be adjusted to provide an optimal delineation of flow pattern. An additional measure of forward flow using PW/CW Doppler across the valve may be useful to study diastolic properties of the RV, or measure TS gradient [Figure 24d]. Tissue Doppler of the lateral tricuspid annulus can also be performed, in a manner analogous to the mitral valve, to measure systolic and diastolic function of the RV.

Subcostal 4-chamber view (right ventricle focused)

**Purpose**

2D: RV free wall thickness measurement.

**Measurements**

2D

- Mandatory – Nil
- Optional – RV free wall thickness measurement.

**Technical description**

To obtain subcostal views, the patient is rolled over to a supine position and knees are bent to relieve muscle strain in the abdominal region. The transducer is placed in the sub-xiphoid region with the orientation marker pointing toward the patient’s left, in the 3 o’clock position. Angling the scan plane cephalad brings the subcostal 4-chamber view. Inspiration generally improves the quality of the image by bringing the heart closer to the transducer.

In this view, the LA, RA, interatrial septum, LV, RV, and intact ventricular septum are visualized [Figure 25 and Video 25]. The two ventricles are seen above the atria, with the RV visualized anterior to the LV. A focused view of the right ventricular free wall permits measurements of wall thickness in the setting of elevated RV afterload. Measurements are taken at end-diastole, beyond the TV leaflets at the level of the chordae.

Subcostal interatrial septal view two-dimensional and color Doppler

**Purpose**

- 2D: Intactness of interatrial septum; RV free wall thickness measurement (from RV-focused view).
- Color Doppler: To exclude ASD, patent foramen ovale.

**Measurements**

2D: Mandatory – Nil

- Optional – ASD size
- RV free wall thickness measurement from RV-focused view

Color: Mandatory – Nil

- Optional - ASD size
- Doppler data: Qualitative detection of shunt.

**Technical description**

From the standard subcostal 4-chamber view, a slight posterior angulation of the transducer stretches out the interatrial septum and brings the two atria into focus. A magnified view of the interatrial septum can be obtained using the zoom function [Figure 26a and Video 26a]. In this view, the interatrial septum is aligned perpendicular to the ultrasound beam, and hence it is the recommended view to profile a patent foramen ovale or ASD. Placing a color Doppler window on this image permits the evaluation of the intactness of the septum [Figure 26b and Video 26b].

Subcostal aorta long axis two-dimensional and color Doppler (pulsed-wave spectral Doppler optional)

**Purpose**

- 2D: Aortic pulsations, aneurysm, dissection flap, etc.
- Color: Phasic versus continuous flow (to diagnose
coarctation), flow reversal, differential flow suggestive of aortic dissection.

**Measurements**

**2D**
- Mandatory – Nil
- Optional – Aorta size

**Color**
- Mandatory – Nil
- Doppler data: Qualitative.

**Technical description**

To obtain the long axis of the aorta, the probe is turned in the counterclockwise direction till the orientation marker faces the patient’s head, and the scan plane is tilted inferiorly, or toward the abdomen. A slight leftward angulation profiles the upper abdominal aorta in long axis [Figure 27a]. The upper abdominal aorta can be identified as thick walled and pulsatile. This view is useful to look for an aneurysm or dissection flap. Placing a color Doppler sector in this view [Figure 27b and Video 27] provides qualitative information on flow hemodynamics such as continuous flow in the setting of coarctation and reversal in the setting of significant AR. Optionally, PW Doppler can be used to assess the flow pattern.

**Inferior vena cava long axis two-dimensional, inferior vena cava/hepatic vein color, pulsed-wave**

**Purpose**
- 2D: Preload status, respiratory variation in IVC size
- Color: Respiratory variation of IVC/hepatic vein flow
- PW: Estimation of RA pressure.

**Measurements**
- 2D: IVC size, along with respiratory variability
- Color: Mandatory – Nil

**Technical description**

From the subcostal aorta long-axis view, angling the probe to the patient’s right will demonstrate the IVC in long axis [Figure 28a and Video 28a]. The IVC is identified as a thin-walled structure that collapses on inspiration in patients with normal RA pressures. With fine angulations, the IVC should be opened to a maximum diameter and clip must be recorded during quiet inspiration. A sniff, or sudden forceful inspiration, demonstrates collapsibility of the IVC and provides information on central venous pressures. The maximal diameter of the IVC must be measured when not collapsed, just proximal to the entry of the hepatic veins. With fine angulation, the hepatic veins can be demonstrated draining into the IVC [Figure 28b and Video 28b]. A color flow window placed over the hepatic vein provides qualitative information on flow direction. PW Doppler can be employed for additional information on systolic, diastolic, and flow reversal velocities [Figure 28c]. To obtain an optimal spectral waveform, a 3–5 mm PW sample volume is placed in the hepatic vein, taking care to align the Doppler axis parallel to the vessel flow.

**Suprasternal long axis of aortic arch two-dimensional, color and pulsed-wave/continuous-wave**

**Purpose**
- 2D: To look for aortic dissection, coarctation, etc.
- Color: Assessment of diastolic flow reversal in AR, differential flow in aortic dissection, turbulence in coarctation, etc.
- PW/CW: Assessment of diastolic flow reversal in AR, coarctation severity.

**Measurements**
- 2D: Mandatory – Nil
Optional – Linear measurements of aortic arch and isthmus.
• Color: Nil; color M-mode for qualitative assessment of diastolic flow reversal in case of AR
• PW/CW: Mandatory – Nil
Optional – Descending aorta PW for diastolic flow reversal, CW Doppler for coarctation gradient.

Technical description
The suprasternal long axis of the aortic arch is obtained by placing the transducer in the suprasternal notch with the orientation marker pointing toward the patient’s left shoulder. With a slight anterior angulation, the aortic arch and branch vessels are seen [Figure 29a]. Moving from proximal to distal arch, the aortic arch first gives rise to the brachiocephalic artery, followed by the left common carotid and the left subclavian artery, respectively. Applying a color Doppler in this view provides information about blood flow characteristics, turbulence or reversal [Figure 29b and Video 29]. PW or CW Doppler may be applied to measure flow reversal or high gradient forward flow, respectively [Figure 29c].

Pathology-specific additional non-conventional views
Apart from the above-described standard views, additional non-conventional views may need to be obtained to better define specific cardiac pathologies. For example, off-axis views may be required to image eccentric regurgitation jets, or for spatial delineation of cardiac masses or any other structure.

RECOMMENDED FORMAT FOR REPORTING A COMPREHENSIVE ADULT TRANSTHORACIC ECHOCARDIOGRAPHIC STUDY
Although as mentioned above, each institution has its own style of reporting echocardiographic findings, it is recommended that the final report should mandatorily include the following details.

Patient data
The patient name, age, gender, blood pressure, heart rate, rhythm, and body surface area.

Overall study impression
The description should include (but not limited to) the following points:

Etiological diagnosis
Etiological diagnosis relevant to the case should include (but not be limited to) the following as applicable: ischemic, infective, degenerative, rheumatic, congenital, idiopathic, etc.

Anatomical/structural diagnosis
Anatomical or structural description relevant to the pathology should include (but not be limited to) the following as applicable: chamber enlargements, hypertrophies, myocardial regional wall abnormalities (thickness, scars, aneurysm), valve/annulus/outflow morphologies, septal defects, IVC size, pericardial/pleural disease, great vessel disease, prosthesis, intracardiac masses (clot/vegetation/tumor), etc.

Functional/hemodynamic diagnosis
Functional or hemodynamic status description relevant to the pathology should include (but not be limited to) the following as applicable (description can be combined with anatomical details for maintaining continuity): LV/RV systolic/global function (qualitative or quantitative parameters/indices),
diastolic function grading, valve gradients, valvular regurgitation grades and mechanism, shunt qualitative estimates, intracardiac pressure quantitative and/or qualitative estimates, prosthesis function, dyssynchrony measurements, etc.

Comment about further management
Therapeutic or management guidance comment relevant to the pathology should include (but not be limited to) the following as applicable: suitability for intervention, future echocardiographic follow-up, need of additional imaging, family screening, etc.

Reporting templates can be created for common pathologies using the above principles [Appendix 1 for ischemic and valvular heart disease templates].

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

REFERENCES
**APPENDIX**

**Appendix 1: Illustrative examples of templates for reporting final impressions from an echocardiographic study**

(Please note, these templates are only for reporting final impressions. A complete report will also include various measurements and other findings, in addition to the final impressions)

A. Ischemic heart disease report template (strike out whatever is not relevant):

1. Ischemic heart disease
2. Regional wall abnormalities
   - Left ventricular basal/mid/apical segments of anteroseptum, apical lateral wall, apical inferior wall are hypokinetic/ akinetic with thinning (…mm)/scarring/preserved thickness
   - Left ventricular basal/mid segments of inferior, posterior wall are hypokinetic/ akinetic with thinning (…mm)/ scarring/preserved thickness
   - Left ventricular basal/mid segments of lateral wall are hypokinetic/ akinetic with thinning (…mm)/scarring/ preserved thickness

Graphical representation of regional wall motion abnormality may be added to textual description.

3. Left ventricle shows normal size/dilatation/left ventricular hypertrophy/spherical remodeling/anatomical aneurysm.
   - Left ventricle clot present/absent
4. Left ventricular systolic function is normal/depressed (left ventricular ejection fraction =……LVEDV……., LVESV……., GLS…….)
5. Left ventricular diastolic function normal/dysfunction grade =…… suggestive of normal/raised LVEDP
6. Left atrium size is normal/increased. Right atrium/right ventricle is normal in size/dilated
7. Aortic and mitral valves: normal/sclerotic. Mitral regurgitation and aortic regurgitation present/absent grade……
8. Pulmonary hypertension present/absent. PASP=…… ml/m2 by Doppler/planimetry at stroke volume =…… ml/m2
9. Right ventricle function normal/depressed. Tricuspid annular plane systolic excursion =……
10. Any intracardiac clot present/absent. Pericardial effusion none/present (further description ……………)
11. Additional abnormalities……………………

B. Valvular heart disease template (strike out nonrelevant):

1. … valvular heart disease with/without evidence of infective endocarditis
   - AVA = …….. cm2 by Doppler/planimetry at stroke volume =…… ml/m2
   - Anulus =…… mm, aortic root =…… mm, Asc Ao =…… mm
   - AV gradient peak =…… mean =…… mmHg at heart rate =…… blood pressure =…… (imaging window: Apical/right parasternal/suprasternal)
3. Mild/moderate/severe aortic regurgitation. Grade =……
   - Aortic regurgitation due to … (mechanism flail leaflet/ fibroed retracted/bicuspid/annular dilatation etc.)
   - Aortic valve annulus =…… mm, aortic root at sinuses =…… mm, STJ =…… mm, Asc Ao =…… mm
4. Mild/moderate/severe mitral stenosis.
   - MVA =…… cm2 by planimetry/hydrostatic pressure
   - Mitral valve gradient peak =…… mean =…… mmHg at heart rate =…… sinus/atrial fibrillation rhythm.
   - Mitral valve score =……
   - Anterior mitral leaflet thickened, pliable/nonpliable, calcification absent/present at …
   - Posterior mitral valve leaflet thickened, pliable/nonpliable, calcification absent/present at …
   - Medial/lateral commissure fused/open, calcification absent/ present at …
   - Subvalvular apparatus: chordae thickened/fused, calcification present/absent at …
5. Mild/moderate/severe mitral regurgitation. Grade =……
   - Mitral regurgitation due to … (mechanism leaflet tethering, posterior mitral valve leaflet p1/p2/p3 scallop, anterior mitral leaflet A1/A2/A3 segment thickened retracted/ myxomatous/prolaping/flail, chordae shortened/ elongated/ruptured/tenting, papillary muscle medial/ lateral…)…
   - Mitral annulus normal/dilated. Anteroposterior =…… mediolateral =…… mm
6. Left ventricle shows normal size/dilatation/Left ventricular hypertrophy/spherical remodeling.
   - LVIDd =…… mm, LVIDs =…… mm
   - Left ventricular systolic function is normal/depressed. (Left ventricular ejection fraction =…… LVEDV =…… ml/m2 by planimetry/pressure half-time.
   - Mitral valve gradient peak =…… mean =…… mmHg at heart rate =…… blood pressure =…… (imaging window: Apical/right para/ suprasternal)
   - LVEDP =…… mmHg, inferior vena cava normal/congested
   - LVESV =…… ml/m2
   - GLS=……
7. Left atrium/right atrium size normal/dilated. Left atrium appendage clot present/absent.
8. Right ventricular size normal/dilated. Right ventricular function normal/depressed. Tricuspid annular plane systolic excursion =……
   - Grade =……
   - Tricuspid valve annulus size =…… tricuspid valve leaflets noncoaptation/thickened, retracted/fused commissures
10. Pulmonary hypertension present/absent. PASP =…… mmHg, inferior vena cava normal/congested
11. Aortic arch normal/dilated. Coarctation present/absent
12. Additional abnormalities……………………