Sector scanning views in echocardiography: a systematic approach

Relationship of 2D echo views to other cardiac imaging techniques

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Two-dimensional echocardiography allows the examiner to obtain multiple cross-sectional views of the heart from several different chest wall transducer positions. This article describes the most commonly used views and aims to indicate the state of standardization of display orientation and nomenclature associated with each of these views. The clinical utility of each view in specific common pathologic conditions is discussed, as well as the relation of left ventricular segments in these echocardiographic views to those in angiographic or scintigraphic images. In addition, the coronary distribution pattern in the echocardiographic views of the left ventricle is described.

Rapid advances have been made in two-dimensional real time echocardiography since its clinical introduction in the early years of this decade [1-3]. Commercially available mechanical, phased array and linear array systems designed for cardiac imaging continue to proliferate. The 'sector scan' format has proven most useful for both pediatric and adult cardiovascular imaging, since it can optimally employ the limited number of echocardiographic 'windows' on the heart (especially that at the left sternal border between ribs, lung and sternum) [3]. 'Wide angle' images (with a sector angle greater than 45°) potentially yield more information but in some systems this is done at the expense of line density. Though there are a limited number of ultrasound windows, transducer rotation and angulation can vary the plane of imaging, to create a large number of two-dimensional echocardiographic 'views' and these can be displayed with the skin surface or apex of the 'sector' in any direction on the output screen. Experience over the past few years has indicated that certain views yield more diagnostic information than others. The need for comparing work from different laboratories and for standardization of views in the literature has led to a limited number of 'standard' views which comprise a routine two-dimensional echocardiographic examination. These eight views (four transducer positions and two roughly orthogonal views from each position) are listed in Table 1. The American Society of Echocardiography (ASE) has recently formulated recommendations to standardize these views with respect to right-left and superior-inferior orientation of the sector apex on

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<th>Number</th>
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<td>1</td>
<td>PSLAX</td>
<td>Parasternal</td>
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Figure 1 The four major transducer positions for echocardiographic examinations. (a) Parasternal, (b) apical, (c) subcostal, (d) suprasternal.

the display screen. Some recommendations should also be made to the manufacturers:

(1) The transducer should have a mark indicating the right side of the sector display. This mark should face superiorly and/or leftward during patient examination.

(2) An 'image inversion switch' should allow up-down, reversal of the sector format for display of the subcostal view and perhaps the apical views.

This article will discuss standard cardiac views, their diagnostic utility, their relation to angiographic and scintigraphic cardiac images and coronary anatomy, and the views most useful to examine specific cardiac structures in common pathologic conditions.

Left parasternal transducer position (also called left sternal border position)
Cardiac images from the third, fourth and fifth intercostal spaces, to the left of the sternum, are best recorded with the patient in the 30° to 90° left lateral decubitus position, in end-expiration with the head and thorax elevated approximately 30° (Fig. 1a).

LONG AXIS VIEW: PSLAX (FIG. 2)
This view was the easiest for early two-dimensional echocardiographic development, since it used the same transducer position and long axis scan plane of imaging familiar from M-mode echocardiography. As with M-mode examination the
third through fifth intercostal spaces to the left of the sternum are initially examined to ascertain the position of optimum imaging (‘best window’). The examiner employs a plane running from the right shoulder towards the cardiac apex (Fig. 2). The transducer will be nearly perpendicular to the chest wall when the mitral valve is in the center of the image. The right ventricular outflow tract, aortic root, aortic and mitral valves, left atrium and left ventricular base and midposition can normally be seen in this view. The true cardiac apex is usually not seen in this view. Foreshortening of the apex, especially with large amplitude apical motion and poorly visualized endocardium, suggests an oblique image plane through the septal-inferior left ventricular wall (too medial) or lateral wall. The transducer should be adjusted to maximize the length of the left ventricular long axis.

Once the standard view has been obtained, the transducer can be angulated towards the cardiac base to examine the aorta and left atrium, towards the apex to examine the left ventricle, laterally and medially to fully examine the aorta, mitral valve apparatus and left ventricle, and further medially through the interventricular septum to image the tricuspid valve and right ventricular inflow tract.

SHORT AXIS VIEWS: PSSAX (FIGS 3 AND 4)

The transducer is rotated clockwise 90° from the long axis plane to obtain this view (the mark on the
Figure 3 Parasternal short axis (PSSAX) views. (a) A family of multiple short axis views results from sweeping the imaging plane from the base (Ao = aortic level) through the mitral valvular level (MV), papillary level (P), and apical level (AP). (b) Diagram of resulting view, MV level. Abbreviations as in Fig. 2. (c) Stop-frame image from a normal PSSAX (MV) echocardiogram.

transducer is to the patient’s left). The plane of imaging at the mitral or papillary level includes both of the minor axes of the left ventricle. Normally the left ventricle is nearly circular at this level and the mitral valve is ‘fishmouth’ shaped, lying centrally in the lower portion of the left ventricular image. The medial and lateral portions of the valve normally have a symmetric opening and closing motion, so that higher amplitude medially suggests ‘underrotation’ and higher amplitude laterally suggests ‘overrotation’ with respect to the clockwise transducer rotation needed to obtain the short axis view from the long axis plane. Once a short axis plane of imaging has been established it can be ‘swept’ toward the apex or base in a manner exactly analogous to the classic M-mode long axis scan. As seen in Figs 3 and 4, various levels allow examination of (a) the aortic valve, left atrium, tricuspid valve and right ventricular outflow tract through the pulmonic valve, (b) the basal interventricular septum, left ventricular outflow tract, posterobasal and posterolateral left ventricle, (c) the mitral valve (both leaflets around the entire circumference) and basal left ventricle and (d) the left ventricular cross section at the papillary muscle level. ‘Scanning’ the plane of imaging from the base to apex and back allows formation of a three-dimensional cardiac image in the examiner’s mind by combining the multiple short axis tomographic views.
attempting to maximize mitral and tricuspid valve leaflet motion and visualize all four cardiac chambers as shown in Fig. 5. The interrogating plane can be swept anteriorly to examine the aortic valve though intervening lung may sometimes prevent successful aortic imaging. In a minority of patients, the plane can be swept posteriorly and an adequate ‘apical short axis’ view is obtained by imaging the circular left ventricular cross-section just below the transducer. There is considerable variation in the standardization of display for this view. Some earlier work presented the left ventricle at the left of the display screen, but this has largely been abandoned. The ASE has recommended two options for display: the sector apex at the top or the sector apex at the bottom of the display screen. The former is currently more standard in the literature (Fig. 5), but it is anticipated that the sector apex (and thus cardiac apex) at the bottom of the display screen will gain adherents when an image inversion switch is available.

Nearly the entire heart with the exception of the atrial appendages and cardiac apex, is accessible to examination in this set of views.

Apical transducer position

Images are best recorded from this position by placing the transducer directly on the palpable apical impulse (Fig. 1b). Often a steeper left lateral patient position is necessary, compared to the parasternal views. Optimal images are recorded during held expiration. Patients with thick chest walls, lung disease, or the lack of a palpable apical impulse frequently have poor quality studies. On the other hand, patients with apical aneurysms, enlarged hearts and pericardial effusions usually have an excellent image quality. The left ventricular apex is usually best imaged from this transducer position. There is a high success rate in imaging dilated hearts and those with anterior aneurysms, since there is less room for lung between heart and chest wall.

APICAL FOUR-CHAMBER VIEW: AP4C (FIG. 5)—(ALSO CALLED APICAL SHORT AXIS VIEW)

The apical examination is begun with the transducer aimed towards the base of the heart (along the left ventricular long axis) and a near-coronal plane of imaging. Once images are obtained, the transducer is rotated, usually slightly clockwise,
The latter is not entirely satisfactory, though, since the apical four-chamber view (Fig. 5) also includes the long axis of the left ventricle. 'Apical long axis' does have the advantage of indicating that a round 'short axis' image cannot be obtained in this orientation without transducer rotation, whereas it can sometimes be obtained from the apical four-chamber (or apical short axis) view by posterior angulation.

Subcostal transducer position (also called subxiphoid position)

Cardiac images from this transducer position are best recorded with the patient supine, the head not elevated and with the hips and knees partly flexed to allow optimal relaxation of the abdominal musculature (Fig. 1c). Since the best images are recorded with the diaphragm low and close to the transducer, the highest success rate in subcostal imaging is during held inspiration and in patients with low diaphragms due to lung disease. In this patient group which tends to give poor images from the parasternal and apical transducer positions, the subcostal view often provides the highest diagnostic yield. In normal adults, though, subcostal images are usually of lower quality than parasternal or apical ones and the left ventricular apex can rarely be imaged.

An important use for these views is the verifica-
Figure 6 Apical long axis (APLAX) view. (a) Diagram of plane of imaging. (b) Diagram of resulting view. Abbreviations as in Fig. 2, and Ao = aorta. (c) Stop-frame image from a normal APLAX study.

tion that pericardial effusion (usually diagnosed from the parasternal transducer position) is indeed present on the diaphragmatic surface of the heart. This is the direction from which pericardiocentesis is often attempted. Elevation of the patient’s head may help to bring out the effusion. The subcostal view is most helpful in imaging the interatrial septum.

In the parasternal short axis and apical four-chamber views the interatrial septum is parallel to the interrogating sound beams and often gives spurious ‘dropout’ patterns in the absence of septal defects. The subcostal view of the atrial septum images it perpendicularly to the interrogating sound beams, thus minimizing false echo dropout.

SUBCOSTAL SHORT AXIS VIEW: SCSAX (FIG. 8)

We begin our examination from the subcostal position with the image plane nearly sagittal, oriented slightly to the right of midline, in order to image the inferior vena cava-right atrial junction and tricuspid valve, as is shown in Fig. 8. This view is the most useful one for the assessment of tricuspid regurgitation by peripheral contrast echocardiography. The transducer is then angulated progressively toward the patient’s left (the cardiac apex), yielding an image of the tricuspid and aortic
Figure 7 (a) Plane of imaging of apical two chamber view, which intersects the anterior left ventricular wall instead of the interventricular septum, as the APLAX plane illustrated in Fig. 6a. (b) Comparison of APLAX plane of imaging (darker shading, as shown in Fig. 6a) to apical two chamber plane of imaging (stippled plane, as shown in Fig. 7a).

valves, left ventricle at the mitral and papillary level. Occasionally short axis imaging of the left ventricle further towards the cardiac apex is possible.

SUBCOSTAL FOUR-CHAMBER VIEW: SC4C (FIG. 9)
The transducer is rotated 90° clockwise from the subcostal short axis view to obtain these views. Since the atrial septum is largely perpendicular to the echo plane in this view, it is perhaps the best ‘standard view’ for assessment of atrial septal pathology. The plane of imaging can be directed towards the ventricle to obtain images as shown in Fig. 9. The left ventricle apex, however, is rarely imaged in this view.

The ASE has proposed two alternate modes of display for this view — with the apex of the sector at the top or at the bottom of the display screen. Most publications up to now have used the ‘apex-up’ format shown in Fig. 9. It is anticipated that as manufacturers install image inversion switches on their equipment a larger proportion of these studies will be displayed with the sector apex at the bottom of the screen.

Suprasternal notch transducer position
Examination from this position is best performed with the patient supine and with a pillow under his shoulders to allow hyperextension of the neck (Fig. 1d). The transducer is placed in the suprasternal notch and angled in a caudad direction.

SUPRASTERNAL NOTCH – AORTIC ARCH LONG AXIS VIEW: SSLAX (FIG. 10)
We begin our examination from the suprasternal notch position by rotating the transducer until the plane of imaging corresponds with the plane of the aortic arch. The innominate, left carotid and left subclavian artery origins are visualized and the right pulmonary artery is seen in cross-section as a circular echo-free structure below the aortic arch. Inferior to the right pulmonary artery is the left atrium. The aorta can be recognized by its characteristic arch with branching vessels only a few centimeters below the transducer, by its systolic pulsations and because it is always more cranial (closer to the suprasternal notch transducer) than the pulmonary artery, even in transposition of the great vessels. Therefore, this view is superior to the parasternal views for differentiation of the great vessels by peripheral contrast echocardiography. The image plane is then angled as much as possible to inspect the ascending and descending thoracic aorta. This must be done separately with a slight degree of transducer rotation between the different segments, because the ascending and descending aorta are rarely in the same plane.

SUPRASTERNAL NOTCH – AORTIC ARCH SHORT AXIS VIEW: SSSAX (FIGS 11 AND 12)
After the thoracic aorta has been imaged, we rotate the transducer approximately 90° and search for the plane where the right pulmonary artery is imaged as a linear echo-free structure just inferior to the aortic arch. The aorta is now seen as a circular pulsating structure. The left atrium remains inferior to the right pulmonary artery.

Relation of two-dimensional echocardiographic images to other cardiac imaging techniques
Angiography and scintigraphy are the two major types of non-ultrasound cardiac imaging currently available. Both of these techniques yield images that are a silhouette of the heart, and integrate all information received along each line perpendicular to the plane of imaging. Echocardiography yields fundamentally different information, for it can sample and image anatomy at each depth in a tomographic plane through the heart. Information from overlying levels is not superimposed, though there are possible resolution problems with structures adjacent to the plane of imaging.

The standard right anterior oblique (RAO) and left anterior oblique (LAO) angiographic segments used at our institution are shown diagrammatically
in Fig. 13. While realizing that the boundary of a silhouette is not the same as the tomographic plane parallel to it, rough equivalents of left ventricular wall segments can be established between these angiographic segments and two-dimensional echocardiographic segments as defined in Fig. 13. This is done in Table 2.

Scintigraphic projections used for cardiac imaging are not entirely standardized between institutions, and segmental analysis can be different for direct thallium imaging of the myocardial segments compared to gated blood pool imaging.

In our institution, routine scintigraphic images are obtained in the anterior, 45° left anterior
oblique (LAO), and 65° LAO projections. Segmental analysis of the left ventricle is performed as diagrammed in Fig. 13, and these segments may roughly be related to two-dimensional echocardiography as listed in Table 3.

**Relation of two-dimensional echocardiographic images to coronary anatomy**

Figure 14 depicts the relation of coronary anatomy to the standard left parasternal and apical echocardiographic views described earlier. This information is a subjective synthesis of the authors' experience comparing two-dimensional echocardiograms to electrocardiographic and invasiv studies in humans and to direct pathologic material in experimental animal infarctions. However, human coronary anatomy varies strikingly and this is especially true when significant co laterals develop during coronary disease. Figure 1 is thus only an approximate guide to the coronary anatomy serving each echocardiographic segment.

**Echocardiographic views most useful in specific pathologic states**

**VALVULAR HEART DISEASE**

The aortic valve is nearly always best image
from the left parasternal transducer position. Increased aortic valve echoes can be seen on both PSLAX and PSSAX views and these correlate with aortic valve thickening and sclerosis but not well with stenosis. Bicuspid aortic valve is best assessed by noting the diastolic closure pattern in the PSSAX view.

Proximal aortic root enlargement is best seen on the PSLAX, but more distal ascending aorta as well as the transverse and descending aorta are best imaged from the suprasternal notch position. Left atrial size can be judged from the parasternal and apical transducer positions. As in M-mode echocardiography noise in the left atrium frequently simulates a mass. On the parasternal views this is probably due to reverberations behind the
strongly reflecting aortic root as well as off-axis echoes from the orifices of the pulmonary veins. In order to diagnose any atrial mass such as myxoma or thrombus, a motion independent of other cardiac structures and verification from both the apical and parasternal positions should be obtained. Calcified mitral annulus is frequently imaged in the area of the posterior mitral leaflet, anterior to its anatomic location in the atrio-ventricular junction. This occurs because the strongly reflecting calcium adjacent to the plane of imaging is visualized. A left atrial mass may be mimicked in this manner.

Characteristic mitral valve motion is seen from both the apical and parasternal transducer positions. Rheumatic mitral stenosis is best diagnosed on the PSLAX view, and best quantified by planimetry of the mitral orifice in early diastole from the PSSAX view. Prolapse is still more reliably diagnosed by M-mode than two-dimensional techniques at present. On two-dimensional study it can be best seen on the PSLAX view. Flail leaflet is also seen on this view. Valvular vegetations are best appreciated in the PSSAX views, but the PSLAX and apical views are always necessary when searching for vegetations.
Fluttering of the anterior mitral valve in aortic regurgitation is best demonstrated by M-mode due to its much higher sampling rate, and thus time resolution, but can exceptionally be appreciated from the parasternal position on two-dimensional studies. Systolic anterior motion of the mitral valve (SAM), characteristic of hypertrophic cardiomyopathy, is best detected in the PSLAX view. The advantage of two-dimensional echocardiography is that it shows which part of the mitral apparatus is involved in the SAM: chordae, distal or proximal leaflet. The tricuspid valve is invariably better imaged using two-dimensional techniques than M-mode. Analysis of the pulmonic valve motion patterns that might indicate pulmonary stenosis or hypertension, however, is more readily done by M-mode. Prosthetic valves are imaged using the same transducer positions appropriate for native valve examination. Apical views are mainly parallel to the long axis of the prosthesis and more likely show maximal amplitude of ball or disc excursion than parasternal views. Both views are helpful in excessive rocking of valves due to partial ring dehiscence, and in the presence of mobile vegetations that move independently of the prosthetic motion. To differentiate valvular obstruction from myocardial failure, M-mode studies and phonocardiography with pulse tracings yield more useful information than two-dimensional studies.

VENTRICULAR DISEASE

The right ventricle can be imaged in the AP4C view and its long axis dimension can be measured. The left ventricle can be imaged from both parasternal and apical transducer positions. Segmental wall motion abnormalities due to coronary disease can be accurately detected and correlate well with those detected using other techniques. The AP4C and APLAX views are the most useful views in coronary disease, because they image the apical left ventricular motion where dyssynergy due to coronary artery disease most commonly occurs. Although volume measurement using two-dimensional techniques is probably quite accurate and M-mode only provides an LV volume estimation, there are as yet no widely employed methods for determining quantitative parameters of regional left ventricular function from two-dimensional studies. M-mode parameters of overall ventricular function are misleading in segmentally diseased ventricles. Complications of coronary artery disease, such as aneurysm formation, pseudoaneurysms, ventricular thrombi, ventricular septal and free wall rupture, and perhaps papillary muscle dysfunction, are detectable using two-dimensional echo studies of the left ventricle.

The left main coronary artery can be imaged in most patients using the PSSAX view at the aortic-left atrial level. It is possible that information about the degree of stenosis of this artery may become available through two-dimensional echocardiography in the future, though at present unprocessed images of the left main coronary artery are unreliable indicators of the degree of stenosis as demonstrated angiographically.
Cardiomyopathies can be diagnosed and classified into dilated, asymmetrically or symmetrically hypertrophied categories by two-dimensional techniques. Generally, the PSLAX view yields the most information, with assistance from the PSSAX view and apical views. The geometric distribution of the structural abnormalities in hypertrophic cardiomyopathy is much better assessed by two-dimensional than M-mode techniques. Two-dimensional echocardiography is useful in both diagnosing and following patients with this disease\textsuperscript{19,22,23}. It enables avoidance of some of the pitfalls of M-mode echocardiography in diagnosing asymmetric septal hypertrophy in some patients whose ventricular septum is directed more anterior than usual but who have no true asymmetric septal hypertrophy (ASH).

**CONGENITAL HEART DISEASE**

Two-dimensional echocardiography probably
has an even wider application in congenital heart disease than in adult cardiac disease. This is due to the higher success rate in children, the ability to use higher ultrasonic frequencies and thereby attain better resolution, and the fact that spatial orientation and definition of anatomy is of paramount importance in many cases of congenital heart disease. Contrast echo techniques are especially helpful in defining shunts and anatomical connections among the great vessels and cardiac chambers. Space does not permit a discussion of the many applications of two-dimensional echocardiography in this field and the interested reader is referred to several recent articles.

Conclusion

Two-dimensional echocardiography has expanded rapidly during the past few years. A full appreciation of the potential diagnostic information from these echocardiographic images requires real-time viewing and a knowledge of cardiac anatomy as displayed in sector scan format. Technical improvements will improve image quality and decrease the size and cost of real time two-dimensional echocardiographic instruments. With these technical improvements and continued clinical investigations echocardiography promises to remain an exciting and rapidly growing field in the 1980s.

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References


Note: Since submission of this article the American Society of Echocardiography Recommendations referred to in the text, have appeared in Circulation: