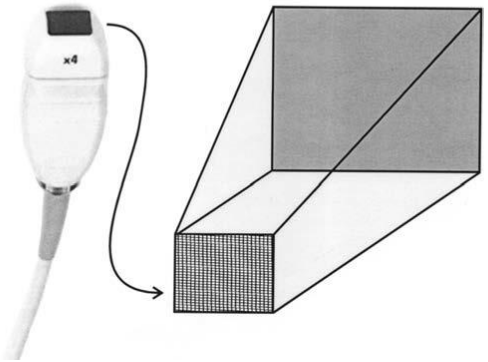
3D ECHOCARDIOGRAPHY

3D imaging uses a matrix array transducer which consist of 2,000 to 3,000 imaging elements in a rectangular array (compared to 2D transducer, which typically contains 128 elements arranged in a linear fashion). The ultrasound beam can be steered in two different planes – the y axis (similar to 2D imaging) and, in addition, the z axis (elevation plane) – to produce a pyramidal volume dataset.



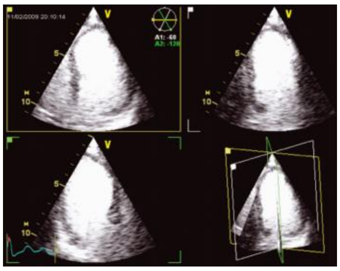
A three-dimensional volumetric probe. Note the relatively square footprint of the probe compared with a standard two-dimensional probe. The face of the probe consists of a nearly rectangular matrix of crystals that results in a pyramidal scan profile.

3D ECHO PHYSICS

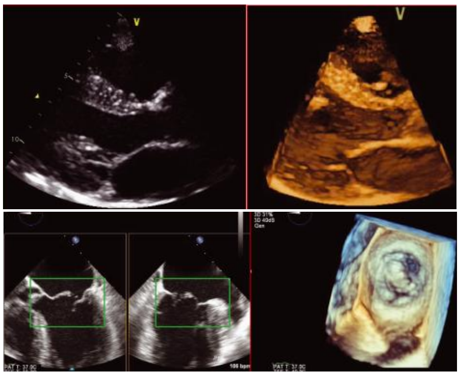
Similar to 2D imaging, there is an inverse relationship between frame rate (temporal resolution), sector width and spatial resolution (scan lines, also called line density) in 3D echo. An increase in one of these factors will cause a decrease in the other two. Manufacturers have developed several techniques such as parallel processing and multi-beat imaging to cope with this challenge.

IMAGE ACQUISITION MODES: in clinical practice 3D examination is often used as a focussed study to complement 2D imaging. A good acoustic window is essential for optimal 3D visualization (difficult because of larger probe size). Use 2D guidance for centring of the region of interest. Adjust gain and avoid drop-out artefacts.

1. **Simultaneous multi-plane:** uses 3D probe to display simultaneously live 2D images from two or three planes. For example, acquisition of a 4-chamber view from the apical window will simultaneously display 2-chamber and 3-chamber views. Although strictly not a 3D image, this feature is useful in situations where assessment of multiple imaging planes from the same cardiac cycle is useful (e.g. stress echo, tissue synchronisation imaging, imaging to locate MV flail scallop or to measure the mitral orifice area). Colour flow can be superimposed on a live 3D image to assess blood flow in real time. This facility is only available from some manufacturers.



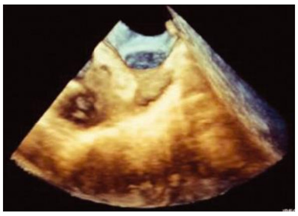
2. **Real-time (live) 3D:** image acquired within one cardiac cycle and updated during acquisition. This method has the advantage of absence of stitching artefact, but is limited by its lower spatial and temporal resolution (can be relatively improved by reducing the sector width). A focussed real-time view of a structure of interest can be obtained by adjusting the lateral and elevation width using a crop box, the system automatically crops the adjacent structures to provide a real-time 3D zoom display of the structure of interest.



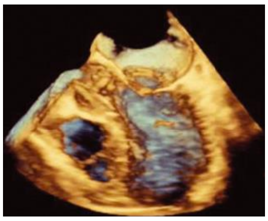
3. **ECG gated multi-beat 3D imaging:** image acquired over 2-7 cardiac cycles and stitched together to create a full volume display. Analysis often requires detailed post-processing. This method overcomes the problem of temporal and spatial resolution and can be used to assess a larger structure (or the entire heart) but has the disadvantage of stitching artefact (due to motion, breathing or improper ECG gating). Artifact-free acquisition in this manner requires a stable, regular cardiac rhythm and patient should be standstill and holding breath.

POST-PROCESSING- Live 3D imaging can be analysed with minimal post-processing whereas multi-beat acquisition requires detailed post-processing.

- **Volume rendering-** As soon as the image is acquired, the intracardiac structures are reconstructed within the computer memory by a process called **volume rendering**.



- **Cropping-** The region of interest is not easily seen in volume-rendered image. This is analogous to a surgeon looking at the heart from outside and not being able to visualise the intracardiac structures without removing the walls. By electronically segmenting and sectioning the dataset, either automatically using pre-sets or manually using a crop box/crop plane, the region of interest can be identified. This process is called cropping and is unique to 3D echo. The processed image can then be displayed from any anatomical plane or rotated along the centre point to view from different angles.



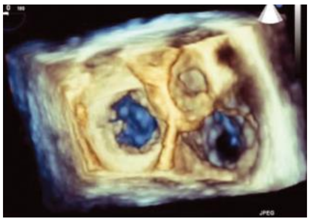
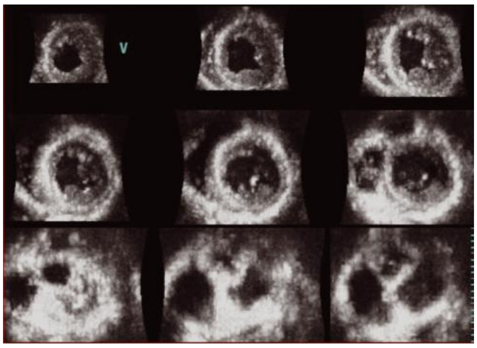
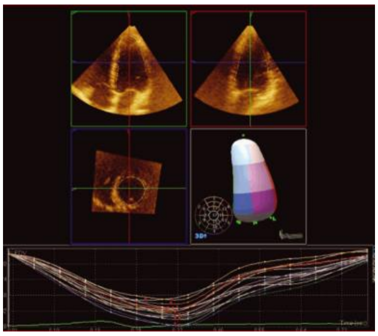


IMAGE DISPLAY- once a dataset is acquired and processed, the images can be displayed in three different formats:

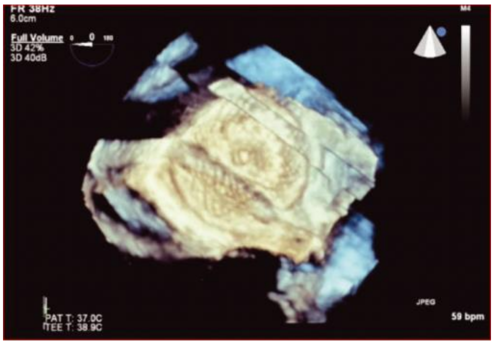
1. **2D tomographic slices:** the 3D full volume dataset can be sliced or cropped to obtain multiple 2D views, using either pre-set buttons or an operator-selected arbitrary plane. The advantage of this mode is the simultaneous display of 2D images in multiple planes from the same dataset, permitting better evaluation of structure and function. A typical example is the display of multiple short axis views of the left ventricle obtained from parallel tomographic slices during the same cardiac cycle, making the assessment of regional and global function more accurate.



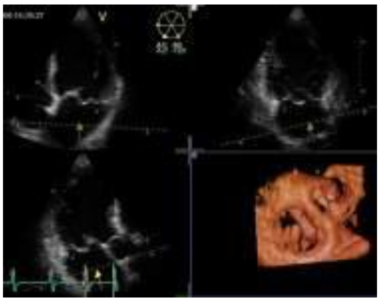
2. **Volume rendering-** is the commonest method of display. This technique uses multiple algorithms to display a 3D image on a 2D screen. This can be used for images obtained both from live 3D and from multi-beat imaging. The images can be cropped to view a specific structure of interest and can also be rotated to be viewed from different orientations. They are most useful for evaluating valve pathology and congenital heart disease.
3. **Surface rendering-** is a technique that allows a structure or organ to be visualised in a solid appearance. To use this technique, the acquired image is opened in a specific software package and the surface of the structure tracked either manually or by using a semi-automatic border detection algorithm. This method of display is commonly used to assess ventricular volumes and function. For the analysis of the left ventricle, the user identifies certain landmarks (such as the medial and lateral mitral annulus and the apex). The software then automatically tracks the endocardium using these landmarks to create a "cast" of the ventricle, producing a time-volume curve from which global and regional function can be assessed



3D ECHO ARTEFACTS- 3D echo is subject to the usual artefacts of 2D imaging, such as side lobe and attenuation artefacts, but two types of artefact are specific to this technique and are commonly encountered in practice:



Stitching artefact- is an improper stitching of the subvolumes acquired from each cardiac cycle during multi-beat image acquisition, due to improper ECG gating, or motion related to respiration or transducer movement. This is common in patients with an irregular heart rhythm or on mechanical ventilators. In patients with regular heart rhythm, this can be minimised by appropriate ECG triggering and a combination of breath holding and a steady transducer position. In patients with irregular heart rhythm, it remains a challenge, and in these situations maximum information should be obtained using real-time imaging.



Drop-out artefacts- appear as “false holes” on thin structures due to the poor echo signal intensity as a result of low gain settings. Avoidance of drop-out artefacts requires appropriate gain settings, especially time-gain compensation (which cannot be recovered during post-processing). Interpretation of a drop-out artefact requires extensive experience and additional information from 2D imaging.