Basic 3D TEE Examination and Measurements

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Acquisition and Display

Current ultrasound transducer technology enables 3D imaging by incorporating 2500 elements in multiple rows and columns of crystals to create a miniaturized matrix array at the tip of a TEE probe which is not much larger than the tip of a standard multiplane probe. Consequently, a matrix transducer enables the acquisition of a real-time, 3D TEE imaging with live, fully sampled scanning in both elevational and azimuthal planes to create a pyramidal volume of ultrasound data. Several imaging modes, unique to the matrix array can be used to permit optimal, acquisition:

Simultaneous Bi-plane ("X-Plane") Mode: Simultaneous bi-plane imaging is unique to the matrix array and permits the use of a dual screen to display a 2D TEE reference image, while simultaneous displaying a second 2D TEE image along an orthogonal plane.

Live Real-Time 3-D Mode - Narrow Sector: Live 3-D using the matrix array permits a real-time display of a relatively narrow, pyramidal volume. While the size of the sector is usually insufficient to visualize the entire LV or a mitral apparatus in any one imaging plane, the superior spatial and temporal resolution permits accurate diagnoses of complex pathology, while preserving optimal frame rates.

Focused Wide Sector – "ZOOM": The "ZOOM" mode permits a focused, wide sector view, after initially identifying a region of interest (ROI). Excessively enlarging the ROI further will result in a further detrimental decrease the frame rate. Subsequent engagement of the ZOOM mode displays the identified ROI in real time as a "magnified", wide sector pyramidal volume with dimensions that are dependent upon the size of the ROI and line density.

Full Volume – "Hybrid Reconstruction": While full volumes using a matrix array can be obtained with single beat construction at the expense of optimal spatial resolution, the classic full volume modality with or without simultaneous color flow Doppler, is essentially a hybrid reconstruction technique that incorporates several individual pyramidal volume slabs gated to the EKG. The resulting scanned data set is a three-dimensional composite pyramidal volume, which can exceed 90^0 x 90^0. Thus the full volume technique cannot be considered a true, live or real-time technique due to the obligatory time requirement, albeit very brief (5-10 seconds) to create the composite volume. Nonetheless, the full volume modality is ideal for imaging by providing the largest sector with the most optimal spatial resolution to permit a detailed diagnosis of complex pathology and temporal resolution (> 30 Hz) when higher frame rates are desirable for example, when diagnosing mechanisms of abnormal mitral leaflet motion.

Any 3D pyramidal volume can be rotated to optimize the display, and cropped to remove tissue planes in order identify components of important intracardiac structures within the volume. Optimal acquisition and display of 3D echocardiography data sets decreases the reliance on scanning and the limitations associated with geometric assumptions, which remain significant challenges during 2D TEE echocardiography.

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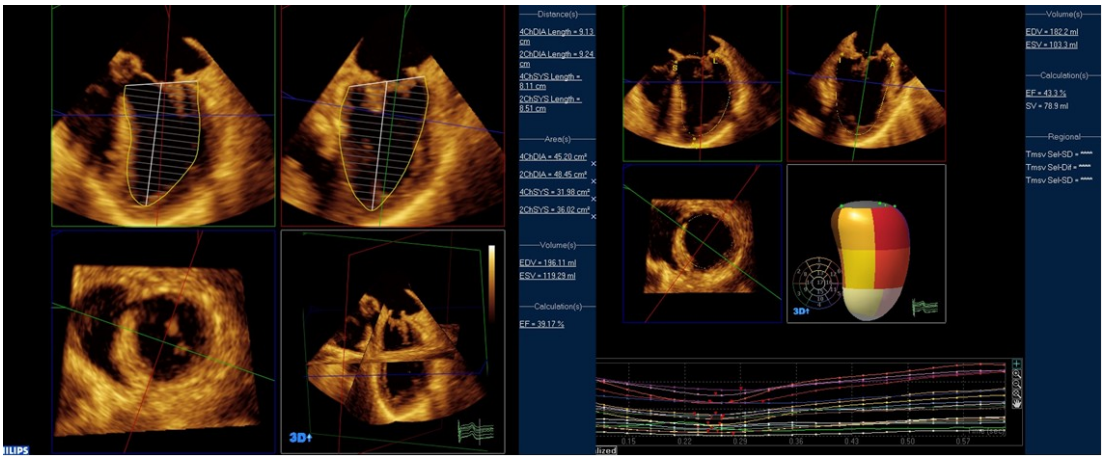
Preliminary Survey :

Although limited in scope, a preliminary survey can be performed by obtaining an initial Live 3-D and subsequent Full Volume view from the ME-5C view to determine the general overall function of the LV and RV and all four heart valves, and to diagnose any major structural valve abnormalities. Basic measurements including length and area can be obtained directly on the 3D volume data set, however this "plate glass" technique may not be accurate. Currently available commercial software from at least two vendors (Philips Healthcare, Inc; Tomtec Imaging Systems GmbH), permit the use of cropping and

multiplanar formatting techniques to acquire accurate 2-D cross-sectional x, y and orthogonal planes using off-line analysis hardware for the accurate measurements of relevant cardiac structures.

Left and Right Ventricle:

In addition to the Full Volume – Hybrid Reconstructed view from the mid-esophageal 5C view to determine the general overall function of the LV and RV, a Live 3-D transgastric midpapillary short axis (SAX) and 2C views may provide additional perspectives. Basic measurements include ventricular diameters, areas and volumes. Basic quantitative packages analysis software also permits semi-automated global and regional measures of LV and RV function.



Heart Valves :

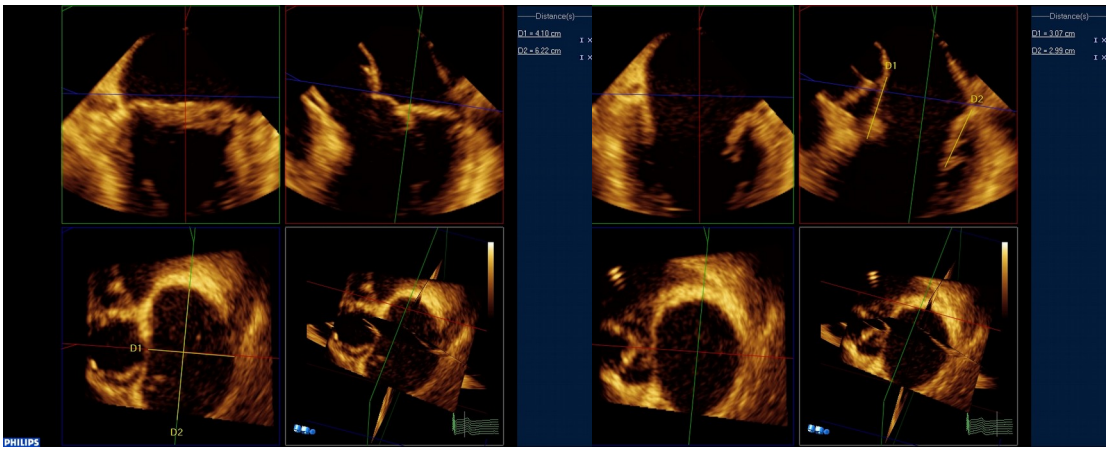
Mitral Valve: The mitral apparatus can be surveyed with an initial Live 3-D ME-5C view to determine the presence of any major structural valve abnormalities. Capturing the mitral apparatus in the ZOOM mode from a ME - 5C view, permits live 3-D echocardiographic imaging with a wide enough sector size to display a pyramidal volume that includes the annulus to papillary muscles. However, the acquisition of a Full Volume of the mitral apparatus with and without color flow Doppler using the highest line density and maxim number of individual gated component slabs should always be attempted when ECG gating and the brief acquisition time are permissible, in order to obtain the most optimal spatial and temporal resolution. The pyramidal volume should first be rotated to view the MV from

the LA perspective – the “cardiac surgeon’s view” and then rotated backward so that the mitral leaflet and subvalvular apparatus can be viewed from the LV perspective.

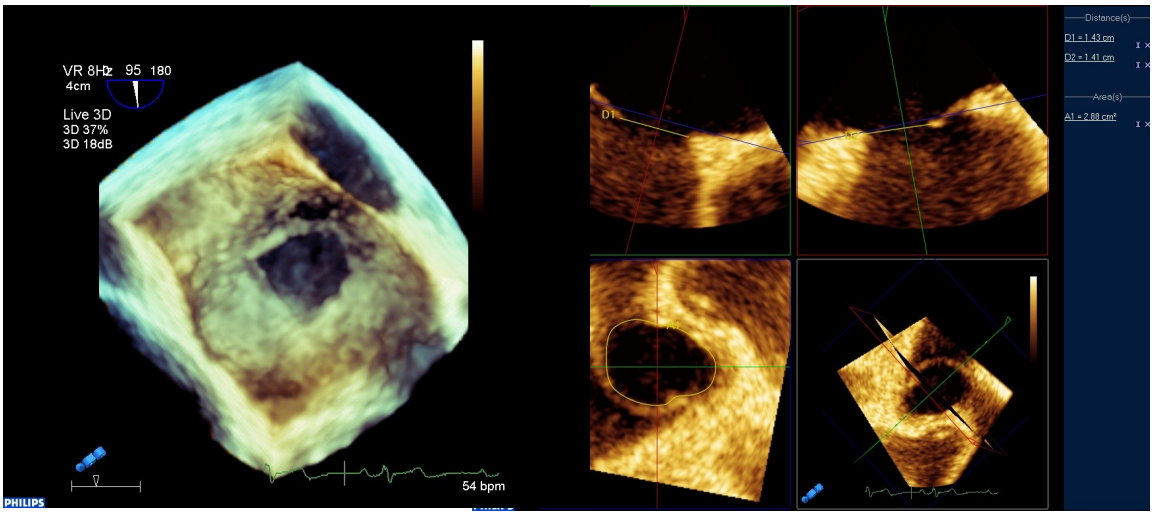
Aortic Valve: The AV can be surveyed with an initial Live 3-D ME-5C view to determine the presence of any major structural valve abnormalities. A more comprehensive examination requires a Live-3D view using a ME-AV SAX image plane. A subsequent Live Wide Sector ZOOM or Full Volume is acquired next, to enable rotation of the pyramidal volume and visualization of the AV apparatus from both the aortic root and left ventricular outflow tract perspectives. Color flow Doppler may be added to the Full Volume to evaluate the regurgitant orifice areas in patients with aortic insufficiency.

Tricuspid Valve: The TV can be surveyed with an initial Live 3-D ME-5C view to determine the presence of any major structural valve abnormalities. A more comprehensive examination requires a Live Wide Sector ZOOM or Full Volume is acquired next from the ME-4C view, to enable rotation of the pyramidal volume and visualization of the TV apparatus from both the right atrial (RA) and RV perspectives. Color flow Doppler may be added to the Full Volume to evaluate effective and regurgitant orifice areas in patients with tricuspid stenosis and insufficiency respectively.

Basic measurements of the valves include annular diameters, leaflet scallop heights, coaptation lengths, and relevant angles using the x, y and z cropping tools and multiplanar formatting techniques.



Left & Right Atrium: The LA atrial appendage (LAA) can be best surveyed with an initial bi-plane ("X-plane) examination, followed by a Live 3-D ME-5C view turned to the patient's left to determine the presence of any major abnormalities. A more comprehensive examination requires a Live Wide Sector ZOOM or Full Volume, to enable rotation and cropping of the pyramidal volume and visualization of the LAA en-face along with the Ligament of Marshall and the left pulmonary veins. The IAS is best approached by obtaining Live 3-D followed by Live Wide Sector ZOOM or Full Volumes from the midesophageal bicaval view and rotating and cropping to visualize the fossa ovalis and any local defects from the LA and right atrial (RA) perspectives. A 3-D TEE exam of the RA is best approached by obtaining a Live 3-D followed by Live Wide Sector ZOOM or Full Volumes from the midesophageal bicaval view and rotating and cropping to visualize the superior vena cava, inferior vena cava and coronary sinus. Basic measurements of the atria and associated structures include LA and LAA diameters and the dimensions of any atrial septal defects using the x,y and z cropping tools and multiplanar formatting techniques.



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