3D-TEE Workshop: LV Quantification

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Objectives and Goals:
At the conclusion of this workshop, the participant should be able to:

1. Describe the steps necessary to use 3D data to quantify the left ventricular function

The perioperative assessment of left ventricular (LV) volumes, ejection fraction (EF), and regional wall motion is important to quantify LV function. Although LV function is routinely assessed using two-dimensional transesophageal echocardiography (2D-TEE), the literature suggests limitations due to image quality, foreshortening, and geometric assumptions regarding volume calculation. The introduction of real-time three-dimensional TEE (RT-3D-TEE) along with semi-automated endocardial border detection capability and associated software presents a promising technology to obtain fast and objective measurements for global LV function and volumes based on a 3D data set.

To date, the only clinical available RT-3D-TEE transducer is the X7-2t TEE (Philips, Andover, MA) transducer, which combines xMATRIX technology and PureWave crystal technology. This technology allows the acquisition of large 3D volume data sets using the 3D Full Volume mode. A typical pyramidal data set will span approximately 65° x 60° up to 100° x 100° and includes a larger cardiac volume. This wide angle data set is composed by merging four to seven narrower RT-3D pyramidal wedges or subvolumes obtained over four to seven heartbeats. While the acquisition of 3D full volumes depends on an undisturbed electrocardiogram, artifacts can be minimized in the anesthetized patient by holding ventilation and acquiring full volume loops while electrocautery is not used. With the goal to minimize artifacts, it is recommended to acquire full volume loops at the beginning of the comprehensive TEE-exam in the operating room before the start of surgery. Left ventricular full volume loops are routinely acquired based on the 2D midesophageal four-chamber view. Once the image is optimized, the full volume mode is activated and a biplane image with the four-chamber view and the correspondent orthogonal plane is displayed on the screen. Depending on the size of the region of interest, one can select either high, medium, or low line density for acquisition which will affect the frame rate and dimensions of the pyramidal volume from narrow (high density) to wide (low density). Following acquisition of a full volume loop, the 3D-volume is first displayed as auto crop showing only 50% of the volume mirroring the four-chamber view. By resetting the crop plane, the whole pyramidal data set is displayed. The full volume can be further processed offline by rotating and cropping to visualize specific structures inside the pyramid. Cropping can be performed by either using one of six available cropping planes selected from a 3D cropping box or by using a freely adjustable plane.
Any volumetric quantification of the LV based on acquired full volume loops is made possible using available built-in software (QLAB, Philips Medical Systems, Andover, MA version 6.0).

The 3DQ Advanced (3DQA) provides data for both global left ventricular function as well as regional wall motion abnormalities and resynchronization therapies (e.g., time to minimal systolic volume). The system relies on semi-automatic endocardial border detection and border tracking algorithms, which can be edited manually. The semi-automated quantification requires a manually performed definition of the septal, lateral, anterior, inferior, and apical endocardial border of the endsystolic and the enddiastolic frames, followed by an automatic border-tracking algorithm. The system will then calculate endsystolic as well as the enddiastolic volumes by summation of the voxels (volume elements) enclosed by the endocardial borders. Thereafter, global stroke volume and EF are derived. The obtained Shell View is subdivided into 17 regions, which are analyzed separately by performing the “segment analysis,” and 17 segmental time-volume waveforms are displayed simultaneously offering the possibility for objective wall motion comparisons. Activation of “show reference mesh” displays the enddiastolic surface mesh as a diastolic reference point. Other viewing modes include the “iSlice” view that displays nine simultaneously moving short axis views of the LV and allows verifying appropriate endocardial border detection as well as the “Slice Plane” view which shows a moving LV surface mesh within three orthogonal axis planes.

The accuracy of 3D quantification of LV function and volumes depends on the number of active elements in the transducer, the spatial resolution of the image and the experience of the observer. Compared with 2D echocardiographic approaches, 3D echocardiography has been shown to represent and quantify LV volumes and function more accurately.\(^1_{3,5}\) This does not come as a surprise as the 3D quantitative approach incorporates more LV endocardial border surface and requires little or no assumptions in regards to LV shape compared to 2D techniques. A complete analysis of the LV 3D data set will also allow for the interpretation of as many as 17 regional waveforms representing all LV segments. This feature allows for objective wall motion comparisons among LV segments. Lastly, 3DQ allows simple quantitative assessment of any 3D data set (e.g., area, distance). This feature may be used to assess the exact thickness of the LV septum in cases of hypertrophic obstructive cardiomyopathy (HOCM).

Despite significant advances in regards to the LV quantification with 3D echocardiography, there remain a number of important limitations. These include, but are not limited to: 1) the often poor image quality that is due to lower line density within the 3D volume compared to 2D data; 2) insufficient endocardial border detection within the 3D volume; 3) stitch artifacts that may be introduced by arrhythmia, respiration, or electrocautery as multiple subvolumes are merged to obtain the full volume data set; 4) time required to perform the acquisition and analysis of a LV 3D data set.

References:

coronary artery bypass graft surgery is associated with long-term major adverse cardiac events. Anesthesiology 2007; 107: 739-45