3D Echocardiography of the LV and RV

G. Burkhard Mackensen, MD, PhD, FASE
Associate Professor
Division of Cardiothoracic Anesthesiology and Critical Care Medicine
Department of Anesthesiology
Duke University Medical Center
Durham, NC

Objectives and Goals:
At the conclusion of this lecture, the participant should be able to:
1. Describe the views necessary to evaluate the LV and RV using 3D echocardiography
2. Assess LV and RV pathology using 3D echocardiography

Left Ventricle

The evaluation of the global and regional left ventricular (LV) function is an essential part of a routine perioperative TEE-examination. To date, the assessment of the LV ejection fraction (EF) is mainly performed by “eye-ballling”, which relies on the echocardiographer’s experience and ability to visually integrate spatial information. Further limitations of 2D-TEE assessment of the LV EF are attributed to the use of foreshortened views of the LV and the reliance on geometric assumptions to calculate volumetric parameters. In addition, chamber quantification based on 2D data remains time-consuming. The addition of a third dimension is supposed to overcome some of these limitations especially in patients with cardiomyopathies or wall motion abnormalities where the geometric assumptions may lead to incorrect estimations of LV function. In this context, 3D echocardiography along with build-in quantification software that is based on semi-automated endocardial border detection allows to obtain fast and accurate measurements of global and regional LV function. Studies comparing MRI with 3D echo-cardiography for the assessment of LV mass and function show very good correlation and agreement that is superior to 2D echocardiography. This also holds true for RT-3D-TTE assessment of patients with cardiomyopathies or regional wall motion abnormalities secondary to myocardial infarction with abnormal LV geometry. A recent study suggest that LV function assessment based on 3D-TEE data offers a more reliable perioperative quantification, especially for less experienced users. However, further research comparing 3D-TEE to a gold standard such as MRI is required to assess if 3D-TEE is superior to 2D-TEE in assessing the LV function.

The best mode to assess global and regional LV function by 3D-TEE is the full volume mode, which is acquired based on the midesophageal four-chamber view. Using built-in software, the 3D Quantification Advanced (3DQAV) program (Philips Medical Systems, Andover, MA), data for both global LV function as well as regional wall motion abnormalities are obtained in a semi-automatic fashion (see Figure 1). The system relies on automatic endocardial border detection and border tracking algorithms, which can be edited manually. Global left ventricular function is assessed by analysis of endsystolic and enddiastolic volumes, stroke volumes, and EF. Upon completion of the analysis, as many as 17 regional waveforms are displayed simultaneously thus enabling objective wall motion comparisons. This requires a manually performed definition of the septal, lateral, anterior, inferior and apical endocardial border of the LV in 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 enclosed by the endocardial borders. Thereafter, global stroke volume and EF are derived. The obtained Shell View (Figure 1A and B) 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 four and up to 16 simultaneously moving short axis views of the LV and allows proof of appropriate endocardial border detection as well as the “Slice Plane” view which shows a moving LV surface mesh within 3 orthogonal axis planes (Figure 1 C).

Figure 1:

The figure above shows a 3D-TEE full volume of the entire heart displayed in three multiplanar reconstruction planes (MPRs, green = four-chamber view, red = two-chamber view and blue = mid-papillary short axis view). Manual definition of the septal, lateral, anterior, inferior and apical endocardial border of the LV in endsystole and enddiastole, followed by an automatic border-tracking algorithm and segmental analysis will display the LV shell in 17 segments along with the corresponding segmental time-volume waveforms (A). The shell view (B) with an enddiastolic reference mesh slice plane view (C) and are alternative options for display of the 3D LV data. Panel D demonstrates the new parametric imaging display that provides easy-to-use color-coded representations of regional left-ventricular (LV) segmental timing and excursion parameters displayed on the standard AHA/ASE 17-segment bull’s eye display. The parametric display may be used in assisting to visualize LV regional function.
Interest in the perioperative assessment of RV function and volume is growing significantly because of its clinical and prognostic significance. Due to its complex geometry, the evaluation of the global and regional right ventricular (RV) function is even more challenging than analysis of the LV. Various echocardiographic indices are utilized to assess RV function but measuring RV volumes and function by 2D echocardiography is inadequate as this approach relies on visual estimation and geometric assumptions. Real-time 3D-TTE imaging overcomes the geometric limitations of 2D techniques, potentially allowing volume assessment without the use of any geometrical assumption. Therefore, 3D echocardiography is thought to be superior and has been shown to improve the accuracy and reliability of RV quantification in adults and children when compared to 2D. New free-standing software (TomTec, Munich, Germany) dedicated to RV quantification appears to facilitate the analysis of RV volume and function and has been validated in comparison with cardiac magnetic resonance (CMR) and radionuclide ventriculography as gold standards (Figure 2). Similar to the assessment of LV volumes and despite the excellent correlation, 3D echocardiography has been demonstrated to slightly underestimate CMR RV volumes. Recent work by Grewal et al. demonstrates the feasibility of quantifying RV ejection fraction and volumes even in a complex patient population such as adult patients with tetralogy of Fallot (TOF) and/or severe pulmonary regurgitation.

References:

1. Lang, R.M., et al. Recommendations for chamber quantification: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr 18, 1440-1463 (2005).