3D TEE for the Left Ventricle

Kent H. Rehfeldt, MD, FASE

Three-dimensional imaging capabilities are now commonplace with modern TEE platforms. There has been a corresponding increase in the number of publications documenting various clinical applications of 3D TEE imaging both in and out of the operating and procedural suites. Many of these applications relate to the characterization of valvular pathology as well as the surgical and catheter-based treatment of valvular disease. However, the use of 3D TEE to more precisely assess the morphology and function of the left ventricle (LV) has also increased as clinicians recognize the incremental value this imaging technology can provide. Specific uses of 3D TEE imaging relative to the LV include, 1) quantification of the LV volumes, 2) determination of LV systolic function, particularly by determining ejection fraction (EF), 3) identifying regional LV segmental dyssynchrony, 4) guiding interventions that require localization of specific LV landmarks, such as the apex.

The use of 3D TEE imaging to determine LV volumes has advantages over 2D techniques. Notably, 3D techniques, through the use of orthogonal imaging planes and off-line analysis, allow users to better identify the true LV apex and avoid foreshortening. Also, 3D techniques that utilize automated border detection and tracking reduce the geometric assumptions that are often needed to generate volume calculations from linear, 2D images. LV volumes can be derived from 3D datasets in a couple ways. First, the echocardiographer can position orthogonal imaging planes more precisely within a 3D dataset in order to facilitate volume measurement using a biplane technique (Fig 1). This reduces foreshortening (Fig 2) that frequently accompanies 2D mid-esophageal images of the LV. The result is an increase in measured volume.

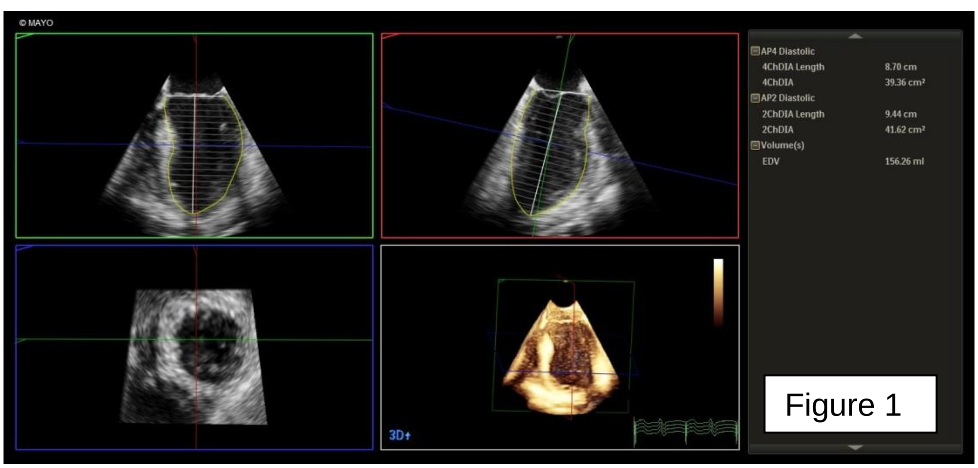


Figure 1

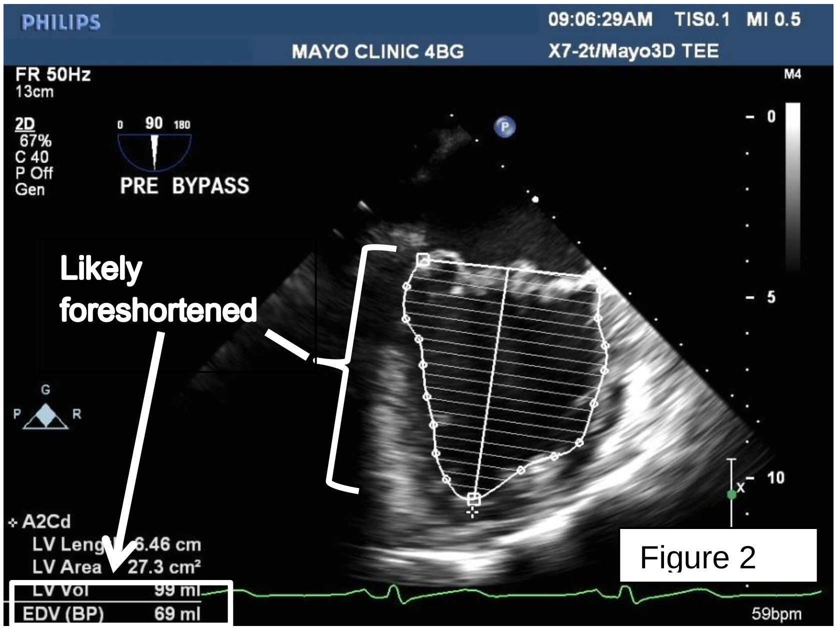


Figure 2

Second, by using automated border tracking, onboard 3D software packages can be used to generate a surface rendered cast of the LV (Fig 3). Compared with the biplane method, direct endocardial border tracking decreases the geometric assumptions used to generate volumes.

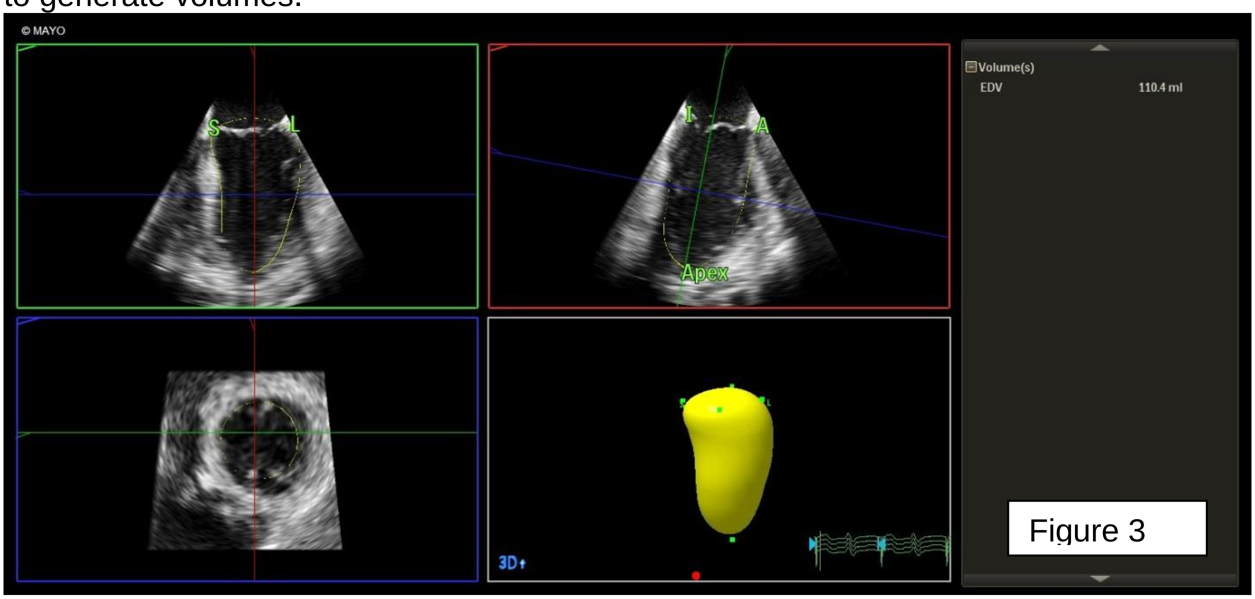


Figure 3

Studies, many of which used TTE rather than TEE, have measured larger volumes with 3D compared with 2D imaging. Moreover, the 3D-derived volumes have tended to correlate better the cardiac MR, considered the gold standard for LV volume determination. One often-cited study found larger LV volumes using 3D TEE compared with 2D TEE (Meris. Anesth Analg 2014;118:711). However this has not been a universal finding. Cowie et al found similar LV volumes using 2D and 3D TEE (BJA 2013;110:201).

Of note, the acquisition of 3D datasets does not typically require substantially more time than the acquisition of 2D datasets for biplane analysis. There is, however, a greater duration of time required to perform measurements from the 3D dataset (117 seconds longer, according to Meris, et al). Also, automated border tracking is not always ideal and several authors have noted the frequent need to manually adjust tracking. Indeed Cowie reported that 50% of 3D datasets required manual adjustment of border tracking.

The determination of EF by 3D TEE techniques often yields similar results when compared with 2D methods. This likely results because 3D-derived volumes are proportionally greater in both systole and diastole. Multiple studies using TEE have shown similar EF values when using 2D and 3D in the same patient. A clinical example is shown in Figure 4.

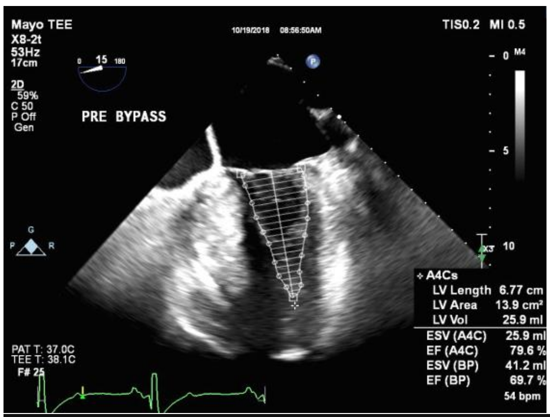
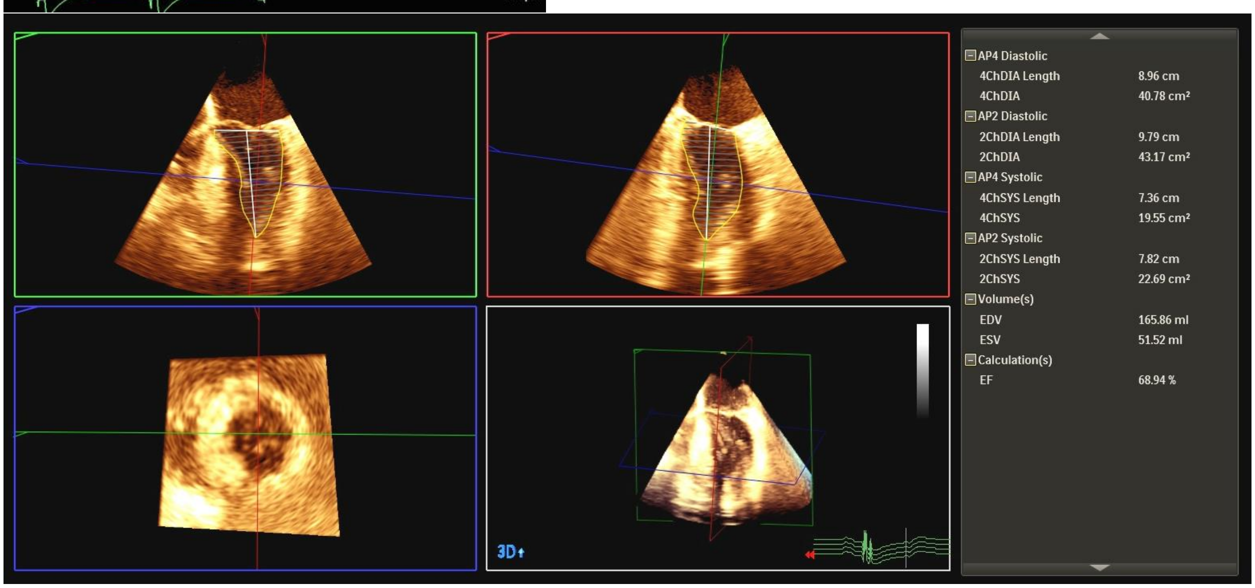


Figure 4. A patient with hypertrophic cardiomyopathy. The 2D biplane LV EF is 70% while the 3D guided biplane LV EF is 69%. Of note, the ESV by 2D is 41 cc while the ESV by 3D is 51 cc.



By using segmental tracking, 3D TEE can provide information regarding the timing and excursion of LV myocardium. This information can be displayed in several ways. A graph of the individual myocardial segments (different colored lines for each segment) can be created showing time on the x-axis and percentage of end diastolic volume on the y-axis (Figure 5). A small red triangle on each line represents the time to minimum systolic volume. In Figure 5A, this patient with dilated cardiomyopathy has a calculated ejection fraction of 11%. Note the small change in systolic volume (lines remain nearly straight). Also there is a wide dispersion of times to minimum volume indicating segmental dyssynchrony. In Figure 5B, the calculated ejection fraction is 68%. There is a noticeable and synchronized “dip” in the lines representing each segment indicating both a reduction in systolic volume and uniformed timing in this event.

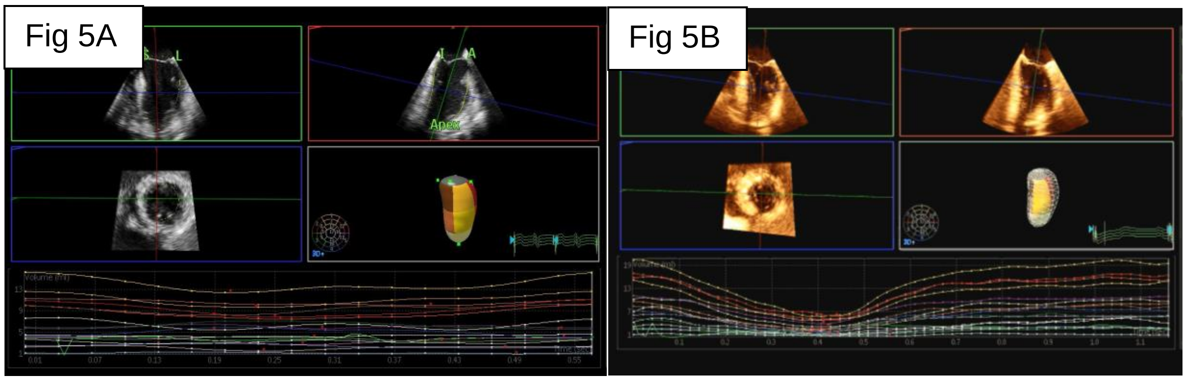


Fig 5A
Fig 5B

Three-dimensional TEE is also quite useful in guiding surgical and procedural interventions on the LV. As an example, the position of an LVAD inflow cannula, as well as its orientation can be reliably determined with 3D imaging (Fig 6) or simultaneous orthogonal plane imaging (a technique that relies on the 3D matrix array probe). This can be quite helpful during minimally invasive procedures, including minimally invasive LVAD placement, where accurate identification of the LV apex is critical.

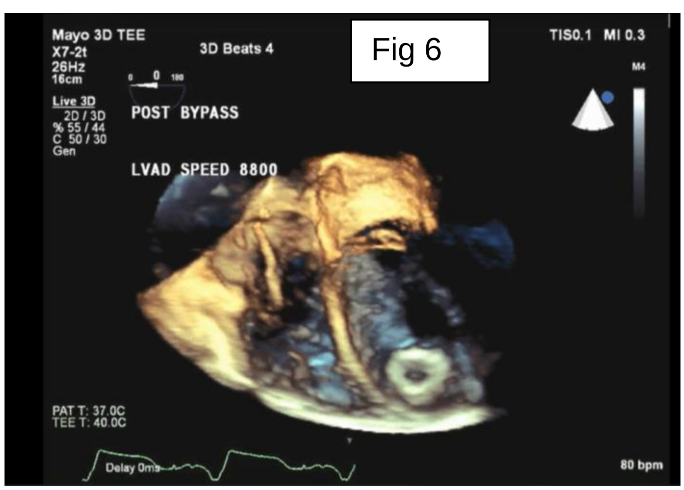


Fig 6