4D Ultrasound Quantification of LV Function and Valvular Pathology

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Abstract

Real-Time 3D Echocardiography is currently limited by factors including accessibility of analysis software to quickly and accurately determine ventricular volumes for assessment of myocardial function. The goal of this study was to examine the capabilities of a 3D system to acquire full 4D echocardiographic datasets and evaluate the ability to obtain both LV function and valvular pathology. 3D exams were performed on 52 patients. 3D apical view datasets were analyzed using a GE Medical Systems workstation with a LV Function plug-in from Tomtec Imaging Systems. 3D data sets were analyzed by 2 independent observers. Interobserver variability varied with image quality, but was approximately 8% across all but 4 poor quality exams. Processing time also improved with better image quality, but averaged about 4 minutes. Tools for providing clinical data for assessment of LV function and valvular pathology are improving.

1. Introduction

There are several convergent trends in medicine and technology that can be integrated to improve health care. Among these convergent trends are the following: (1) ultrasound has emerged as the most commonly applied diagnostic imaging test; (2) miniaturization has led to high quality, light weight ultrasound imaging equipment; (3) internationally standards for digital file storage in ultrasonography; (4) growth of the internet and other networked applications has allowed remote telemedicine using ultrasound; (5) explosion in wireless telemetry and bandwidth should allow telemedicine applications in remote areas underserved by hardwired networks; (6) ultrasound is now routinely used to guide therapeutic interventions, with further automation possible for remote guidance; (7) as ultrasound technology advances, real-time three-dimensional ultrasonography will emerge as a standard of acquisition which should simplify the problem of poorly trained individuals acquiring images of diagnostic quality.

While the ability to obtain 4D echocardiographic data has been possible for some time,[1-3] advances in acquisition and post-processing continue to evolve and may lead to more routine utilization of this technology. Current tradeoffs in spatial and temporal resolution exist when compared to standard two-dimensional imaging; however advanced processing abilities with 4D datasets may have clinical benefit. The goal of this study was to examine the capabilities of a system to acquire full 4D echocardiographic datasets and evaluate the ability to obtain both LV function and valvular pathology using both grayscale and color Doppler echocardiography.

2. Methods

3D echocardiography is now available from several vendors. Acquisition of datasets is currently similar in that data from multiple cardiac beats are combined to collect a large, or full LV volume. Echocardiographic datasets from 52 consecutive subjects were acquired on the Vivid 7 echocardiograph (GE Medical Systems, Milwaukee, WI). Full left ventricular volume acquisitions were performed over 4 cardiac cycles and stored digitally in DICOM format with raw private elements containing the 3D raw data. Data sets were analyzed using EchoPac (GE Medical Systems) and a LV Function plug-in (Tomtec Imaging Systems, Unterschleissheim, Germany). 3D ultrasound data was acquired all patients during with a large range of clinical indications including dilated and hypertrophic cardiomyopathy, valvular disease, and postoperative evaluation. As well as presenting a large range of clinically significant abnormalities, the consecutive series collected also was mixed in terms of patient size, leading to a variety of technically difficult ultrasound exams. Despite these issues, only a small number of cases were excluded.

The datasets were retrieved from the DICOM image storage system (ProSolv, Problem Solving Concepts, IN) for analysis using EchoPac (Figure 1).

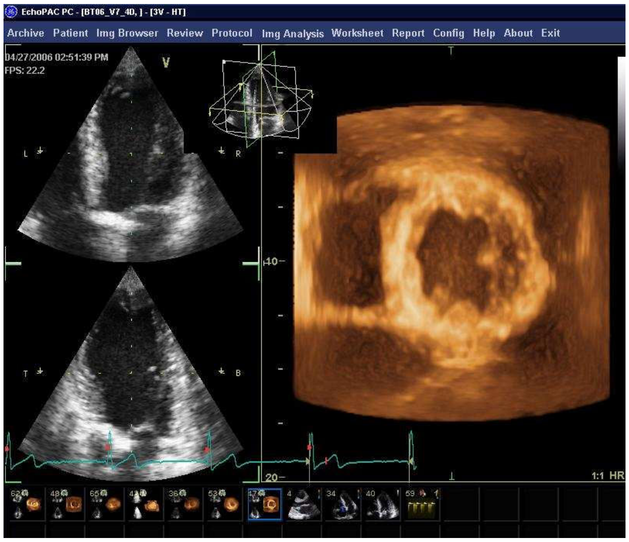

Figure 1: EchoPac display of 3D echocardiographic data. A volume rendered representation is shown on the right while cut-planes of 4 and 2-chamber views are displayed to the left.

Once a study was available in EchoPac, the 3D acquisition was selected and an option to launch the Tomtec plug-in was initiated. With data transferred to the plug-in, the raw 4D data files were analyzed thru a stepwise process to semi-automatically determine optimal geometry (multiplanar reconstruction to define LV long axis), perform segmentation (initialization using 4-chamber view contour), and quantitative assessment of 4D global and regional volumes.

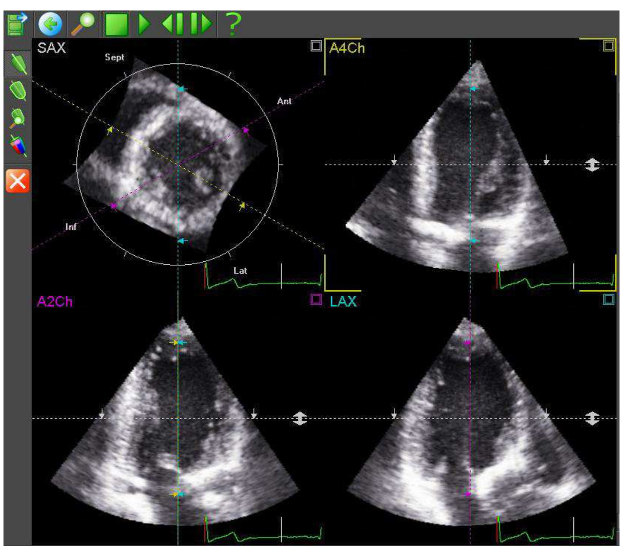

Figure 2: Tomtec 4D Volume plug-in activated through EchoPac provides LV short–axis orientation tool shown in upper left to adjust three ventricular planes.

The first step was to select and adjust the long axis of the ventricle using a wheel-like control or the wheel on a three-button mouse. A short-axis LV view (Figure 2) provided orientation markers to adjust simultaneous 2 and 4-chamber views of the LV.

Once the geometry of the LV long-axis is defined, the segmentation of the 3D dataset requires an initial contour made on the end systolic and end-diastolic frames of the extracted 4-chamber view as shown in Figure 3 from a small set of 6 initial points.

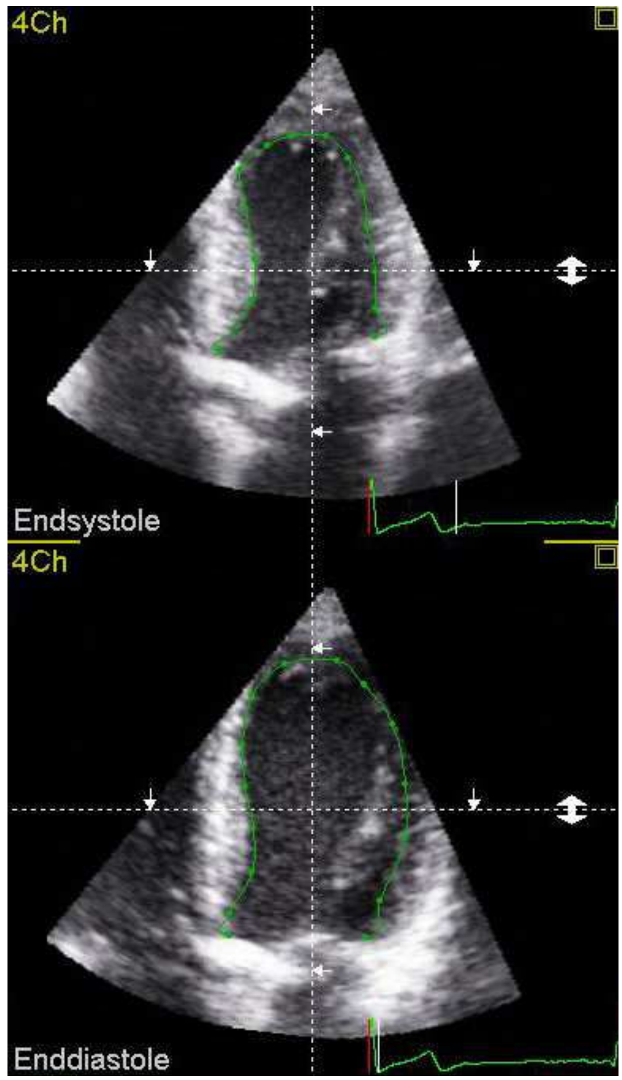

Figure 3: Tomtec 4D Volume plug-in determines LV contours and 3D LV geometry from a small number of data points placed on the 3 extracted planes.

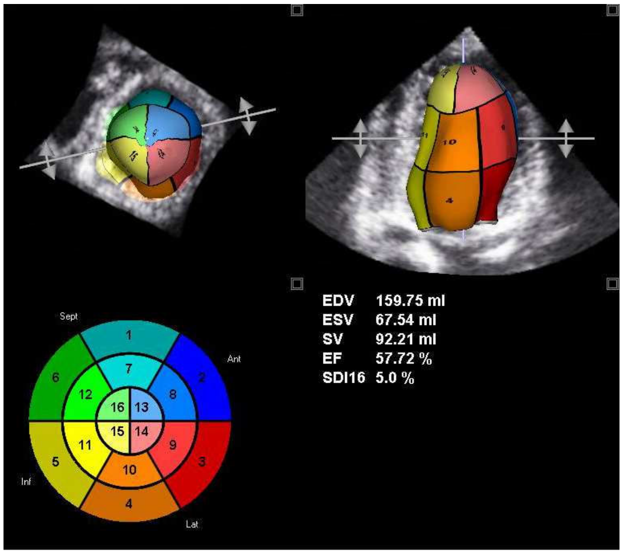

Figure 4: Tomtec 4D Volume Plug-in displays surface of LV boundary within the grayscale ultrasound data for confirmation of detected geometry. Global and segmental information is then displayed for review.

The algorithm calculates and displays automatic contours for the 2-chamber and long-axis views. Surface rendering and visualization of LV volume waveforms was performed during review and utilized to determine if corrections were required. Corrections are made using left and right mouse controls to adjust the contours by re-tracing and/or moving control points. The revision made on one tracing is then used to adjust the 3D surface.

When the detected boundary is approved, the tool provides both global and segmental information including EDV, ESV, SV, and EF.

3. Results

Acquisition of real-time 4D data was routinely possible with fair to good quality datasets. LV volume assessment is feasible in a timely fashion. Four patients (8%) were excluded due to inadequate image quality of 3DE. In the remaining 48 patients, measurement was done without any manual corrections in 6 patients, and with manual corrections in 42 patients. End-systolic and diastolic LV volumes were measured semi-automatically by two independent observers using Echopac and the Tomtec plugin for LV function assessment.

The mean analyzing time was 241±50 s. Good interobserver variability was obtained for LV end-diastolic volume (EDV), LV end-systolic volume (ESV) and EF (Table 1). When the image quality was excellent or good (n=16), the necessity of manual collections was decreased, resulting in the shorter analysis time (200±25 vs. 264±46 s $p<0.005$) and higher reproducibility than when the image quality was only fair (n=32) (Table 1).

Table 1: Interobserver Variability.

		Interobserver Variability	r
All Patients (n=48)	EDV	10.5 mL (7.5 %)	0.97
	ESV	5.6 mL (6.9 %)	0.98
	EF	7.5 %	0.80
Patients with good image quality (n=16)	EDV	6.4 mL (3.9 %)	0.99
	ESV	3.4 mL (3.5 %)	0.99
	EF	0.8 %	0.99
Patients with fair image quality (n=32)	EDV	12.6 mL (9.9 %)	0.96
	ESV	6.7 mL (9.1 %)	0.97
	EF	4.8 %	0.63

4. Discussion and conclusions

4D echocardiography using standard clinical hardware is available and improving along with post-processing capabilities that provide tools to derive clinical data for assessment of LV function and valvular pathology.

3DE combined with automated contour tracing method utilized in this study is easy, fast and feasible, resulting in reproducible 3D assessment of LV volumes and EF. This new method may contribute to the wide spread use of 3DE in the clinical setting. Further research is underway on the accuracy of measures provided by these new tools as compared to other volumetric techniques such as MRI.

Acknowledgements

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