3D Echocardiography in a Dynamic Heart Phantom: Challenging the Contour Finding Algorithm in an Abnormally Shaped Ventricle

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Background

Several methods are available to assess left ventricular (LV) volumes from a three-dimensional (3D) dataset, but these methods have not been compared in a heart phantom without the errors associated with limited image quality in humans. The currently established methods, in particular the semi-automatic contouring methods performed on long-axis planes, have all been reported to underestimate volume calculations in comparison with cardiac magnetic resonance imaging (MRI).

Purpose

To investigate the accuracy and reproducibility of LV volume measurements using a 3D method of discs (3D MOD) with manual tracing of multiple short axis areas similar to the MRI method. We tested this method in comparison with other 3D methods in a dynamic heart phantom with known volumes.

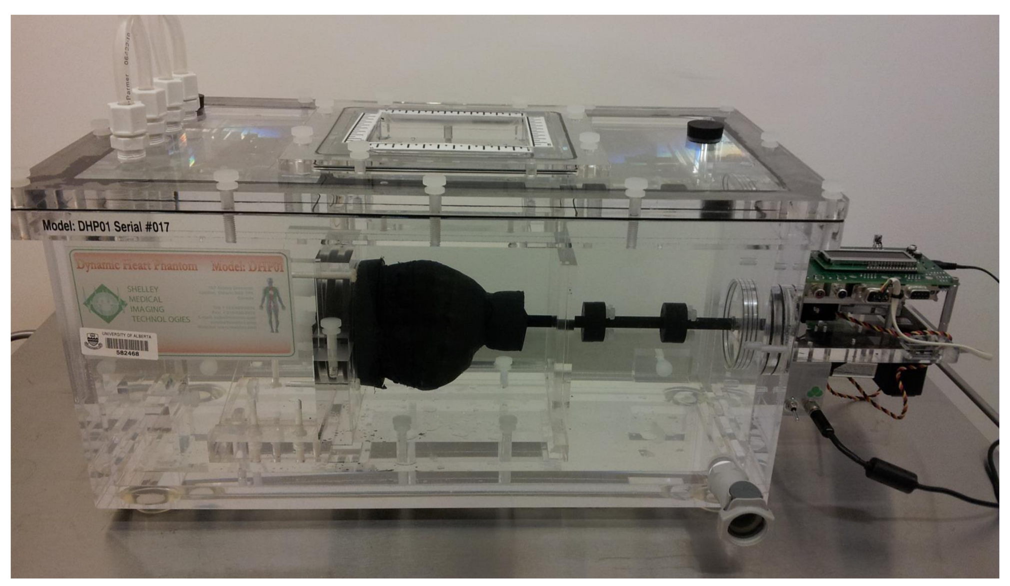

Figure 1. The Dynamic Heart Phantom containing a black anatomically accurate polyvinyl alcohol heart with a computerized hub programmed to mimic human contraction with compression and twisting movements of the heart.

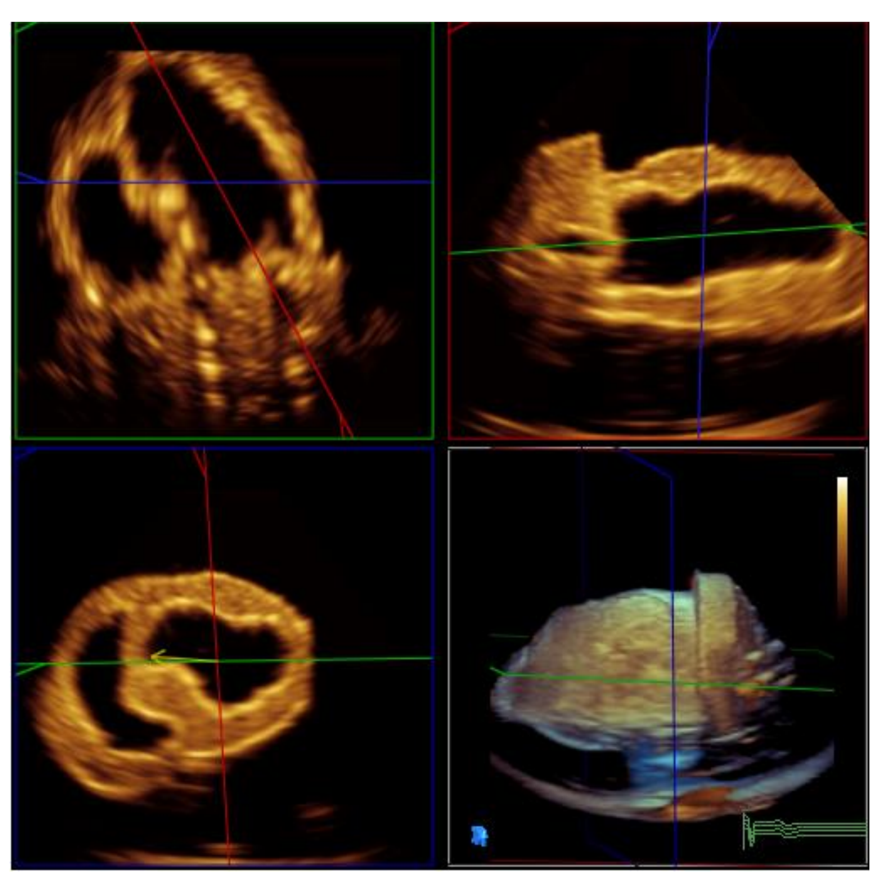

Figure 2. Quad screen displaying three reconstructed two-dimensional views from a 3D dataset, 4 chamber (top left), 2 chamber (top right) and short axis (bottom left), and a three-dimensional ultrasound image of the phantom heart.

Method

3D echo datasets were recorded in a dynamic heart phantom with an asymmetrical LV (apical aneurysm), using a commercially available scanner (IE33, Philips Inc.) and Q-lab software. Two independent readers measured LV volumes at multiple time points of the cardiac cycle using different methods of LV volume calculation (semi-automatic volume calculation – A1, with two manual correction methods – A2 and A3, Simpson's biplane – B, and 3D method of discs – C) against the true volumes of the phantom LV.

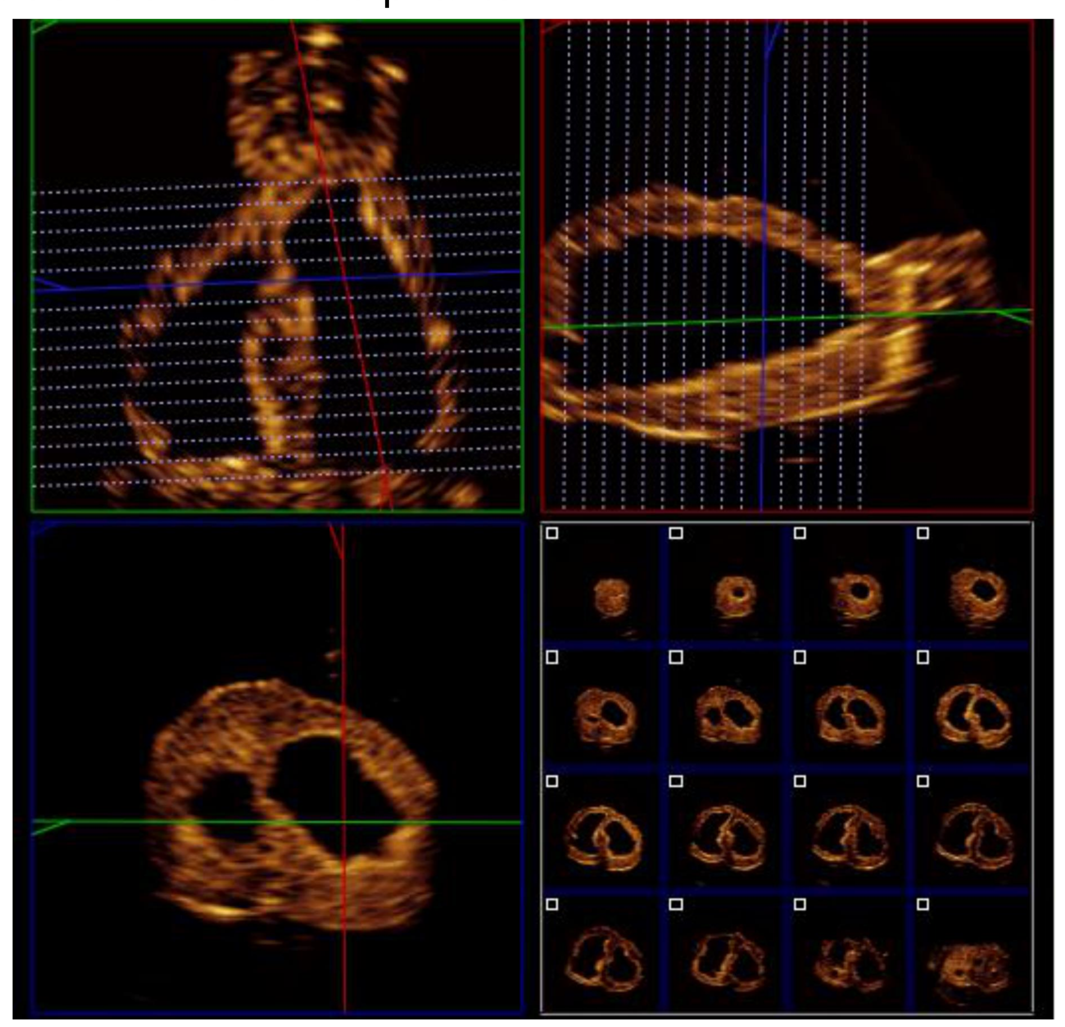

Figure 3. Quad screen view of the phantom heart with the Philips islice application selected, allowing for display of 16 short axis slices. The slice widths can be calculated by dividing the length of the ventricle by the number of slices. The two end slices void of volume to define the apical and basal borders..

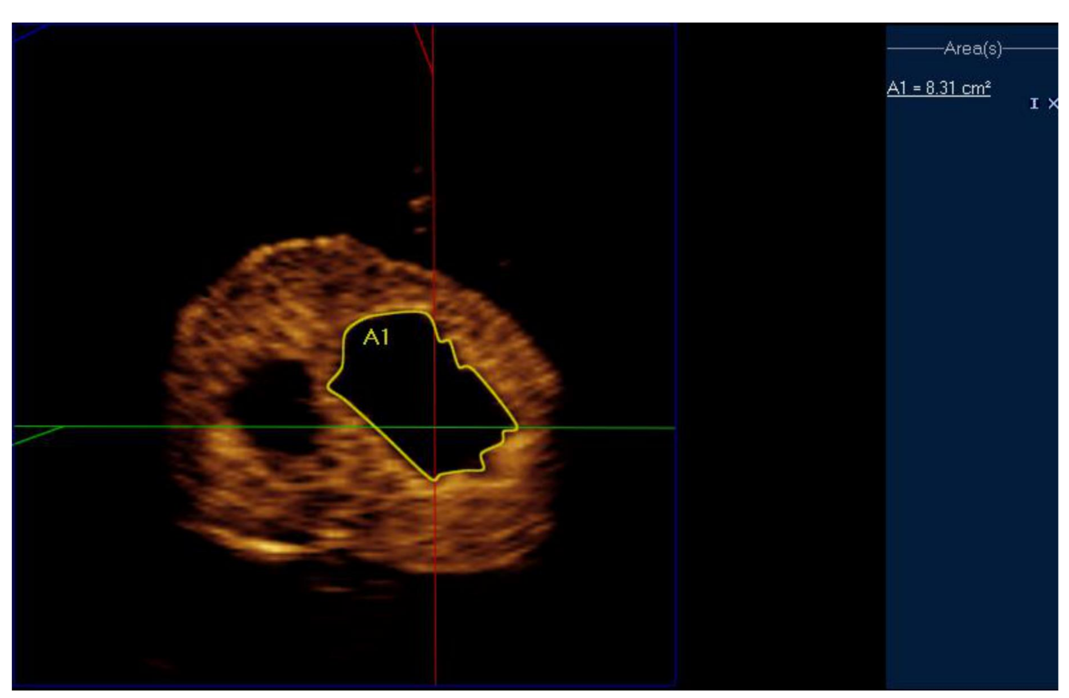

Figure 4. Zoomed in view of the 6th slice illustrating the area tracing option which allows for calculation of slice volume by multiplying against the width of the slice.

Results

Compared to the true volumes method A1 resulted in an average underestimation of 16.5% ± 7.0 with a good **interobserver agreement (bias = 4.4 mL; LOA = 3.35 to 5.4mL).** In methods A2 and A3 there was an average difference of 9.9% ± 7.3 and 9% ± 7.8 respectively; **interobserver variability worsened (A2 bias = 6mL, LOA = -2.3 to 14.4mL; A3 bias 3.4mL; LOA = -9.8 to 16.7mL).** Simpson's biplane had an average underestimation of 10.2% ± 8.0. 3D MOD was the most accurate technique with an average underestimation of 3.5% ± 2.4 and the best **interobserver variability (bias = 0.9mL; limits of agreement -2.3 to 4.1mL).**

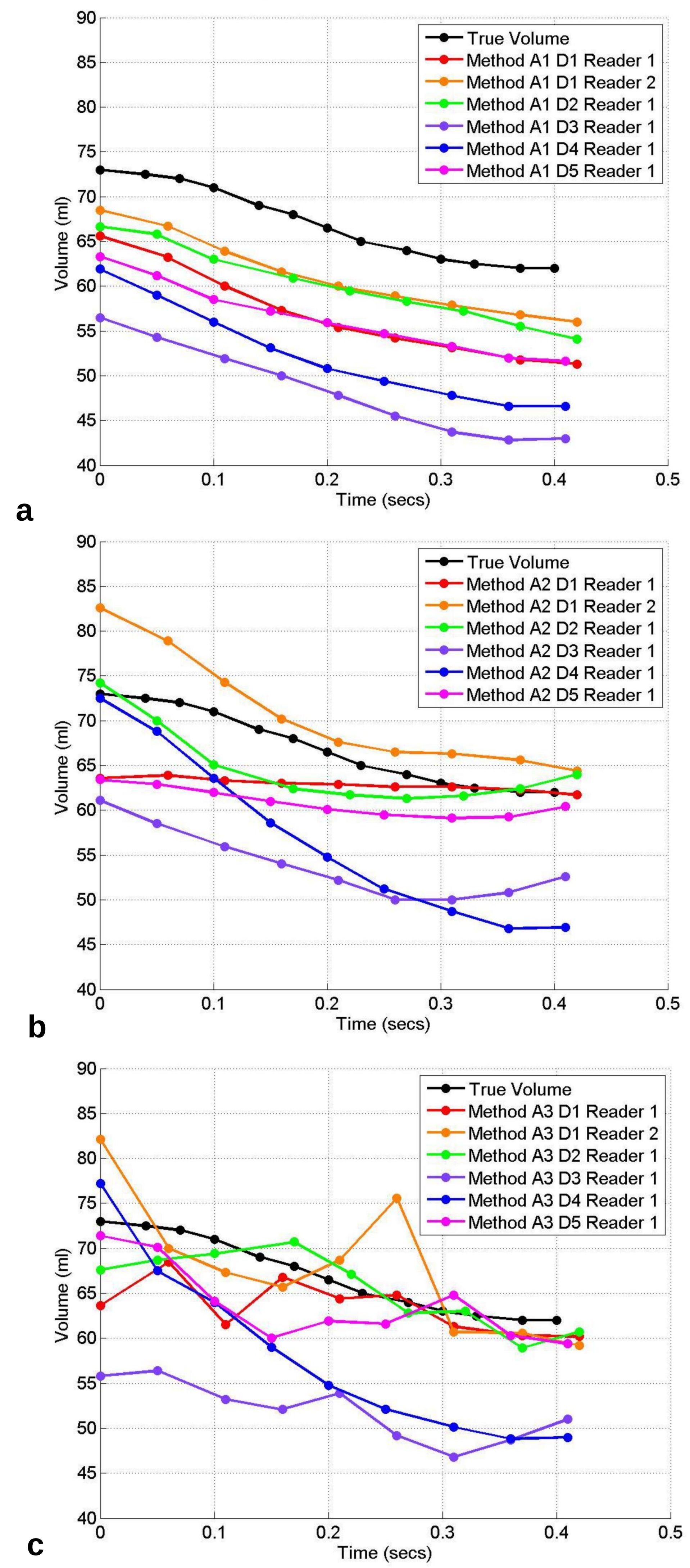

Figure 5. Comparison of method A1 (a), A2 (b) and A3 (c) with the true volumes and two readers. Method A1 = semi-automated volumetric method with no manual correction; Method A2 = semi-automated volumetric method with pre-processing manual correction; Method A3 = semi-automated volumetric with post-processing manual correction; D1 = Dataset 1; D2 = Dataset 2; D3 = Dataset 3; D4 = Dataset 4; D5 = Dataset 5.

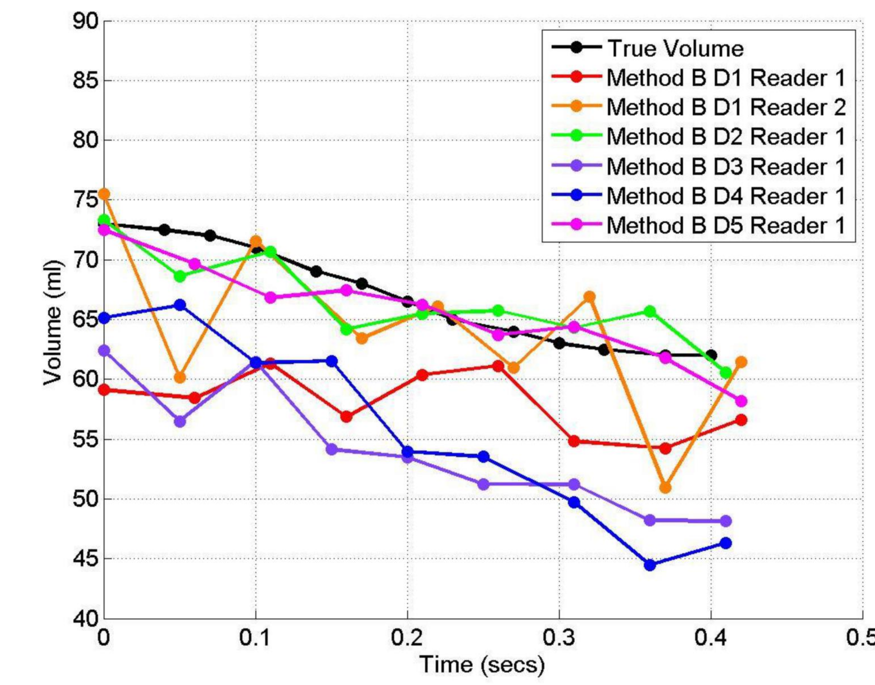

Figure 6. Comparison of method B with the true volumes and two readers. Method B = Simpson's biplane method of discs on a 3D dataset. Other abbreviations as Fig. 5.

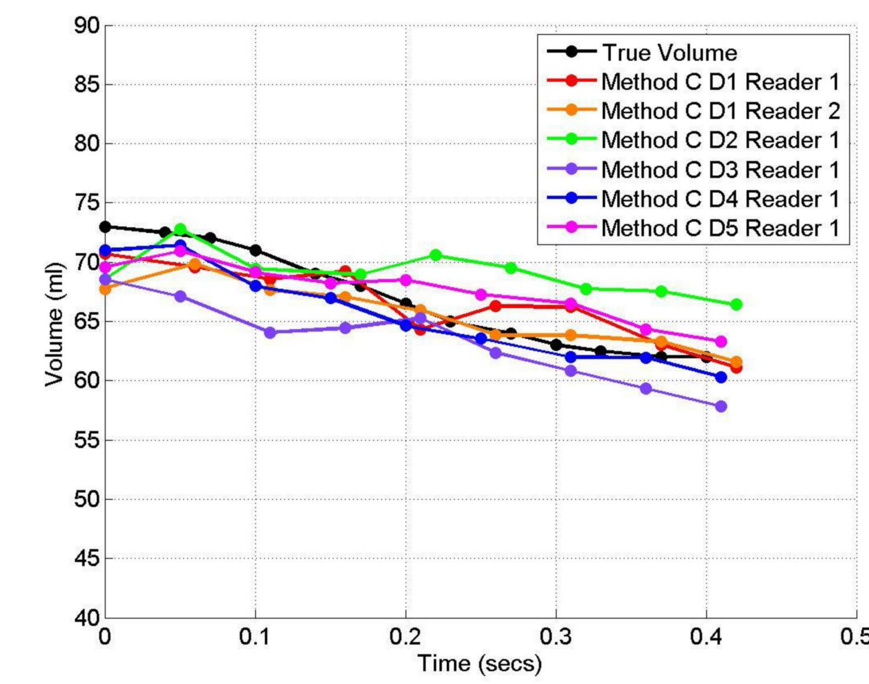

Figure 7. Comparison of method C with the true volumes and two readers. Method C = 3D method of discs . Other abbreviations as Fig. 5.

Conclusion

In a heart phantom with good image quality the method of discs proved to be the most accurate and reproducible method of LV volume calculation. However, further development on semi-automated processing is needed in order to reduce the long time required for manual tracing.

References

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THE AUTHORS HAVE NO CONFLICTS OF INTEREST TO DISCLOSE.

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