Three-Dimensional Cardiac Image Segmentation with Sparsely-Sampled Datasets: Cardiac Image Modeling versus Numerical Integration

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Background

The importance of image processing and analysis in functional cardiac MR imaging is being increasingly recognized. For measurement of global left ventricular (LV) parameters (mass, end-diastolic volume, end-systolic volume, and ejection fraction), MR is now the gold standard. However, the speed and accuracy with which these parameters are derived is dependent both on the completeness of the cine-MRI data sets and on the image processing algorithms. Previous work has shown the reliability and accuracy of Cardiac Image Modeling (CIM, University of Auckland) with a complete dataset of eleven to thirteen cines [1]. CIM uses an internally referenced geometric model and user-defined guide-points to conform the model to an individual heart. Other studies have also demonstrated the reliability and accuracy of Argus (Siemens Medical Solutions), which uses the Simpson rule to estimate LV indices [2]. The purpose of this study was to evaluate the stability and rate of convergence of these two computer algorithms for the assessment of left ventricular mass (LVM), left ventricular end-diastolic volume (LVEDV), left ventricular end-systolic volume (LVESD) and left ventricular ejection fraction (LVEF) as the number of available image slices on cine-MRI is incremented from sparse (3) to full (8). In this way, the more appropriate algorithm for evaluation of global cardiac functional parameters with limited data sets may be determined.

Method

Seven patients with abnormal hearts and six normal volunteers were enrolled in the study group. They underwent segmented SSFP cine MR imaging with multiple breath-holds to obtain a minimum of two long-axis and eight short-axis cines through the left ventricle. Ventricular volumes and mass were evaluated independently using manual tracing for Argus and the guide-point method for CIM. Manual tracing and guide-points were placed on the epi- and endocardial boundaries of the LV in the ED and ES phases. Cardiac MR cines were analyzed in four stages. Argus evaluates only short-axis cross sections. CIM requires at least one long-axis and two short-axis cross sections. In the first stage three cines were analyzed. In the second stage four cines were analyzed, two short-axis and two long-axis using CIM. For each subsequent stage, two short axis cines were added. The first long-axis cine chosen was the horizontal long-axis and the second was the vertical long-axis through the LV. Since the analyses with eight cines had the most data points to evaluate LV indices, we reasoned that those would be the most accurate. Therefore, the performance of each program was based on the rate of convergence to the final (eight slice) value.

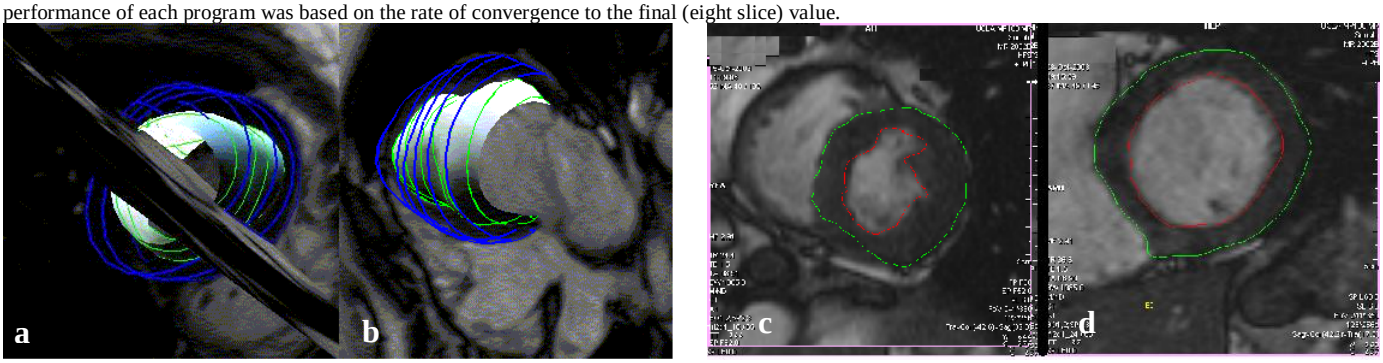

Figure 1. Shows contours in CIM (a,b) and Argus (c,d) for end-systolic and end-diastolic cardiac phases.

Results and Conclusion

CIM converged to a final value more rapidly than Argus for EDV and LVM (figure 2). On average, CIM converged to within 5% of the final EDV value using just 3 cines on normal volunteers and abnormal patients. On average, Argus converged to within 5% of the final EDV value after 6 cines for normal volunteers and converged to within 8% after 6 cines for abnormal patients. CIM was more variable for ESV, converging to within 6% of the final value after 4 cines for normal volunteers and to within 1% of the final value after 6 cines for abnormal patients. Argus converged more rapidly for normal volunteers to within 5% of the final value with 6 cines for normal volunteers, but less rapidly for abnormal patients, not converging to within 10% of the final value with 6 cines. EF in normal volunteers measured within 5% of its final value after 3 cine positions with Argus, and after 4 cine positions with CIM. In abnormal hearts, Argus-derived values converged to within 5% of the final value after 4 cines; CIM-derived values converged to within 5% after 6 cines. Both programs converged equally rapidly to a final value for LVM of normal volunteers (within 5% after 6 cines). CIM converged more quickly than Argus to within 5% of the final value for LVM of abnormal patients (3 cines versus 6 cines, respectively).

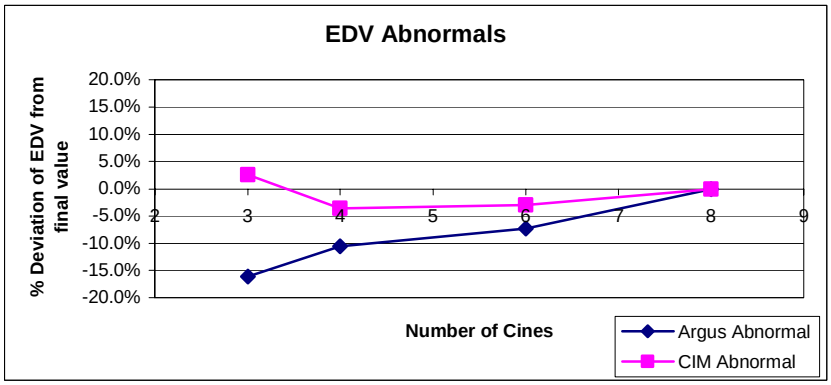

Figure 2. Shows deviation from the final value for EDV versus number of slices for CIM and Argus. CIM converges rapidly to within 5% of its final value.

Overall CIM-derived calculations converged to a final value more rapidly than did Argus-derived values for normal volunteers and abnormal patients. This is likely because CIM has an internal model that it conforms to fit the images based on guide-point placement. Argus, by contrast, uses only the information from the image data set it is given and interpolates the volumes inside the outermost frames to arrive at a final value. Although further clinical investigation is necessary, these preliminary results suggest that CIM may be a better tool than Argus for analyzing LV EDV, ESV, EF, and mass using a limited subset of cardiac MR cines during stress imaging.

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[2] Fieno DS, Jaffe WC, Simonetti OP, Judd RM, Finn JP. TrueFISP: Assessment of Accuracy for Measurement of Left Ventricular Mass in an Animal Model. JMRI 2002; 15(5):526-531