32-Channel Non-Angulated Cine Cardiac Volumes - Automatic Reformatting

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Introduction: In this work, we address two of the major obstacles to the uptake of cardiac MR as a high throughput diagnostic tool: the required presence of a highly skilled operator to identify scan planes, and the long scan duration. A typical exam for the analysis of cardiac function contains short-axis, two-chamber and four-chamber images acquired during 6-8 breath-holds. We acquired non-angulated whole-heart cine volumes in a single breath-hold using SENSE acceleration using a 32-channel array coil. Two-chamber, four-chamber and short-axis images were subsequently created by automatically reformatting the non-angulated volumes. This approach has two benefits: firstly it reduces total scan time by reducing the number and duration of scans acquired - only one scan is obtained; secondly it removes the need for clinician interaction during scanning planning.

Methods: Nine healthy male volunteers (age 34±6years, weight 76±7kg) were imaged on a Philips Achieva 1.5T with 32 receive channels using a prototype 32-element thoracic coil. Non-angulated SSFP SENSE factor 4 half-Fourier cine 3D volumes were acquired during a single breath-hold. Reconstructed resolution was 1.52x1.52x1.50mm with 20 cardiac phases. To enable subsequent comparison, the short-axis, two-chamber and four-chamber views were manually identified during real-time interactive scanning.

To automatically identify the viewing planes, each end-diastolic non-angulated volume was registered to a 3D cadaver atlas of the heart. The atlas came from the visible human data set and had been manually segmented and labeled (http://voxel-man.de). An initial average orientation was used as a starting estimate for a rigid plus scaling registration using normalised mutual information as the similarity measure. Scan planes identified in the atlas were then transformed according to the registration results to determine the short-axis, two-chamber and four-chamber views. The non-angulated volumes were reformatted into these orientations using tri-linear interpolation.

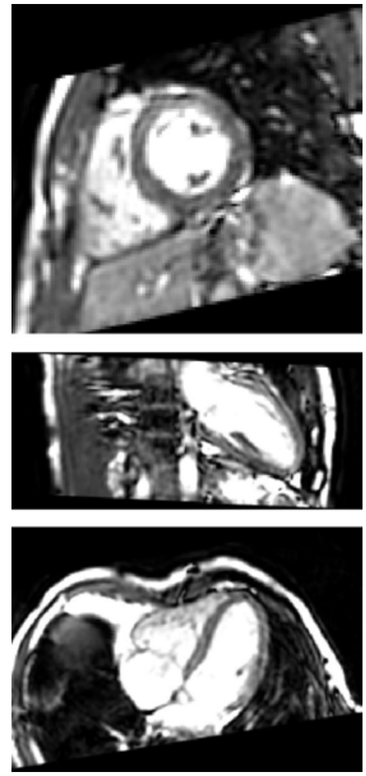

Figure 1: Automatically identified views, showing the short axis (*top*), two-chamber (*middle*) and four-chamber (*bottom*).

The results were evaluated both qualitatively and quantitatively. For the qualitative analysis, three clinicians with experience of reporting cardiac MR images were shown movies of both manually and automatically identified short-axis, two-chamber and four-chamber orientations in a random blinded manner. The observers were asked to identify whether the orientations were clinically acceptable (1) or not (0). A combined score of two or more indicated a consensus of acceptability. Quantitative analysis was performed by expert delineation in the short axis of the manually and automatically reformatted images to determine left ventricular End-Diastolic Volume (EDV) and End-Systolic Volume (ESV). These results were then assessed using Bland-Altman analysis.

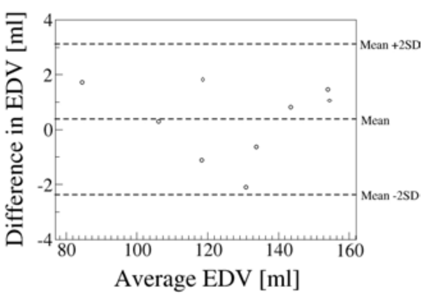

Figure 2: Bland-Altman plot of EDV.

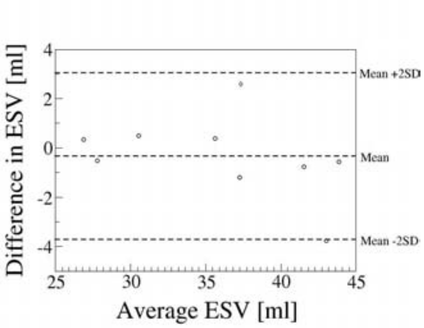

Figure 3: Bland-Altman plot of ESV.

Results: Figure 1 shows reformatted example images following automatic planning. View identification took 50±23s on a 2GHz AMD Athlon64 3000+. All of the automatically reformatted images were judged to be clinically acceptable. Figures 2 and 3 show Bland Altman plots for EDV and ESV. The biases were 0.34ml and -0.37ml for EDV and ESV. The Bland-Altman limits of agreement were [-2.38,3.12]ml and [-3.73,3.05]ml for EDV and ESV respectively. If 10ml is taken as the minimum clinically significant change in EDV or ESV, we can say that EDVs and ESVs evaluated following automatic planning are equivalent to those evaluated following manual planning.

Conclusion: A new technique has been introduced to automatically reformat non-angulated cardiac volumes. Only a single cine volume need be acquired to obtain short-axis, two- and four-chamber views. This can be performed in a single breath-hold which considerably reduces total scan time. Our technique automatically identifies and reformats the volumes into conventional orientations, removing the need for skilled anatomical planning. It is quick, reliable, and there is no clinically significant difference in EDV or ESV when compared to manual planning.