Introduction

Multi-slice, multi-phase Short-Axis (SA) cardiac MR-imaging has proven to be highly suitable to assess Left-Ventricular (LV) function, and is now considered to be the ‘gold standard’ for analysis of global and regional cardiac function. However, the acquisition planning of these scans is a timely process and requires substantial insight in cardiac anatomy, and planning of SA views in a reproducible manner has shown to be difficult in daily clinical practice.

Recently, image analysis tools were introduced towards the automated planning of the SA view [1,2], thereby potentially eliminating operator interaction. The goal of this study was to investigate the accuracy and reproducibility of this novel, automated technique to define the scanning planes for SA cardiac MR images.

Methods and Materials

In previous work[1,2], a 3D deformable atlas has been described by which a thoracic MR-set can be fully automatically segmented into the lungs, heart and cardiac ventricles. This atlas matching procedure results in a set of geometric transformations, which define a one-to-one mapping between an atlas thoracic anatomy and that of a subject. When the model has been fully aligned with the image set, the locations of the boundary surfaces of the heart, cardiac ventricles and both lungs in the scanner space are known. This procedure has been validated in normal subjects[1] and in patients[2], and was shown to be robust with respect to noise, initial model position and pathological variations in heart shape.

By matching the thorax model to a set of scout views, the same geometric transformations mapping the model to the images can be applied to estimate the position and orientation of the LV long axis. Based on these estimates, the SA image volume can be fully automatically defined directly from the scout views, where the three-dimensional angulation of the LV long axis defines the orientation of the image set. This procedure is exemplified in Figure 1.

Figure 1 Example of the automatic definition of a short-axis image volume. By matching a 3D deformable thorax atlas to a set of scout views (top row), the calculated location and orientation of the LV long axis can be applied to define the SA scanning grid (bottom row).

To compare the accuracy and reproducibility of the automated planning method with the accuracy as achieved in routine clinical practice on a standard MR system, 20 examinations were collected retrospectively from patients suffering from various cardiac pathologies. The automated matching procedure was applied directly to the patient scout views acquired prior to the manually planned SA volumes, yielding the two parameters required for the SA scan planning: the position of the image volume and the normal vector for the image planes. In this step, no user interaction was required.

As a gold standard for the short-axis orientation in these patient studies, the orientation of the LV long-axis at End Diastole (ED) was assessed by manually drawing the ED endocardial contours and fitting a straight line through the contour centroids. The variabilities in the manual scan planning process were analyzed by calculating the angle $\phi_{\text{man}}$ between the gold standard LV long axis and the normal vector of the manually planned SA images. This angle is an indicator for the accuracy by which the LV long axis is determined manually in routine clinical practice. To evaluate the automatically estimated LV axis against the reference LV long axis, the angle $\phi_{\text{auto}}$, was calculated between the reference LV axis and the automatically estimated LV long axis.

In addition, 5 normal subjects were scanned in two examinations by acquiring a manually and an automatically planned SA image set, and repeating this procedure after repositioning the subjects in the scanner bore, resulting in 20 SA volumes in total. A comparison between a manually and an automatically planned SA set is given in Figure 2. To compare global functional measurements in both scan types, the endo- and epicardial contours were drawn by an expert in all 20 image sets, and the LV masses and Ejection Fractions (EF) were assessed.

Figure 2 Comparison between a manually planned (top two rows) and an automatically planned (bottom two rows) SA set (ED).

Results

The results of this study can be summarized as follows:

- In the 20 patient studies, the manual variation, $\phi_{\text{man}}$, was on average 9.7 ± 5.8 degrees (range [2.2-28.9 degrees]), while the angular offset in the automatic planning procedure, $\phi_{\text{auto}}$, amounted on average 12.2 ± 6.8 degrees (range [1.9-25.2] degrees). The paired differences between $\phi_{\text{man}}$ and $\phi_{\text{auto}}$ were found to be not statistically significant (p=0.23).
- The EF’s calculated from both scan types corresponded excellently, with an average paired difference between the EF’s of 1 % ± 5.7 %.
- The end-diastolic LV mass calculated from both scan types corresponded well, with an average paired difference of 3 ± 8.5 g.
- Both methods showed good correlation between repeated studies, both in image content, in EF (avg. paired difference: automatic: 3±3%, manual: ±25%) and in LV mass (automatic: 3±10g, manual: ±28±4g).
- Differences in EF and LV mass as measured in both scan types were not statistically significant (p=0.53 and p=0.29 respectively) and were well within the best accuracy ranges reported in the literature [3].

Conclusions

In contrast to manual (real-time) planning protocols, the automated SA scan planning presented here requires no user interaction and expert knowledge. The method provides a uniform, observer independent planning approach, yielding images of equal diagnostic quality as manually planned images. The manually and automatically planned SA scans showed to be equally suitable to quantitate global LV function.

References