Helix Angle Mobility During Contraction Using High Resolution Cardiac Diffusion Tensor Imaging

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Motivation

Cardiac Diffusion Tensor Imaging (cDTI) is an emerging method for probing the organization of the heart's microstructure *in vivo* [1,2]. The complex and highly organized cardiomyocyte network can be characterized by measuring the helix angle (HA) at each voxel. HA describes the elevation of the preferential cardiomyocyte orientation as it is projected onto the epicardial plane. Cardiomyocytes form the functional basis of systolic contraction, but *in vivo* microstructural mobility (i.e., changes in HA) during systole remains poorly described. Our **objective** was to use multi-phase, high-resolution cDTI to measure transmural changes in cardiomyocyte mobility during systolic contraction.

Methods

Image Acquisition

cDTI at early systole (ES), late systole (LS), and diastole were acquired at 3T (Prisma, Siemens) in healthy human volunteers (N = 9) after obtaining IRB approved informed consent. Images were acquired using a high resolution, first and second order motion compensated, single-shot spin-echo EPI cardiac sequence (TE=61ms, TR=4000ms, 1.6x1.6x8mm interpolated to 0.8x0.8x8mm, end-respiratory, and ECG triggering). For each cardiac phase, two b-values (0 and 350s/mm²) with 12 diffusion encoding directions and 5 averages were obtained in a single mid-ventricular short-axis slice (~5 minutes per cardiac phase). A patient-specific trigger delay (TD) scout was used before every cDTI scan to determine the earliest and latest possible TDs during systole, as well as a single phase in diastole.

Post Processing

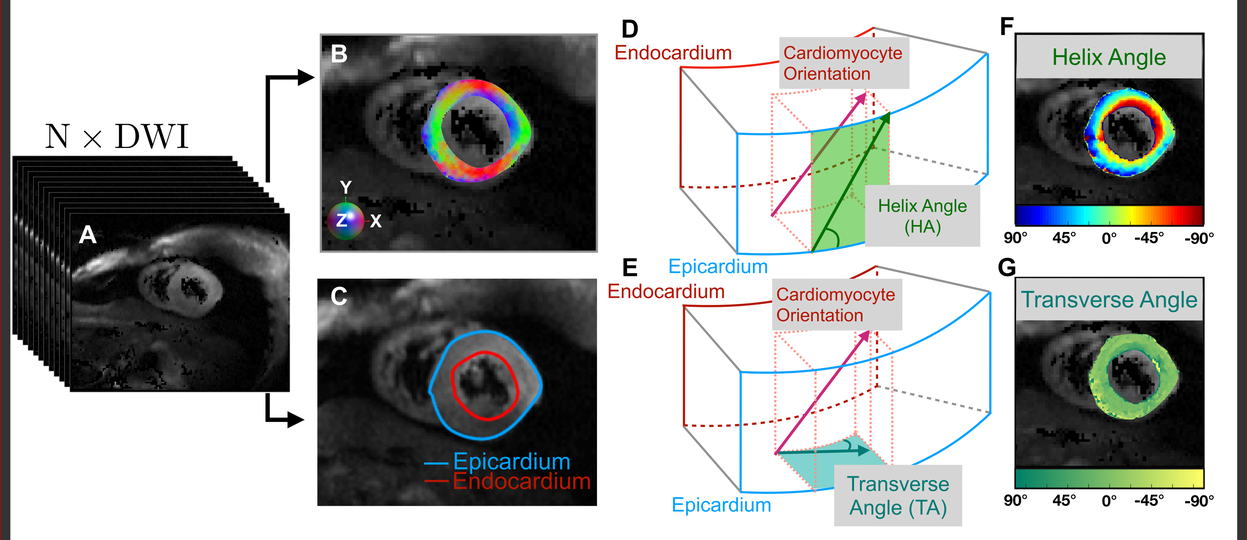

Figure 1 - Post processing pipeline. (A) Stack of DWI at a single cardiac phase. (B) Map of cardiomyocyte orientations. (C) Epicardial and Endocardial contours. (D) Schematic of helix angle calculation. (E) Schematic of transverse angle calculation. (F) Helix angle (HA) map. (G) Transverse angle (TA) map.

Results

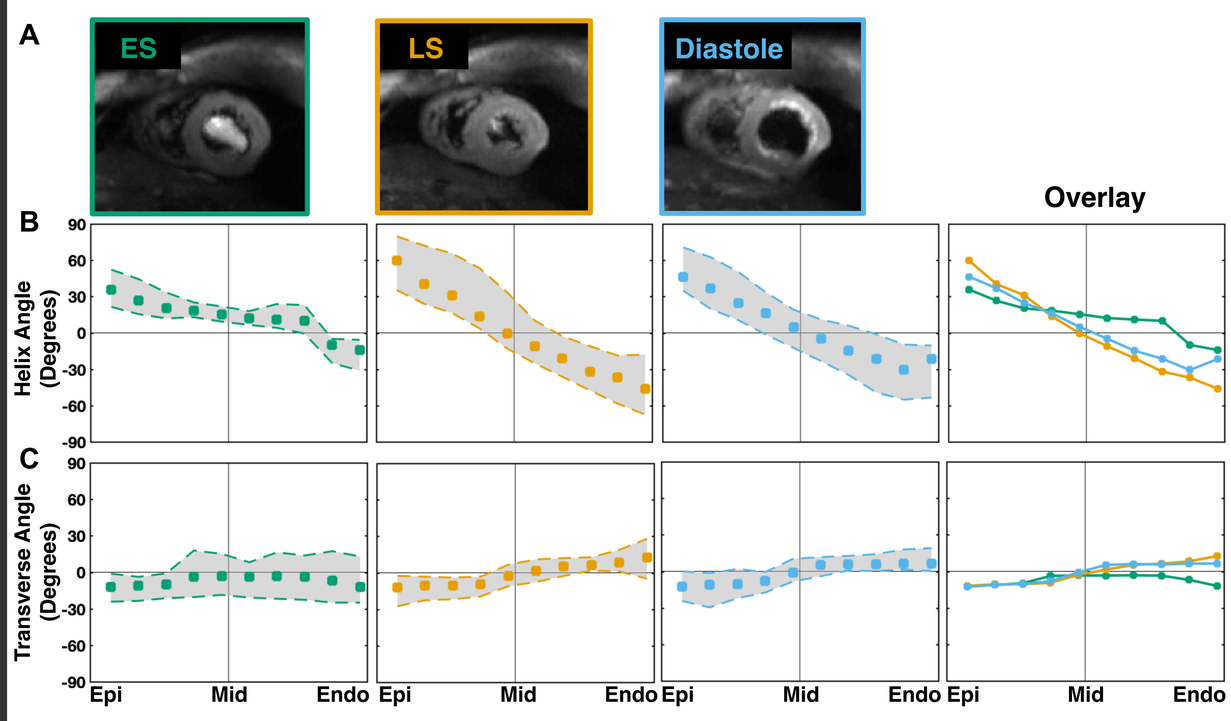

Figure 2 - Processed DTI data at three phases for one representative volunteer. (A) Diffusion tensor trace maps. (B) Transmural helix angle results and overlaid trends. (C) Transmural transverse angle results and overlaid trends. Squares represent medians and dashed lines represent interquartile range.

Results (cont.)

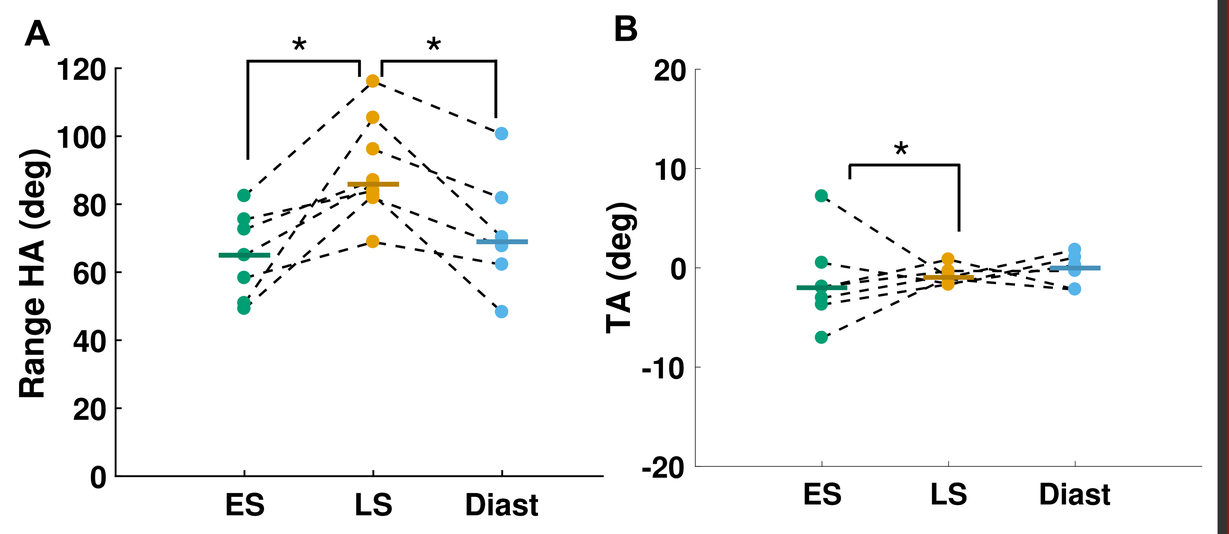

Figure 3 - Helix angle (HA) results for all volunteers across all imaged cardiac phases. (A) HA range for volunteers across three cardiac phases. (B) Median TA for volunteers across 3 cardiac phases. Dots represent value for each volunteer and horizontal lines represent overall median at each cardiac phase. * $p < 0.05$

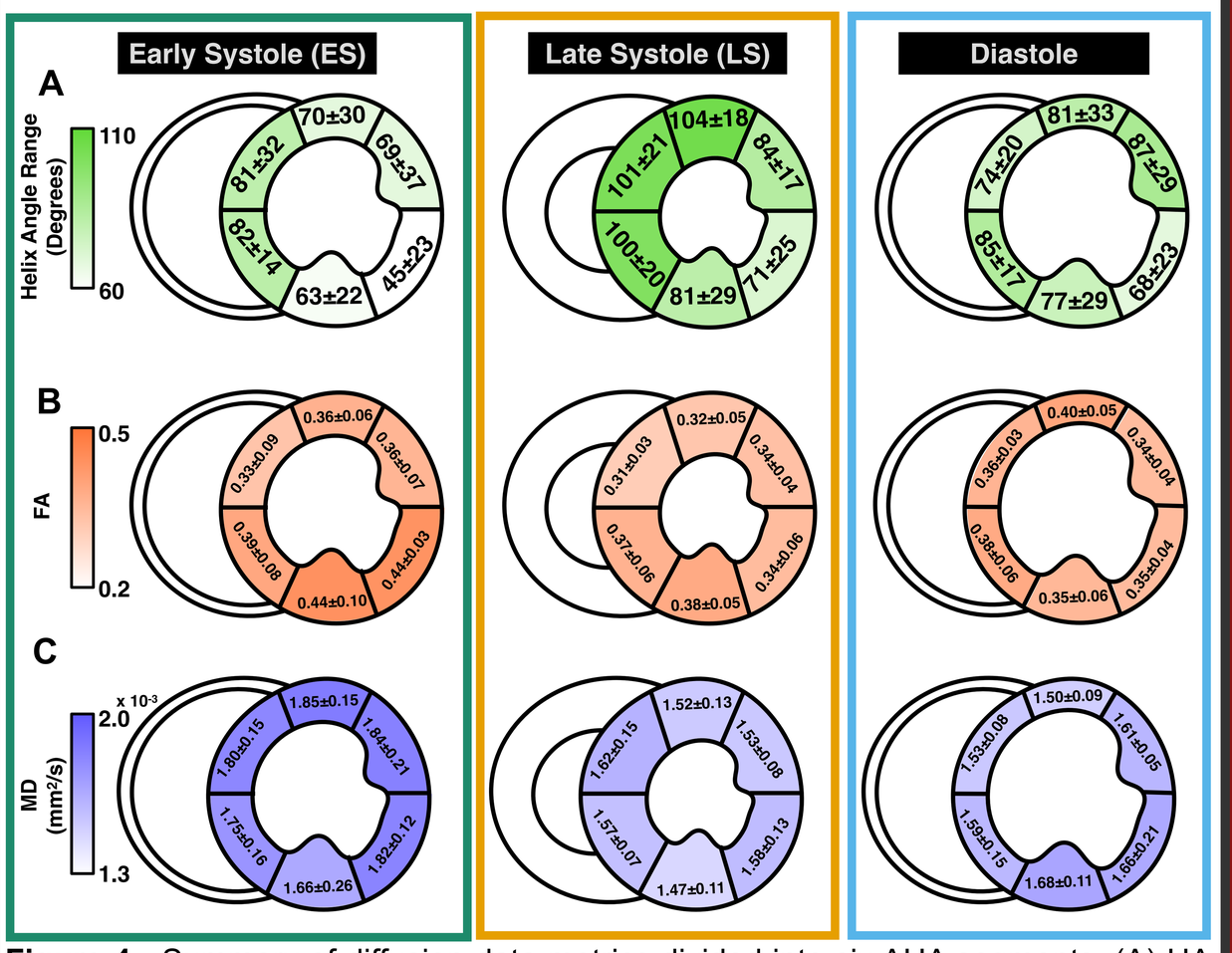

Figure 4 - Summary of diffusion data metrics divided into six AHA segments. (A) HA range. (B) Fractional Anisotropy (FA). (C) Mean Diffusivity (MD, mm²/s). All results are reported as mean ± standard deviation

Conclusions

A significant steepening of the HA was observed between ES and LS phases and a shallowing of HA was observed between LS and diastole in healthy volunteers. This change in HA was especially pronounced in the anterior segment of the left ventricle. The measured increase in HA range from ES to LS agrees well with previous DTI studies performed on *ex vivo* hearts in multiple contractile states [4].

Microstructural mobility during contraction has been shown to differentiate purported mechanisms of wall thickening in diseased hearts [5]. In this work, we characterize HA mobility in healthy human subjects, thus laying the groundwork for future analysis of HA mobility in patients with cardiovascular disease.

References

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