Fully automated strain analysis from SSFP cines of the heart using non-rigid registration techniques

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Purpose - Cardiac strain quantification is important in the assessment of regional myocardial function, and has many different clinical applications[1-2]. The current gold standard for non-invasive myocardial strain measurement is cardiac magnetic resonance (CMR) tagging[2]. It is also possible to estimate global and regional strain from standard (non-tagged) steady-state free-precession (SSFP) cines using non-rigid registration[3], thereby removing the need to acquire additional sequences. We report an 'inline' implementation providing automated numerical and graphical strain measurements without user interaction as part of the standard SSFP acquisition.

Method - A 2D finite-element non-rigid registration modelling algorithm was inserted into the image reconstruction pipeline of a multi-slice CINE SSFP acquisition. As part of the reconstruction process, the left ventricle was automatically located and endo- and epicardial contours determined for each of the cardiac phases. On a 3T Magnetom Skyra scanner (Siemens Healthcare, Erlangen, Germany), SSFP and grid tagged images were acquired in six short-axis slices of the left ventricle in 10 healthy volunteers (6 female, mean age 36 years). The tagging images were analysed offline using the Cardiac Imaging Modelling (CIM) 2D Tagging program (V8.1.2 University of Auckland). The SSFP strain was calculated during reconstruction using the non-rigid registration algorithm.
In each slice, circumferential (CC) and radial (RR) strain for the whole wall, and each of the six standard American Heart Association (AHA) regions were compared at end-systole. Statistical analysis was performed using IBM® SPSS® Statistics with significance defined as $p<0.05$.

Results - The average end-systolic (ES) whole wall CC SSFP strain was -16.3 vs -19.2% for tagging ($p<0.001$), and RR strain was 45.1 and 23.1% respectively ($p < 0.001$). Regional CC strain (figure 1) was significantly different in the antero-lateral ($p < 0.001$), posterio-lateral ($p<0.001$) and inferior regions ($p<0.035$). RR strain was statistically different in all regions apart from the inferior septum. The temporal evolution of the whole wall circumferential strain for SSFP and tagging is shown in figure 2 averaged over all slices and participants. A graphical display of the automated strain analysis from the inline SSFP cine is shown in figure 3.

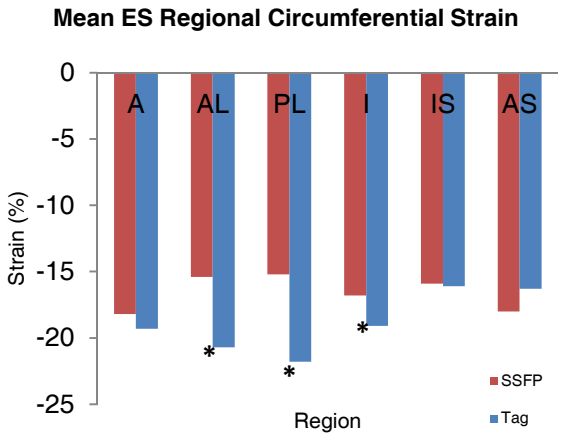

Figure 1: Regional circumferential strain SSFP (red) versus tagging (blue), (*) indicates statistical fignificance $p<0.05$. A=anterior, AL=antero-lateral, PL=postero-lateral, I=inferior, IS=infero-septal and AS=antero-septal

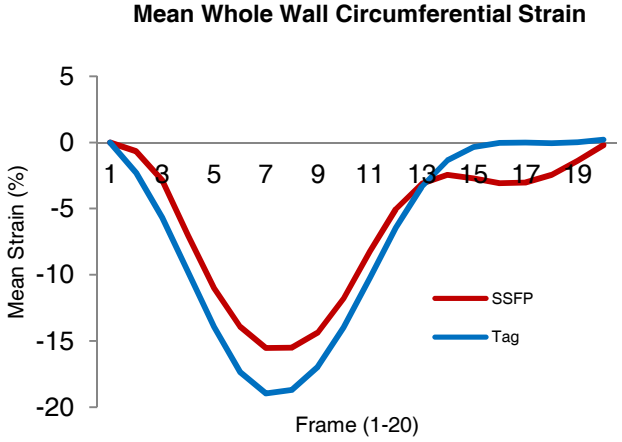

Figure 2: Temporal evolution of mean whole wall circumferential (CC) strain for SSFP and tagging averaged over all slices and participants

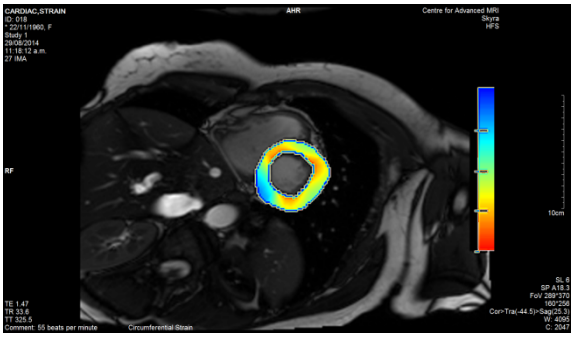

Figure 3: Graphical display of SSFP circumferential strain calculated without user intervention. Red represents strain of -40%, and blue 20%.

Conclusion

The global SSFP circumferential strain was clinically comparable with tagging. Radial strain by tagging is recognised to be inaccurate and was implausibly low for normal volunteers making comparison difficult. Regional strain measurements from SSFP cine using non-rigid registration show more variability, with a trend towards greater differences away from the ventricular septum. This may be due to the contribution of image features such as the insertion points of the right ventricle providing circumferential 'anchor points' for the non-rigid registration algorithm.

References

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