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Development of a realistic numerical phantom to test and validate CMR feature tracking software

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Purpose/Introduction:

Feature tracking (FT) is a relatively recent post-processing technique that uses standard clinical Cardiovascular Magnetic Resonance (CMR) cine images to derive myocardial deformation parameters such as strain for early patient diagnosis and follow-up. However, differences in calculated values between soft- ware packages and the lack of absolute validation have hindered its clinical acceptance. Research is active in the development of realistic cine model simulations for which motion deformation parameters are known a priori, to be used as the ‘‘gold-standard’’ to validate CMR- FT packages. The aim of the present work was to use numerical simulation to generate a realistic single slice short-axis bSSFP cine model with known myocardial motion parameters to use as a gold- standard for CMR-FT comparison and validation.

Subjects and Methods:

An acquired end-diastole (ED) T1 map, a T2 map, and a proton-density weighted image were used as input to the pulse sequence simulator JEMRIS [1] to simulate a bSSFP sequence. Images were registered to the ED contours of an acquired tagging cine and deformed from ED to simulate the cine frames. The myocardial deformation was extracted from the tagging cine using CIMTag2D (Auckland MRI Research Group, New Zealand) and merged with defor- mation outside of the left ventricle extracted from B-spline based non-rigid registration [2] through an acquired FLASH cine (Fig. 1). A zero-end- displacement condition was applied to ensure that the cine start and end displacements were matching. The resulting model was analysed with 2 FT software packages: TomTec 2D CPA MR (TomTec Imaging Systems, Munich, Germany) and cvi42 (Circle Cardiovascular Imaging Inc., Calgary, Canada) and the results compared with the analytical strain values. Analytical values included both 1D and 2D ground-truth strain because the CMR-FT software packages investigated report these differing strain measures [3].

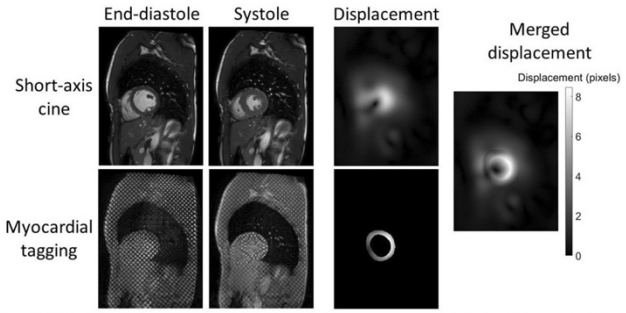

Figure 1: Summary of methodology: The displacement field from the short-axis FLASH cine, obtained using B-spline based non-rigid registration, was merged with the displacement field from the tagging cine, obtained using CIMTag2D software.

Results:

The simulated cine showed realistic motion and image texture (Fig. 2). The global strain results of the two FT software packages were comparable to the analytical 1D and 2D ground-truth global strains (Fig. 3). Differences between measured strain and ground-truth strain could be due to regularization.

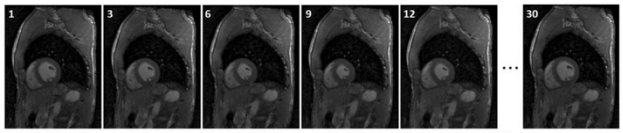

Figure 2: Selected frames of the single-slice short-axis bSSFP cine model (30 frames) simulated using JEMRIS.

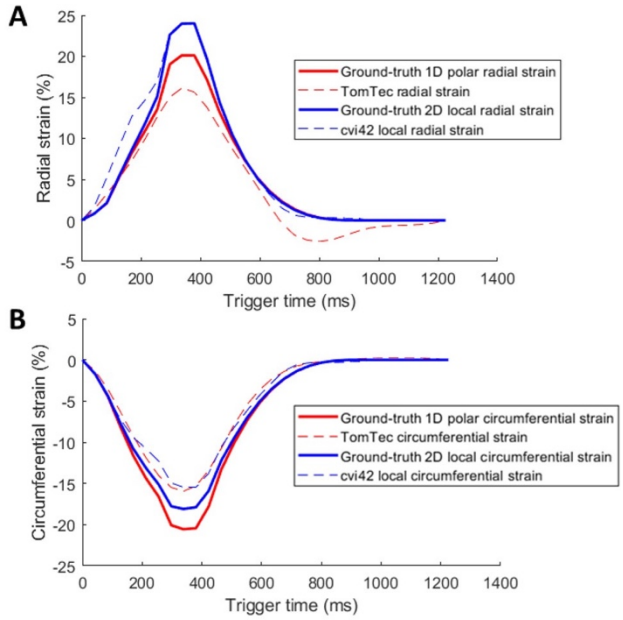

Figure 3: Comparison between the ground-truth global radial strain (A) and global circumferential strain (B) for the cine model with TomTec 2D CPA MR and cvi42 results for 1D and 2D strain (2D uses a local LV coordinate system).

Discussion/Conclusion:

This work provides a basis for further work in developing a realistic cine model for CMR-FT validation. The results reaffirm the significance of the effects of regularization and the strain calculation methods on inter-vendor FT strain disagreement. Future work could investigate the effects of spatial and temporal resolutions on measured parameters.

References:

[1] Stöcker, T et al., MRM, vol. 64, no. 1, pp. 186–193, January 2010

[2] Kroon, D J, ‘‘B-spline grid, image and point based registration’’ [Internet], File Exchange MATLAB Central, 2011

[3] Wehner, G J et al., JCMR, vol. 20, no. 1, September 2018