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

David Adams[1,2], Dr Redha Boubertakh[1,3] ,Dr Marc Miquel[1,3]
[1]Barts Health NHS Trust, [2]King's College London, [3]Queen Mary University of London Correspondence: david.adams@nhs.net

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 software 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.

Aim

The aim 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.

Method

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 deformation outside of the left ventricle extracted from B-spline based non-rigid registration [2] through an acquired bSSFP cine. 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. The simulated cine was produced with a range of spatial resolutions (1.4 to 3.0 mm) and temporal resolutions (30.8 to 61.7 ms). Analytical strain values included both 1D and 2D ground-truth strain because the CMR-FT software packages investigated report these differing strain measures [3].

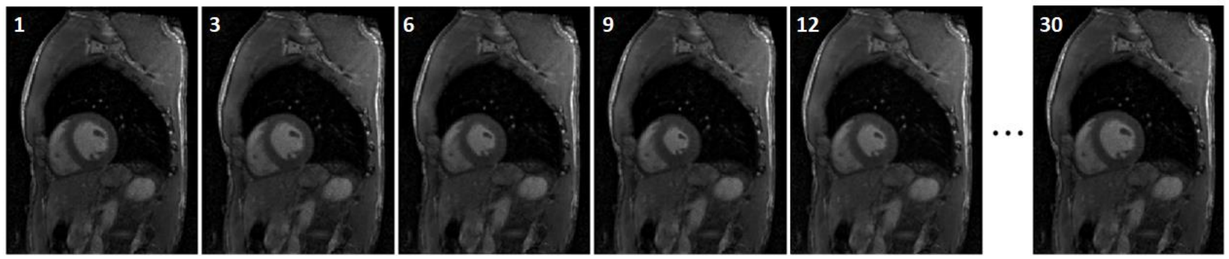

Figure 1: Selected frames of the single-slice short-axis bSSFP cine model (30 frames) simulated using JEMRIS.

Discussion

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 intervendor FT strain disagreement.

Results

The simulated cine showed realistic motion and image texture (Figure 1). The global strain results of the two FT software packages were comparable to the analytical 1D and 2D ground-truth global strains (Figure 2). Differences between measured strain and ground-truth strain could be due to differences in the implementations of the feature tracking algorithms.

There was not a linear trend of strain error with spatial and temporal resolution, but increased voxel size and decreased number of cardiac phases gave broadly increased peak strain error, as well as greater variation from the ground-truth strain curve. However, increasing the number of cardiac phases increased the peak radial strain error.

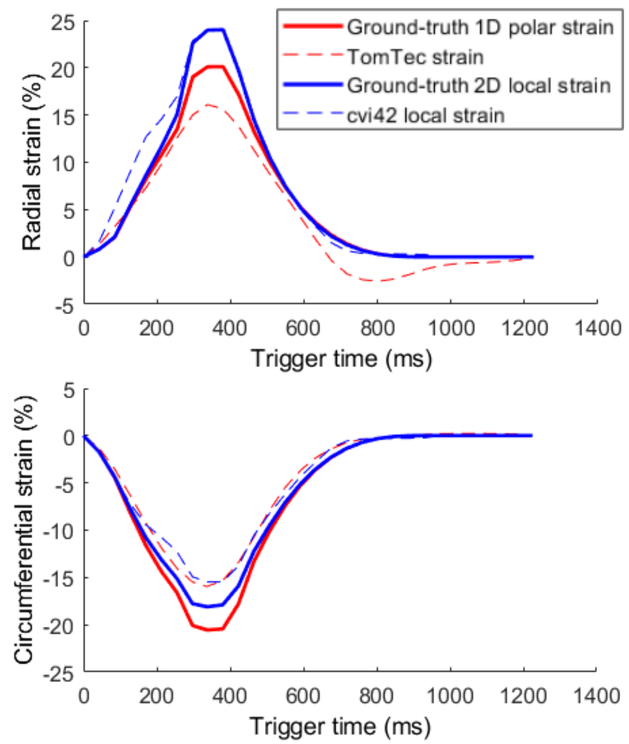

Figure 2: Comparing feature tracking results to ground truth strain for the simulated cine (30 cardiac phases, temporal resolution 41.1 ms, spatial resolution 1.4 mm).

References

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