Registration of Multiparametic Breast MRI

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Introduction: Motion, such as respiratory, during MRI examination can degrade both empirical and pharmacokinetic data, as well as causing mismatch between morphological and functional imaging. In this abstract we present a simple methodology using FMRIB Software Library (FSL)[1] for retrospectively correcting motion during DCE MRI examinations, and a registration scheme to combine multiple breast MR series into a common 4D space for simultaneous interrogation.

Methods: Data were acquired from 19 patients undergoing breast MR examinations using a 3.0T GE 750 Discovery system and an eight channel phased array breast coil. T_1 weighted DCE (pre and early contrast phases, tdel=30s, VIBRANT-flex, FOV=32x35.8cm, 324x512 matrix, 2.5mm slice thickness) was followed by a T_1 weighted high spatial resolution volume (VIBRANT-flex, FOV=32x35.8cm, 324x536 matrix, 0.9mm slice thickness) 2 minutes after contrast injection when image contrast between tumour and normal parenchyma was expected to be greatest. Following this, a late phase T_1 weighted DCE phase (FOV=32x35.8cm, 324x512 matrix, 2.5mm slice thickness) was acquired to assess washout, followed by a T_2 IDEAL sequence (FOV=22x33cm, 224x256 matrix, 1.3mm slice thickness).

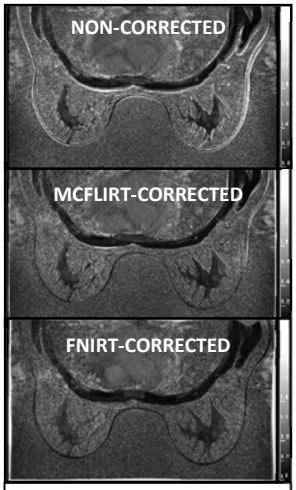

Figure 1 – Coefficient of variation maps from a DCE volume showing the effects of rigid and non-rigid motion correction (all scaled identically, 0-200%).

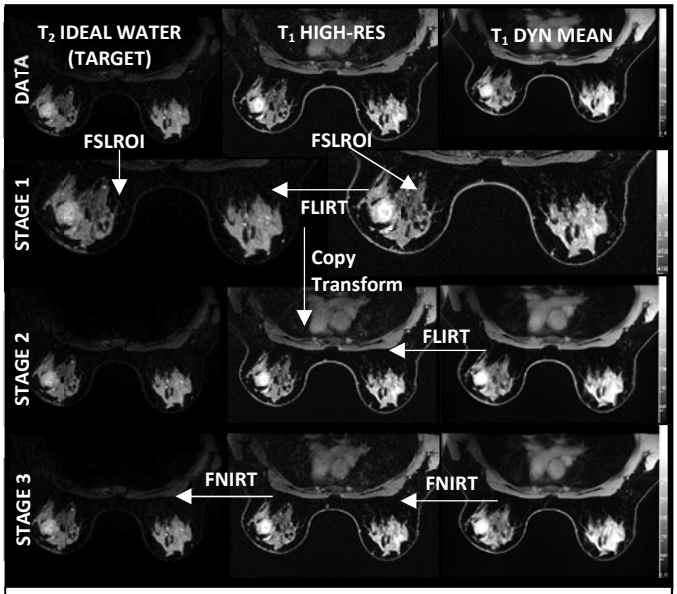

Figure 2 - Schematic of 4D registration scheme which converts all MR series to the T_2 IDEAL space.

Motion Correction of DCE MRI: Retrospective rigid and non-rigid motion correction was applied to each phase of the dynamic data using FSL[1]. Dynamic contrast enhanced T_1 volumes were cropped to reduce computation time, and maximise motion correction of the breast and axilla regions. For rigid motion correction, MCFLIRT was implemented with 12 degrees of freedom (dof), correlation ratio cost function and contour search on. Non-rigid registration (FNIRT) was subsequently initialised using the MCFLIRT transformation matrices using subsampling factors of '8,4,4,2' and a spline order of 3. Coefficient of variation (COV) maps (standard deviation/mean) were used to assess motion correction (figure 1). Rectangular regions of interest that encompassed both breasts were drawn onto a single representative slice for each patient and the mean COV was recorded.

4D Volume Generation (Figure 2): T_2 IDEAL and T_1 high spatial resolution sequences were cropped to remove the heart (Stage 1) and rigidly registered to the T_2 IDEAL space (Stage 1). The mean signal intensity volume of the non-rigid motion corrected DCE was registered to the previously registered T_1 high spatial resolution volume (Stage 2). Non-rigid registration of the T_1 high spatial resolution imaging to the T_2 IDEAL was initialised using the transformation matrix previously generated by FLIRT (Stage 3). The non-rigidly registered T_1 high resolution volume subsequently became the target for the DCE registration (Stage 3). Subtractions between the 4th and pre-contrast phases were generated following registration. 4D volumes containing the DCE, high spatial resolution T_1 post-contrast and T_2 IDEAL imaging were generated using FSLMERGE (figure 2).

Results: Mean coefficients of variation were found to be 45.2±3.9%, 40.0±3.1% and 35.7±2.5% for the raw data, rigid motion corrected data and the non-rigid motion corrected data respectively. Non-rigid registration between MR series was successfully applied to all patients and showed good visual agreement (figure 3).

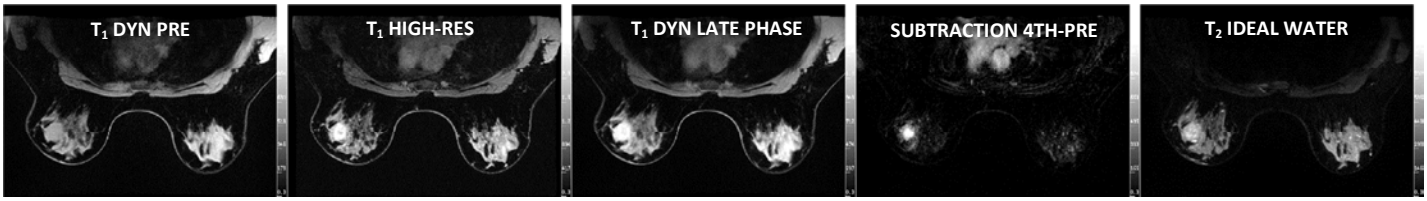

Figure 3 – Example slice from a 4D volume showing co-registration of motion corrected DCE, T_1 high resolution and T_2 IDEAL imaging.

Discussion: Non-rigid registration performed best at correctly aligning dynamically acquired breast MR images, and has benefits for both empirical and pharmacokinetic modelling. A global registration scheme rather than a local registration scheme[2] was developed to help identify disease dissemination and may improve tumour characterisation close to the chest wall. Higher than expected observed COVs are due to the inclusion of suppressed fat regions, skin and air, but still showed a marked improvement using non-rigid correction. The global 4D registration methodology enables researchers and clinicians to contour single volume of interests that can be used to simultaneously interrogate multiple breast MR series. This has potential applications for the assessment of multiparametric breast MR and research areas such as texture analysis[3]. It is also possible that subtle abnormalities may be more identifiable on images that have been co-registered. This 4D volume can subsequently be used to register whole MR studies between sequential scans[4 5].

Conclusions: This work demonstrates a simple scheme for retrospectively correcting motion during DCE MRI examinations, and a method for the generation of a 4D multiparametric volume usable by clinicians and researchers.

References: 1. Jenkinson *et al*, Medical Image Analysis. 2001;5(2):143-156. **2.** Schäfer *et al,* Annals of the BMVA 2011; 2011(3):1–13. **3.** Ahmed *et al*, Journal of Magnetic Resonance Imaging. 2013;38(1):89-101. **4.** Li *et al*, Magnetic Resonance Imaging. 2009; 27(9):1258-1270. **5.** Kenning *et al*. Proc. 21st ISMRM. (2013). 0975.