Motion Correction in Small Bowel DCE-MRI using Robust Data Decomposition Registration

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Introduction: Dynamic Contrast Enhanced (DCE) MR imaging is of interest for the detection of small bowel disorders including ulcerative lesions in Crohn's disease [1]. However contrast agent uptake and washout takes several minutes and misalignments arise due to patient motion during the acquisition. This is likely to alter the time intensity curve (TIC) shape of a given region of interest (ROI) and can affect data analysis. Butylscopolamine injection prior to acquisition can limit the effect of bowel peristalsis but correcting for breathing motion in the presence of contrast changes remains challenging. In this study we investigate the application of a registration approach, robust to contrast changes, to obtain accurate realignment of clinically relevant features in small bowel DCE-MRI.

	CC	NMI	SSD
Non-registered	0.95	1.272	9.191
FFD	0.935 (-1.39%)	1.259 (-1.07%)	10.03 (+9.22%)
RDDR	0.967 (+3.35%)	1.313 (+4.30%)	7.486 (-25.4%)

Table 1: Similarity measures and relative changes after registration across all data: CC (values between -1 and 1, optimal is 1); NMI (Values between 1 and 2, optimal is 2); SSD (values>0, optimal is 0)

Material and Methods: 11 high temporal resolution small bowel DCE-MR datasets of patients diagnosed with Crohn's disease were acquired at 3-T (Achieva, Philips Healthcare, The Netherlands). Patients were imaged using a free-breathing protocol after injection of butylscopolamine (Buscopan, Boehringer, Germany). For each time-series a total of 200 volumes were obtained in 3min20s. Moreover 13 ROIs (including both disease and normal tissue) were contoured by a gastroenterologist in single time-points. Registration was performed using Robust Data Decomposition Registration (RDDR) technique [2]. RDDR relies on iterative separation of motion from contrast changes using robust principal component analysis [3]. Hence misalignments can be removed while enhancement information is left unchanged. A highly optimised free-form deformation algorithm [4] was sequentially applied to each dataset to provide a point of comparison for registration. Each ROI was copied through time-series before and after registration and TICs were derived. Ground Truth (GT) TICs were obtained by manually adjusting ROIs in every time-point across corresponding datasets. The resulting enhancement shape and Root Mean Squared Error (RMSE) compared to GT were used to assess registration accuracy. In addition classic similarity measures including Correlation Coefficient (CC), Normalized Mutual Information (NMI), and Sum of Squared Difference (SSD) between in each time-frame and the median frame were computed for non-registered and registered time-series.

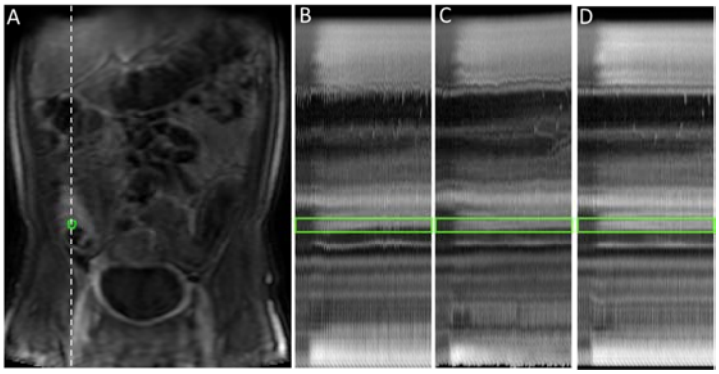

Fig. 1: Illustration of the effect of registration: (A) time point example – a white dashed line indicates the location chosen for time-intensity profile in (B) non-registered data, (C) data registered with FFD and (D) data registered with RDDR. An ROI is contoured in green

Results and Discussion: Misalignments due to breathing were reduced by both RDDR and FFD. However, in some cases FFD introduced additional unlikely deformations. The robustness of RDDR is further supported by the similarity metrics presented in Table 1. Figure 1 illustrates these results by showing time-cut images of a time-series along a pixel wide line before and after registration. ROI analysis showed a reduction of intensity deviation in registered time-series (8 to 10% across all ROIs for both techniques). ROIs were small and located within bowel walls thus slight misalignments can cause large changes in RMSE. TIC shapes after registration were in improved agreement with GT in 77% of cases with RDDR and 40% with FFD. In these cases, the average RMSE decreases were 32.3% (RDDR) and 22.2% (FFD). This suggests that RDDR is more robust and yields time intensity profiles closer to the ground truth (Figure 2). For visualisation only, a sigmoid model [5] was fit to the GT points.

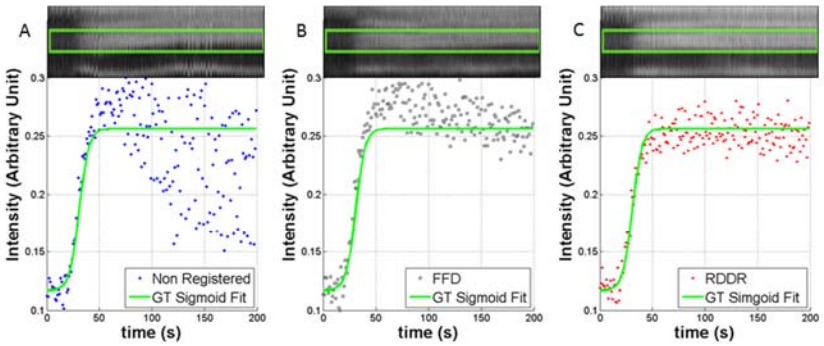

Fig. 2: TIC obtained for a disease tissue ROI along with a zoom on the corresponding area in time-cut images: (A) non-registered *RMSE = 0.0312*; (B) FFD *RMSE = 0.0185*; (C) RDDR *RMSE = 0.0162*. GT sigmoid fit as a guide (green)

Conclusion: RDDR appears to provide accurate registration of small bowel DCE-MRI. The more realistic TICs obtained suggest that a more accurate discrimination between disease and normal tissue could be possible thanks to such technique. Hence the use of RDDR could be helpful for Crohn's disease diagnosis.

References: [1] Ziech M.LW. et .al. European Journal of Radiology 81 (2012) 3019-3027 [2] Hamy V. et.al ISMRM 2012, 749 [3] Modat, M. et al. Comput. Methods Prog. Biomed. 98 (2010) 278-284 [4] E.Candès et al. J. ACM 58 (2011) [5] Melbourne et al. Phys. Med. Biol. (56) 2011 7693 - 708