Evaluation of Perfusion in Rheumatoid Arthritis Patients with Highly Accelerated Dynamic Contrast Enhanced Wrist MRI

Jing Liu[1], Valentina Pedoia[1], Ursula Heilmeier[1], Favian Su[1], Sameer Khanna[2], John Imboden[3], Jonathan Graf[3], David Saloner[1], and Xiaojuan Li[1]

[1]*Radiology and Biomedical Imaging, University of California San Francisco, San Francisco, CA, United States,* [2]*University of California Berkeley, Berkeley, CA, United States,* [3]*Medicine, University of California San Francisco, San Francisco, CA, United States*

INTRODUCTION

Early diagnosis and prediction of Rheumatoid Arthritis (RA) progression is important but challenging. Synovial angiogenesis has been proposed as one of the earliest markers of RA. Dynamic contrast-enhanced (DCE) wrist imaging has been shown to be promising for evaluating perfusion changes in RA [1]. However, current wrist DCE techniques are limited to relatively low spatial and temporal resolution, and are not yet clinically used. In this study, we applied a novel data undersampling strategy CIRcular UnderSampling (CIRCUS) [2] combined with k-t, compressed-sensing and parallel imaging reconstruction techniques (k-t SPARSE-SENSE) [3-4], to highly accelerate data acquisition for achieving high spatial and temporal resolution. Perfusion changes in synovium and bone marrow edema were evaluated and compared to conventional clinical evaluation scores.

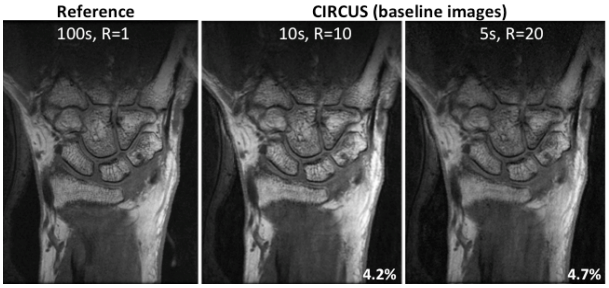

Fig. 1 Comparison of highly accelerated images with the reference. Normalized root-mean-square error was calculated.

MATERIALS AND METHODS

Ten RA patients (51.3±14.3 years, seven female, disease activity score (DAS28-CRP): 4.7±1.8 at baseline scan, RA duration: 46.4±39.6 months) were imaged. Eight of them were treated with Anti-Tumour Necrosis Factor (TNF) therapy. Six of them (including two control patients) had 3-month follow-up scans (score 3.2±1.3). Data was acquired on a 3.0T MR scanner (GE Medical Systems, Milwaukee, WI) with an 8-ch phased array wrist coil in coronal view, 3D gradient-echo sequence (SPGR), FOV=12x9 cm, TR/TE=11.1/2.5ms, FA= 20°, BW= ±62.5kHz, image matrix= 384×288, 0.3×0.3×1.5mm, 28~32 slices. A fully sampled 3D data set was acquired without contrast (~100s). DCE imaging with CIRCUS [2] was applied for 400s with a 40s injection delay (Gd-DTPA, 0.2mmol/kg). Images with CIRCUS were compared with the reference images by calculating the Normalized Root-Mean-Square Error (NRMSE) [6]. DCE as well as T_2 IDEAL Fast Spin Echo (Water) images, were non-rigidly aligned to the first time point (baseline image) of DCE images using an image-based registration method (Elastix library) [5]. Synovitis (SYN) and Bone marrow edema (BME) were identified in IDEAL images, and their mean intensities throughout time (signal-time curves) were measured to calculate six perfusion parameters: maximum intensity (MaxI (%), relative to baseline image), transition time (dT (s), time between 20% and 80% MaxI), slope (% per min, MaxI(80%-20%)/(dT/60)), time to peak (TTP (s)), area under the curve (AUC, %•hour), and area under the curve before TTP (AUCP, %•hour). Correlations between perfusion parameters with clinical activity scores were calculated. Perfusion parameters with strong correlation were identified and their changes between baseline and follow up scans were evaluated.

Table 1 (n=9)	dT (s)	MaxI (%)	TTP (s)	Slope (% per min)	AUC (%•hour)	AUCP (%•hour)
SYN 10s	112.8± 52.1	219.6± 79.0	364.4± 41.0	60.8± 64.2	20.3±6.8	17.7±4.6
	r=-0.70*	**r=0.69***	r=-0.35	r=0.62	**r=0.70***	r=0.66
SYN 5s	125.9± 63.7	223.3± 81.4	362.2± 68.8	60.2±64.1	20.4± 6.9	17.8 ±5.0
	r=-0.87*	**r=0.68***	r=-0.38	r=0.65	**r=0.69***	r=0.64
BME 10s	89.4± 56.2	168.9± 49.3	290.0± 88.6	56.0±61.3	16.4±4.0	11.5 ±4.5
	r =0.17	r=-0.56	r=-0.53	r=-0.52	r=-0.53	**r=-0.77***
BME 5s	104.1± 57.1	172.0± 49.0	265.6± 175.5	44.5±45.5	16.5±4.0	10.5 ±4.3
	r=0.14	r=-0.57	r=-0.54	r=-0.51	r=-0.55	**r=-0.72***

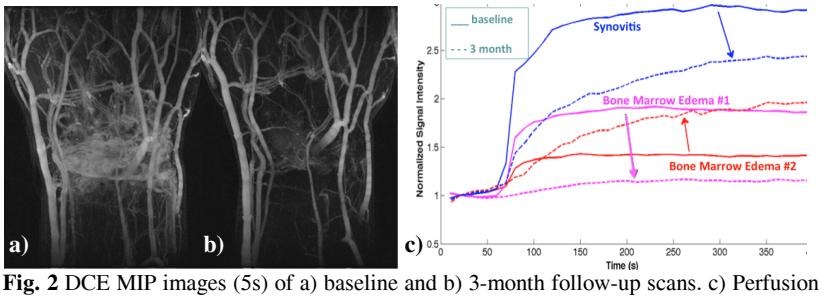

Fig. 2 DCE MIP images (5s) of a) baseline and b) 3-month follow-up scans. c) Perfusion curves of SYN and BMEs with larger transition times in the follow-up scan.

RESULTS & DISCUSSION

DCE data with CIRCUS can be reconstructed with a flexible temporal resolution. In this study, DCE images of temporal resolution 10s (acceleration factor R=10) and 5s (R=20) were reconstructed. We compared their baseline images with the reference images (Fig.1). NRMSEs from ten patients' baseline scans were 4.0±2.5% and 4.1±2.3% for 10s and 5s data sets respectively. Perfusion parameters of SYN and BME derived from baseline scans are shown in Table 1 (n=9 found to have SYN and BME). Their correlations with the activity scores were listed, where * denotes strong correlation ($p<0.05$). Overall, 10s and 5s data sets give similar results. Higher temporal resolution (5s) significantly improves the correlation between dT of SYN and the activity score (r=-0.87). We evaluated the perfusion changes between baseline and 3-month scans. For patient#6, who achieved reduced RA symptoms after the therapy (score from 6.28 to 2.83), the enhancing regions in the wrist were significantly reduced (Fig2a&b) and contrast enhancement of SYN and BME were slower in the follow-up scan (larger transition time). Although several perfusion parameters are correlated with the activity scores (Table 1), only dT of SYN with 5s resolution was found to track the RA progression accurately (Fig.3).

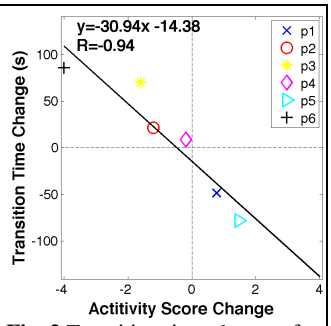

Fig. 3 Transition time change of synovitis (5s resolution) is highly correlated with the activity score change between baseline and follow-up scans.

CONCLUSIONS

High image quality DCE wrist MRI with temporal resolution of 5s and spatial resolution of 0.3x0.3x1.5mm has been successfully achieved and applied to evaluate neovascularization and perfusion in RA patients.

REFERENCES 1. Li X, et al, MRM 35:p211, 2012. **2.** Liu J, et al. QIMS, 4(1):p57, 2014. **3**. Otazo R et al. MRM 64(3):p767, 2010. **4**. Feng L et al, MRM 70(1):p64, 2013. **5.** Klain S, et al IEEE TMI 29(1):p196, 2010. **6.** Lustig M et al. MRM 64:p457, 2010. **ACKNOWLEDGEMENT:** NIH, UCB Inc