

Inversion Recovery Sodium MRI of Cartilage in Controls and Patients with Osteoarthritis at 7T

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Introduction.

Osteoarthritis (OA) is a degenerative disease of articular cartilage associated with a loss of glycosaminoglycans (GAG). Sodium MRI is highly specific to the GAG content and could be used to assess the biochemical degradation of cartilage in early stages of OA [1]. Due to the low resolution of the sodium images, the presence of synovial fluid in the voxels generates a partial volume effect that can affect the sodium quantification in cartilage and reduce the sensitivity of the method to changes of the GAG content in the cartilage. Therefore, fluid suppression with adiabatic inversion recovery (IR) has been proposed in order to increase the sensitivity of quantitative sodium MRI to cartilage degradation [2]. IR was obtained by applying an adiabatic inversion WURST pulse [3]. The goal of this preliminary study is to compare sodium quantification from sodium MRI with and without fluid suppression on controls and OA patients at 7T.

Materials and Methods.

Sodium images were acquired on 7 asymptomatic volunteers (mean age: 29±2 years) and 7 OA patients (mean age: 63±15 years, KL scores from 1 to 3) at 7T (Siemens) with a birdcage coil tuned at 78.6 MHz, with 2 sequences: Radial 3D (R3D) and Radial 3D with IR WURST (IRW). Acquisition parameters were, for R3D: 10,000 projections, TE 0.15ms, TR 100ms, FA 90°, TA 17min; for IRW: TE 0.15 ms, TR 140ms, FA 90°, WURST pulse 240Hz/10ms, TI 24 ms, TA 25 min. FOV was 200mm. Images were reconstructed in Matlab with a NUFFT algorithm [2-4] with an isotropic resolution of 2 mm. **Sodium quantification:** Sodium maps were calculated by linear regression using calibration phantoms of known sodium content and relaxation times (150, 200, 250, 300 mM) [2]. For each volunteer, the mean tissue sodium concentration (TSC) was measured in 4 slices in 3 regions in the cartilage: patellar (PAT), femoro-tibial medial (MED), femoro-tibial lateral (LAT). **Statistical analysis:** A Wilcoxon rank-sum test was applied on each pair of data OA R3D/OA IRW, CO R3D/CO IRW, OA R3D/CO R3D and OA IRW/CO IRW, in order to compare the TSC measured from all slices in controls (CO) and OA patients (OA) acquired with and without fluid suppression (IRW and R3D respectively). Statistical significance was defined as p<0.05.

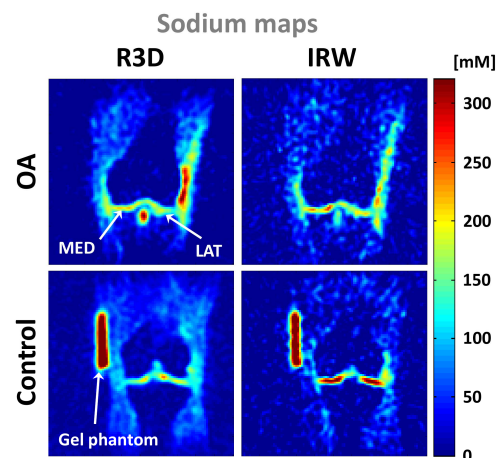


Fig. 1. Sodium maps.

Results and Discussion

Representative examples of sodium maps from one OA patient and one control, acquired with R3D and with fluid suppression (IRW), are shown in Fig. 1. **Tissue Sodium Concentrations (TSC):** Mean and standard deviation (std) of TSC over all slices measured in all volunteers are presented in Table 1. Due to the presence of synovial fluid ($[Na^+] = 150$ mM) and partial volume effect, the TSC are underestimated in the R3D images compared to the IRW images, which give values closer to the ones reported in the literature ($[Na^+] \sim 250-350$ mM in healthy cartilage, $[Na^+] \sim 150-250$ mM in depleted cartilage) [1,5]. The mean TSC from IRW in OA patients was detected below the limit of 250 mM for PAT and LAT cartilage, and very close to the limit for MED cartilage. **Statistical analysis:** Results from the statistical analysis are presented in Table 2. For both OA patients and controls, TSC measurements show significant difference between R3D and IRW ($p < 0.05$), due to the underestimation of TSC with R3D. No significant difference was observed between OA and controls in all three cartilage regions with R3D, but significant difference was detected in PAT and LAT from the data from fluid suppression IRW ($p < 0.01$). This shows the better sensitivity of IRW compared to R3D.

Table 1. Mean and std of TSC in OA patients and controls.

TSC (mM)	Seq.	PAT		MED		LAT	
		Mean	Std	Mean	Std	Mean	Std
OA	R3D	191	44	175	21	188	22
	IRW	231	60	251	32	216	33
Controls	R3D	204	51	211	55	194	41
	IRW	283	50	270	42	249	52

Table 2. P values from the Wilcoxon rank-sum statistical test. OA = OA patients, CO=Controls.

ranksum test		PAT		MED		LAT	
		p	p	p	p	p	p
OA R3D vs	OA IRW	0.007	<0.001	<0.001	<0.001	<0.001	<0.001
CO R3D vs	CO IRW	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
OA R3D vs	CO R3D	0.399	0.075	0.075	0.571	0.571	0.571
OA IRW vs	CO IRW	<0.001	0.118	0.118	0.008	0.008	0.008

Conclusion.

In this preliminary study, we show that quantitative sodium MRI with fluid suppression by adiabatic inversion recovery (IRW) reduces significantly the partial volume effect from synovial fluids or joint effusion in the measurements of sodium concentrations in articular cartilage, and therefore may allow to better differentiate OA patients from healthy controls. Future work includes studying more volunteers in order to assess the accuracy and specificity of the IR method.

References

[1] Borthakur A. et al, NMR Biomed 19(7), 781-821, 2006. [2] Madelin G. et al, JMR 207, 42-52, 2010. [3] Kupce E. et al, JMR A115, 273-276, 1995. [4] Inati S. et al, 2297, ISMRM 2005. [4] Greengard L. et al, SIAM, 443-454, 2004. [5] Shapiro E.M. et al, MRM 47, 284-291, 2002.

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