Delayed Contrast Enhanced MRI of Meniscus

W. Li[1], R. R. Edelman[1], and P. V. Prasad[1]

[1]Department of Radiology, Center of Advanced Imaging, NorthShore University HealthSystem, Evanston, Illinois, United States

INTRODUCTION

Osteoarthritis (OA) is considered as a multisystemic disease and its origin and progression are believed to be attributable to disease in one or more tissues in the joint such as articular cartilage, sub-chondral bone, synovium, capsule and meniscus (Radiology 2008. 249:591-600). Meniscus is a crucial load-attenuating fibrocartilage in the knee. The total concentration of GAG in the meniscus is lower than that in articular cartilage (Biochem J 1980; 185:705), and significant regional variations (higher in the inner and lower in the outer zones) have been demonstrated in porcine and bovine menisci (J Orthop Res 1997; 15:213). It was also found that only peripheral 10-25% of the meniscus has blood supply (The American Journal of sports Medicine 1982; 10:90) and the difference of MR contrast enhancement between inner (white) and outer (red) zone has been observed (The British Journal of Radiology 2004; 77: 641–647).

Delayed gadolinium enhanced MRI of cartilage (dGEMRIC) has been widely applied in articular cartilage, and demonstrated as an effective method for determination of glyconsaminoglycan (GAG) levels within the joint cartilage. It has also been shown that T1Gd (dGEMRIC index) in the meniscus showed a weak but statistically significant correlation with T1Gd in articular cartilage (Arthritis Rheum. 2007;56:1507). Since dGEMRIC in principle depends both on transport of contrast to the region of interest and the presence of GAG, the purpose of this study was to perform retrospective analysis of $T1_0$ and $T1_{Gd}$ in menisci (from subjects previously studied for dGEMRIC of the articular cartilage of the knee (Proc. ISMRM. 15 (2007) p. 3812)). The use of 3D Look Locker (3DLL) with a short echo time (~2 ms) allowed for this analysis. We have specifically evaluated any potential variations in $T1_0$ and $T1_{Gd}$ in the inner and outer zones of menisci and also compared contrast uptake with an ionic and a non-ionic contrast agent.

MATERIALS AND METHODS

Subjects: Data from eighteen subjects, including 10 patients with self reported OA and 8 healthy subjects without evidence of OA (HS) were included. **Imaging:** All subjects had post contrast studies at 120 min, using 0.2 mmol/kg $Gd(DTPA)^{2-}$ (Magnevist) as ionic and Gd(DTPA-BMA (Omniscan) as non-ionic contrast agent respectively. Ten subjects (HS=4, OA=6) also had pre-contrast studies. The acquisition related specific information can be found in previous report (Proc. Intl. Soc. Mag. Reson. Med. 15 (2007) p. 3812). **Data analysis:** ROIs for T1 mapping were defined at meniscus (anterior and posterior horns of both medial and lateral condyles) and weight-bearing regions of articular cartilage (the femur and tibia of both medial and lateral condyles). Each meniscus horn was further defined as the outer region (~ peripheral ¼ of the horn) and the inner region (central part to the outer region) separately (Figure 1). T_1 mapping was performed with a custom software analysis routine written in MATLAB (The Mathworks; Natick, MA). For the 10 subjects who had both pre- and post-contrast imaging, the enhancement was calculated by $|T1_0 - T1_{Gd}|/ T1_0$. The correlation of $T1_{Gd}$ in meniscus (averages of the anterior and posterior horns) with that in articular cartilage (the average of femur and tibia cartilage) obtained in every subject (OA & HS) was performed. Regression method and t-Test were used for data analysis.

RESULTS

T1 values of meniscus and articular cartilage are summarized in Table 1. The relationships in $T1_{Gd}$ of meniscus *vs.* cartilage, inner *vs.* outer zones, and with ionic *vs.* non-ionic contrast agent is shown in Figures 2-4 respectively.

Table 1. T_1 values of articular cartilage and menisci with Gd-DTPA

	Articular Carti.	Menisci	Outer Zone	Inner Zone	*p**
HS-$T1_0$ (n=4)	871 ± 59 (711-946)	809 ± 67 (657-907)	821 ± 91	800 ± 64	0.271
HS-$T1_{Gd}$ (n=8)	547 ± 53 (388-618)	376 ± 53 (302-515)	380 ± 54	372 ± 57	0.183
Enhancement**	~38%	~54%	~54%	~53%	
OA-$T1_0$ (n=6)	971 ± 77 (838-1171)	862 ±105 (733-1098)	891 ± 116	851 ± 129	0.079
OA-$T1_{Gd}$ (n=10)	445 ± 87 (273-608)	340 ± 46 (267-468)	345 ± 48	335 ± 53	0.169
Enhancement**	~55%	~61%	~62%	~62%	

* With paired t-test for inner and outer regions. ** Based on cases who had both $T1_0$ and $T1_{Gd}$

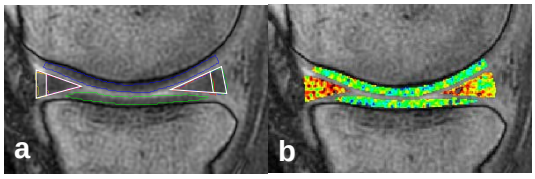

Figure 1. a. ROIs for inner and outer zones; **b**. T1 maps.

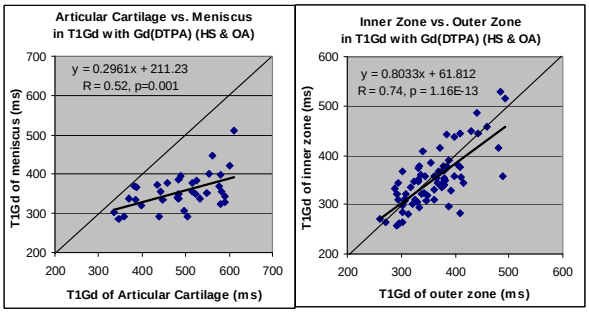

Fig 2 Cartilage vs. meniscus. **Fig 3** Inner zone vs. outer zone.

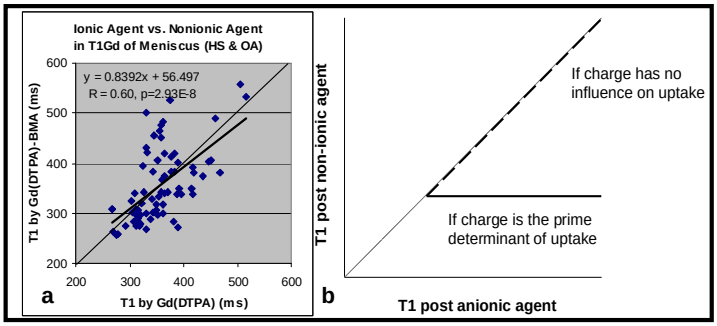

Fig 4 a. Ionic vs. Nonionic; **b.** the two extreme scenarios

DISCUSSION AND CONCLUSIONS

1) Compared to HS, the mean $T1_0$ of meniscus in OA were slightly higher, probably related to the higher level of hydration in OA. This finding is consistent with previous report on T2 and T1rho (Radiology 2008. 249:591-600) (Table 1).

2) On the other hand, the mean $T1_{Gd}$ of meniscus in OA is lower than in HS, indicating more contrast uptake in OA. The difference between OA and HS in T1 enhancement in articular cartilage was much higher (17%) then in meniscus (7%) (Table 1), which is consistent with the higher GAG content in articular cartilage.

3) Consistent with previous report (Arthritis Rheum. 2007;56:1507), the $T1_{Gd}$ of meniscus showed a modest but statistically significant correlation with $T1_{Gd}$ in articular cartilage (Fig 2).

4) Unlike previous report based on *ex vivo* measurements (J Orthop Res 1997; 15:213), our study failed to show any significant difference observed in T1 between the two zones (Table 1, Fig 3). This finding further indicates that the distribution of Gd-$DTPA^{2-}$ in the meniscus may not be dominated by GAG distribution.

5) The relationship of $T1_{Gd}$ in meniscus with the ionic and non-ionic agents (Fig 4 a), suggest the contrast distribution is less dominated by charge distribution. This behavior was similar to what we previously observed in articular cartilage of the control group (Arthritis Rheum. 2007;56:1507). Fig 4 b illustrates the two extreme theoretical scenarios. If charge had no effect on the uptake, there would be a 1:1 correspondence between the T1 measurements with either agent.

These findings collectively suggest minimal GAG based contrast distribution within the meniscus. The reason for the apparent modest but statistically significant correlation between $T1_{Gd}$ values of meniscus and articular cartilage (Fig. 2) may be related to parallel and synergistic changes (along with loss of GAGs) in transport of contrast in to the cartilage in OA