Perfusion measurements of subchondral bone in patellofemoral joint of rats with experimental OA model

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Introduction

Osteoarthritis (OA) is a disease related to the degeneration of cartilage, pathological change of subchondral bone and so force, which may lead to a series of inflammation and pain responses [1]. Previous reports have demonstrated the feasibility of using quantitative MR T2 measurements of articular cartilage or meniscus to monitor and early detect the progression of OA, which would contribute to clinical treatments [2,3]. On the other hand, altered perfusion in subchondral bone results in changes of fluid flow pressure and oxygen gradient, which could result in bone remodeling and degeneration of cartilages [4]. Dynamic contrast-enhanced (DCE) MRI provides a non-invasive method to measure bone perfusion, in which several perfusion parameters could be derived based on specific pharmacokinetic model [5]. Therefore, the purpose of this study is using DCE-MRI to investigate perfusion changes of subchondral bone in patellofemoral joint of rats with experimental OA model.

Methods

Eighteen Sprague Dawley rats (aged 8-week-old, weighed around 300g) were enrolled in this study and randomly separated into three groups (n=6 for each group). Group 1 was the control group. Group 2 was the experimental group whose right knee was performed with anterior cruciate ligament (ACL) transection for induction of cartilage degeneration at 8 weeks of age. Group 3 was sham group whose skin of the right knee was wounded. At 0, 4th, 13th and 16th week after ACL transection, all the right knees of the rats were imaged in a supine position in a 4.7T MR system (Bruker, Ettlingen, Germany) after being anesthetized with a halothane/oxygen mixture. The proceeding of this study is illustrated in Fig 1. The images were acquired with a quadrature surface coil using T1-weighted fast gradient echo sequence with TR = 100 ms, TE = 3.5 ms, slice thickness = 1 mm, matrix size = 256 x 256, in-plane resolution = 156 x 156μm^2, acquisition time = 6m24s. Temporal resolution is 12 seconds with a single slice acquired. ROIs of the patellar and femoral subchondral bones in the first imaging frame were selected as shown in the Fig. 2. Signal intensities in the ROIs were then averaged to fit the time-intensity curve based on Brix model and calculated the perfusion parameters. Student t-test was performed to investigate the difference between control and experimental groups on the parameters.

Results

Fig 3(a) illustrated the time-intensity curve of the patellar subchondral bone of rat in Group 2 at week 0, which showed moderate washout or elimination of the contrast agent from the bone marrow. Fig 3(b) displayed the corresponding curve of the patellar subchondral bone at 16th week, which showed reduced washout rate of the contrast agent. The results of the perfusion parameters of rats in Group 2 were shown in Table 1. There were no significant differences in parameter A (amplitude) at any time points. On the contrast, significant differences were shown in parameters k_{ep} (rate constant) and k_{el} (elimination rate) at the patellar subchondral bone from 8th and 16th weeks, respectively ($P<0.05$). Same results were obtained at the corresponding femoral subchondral bone.

Discussion

The present study indicated that the feasibility of MR perfusion imaging to assess the fluid change of subchondral bone in patellofemoral joint and early detect the progression of OA after ACL transaection. To our knowledge, this is the first time to analyze perfusion changes in patellar and femoral subchondral bones with dynamic contrast-enhanced MRI. A previous paper showed that bone marrow edema could be a biomarker of dynamic fluid changes and indicate variations in intraosseous pressure and blood flow, which is related to the regulation of bone remodeling and cartilage degeneration [4]. Significant decreases of perfusion parameters at 8th and 16th weeks after ACL transection reflected the early changes in capillary permeability and out flow. Hence, our results demonstrated that using DCE-MRI provides a method to investigate bone perfusion during the progression of OA, and it may be possible to early detect OA prior to the degeneration of knee cartilage.

References

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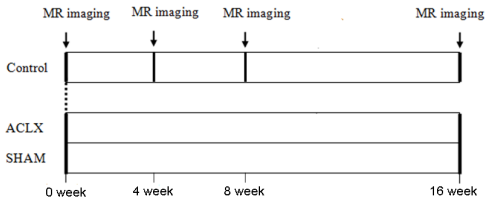


Figure 1 A diagram to represent the proceeding of this study.

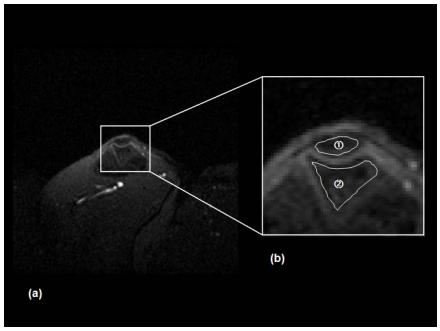
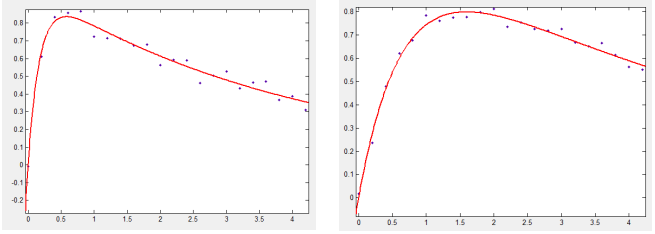


Figure 2 Illustration of the ROI selections.
(1) patellar subchondral bone (2) femoral subchondral bone



(a) (b)

Figure 3. Time-intensity curves of the patellar subchondral bone in Group 2 rat at week 0 (a) and 16th week (b) respectively.

Table 1

Perfusion parameters of patellar subchondral bone

	Weeks of age			
	0	4	8	16
A	5.16±2.27	4.49±1.13	5.05±2.69	4.58±2.56
K_{ep}	7.71±2.87	7.07±1.73	6.73±2.56	* 4.09±2.04
K_{el}	0.34±0.04	0.32±0.05	* 0.26±0.04	* 0.21±0.04