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RESEARCH ARTICLE

Diffusion-Weighted MRI Imaging and ADC Map of Patellar Chondromalacia

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ABSTRACT

Background: Chondromalacia patellae is damage to the cartilage at the back of the kneecap (patella). Magnetic resonance imaging is a valuable noninvasive technique with a unique ability to image soft tissue and has been used for cartilage evaluation.

Objective: This study examines the role of apparent diffusion coefficient (ADC) map and diffusion-weighted imaging (DWI) techniques in diagnosing chondromalacia patella.

Materials and Methods: The study consists of 31 participants, 19 patients with chondromalacia patella, and 12 healthy volunteers. The DWI imaging and ADC maps for all patients were recorded. Later the average amount of ADC for a lesion was calculated by drawing regions of interest.

Results: The results of DWI imaging in patients with patellae chondromalacia were observed as a nonhomogeneous patella signal and with an increase in the signal intensity at the focal, thickening of cartilage with surface irregularities, reactive changes subchondral, and bone marrow edema. The mean ADC values of the chondromalacia group and the health group were 1.34×10^{-3} mm^2/s and 1.07×10^{-3} mm^2/s, respectively.

Conclusion: Diffusion-weighted imaging can detect early-stage patellar chondromalacia. Besides, it may also help in the detection of cartilage defects.

KEYWORDS:
apparent diffusion coefficient; diffusion-weighted imaging; patellar chondromalacia

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INTRODUCTION

The knee is the largest joint in the body and has hinge a motion like opening and bending with rotational movements around the longitudinal axis. The knee joint is susceptible to more injury than any other joints in the body as it can tolerate heavy forces.[1] The irreversible cartilage damages are caused by trauma, arthritis, osteoarthritis, osteoarthritis chondrite disc, and chondromalacia.[2] Self-healing ability in articular cartilage damage in the knee is limited, leading to the change in the internal matrix of the chondral defect that includes collagen network degradation, reducing proteoglycans contents, and water content increase because of cartilage swelling.[3] Therefore, one of the most pivotal steps for early diagnosis of knee joint degradation is to examine the cartilage health.

Magnetic resonance imaging (MRI) is a noninvasive valuable imaging technique that is applied to picture soft tissues to examine

cartilage damages. The articular cartilage health could be checked by advanced techniques in MRI like diffusion-weighted imaging (DWI).[5] This method shows the tissue abnormality by microscopic changes in water molecules movement in the cartilage.[6] DWI sequence in musculoskeletal assessment system is necessary when other cartilage tests fail to analyze the joint problems.[7]

In a fast-spin echo (FSE) imaging, the contrast T2 of hyaline cartilage signal is average. Hence a observable fluid allows a good contrast for identification of abnormalities and the cartilage pathology. Numerous clinical studies have suggested the FSE T2-weighted (W) usage in the cartilage abnormalities evaluation for its high sensitivity and specificity. Artifacts, a pattern that may mistakenly show sickness, are rarely found in the FSE sequences.[8]

Diffusion imaging is obtained based on the molecular movement of water under internal and external obstacles. As a result, the biochemical structure of the cell is determined by measuring the movement of water molecules.[9] DWI is achieved by the pulse sequence of spin-echo echo-planar imaging (SE EPI). An apparent diffusion coefficient (ADC) map helps remove the effects other than diffusion (like T2 weighting). ADC mapping is created by combining two images with and without DWI and using two b-value images. The advantage of using two b-values images is that an ADC map free of all contrast influences apart from the displacement of water during the diffusion gradient application can be created. ADC mapping could also be applied with a b-values from 0 to 1000 mm^2/s. The ADC mapping sensitivity is higher versus DWI because the latter can be affected by the magnitude of the diffused water molecules.[10] So, the present study mainly aims to use ADC map and DW-MRI imaging to examine the patellar chondromalacia health.

MATERIALS AND METHODS

After obtaining the consent of patients, our institutional review board approved the present prospective study. This study included 31 patients (12 healthy people and 19 patients with patella chondromalacia). Patient screening was performed with an MRI imaging and questionnaire of the MRI department. The confirmed cases, underwent an MRI scan. A four-channel quadrature coil with a full cover of the knee was installed and configured for all the patients.

All images were performed with a GE 1.5 Tesla scanner (GE, Chicago, IL). A typical sequence of MRI includes the axial spin-echo T1-w with a repetition time (TR) of 700ms, echo time (TE) 18ms, and T2-w (TR, 3260 ms; TE, 35ms). Axial diffusion-weighted single-shot SE EPI sequence was as follows: TR, 2000ms; TE, 88 ms; b-value, 0 and 600 mm^2/s; image matrix, 256 × 256; fild of view (FOV), 180×180; Slice thickness, 3mm; Gap, 3.3; and acquisition time, 4 min and 52 s. The average ADC value for the target lesion was reported by dragging a certain area (ROI) in the injured part and considering the ADC value as a quantity. This style of ROI drawing with consideration of data about the lesion part helps in precise calculation. ROI was drawn in a axial section series for every lesion. The target lesion was presented with maximum diameter, and the surrounding normal tissue was off the scope in the ROI drawing (Figure 1). Finally, the research outcomes were statistically analyzed using SPSS16 software (SPSS, Chicago, IL).

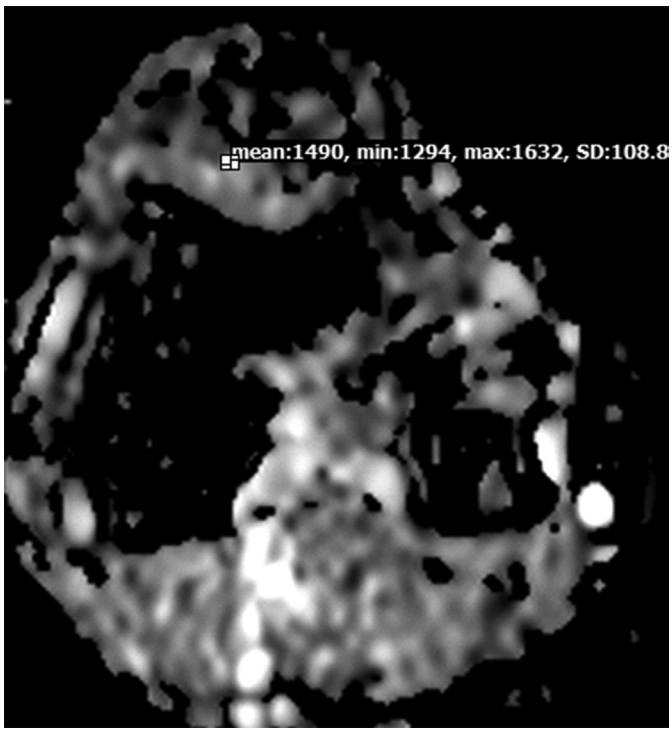

Figure 1 Placement of ROI and measurement of the average ADC.

RESULTS

DWI imaging outcomes exhibited degree one of the articular cartilage damage in DWI imaging was a nonhomogeneous patella signal with an increase in the signal intensity at the focal. The articular cartilage injury in degree two of the DWI images indicated increased cartilage thickness along with surface irregularities. Besides, A sharp increase in the signal intensity, subchondral reactive changes, and bone marrow edema, was also observed (Figure 2).

The lesion with a high signal intensity in DWI images is denoted as patellar chondromalacia with a b-value of zero, if the signal intensity was decreasing with increasing b-value. Moreover, in this situation, the ADC maps are specifically seen to exhibit hyper signal compared with their surrounding tissues. Finally, different degrees of cartilage damages were determined according to their signal intensity.

The lesion degree in study patients with cartilage damage in DWI images were evaluated using χ^2. In two patients (10.5%) lesions were absent, four (21.1%) had first-grade cartilage injury, and 13 cases (68.4%) exhibited second-grade cartilage injury (Table 1).

The amount of ADC was analyzed in the control patients and the group of Chondromalacia Patellar (CMP) lesions through an independent t-test. The study groups had a significant difference in terms of ADC map average ($P < 0.0001$; Table 2).

The amount of ADC in the group of the CMP and the control patients was recorded as 1.34×10^{-3} and 1.07×10^{-3} mm^2/s,

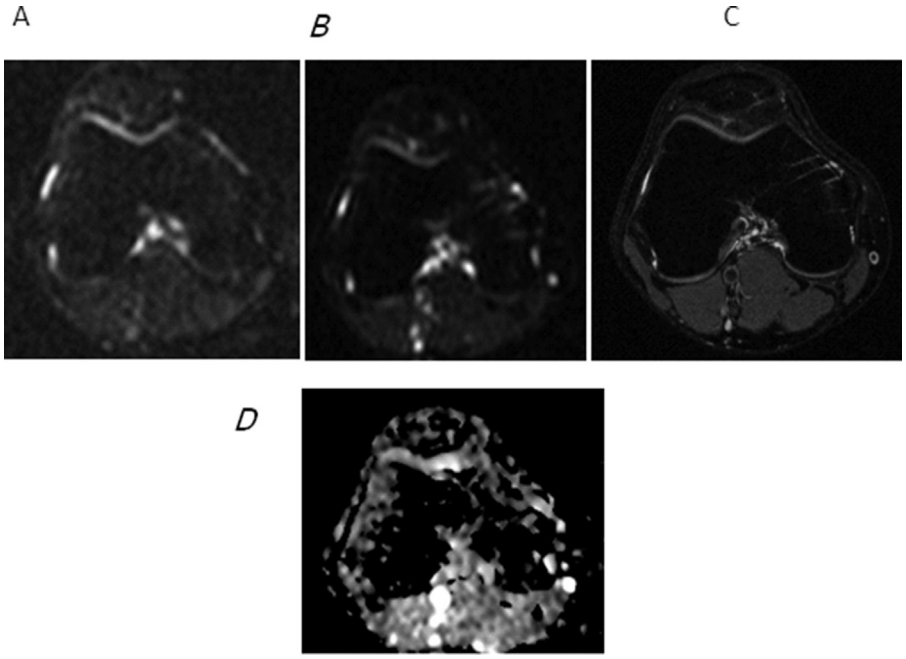

Figure 2 Visual presentation of the articular cartilage damage (chondromalacia) in DWI images with a b-value of 600 (A) and 0 (B). Visual presentation of a T_2 contrast image (C). ADC map (D).

Table 1 Evaluation of DWI image results in the study and control patients.

Gradation with DWI	Normal		Grade 1		Grade 2		Total	
Study group	**2 (10.5%)**		**4 (21.1%)**		**13 (68.4%)**		**19 (100%)**	
Control patients	12	100	0	0	0	0	12 (100%)	100
Total	14	45.2	4	12.9	13	41.9	31	100

Table 2 Comparison of ADC map average between the control and patient groups.

Signal detection		N	Mean	Standard deviation	Standard error mean
ADC map	Normal	12	1070.0000	44.84722	12.94628
	Abnormal	19	1342.1579	153.56043	35.22918

respectively. The amount of ADC in the control patients and the group of patellar chondromalacia had a significant difference and showed a dramatic increase in the group of CMP.

DISCUSSION

DWI can provide useful information about the diagnosis of damage in the bone marrow, cartilage, and muscle.[11] Abnormality detection in diffusion images is performed by using the display of restrictions on the free movement of water molecules. If the tissue damage causes restrictions on the free movement of water molecules, image appearance is seen brighter, and if the lower limitation occurs in the movement of water molecules, the images appears with lower signal intensity.[12]

DWI can predict changes in the structural changes of the cartilage. In many cases of articular diseases, one of the most important steps is to assess the cartilage tissue composition. The prevalence of degradation of articular cartilage among people is increasing. Hence, immediate diagnosis of early degradation is an important step in their diagnosis process.[12] DWI imaging is seen to provide some deformations that an ordinary MRI fails to detect.[13] In such cases a further assessment of the DWI sequence in the musculoskeletal system is recommended.[14]

Another technique that aids in detecting abnormality in diffusion images is an ADC map, which can measure diffusivity in tissue. ADC maps are correlated to the clinical deficit and are potentially useful for early diagnosis and longitudinal evaluation, especially in pharmacological trials. ADC maps need to be investigated to avoid misinterpretation of visual assessment.[15]

Many previous studies support the use of DWI and ADC maps. Aydin et al.[16] used this technique for the diagnosis of meniscal tears of varying types. They performed ADC mapping in coronal planes with b-factors of 50, 400, and 800 sec/mm^2 and DWI by 3D-SE EPI in sagittal and coronal planes. No significant statistical differences between ADC mapping and applied b-values versus DWI, routine MRI sequences. But ADC mapping with a b-value of 600 sec/mm^2 revealed a higher specificity and sensitivity compared to other imaging modalities. Their study

outcomes suggested that ADC mapping and DWI imaging techniques particularly with a b-factor of 600 sec/mm^2 can be an effective imaging technique compared with the routine MR imaging sequences for patellar chondromalacia.

The most common MRI pulse sequence used for DWI; is EPI. The single-shot EPI technique enhances the information gathering. Furthermore, it is the most effective way to cover a wider anatomic area in a short time. Unfortunately, this method is often associated with magnetic susceptibility artifacts.[17]

Magnetic susceptibility artifact occurs between the two tissues with different magnetic characteristics such as air and tissue or bone and soft tissues. Musculoskeletal system structures are more affected by magnetic susceptibility artifacts versus brain tissue. Hence, the EPI with other sequences is used to reduce the magnetic susceptibility artifacts in their diffusion images.[18]

DWI restricts the quality, resolution, contrast, and long echo time affecting the interpretation of diffusion images of the articular cartilage versus the brain.[19]

Diffusion measurements of articular cartilage are a promising technique for the evaluation of cartilage damage. Unfortunately, limited clinical trials examining DWI and ADC mapping of the knee are present. This study performed the DW-MRI imaging and ADC map of patellar chondromalacia for the first time in Iran. Along with the support of previous studies has proven that the available sequences are fast and can be easily applicable with routine MRI sequences. Moreover, these new MRI techniques describe critical information about patellar chondromalacia, mainly ADC mapping by b-value of 600 sec/mm^2 for menisci of the knee.

CONCLUSION

This study showed diffusion as a biomarker for cartilage damages is a valuable method in early osteoarthritis diagnosis.

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