CASO QUIZ

Utility of the T2 mapping sequence in the early diagnosis of chondromalacia using non-invasive MR cartilage imaging techniques

María del Carmen Cadena-Villela,* Juan Eugenio Cosme-Labarthe,*
Carmen Rocío Ramírez-Carmona,* Ernesto Roldán-Valadez*

Resumen

El cartílago de las articulaciones diartrodias reviste sus superficies de contacto y es de gran importancia para una adecuada dinámica articular, absorbe y distribuye las cargas (la mayor parte la absorben los meniscos), también disminuye la fricción entre cóndilos femorales, favorece la adecuada distribución de líquido sinovial y contribuye a mantener la amplitud articular. Las lesiones condrales están asociadas a eventos traumáticos, degenerativos e inflamatorios y tienen un impacto importante sobre la calidad del aparto locomotor, tanto del deportista profesional o amateur como de la población en general. Las alteraciones degenerativas articulares en EUA implican la segunda causa de ausencia laboral después de las enfermedades cardiovasculares. La evaluación por resonancia magnética permite una evaluación precisa, detallada y no invasiva del estado estructural y fisiológico del cartílago; en un estudio de resonancia magnética de rodilla convencional se demuestra la morfología del cartílago, se detectan lesiones internas, defectos, erosiones y fisuras; hay secuencias fisiológicas específicas tales como el mapeo T2, el cual detecta alteraciones en la matriz condral, estadios tempranos de condromalacia, que pueden correlacionar con tiempos de relajación T2 alargados, si existe depleción de fibras de colágeno y proteoglicanos, dependiendo del posproceso de la imágenes con el software específico. Se presenta el caso de un futbolista con lesión del ligamento colateral medial y rodilla dolorosa, en la cual el cartílago no demostró alteración en la RM de rodilla convencional (secuencias morfológicas); sin embargo, el uso del mapeo T2 (secuencia fisiológica) permitió demostrar el incremento en los valores de los tiempos de relajación en T2 que correlaciona con un estadio temprano de la degradación de la matriz condral.

Palabras clave. Matriz del cartílago de proteínas. Condromalacia rotuliana. Secuencia funcional.

Abstract

The articular cartilage is the chondral lining of joint surfaces which has crucial importance on appropriate articular dynamic functioning, it absorbs and distributes load forces (most of them are absorbed by menisci), it also decrease friction between femoral condyles, favors an adequate synovial fluid distribution and contributes to maintain the articular width. Chondral lesions are associated to traumatic, degenerative and inflammatory events, and have an important impact on life quality of musculoskeletal system in amateur and professional athletes, and in general population. Nowadays articular degenerative conditions in US represent the second cause of labour absenteeism following to cardiovascular diseases.
Magnetic resonance imaging allows an accurate, detailed and noninvasive evaluation of the structural and anatomic cartilage condition; the sequences in a conventional knee MRI demonstrate the cartilage morphology, detect inner lesions, defects, erosions and fissures; and there are specific physiologic sequences as the T2 mapping which detected alterations in the matrix, earlier stages of chondromalacia, and can correlate the T2 values with the depletion of collagen fibers and proteoglycans depending on post-processing of images with specific software. We present the case of a painful knee in which the cartilage did not show any alteration in the conventional knee MRI (morphologic sequences), however the use of the T2 mapping (physiologic sequence) allowed demonstration of increased T2 relaxation-time values representing an early chondral-matrix degradation stage.

Key words. Cartilage matrix protein. Chondromalacia patellae. Functional sequence.

* Magnetic Resonance Unit, Medica Sur Hospital.

Correspondence:
Juan Eugenio Cosme-Labarthe, M.D.
Professor, postgraduate course in Whole Body MRI; UNAM.
Attending Radiologist at Magnetic Resonance Unit. Medica Sur Hospital & Clinic Foundation.
Puente de Piedra 150. Col. Toriello Guerra. Tlalpan. C.P. 14050. Mexico City, Mexico.
E-mail: drcosme@gmail.com

INTRODUCTION

The articular cartilage lesions are frequent; their etiology is multifactorial, including traumatic, inflammatory (arthropathies), infectious (septic arthritis) and degenerative causes. Lesions of degenerative origin are the most common, and constitute an important public health problem due to the high economic and social cost that causes the treatment and labour absenteeism related expenses.[1]

Currently magnetic resonance (MR) is the best method for evaluating articular cartilage lesions because of its non-invasive nature, high sensitivity and specificity, and high contrast and multiplanar capability;[2] furthermore it has the potential to provide morphologic information about cartilage, such as the presence of fissures and defects of variable thickness, as well as obtaining quantitative functional parameters of the cartilage tissue.

Conventional plain films and computed tomography (CT) studies are still used in some centers with no MRI equipment to detect secondary articular damage such as articular space narrowing, osteofites formation or subchondral cysts, but are not able to directly visualize the chondral lining; besides its sensitivity is low for detection of early chondral lesion when used as single image modality.[3],[4] The combination of arthrography, conventional plain film and CT is mildly invasive and provides limited information about only the chondral surface,[5] moreover requires ionizing radiation.

The gold standard for the evaluation of the articular cartilage surface is the arthroscopic procedure, permits a direct visualization of color changes and detection of fissures;[6] however arthroscopy is invasive and expensive. MR assessment using T2 map allows a quantitative evaluation of chondral matrix. This method is fundamentally based on the documentation of the collagen fibers matrix disorganization caused by degenerative conditions, which becomes loose enabling a higher content of water molecules, producing an increased T2 relaxing times over normal levels.[1] This means that increased T2 relaxing times in a cartilage focal area correlate with early chondral matrix degradation, especially of the collagen fibers component (early stage of chondromalacia). In this report we present a case of a painful knee in which the cartilage did not show any alteration in the conventional knee MRI (morphologic sequences), however the use of the T2 mapping (physiologic sequence) allowed demonstration of increased T2 relaxation time values representing an early chondral-matrix degradation stage. A brief review of the literature is also presented.

CASE REPORT

A 28-year-old professional soccer player attended the emergency room after a forced valgus mechanism during his soccer game. Physical examination performed by an orthopedic surgeon suspected medial collateral ligament injury. The patient underwent knee protocol that show partial tear of medial collateral ligament (Figure 1), the rest of the ligaments and the cartilage in the morphologic sequences were intact, the additional physiologic sequence T2 mapping (for cartilage assessment) was also performed, and the post-acquisition processing revealed focal areas whit enlarged T2 relaxing times in the posterior surface of the medial femoral condyle of the left knee (Figure 3) which correlates whit early chondral matrix degeneration, the patellar cartilage revealed normal T2 relaxing times (Figure 2), the patients was managed whit

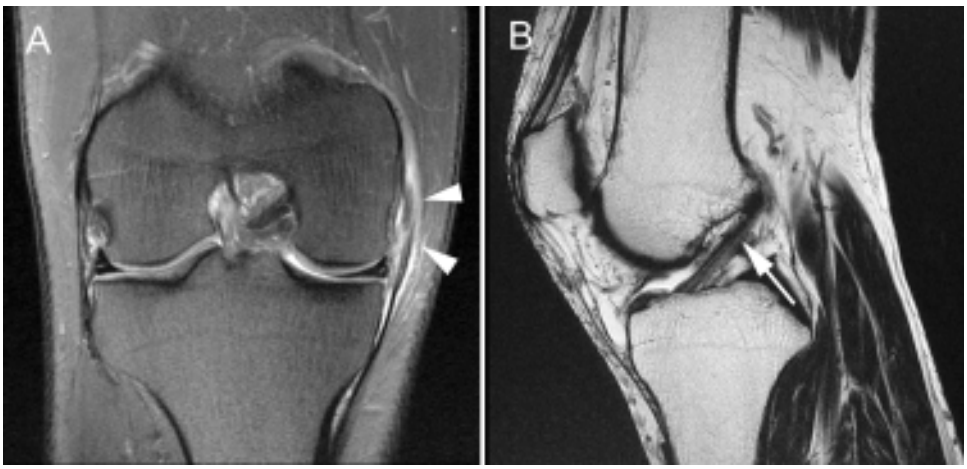

Figure 1. A. Coronal proton density fat suppressed image which demonstrates a partial tear of the medial collateral ligament with apparent integrity of the chondral lining. **B.** Sagital T2-weighted image shows normal anterior cruciate ligament.

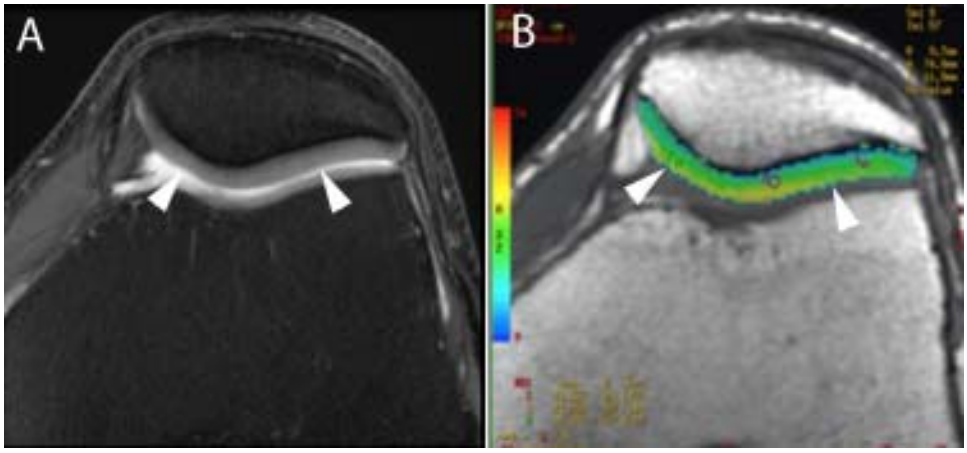

Figure 2. A. Axial proton density fat suppressed image demonstrates normal cartilage morphology, contours and signal. **B.** T2 map which confirm the integrity of chondral matrix in the color map and in the quantitative analysis of the T2 relaxing time values less than 50 miliseconds.

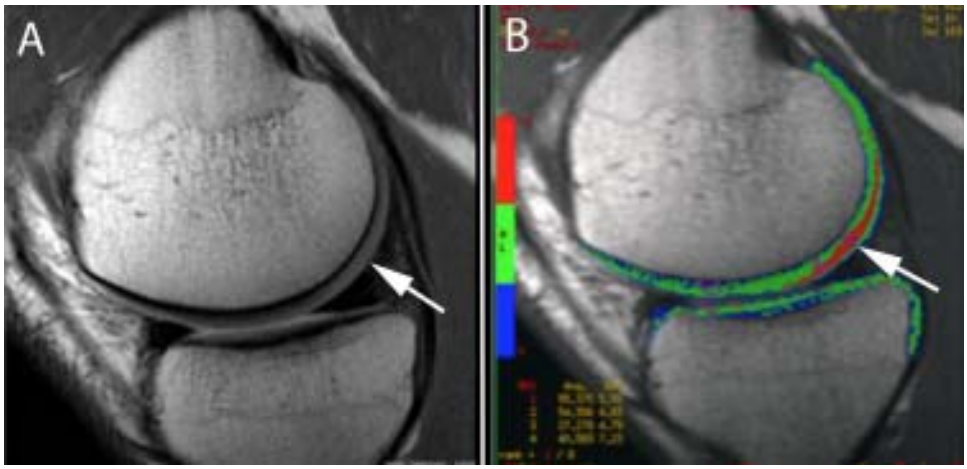

Figure 3. A. Sagital proton density image, cartilage shows integrity with normal thickness and signal. **B.** T2 mapping physiologic sequence shows in the posterior margin of the medial femoral condyle, increased T2 relaxing time values greater than 60 miliseconds which correlates with an early chondral-matrix degradation stage (precocious chondromalacia) especially of the type 2 collagen fibers.

conservative measures and a follow-up evaluation whit MRI and T2 mapping sequence was scheduled in 6-months.

DISCUSSION

An early detection of the structural alteration of articular cartilage has great importance in prevention, considering this finding is the first element in the disturbance cascade of osteoarthrosis, it causes matrix degradation and increased water content, which is detected in the evaluation by the T2 mapping MR sequence.

Morphologic evaluation in a conventional knee MRI

MR ideally should provide an accurate evaluation of the cartilage thickness, demonstrates morphologic changes in the surface and shows signal intensity changes in the inner cartilage, such as anomalies in the subchondral bone signal.[7] The sequences with higher contrast between cartilage and fluid, and good contrast between cartilage and subchondral bone are the best for the evaluation of chondral pathology. The sequences that better accomplish this contrast conditions are spin echo and fast spin echo with proton density (PD), STIR and T1 weighted on its arthro-resonance modality and SPGR. On fat saturated PD and STIR there is a high tissue contrast, on these sequences the cartilage shows intermediate signal, fluid has a higher signal and subchondral bone, low signal. On fat suppressed T1 weighted SPGR, the cartilage has high signal, and fluid has low signal such as the subchondral bone.[1,2]

There are several chondral lesions classifications with both arthroscopic and radiologic perspectives, one of the most often used by the orthopedists is the classification established by the International Cartilage Repair Society (ICRS) (Table 1).

Table 1. Arthroscopic and magnetic resonance classification system for chondral lesions suggested by Outerbridge in 2001 and the International Cartilage Repair Society (Brittberg) in 2005.

Grade	Arthroscopic classification	MR classification
0	Normal.	Normal.
1	Softening or swelling.	Normal contour ± abnormal signal.
2	Shallow fibrillation, cartilage defects (< 50% of cartilage thickness).	Superficial fraying; erosion or cartilage defects of less than 50%.
3	Surface irregularities and areas of thinning (> 50% of cartilage thickness).	Partial-thickness defect of more than 50% but less than 100%.
4	Cartilage defects and exposure of subchondral bone.	Full-thickness cartilage loss.
5		Full thickness lesions with penetration of the bony endplate.

The morphologic features of the chondral lesions that should be stated on a magnetic resonance report are the following:

- Surface extension (with anteroposterior and transverse measures).
- Lesion depth (percentage of the cartilage thickness involved).
- Location in the articular surface (load zone compromise).
- Subchondral bone alterations (edema, cysts).
- Chondral or osteochondral intra-articular loose bodies.

Functional evaluation and chondral composition

Special MR methods have been developed in order to assess articular cartilage, as T2 map, diffusion weighted sequence, late enhancement and detection of sodium concentration. Most of them remain under investigation, T2 mapping is the most developed in daily practice.[7]

Articular cartilage is composed 70% of water, the rest consist essentially on collagen type II fibers in 25% and 5% on glycosaminoglicans.[7] These elements are arranged on four different layers and different orientation.

T2 mapping is based fundamentally on the fact that degenerative alterations cause collagen matrix disorganization, which becomes loose and allows a higher water content inside, this produce an arising on T2 relaxing times over normal values (> 50-60 milliseconds).[8] Cartilage T2 mapping makes possible to measure spatial distribution of water molecules, revealing increased or decreased water content areas on cartilage, this is directly related with chondral damage.[9]

Several layers of collagen fibers can be recognized in articular cartilage, depending on its depth and orientation, a superficial layer where collagen fibers are arranged parallel to cartilage, the transitional layer where collagen fibers have a random orientation (in this zone occur the first age related changes)[10] and the radial layer where the fibers are organized perpendicularly to subchondral bone and where the collagen fibers plaiting is more compact. Thus, T2 relaxing times are lower on deeper layers of normal cartilage and higher toward the superficial portions.[1]

The measuring of T2 relaxing times requires locating a ROI using dedicated software in a workstation, which permits quantifying chondral alterations. T2-mapping post-processing uses this information and generates gray and color maps, representing variations in cartilage relaxing times, according to hydration and existing collagen fibers. Since T2 sequence is highly effective on detecting hydration changes, T2 mapping has demonstrated an excellent usefulness in quantifying alterations on degeneration sites (rupture or early degradation of collagen matrix).[11-13]

The indications of T2 mapping are pointed toward general symptomatic and asymptomatic populations especially overweight, patients with any loading axis alteration, and amateurs or professional athletes. Its major usefulness is to detect early intra-substance cartilage alterations and to monitor postsurgical or conservative treatment follow-up of chondral injuries.[10,12,14] With this method is possible also to survey the progress of chondral alterations after pharmacological treatment or other type of therapy.

CONCLUSION

MR has proved to be the best non-invasive method in imaging assessing of articular cartilage. T2 mapping is able to perform a quantitative analysis of the

collagen matrix and detect its damage in early stages, these alterations can be overlooked in purely morphologic MR studies, carrying a delay in diagnosis and treatment. Currently, molecular biochemistry and pharmacology developments have made possible the treatment of early chondral lesions, which require a timely diagnosis.

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