Global Journal of Imaging and Interventional Medicine
2020; 1(1): 2-9.
ISSN Online: 0000-0000; ISSN Print: 0000-0000
Website: http://naturescholars.com
Email: Glo_J_Iim@126.com
Publisher: Scholars Publishing, LLC

Review

The Application of Magnetic Resonance Imaging T2 Mapping in Detecting Early Knee Joint Injury

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Received: May 29, 2019; Accepted: June 30, 2019; Published online: September 6, 2019.
Cite this paper: Chun-Lin Li, Bo-Xu Ren. (2020) The application of magnetic resonance imaging t2 mapping in detecting early knee joint injury. *Global Journal of Imaging and Interventional Medicine*, 1(1):2-9.
http://naturescholars.com/gjiim.010102. https://doi.org/10.46633/gjiim.010102.

Abstract

The knee is the largest flexion joint of the human body. Its structure is complex, for instance, it can withstand strong leverage, but nevertheless it is extremely vulnerable. In recent years, with the changes in people's lifestyles and increasing pressure in work and life, the risk of knee joint injury, especially the risk of meniscus and articular cartilage damage, has increased significantly. Arthroscopy is the golden standard for the diagnosis of knee injury, but it has certain limitations in the early and convenient diagnosis of the injury. Moreover, although this examination is an invasive operation, it may causes a certain degree of secondary damage to the patient during the examination. Magnetic resonance imaging (MRI) T2 mapping technology is a new MRI technology that is developed in recent years. It can indirectly reflect the structures and histological composition of articular cartilage before the morphological changes of articular cartilage. Therefore, this technique is of great significance for early knee injury diagnosis. In this article, we reviewed the basic physiological and pathological changes before and after knee injury, as well as the conventional knee joint technique, focusing on the imaging principle and diagnostic advantages of the T2 mapping sequence and comparing it with conventional MRI sequences.

Key words: MRI, T2 mapping, Knee, Articular cartilage, Meniscus

Introduction

The knee joint is the largest, most complex, most durable and most vulnerable joint in the human body (1). Its function is to adjust the distance between the pelvis and the foot to complete

various activities. The knee joint has a large negative gravity between the lower limb and the femur and tibia, and the articular cartilage has a non-learning effect on the shape and function of the joint, and the knee joint cartilage damage is quite common. In foreign countries, some scholars have done statistics, and more than 60% of patients undergoing arthroscopy have articular cartilage damage (2). Therefore, it is necessary to develop a simple, non-invasive technical method to evaluate the early damage of the knee joint. As a non-invasive imaging test, MRI is easy to operate and procedurally strong. MRI routine sequences are often used to assess anatomical and morphological changes in knee joint cartilage (3). With the continuous updates of MRI equipment and the continuous innovation of various inspection techniques, the diagnostic accuracy of knee joint injuries has also been continuously improved. Especially for the knee joint ligament, muscle, meniscus and cartilage of knee joint, the diagnostic effect is more obvious, because the test results are more intuitive and the misdiagnosis rate is relatively low. Thus, it has been widely used in clinical examination. In recent years, with the continuous development of molecular biology, molecular imaging methods have become one of the most commonly used techniques for studying the physiology of articular cartilage physiological imaging technology at home and abroad. T2 mapping can be used as a marker to evaluate cartilage tissue repair (4). It quantifies the changes in tissue components in the articular cartilage by measuring the MRI T2 relaxation time, which can be visualized more visually before morphological changes occur after cartilage injury (5, 6). A number of studies have shown that its great value in the early diagnosis of knee osteochondral injury. 1.5 Tesla and above devices produced by most manufacturers in China, almost all can process T2 mapping technology. The most representative one is the uMR570 series independently developed by Shanghai United Imaging (Figure1). The purpose of this article is to explore the clinical value of this new technology in knee cartilage injury.

Figure 1. uMR780 magnetic resonance imaging equipment developed by Shanghai United Imaging Healthcare Co., Ltd.

1. Normal structure of knee joint articular cartilage

The hyaline cartilage of the knee joint is a special connective tissue containing type II collagen fibers. In histology, it is divided into 4 layers, the outermost surface layer, the middle transition layer, the lower radioactive layer and the deepest calcified layer (7). The surface layer is mainly composed of dense collagen fibers parallel to the cartilage surface, and has low permeability to liquid flow; the transition layer is located between the surface layer and the deep layer, and the collagen fibers are randomly or obliquely arranged, rich in

proteoglycans; The collagen fibers are bundled in a large bundle and arranged perpendicular to the subchondral bone surface. The deepest layer contains a small amount of protein polysaccharide where there is a wavy tidal line between the calcified layer and the subchondral layer, which is composed of dense collagen fibers parallel to the cartilage surface. MRI signal characteristics of articular cartilage can reflect tissue structure and biochemical characteristics, which are affected by different scan sequences and parameters. For example, in the FSE T2WI sequences, its signal do reflect the structural characteristics of the cartilage surface containing three layers. Many scholars have performed MR signal performance on normal articular cartilage (8). Histologically controlled studies and analysis of multi-slice MRI findings have many explanations for the causes of delamination of articular cartilage on MRI, and the phenomena observed are not completely uniform (9).

2. Pathological basis of articular cartilage injury

The early stage of articular cartilage injury is characterized by focal changes in the surface layer and shallow fragmentation of the cartilage matrix, such as cilia tears on the joint surface. The fissure progresses gradually, and the surface of the joint surface is called exfoliation. When the cartilage is involved, it is called cartilage fibrosis (10-12). Under the combined action of various pathogenic factors, the crack affects the whole layer of cartilage and changes in the metabolism of cartilage matrix. Among of them, the most important manifestation is the decrease of the concentration of proteoglycan. After the articular cartilage was finally completely worn, and the subchondral bone was exposed (13-15). In the progress, the earliest pathological changes of subchondral bone are bone micro-injury and bone marrow edema. Further development leads to subchondral bone hyperplasia, cartilage thinning and exfoliation, until the articular surface of the bone is exposed, that is, the bone is ivory-like. The exfoliated cartilage and broken bone fragments form a free body in the joint cavity. Increased intra-articular pressure leads to local tissue necrosis and loose structure. Pseudocysts are formed in the subchondral bone, and osteoporosis is formed by bone hyperplasia at the joint edge. Subchondral bone changes after chronic cartilage injury last for 10 to 20 years, or even longer, but in general, symptomatic patients have more obvious subchondral bone abnormalities (16).

3. Conventional sequence of MRI for the diagnosis of knee cartilage injury

MR imaging by GE Signa 3.0 T HDxt is a typical example for MRI routine inspection. Scanning sequences include FSE sequence sagittal fat inhibition proton density image, FSE sequence sagittal T1WI, FSE sequence coronal fat suppression proton density image, FSE sequence coronal T1WI, sagittal 3D T1WI FSPGR and sagittal 3D T2WI Cube Sagittal T2 mapping. The main scanning parameters are shown in Table 1.

4. Diagnosis of knee joint cartilage injury by MRI T2 mapping sequence

A study by Taehee Kim et al. showed that T2

mapping was associated with histological degeneration of the cartilage, it may be a biomarker for osteoarthritis articular cartilage. So T2 mapping may be more beseem for the early diagnosis of articular cartilage degeneration in the knee joint (17).

Table 1: MRI main scan parameters for knee articular cartilage

Sequence	TE (ms)	TR (ms)	FOV (cm)	Thickness/ gap(mm)	Scanmatrix	NEX
FSE PD FS	31.6	1860	16×16	5.0/1.0	320×256	2
FSE T1WI	10.4	440	16×16	5.0/1.0	320×224	2
3D Cube	2.4	3000	25×25	1.2/-0.6	288×288	1
3D FSPGR	116.5	6.6	18×16.2	1.2/-0.6	320×256	1
T2-mapping	30,60,90,120	2400	20×20	4.1/1.0	256×192	1

4.1 Principles of imaging technology for T2 mapping

T2 mapping technology is a widely used MRI physiological imaging technique applied to cartilage both at home and abroad(4). It uses a multi-layer and multi-echo spin echo sequence to form a pseudo-color image through post-processing of the workstation, and then measures the T2 value of the tissue by ROI (Figure 2) to achieve–quantitative evaluation of organizational structure (18). T2 mapping imaging refers to the technical process of obtaining T2 relaxation time map that can be generally divided into two basic steps. Firstly using multi-layer and multi-echo SE sequence, scanning with the same TR time and multiple different TE times Obtain the T2WI series was obtained; then, use the formula S(t)=so exp(-7t/T2) was used to calculate the T2 value of each voxel (voxel) in T2WI. After calculating the pixels and voxels, the reconstructed image can be quantified by analysis of color-order or gray-scale of T2 relaxation time images. The T2 values can reflect the specificity of the tissue by describing the attenuation of the transverse magnetization vector of the tissue. The value of the MR signal by measuring different echo times is calculated by the equation formula (19). The T2 value in T2 mapping imaging is one of the non-invasive indicators for detecting cartilage degeneration as it is sensitive to hydration and molecular changes in tissues. Changes in the internal macromolecules before the general morphology of the cartilage changes, cause corresponding changes in their moisture content. Because T2 mapping technology is very sensitive to tissue water and biochemical structures. The combination of water protons in cartilage collagen-proteoglycan promotes the attenuation of T2 value, which reduces the signal of cartilage on T2WI, while the free water proton in surrounding synovial fluid is high signal. When the collagen and proteoglycan in the cartilage are reduced, the signal on the T2WI is also increased, and the edema of the cartilage also enlarges this effect. Therefore, the matrix changes and edema changes of cartilage can be reflected in T2 mapping, so the T2 relaxation time map can detect the changes of early osteoarthritis (OA) early cartilage matrix

macromolecules before the obvious changes in articular cartilage morphology (13, 14).

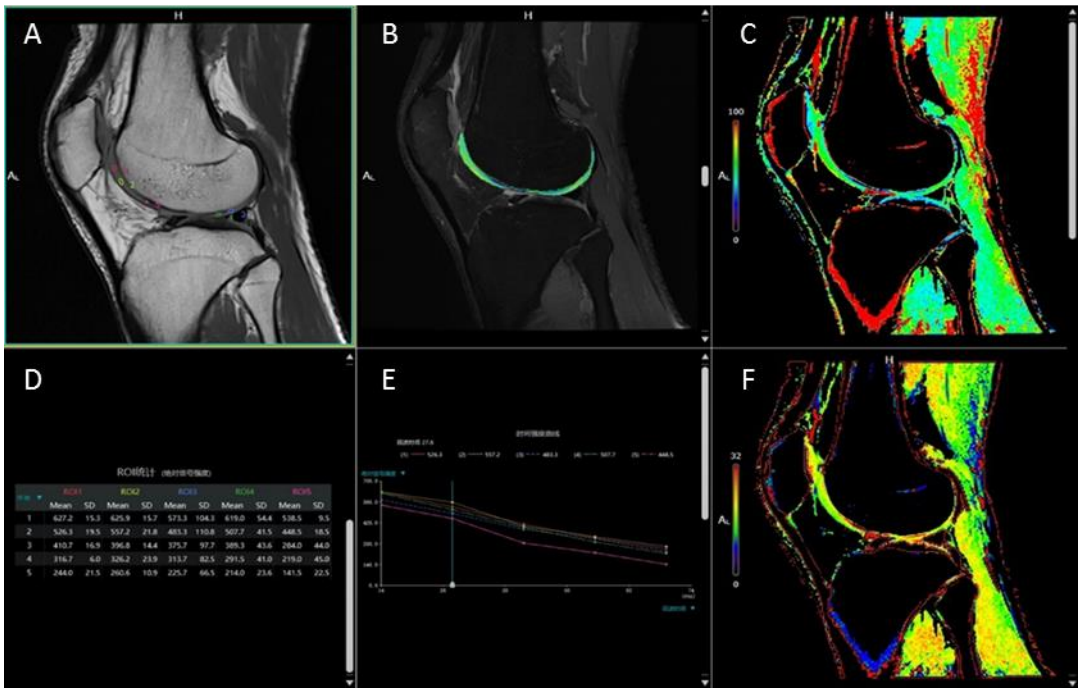

Figure 2 Magnetic Resonance Imaging T2 Mapping in Detecting Early Knee Joint Injury From the top left to the bottom right are: A) the amplitude map of the second echo of SE_ME, and B) mark the area of interest on the articular cartilage; C) the result of the T2 mapping image fused to the PD anatomy in pseudo-color form; D) T2 mapping corresponding to the signal value statistics of different ROI regions of the articular cartilage on different echoes; E) the average value of the signal values corresponding to the different echoes of the ROI regions of the articular cartilage; F) T2 mapping.

4.2 Clinical application value of MRI T2 mapping

Although the traditional MRI examination sequence can better display the morphology of articular cartilage, it is difficult to clearly show the pathophysiological changes before and after morphological changes, including changes in components and matrix, and the changes in these signals are also lacking of specificity. In addition, early changes before morphological changes are difficult to observe, so the diagnostic accuracy of cartilage damage needs to be further improved. As is mentioned earlier, the T2 value in T2 mapping reflects the water content in the articular cartilage, and the change of its internal macromolecules before the gross morphological changes of the cartilage will cause a corresponding change in its water content. The T2 mapping technique is very sensitive to changes in tissue water and biochemical structures. The T2 value depends not only on the type of scan sequence, but also on the method of its calculation. Images obtained with MESE and FSE are smoother, and cartilage-meniscus is better than SESE and TGSE. The TGSE scan time is short and can be used for high resolution T2 mapping. Due to the thin structure of the cartilage tissue, the shorter T2 value, and its poor signal-to-noise ratio, the main TE value of the MRI signal is determined, so a longer TE value can be used to obtain a better signal (20).

There have been research results where the

MR T2 mapping technique was used to compare the T2 values between group B and group A (21). The statistical data showed that the difference in mean T2 values between the two groups was statistically significant. In group A, the average T2 value was significantly higher than that of group B, and the T2 value of group A had a strong correlation with WORMS score ($r=0.405 \sim 0.847$, $P<0.01$), indicating that the measurement of T2 value by MR T2 mapping technique can be early and sensitively reflecting changes in cartilage water content and biochemical composition, combined with appropriate cartilage scoring standards, quantitative observation and evaluation of articular cartilage lesions can effectively guide clinical diagnosis and treatment.

Studies by Matzat SJ et al. have shown that MRI T2 mapping can be used for early detection of knee cartilage matrix degeneration. When using the T2 mapping technique clinically, it is necessary to consider the spatial variation of the T2 relaxation time, rather than simply using absolute values (22).

5.0 Conclusion and prospects of MRI T2 mapping

In general, this article reviews the conventional MRI sequence of knee joint injury from the normal physiological anatomy of the knee joint and explores the new MRI T2 mapping technique. At present, T2 mapping technology still has certain limitations. For example, the measurement of T2 value is easily affected by related factors such as background uniformity, partial volume effect, magic angle effect and chemical shift (23). In addition, the T2 value of knee cartilage increases with age. We believe that with the continuous development of medical technology, these shortcomings will be overcome. The T2 mapping sequence will provide some significant guidance for the clinical diagnosis of knee joint cartilage injury.

Declarations

1) ***Consent to publication***
We declare that all authors agreed to publish the manuscript at this journal based on the signed Copyright Transfer Agreement, and followed publication ethics.

2) ***Ethical approval and consent to participants***
Not applicable.

3) ***Disclosure of conflict of interests***
We declare that no conflict of interest exists.

4) ***Funding***
None

5) ***Availability of data and material***
We declare that the data supporting the results reported in the article are available in the published article.

6) ***Authors' Contributions***
Authors contributed to this paper with the design (LCL and BXR), literature search (LCL and BXR), drafting (LCL), revision (LCL and BXR), editing (LCL and BXR) and final approval (LCL and BXR).

7) ***Acknowledgement***
None

8) ***Authors' biography***
None

References

1. Cassiolas G, Berni M, Marchiori G, et al. How cartilage status can be related to joint loads in anterior cruciate ligament reconstruction: a preliminary analysis including MRI t2 mapping and joint biomechanics. Journal of biological regulators and homeostatic agents. 2018;32(null):35-40.
2. Curl WW, Krome J, Gordon ES, et al. Cartilage

injuries: a review of 31,516 knee arthroscopies. Arthroscopy : the journal of arthroscopic related surgery 1997;13(4):456-60.

3. Chu CR, Williams AA, Coyle CH, et al. Early diagnosis to enable early treatment of pre-osteoarthritis. Arthritis research. 2012;14(3):212.
4. Kijowski R, Blankenbaker DG, Munoz Del Rio A, et al. Evaluation of the articular cartilage of the knee joint: value of adding a T2 mapping sequence to a routine MR imaging protocol. Radiology. 2013;267(2):503-13.
5. Glaser C. New techniques for cartilage imaging: T2 relaxation time and diffusion-weighted MR imaging. Radiologic clinics of North America. 2005;43(4):641-53, vii.
6. Dunn TC, Lu Y, Jin H, et al. T2 relaxation time of cartilage at MR imaging: comparison with severity of knee osteoarthritis. Radiology. 2004;232(2):592-8.
7. Setton LA, Elliott DM, Mow VC, et al. Altered mechanics of cartilage with osteoarthritis: human osteoarthritis and an experimental model of joint degeneration. Osteoarthritis. 1999;7(1):2-14.
8. Mars M, Chelli M, Tbini Z, et al. MRI T2 Mapping of Knee Articular Cartilage Using Different Acquisition Sequences and Calculation Methods at 1.5 Tesla. Medical principles and practice : international journal of the Kuwait University, Health Science Centre. 2018;27(5):443-50.
9. Link TM, Neumann J, Li X. Prestructural cartilage assessment using MRI. Journal of magnetic resonance imaging: JMRI. 2017;45(4):949-65.
10. Buckwalter JA, Mankin HJ, Grodzinsky AJ. Articular cartilage and osteoarthritis. Instructional course lectures. 2005;54(undefined):465-80.
11. Buckwalter JA, Mankin HJ. Articular cartilage: degeneration and osteoarthritis, repair, regeneration, and transplantation. Instructional course lectures. 1998;47(undefined):487-504.
12. Waldschmidt JG, Rilling RJ, Kajdacsy-Balla AA, et al. In vitro and in vivo MR imaging of hyaline cartilage: zonal anatomy, imaging pitfalls, and pathologic conditions. Radiographics. 1997;17(6):1387-402.
13. Garnero P, Peterfy C, Zaim S, et al. Bone marrow abnormalities on magnetic resonance imaging are associated with type II collagen degradation in knee osteoarthritis: a three-month longitudinal study. Arthritis. 2005;52(9):2822-9.
14. Zhai G, Ding C, Stankovich J, et al. The genetic contribution to longitudinal changes in knee structure and muscle strength: a sibpair study. Arthritis. 2005;52(9):2830-4.
15. Chapovsky F, Kelly JD, related surgery : official publication of the Arthroscopy Association of North America, et al. Osteochondral allograft transplantation for treatment of glenohumeral instability. Arthroscopy : the journal of arthroscopic. 2005;21(8):1007.
16. Kijowski R, Stanton P, Fine J, et al. Subchondral bone marrow edema in patients with degeneration of the articular cartilage of the knee joint. Radiology. 2006;238(3):943-9.
17. Kim T, Min BH, Yoon SH, et al. An in vitro comparative study of T2 and T2* mappings of human articular cartilage at 3-Tesla MRI using histology as the standard of reference. Skeletal radiology. 2014;43(7):947-54.
18. Bining HJ, Santos R, Andrews G, et al. Can T2 relaxation values and color maps be used to detect chondral damage utilizing subchondral bone marrow edema as a marker? Skeletal radiology. 2009;38(5):459-65.
19. Mosher TJ, Smith H, Dardzinski BJ, et al. MR imaging and T2 mapping of femoral cartilage: in vivo determination of the magic angle effect. AJR American journal of roentgenology. 2001;177(3):665-9.
20. Mars M, Chelli M, Tbini Z, et al. MRI T2 Mapping of Knee Articular Cartilage Using Different Acquisition Sequences and Calculation Methods at 1.5 Tesla. Medical principles. 2018;27(5):443-50.
21. Nebelung S, Post M, Knobe M, et al. Detection of Early-Stage Degeneration in Human Articular Cartilage by Multiparametric MR Imaging Mapping of Tissue Functionality. Scientific reports. 2019;9(1):5895.
22. Matzat SJ, McWalter EJ, Kogan F, et al. T2 Relaxation time quantitation differs between pulse

sequences in articular cartilage. Journal of magnetic resonance imaging : JMRI. 2015;42(1):105-13.

23. Khushu S, Rana P, Sekhri T, et al. Bio-energetic impairment in human calf muscle in thyroid disorders: a 31P MRS study. Magnetic resonance imaging. 2010;28(5):683-9.