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Quantitative Magnetic Resonance T2 Relaxometry Imaging of Knee Joint Tibia & Femoral Articular Cartilage

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ABSTRACT

Background: The knee joint is the largest synovial joint in the body with multiple articulating surface. The major consists of the articulation between the femur and tibia, which is weight bearer of the whole body weight and for the balance; and this articulation surface has a major chance of breakdown easily due to various reasons.

MR imaging is a powerful tool for the morphologic and compositional imaging of cartilage in the knee for the detection of early cartilaginous degeneration and increased utility for the assessment of cartilage repair techniques.

Aim: To obtain T2 relaxometry value of knee joint tibia and femoral articular cartilage & to compare the T2 relaxometry values of the early Osteoarthritic patients with that of the other cause.

Material & Methods: 20 patients who presented themselves in Radiology department of either sex whose reports and image data's are collected prospectively during the study period of December 2011 to February 2012. All the patients' data within the study period were collected. Patients were selected irrespective of their age group, gender and pathologic findings, a detailed history with various patient's data includes patient demography, age, sex and the study reports are collected and is entered in a specially designed Profoma. The acquired study data of Sagittal T2 Mapping High Resolution sequence of each patient are then post processed by using a GE Advantage Workstation (version 4.4) and T2 Relaxometry values of various knee joint cartilages (Medial & Lateral femoral and tibial cartilage) are collected by using a special software and is entered in the table.

Conclusion: Conventional MRI may not show early cartilage changes; Cartilage edema following trauma (or) Due to osteoarthritis can be picked up early by T2 Mapping. hence it is useful in early patient management.

***Key words*:** MRI, Knee joint imaging, tibia and femoral cartilage Imaging, Joint cartilage, T2 Relaxometry, T2 Mapping, osteoarthritis, Knee trauma, Medial and Lateral Tibia and Femoral Cartilage.

1 Introduction

The knee joint is the largest synovial joint in the body with multiple articulating surface. The major consists of the articulation between the femur and tibia, which is weight bearer of the whole body

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weight and for the balance; and this articulation surface has a major chance of breakdown easily due to various reasons.

MR imaging is a powerful tool for the morphologic and compositional imaging of cartilage in the knee. MRI offers multi-planar capabilities, high spatial resolution without ionizing radiation, and superior contrast between joint tissues. For routine clinical examinations of the knee joint, most departments are still applying a multiplane 2D fast SE sequence, alone or in combination with a 3D GRE sequence to improve cartilage assessment. The combined use of high-resolution morphologic imaging techniques and compositional imaging techniques may lead to increased sensitivity of MR imaging for the detection of early cartilaginous degeneration and increased utility for the assessment of cartilage repair techniques.

T2 MAPPING/MR CARTIGRAM: T2 relaxation time is a non-invasive marker of cartilage degeneration because it is sensitive to tissue hydration and biochemical composition. When collagen breaks down, there is increased mobility of water in the cartilage and therefore a prolongation in T2 relaxation times. It is based on a multi-echo pulse sequence derived from the existing FSE-XL that can create up to 8 echoes per single acquisition not more than eight echoes are acquired, due to the cartilage short T2 relaxation times. Cartigram automatically generates color-maps based on a scale of T2 values that allows visualization of changes in the composition of articular cartilage in some cases before changes in the thickness can be seen.

2 Aim

- To obtain T2 relaxometry value of knee joint tibia and femoral articular cartilages
- To compare the T2 relaxometry values of the early Osteoarthritic patients with that of the other causes.

3 The Knee Anatomy - Tibia and Femoral Cartilage

The contacting surfaces of the bones of most di-arthrodial joint are covered with articular cartilage, an avascular, highly durable hydrated soft tissue that provides shock absorption and lubrication functions to the joint called hyaline cartilage (see illustration Fig:.1). Articular cartilage is composed mainly of water, proteoglycans, and collagen. The joint is surrounded by a fibrous joint capsule lined with synovium, which produces lubricating synovial fluid and nutrients required by the tissues within the joint. Joint motion is provided by the muscles that are attached to the bone with tendons. Strong flexible ligaments connected across the bones stabilize the joint and may constrain its motion.

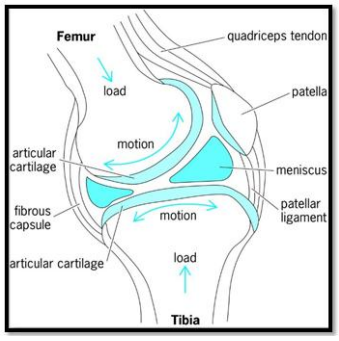

Figure 1: Pictorial illustration of knee anatomy (mid-sagittal plane)

The articular surfaces of the bones that contribute to the knee joint are also covered by hyaline cartilage. The major surfaces involved include

- The femoral condyles and
- The adjacent surfaces of the superior aspect of the tibial condyles.

The surfaces of the femoral condyles that articulate with the tibia in flexion of the knee are curved or round, whereas the surfaces that articulate in full extension are flat.

The menisci improve congruency between the femoral and tibial condyles during joint movements where the surfaces of the femoral condyles articulating with the tibial plateau change from small curved surfaces in flexion to large flat surfaces in extension and thus they act as cushions between femoral condyles and tibial plateau, dissipate load, and facilitate motion of the joint. The articular surfaces between the femur and patella are the V-shaped trench on the anterior surface of the distal end of the femur where the two condyles join and the adjacent surfaces on the posterior aspect of the patella. The joint surfaces are well enclosed within a single articular cavity, as are the intra-articular menisci between the femoral and tibial condyles

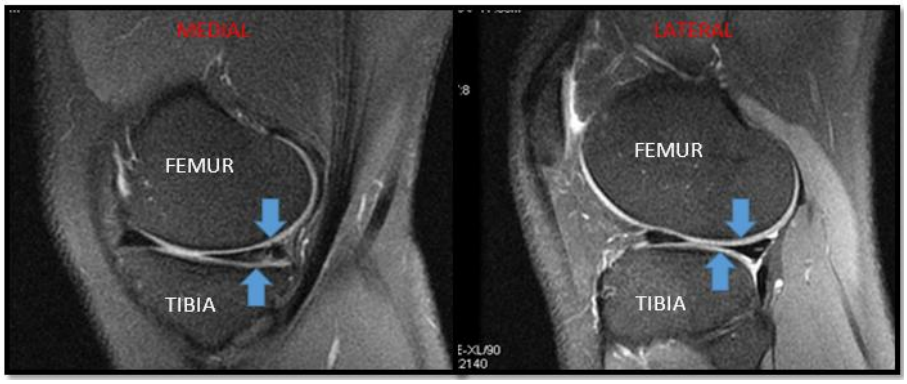

Figure 2: MRI Sagittal Image shows long section of medial and lateral part of femoral and tibial articular cartilage (blue arrows)

4 Material and Methods

A population of 20 subjects who presented themselves in Sri Ramachandra Hospital (A tertiary care university hospital in Chennai, India) to the Department of Radiology and Imaging Sciences of either sex whose reports and image data's are collected prospectively during the study period of 3 months (December 2011- February 2012). All the patients' data within the study period were collected. Patients were selected irrespective of their age group, gender and pathologic findings. A detailed history with various patient's data includes patient demography, age, sex and the study reports are also collected and is entered in a specially designed tabular column.

MATERIALS: The GE Signa HDx MRI system (1.5T) whole body magnetic resonance scanner with the 8 channel, 9-element phased-array knee coil is used for imaging. The MR imaging sequences most commonly used in the assessment of joint cartilage are 2D or multisection sagittal & axial (FSE) Proton Density Weighted with Fat Suppression (PD FS), sagittal gradient echo sequence, T2 weighted Fast Spin Echo, T1 weighted (T1w SE) and coronal Shot TAU Inversion Recovery (STIR); In addition to the routine protocol the T2 Mapping sequence is added.

Table 1: Protocol for T2 Mapping – Sagittal plane

PARAMETERS	
Scan plane	Sagittal
Mode	2D
Pulse sequence family	Spin echo
Pulse sequence	FSE-T2
TR (ms)	1000
TE (ms)	(1)08.9, (2)17.8, (3) 26.7, (4)35.6, (5) 44.4, (6) 53.3, (7)62.2, (8)71.2
FOV (cm)	16 x 16
Slice thickness (mm)	2
Spacing (mm)	4
Flip angle (degree)	90
Frequency	288
Phase	224
NEX	1
Scan time	3:46 min

T2 MAPPING: Routine MR imaging allows a subjective assessment of cartilage T2 changes, whereas quantitative T2 mapping provides objective data by generating either a colour or a grey-scale map representing the variations in relaxation time within cartilage. A multiecho SE technique is used to measure T2 values. T2 Map acquires multiple scans at each location; each set of scans has a unique TE, resulting in a data set of images that represent different T2 weighting. The number of TEs per scan (not a selectable parameter) is the scan parameter that determines the number of images that are acquired at each location. For example, if 10 locations are prescribed with 8 TEs per scan, then there are 10 data sets with 8 images per location. Each image within a data set or location has 8 unique T2-weighted images, because all lines of k-space are filled with one TE. The data is processed in Functool

T2 MAPPING FUNCTOOL: T2 MAP protocol post processes data sets acquired using the T2Map application. The T2Map acquisition is displayed in Functool where the T2 relaxation time color map is coded to capture T2 values from the TE range of the acquired images.

5 Observations

The post processing of MR Cartigram (Sagittal) of 20 patients on the Functool reveals the following,

In this study we calculated the T2 relaxation times of the cartilages, and found that there is an increase in those values due to various reasons, and thus commercial MR imaging has been used to confirm the diagnosis. It allows a subjective assessment of cartilage T2 changes, whereas quantitative T2 mapping provides objective data by generating either a colour or a grey-scale map representing the variations in relaxation time within cartilage. A multiecho SE technique is used to measure T2 values.

In the study,

- Out of 9 patients with the history of trauma there is an increase in the T2 relaxometry values for 6 patients.

- Out of 7 patients with the history of unknown knee pain shows increase in the T2 relaxometry values for 5 patients.
- Patients with history of knee instability/ pain on action and others (No. of patients 2/1/1 respectively) shows less significant increase in the T2 Relaxation time.

On comparing the T2 Relaxometry values of the patients with the history of Osteoarthritis vs. others, shows an increase in the T2 relaxation time of the knee joint cartilages. This is due to the early morphological changes occurs due to osteoarthritis in the knee joint cartilages.

There is good evidence that T2 mapping is useful for identifying sites of early-stage degeneration (early disruption of the collagen matrix) in cartilage.

Table 2: Comparison of T2 relaxometry values of Osteoarthritis and other patients

Osteoarthritis	6
Others conditions	14

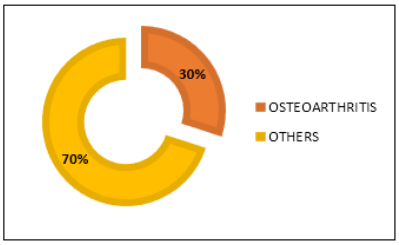

Figure 1: Percentage of T2 relaxometry values of Osteoarthritis over other patients

Table 3: Clinical symptomatology for other patients

Clinical Symptoms	No. Of Patients	Percent (%)
Trauma	9	45
Rest Pain	7	35
Instability	2	10
Pain On Activity	1	5
POLIO	1	5

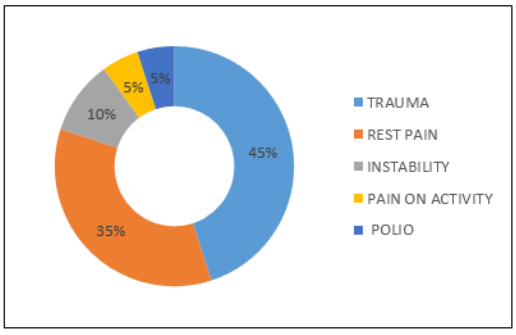

Figure 2: Distribution of other patient's symptomatology

This graph 2 shows that 45% of the patients are with the history of trauma, followed by rest pain that is around 35 %, then with the knee instability 10 %, and with least symptoms of pain on action & with polio disorder of 5 % each.

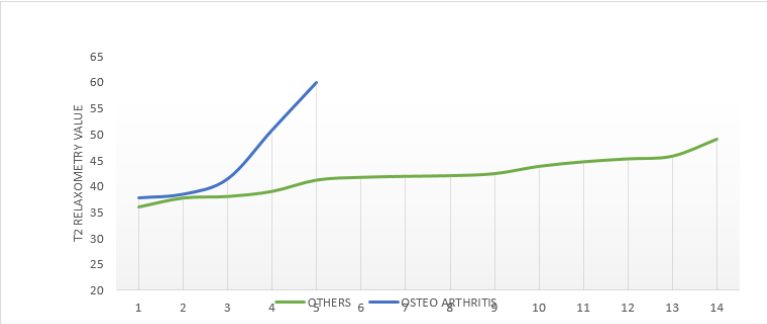

Figure 3: The graph shows the Comparison of T2 relaxometry values of the medial femoral Cartilage in osteoarthritis patients and in other symptoms.

Table 4: Shows the T2 relaxometry values of the medial femoral Cartilage in osteoarthritis patients and in other symptoms

NO. OF PATIENTS	OTHERS	OSTEOARTHRITIS
1	*36.03*	*37.71*
2	*37.74*	*38.41*
3	*38.03*	*41.35*
4	*39.01*	*50.74*
5	*41.18*	*59.92*
6	*41.70*	
7	*41.89*	
8	*42.01*	
9	*42.40*	
10	*43.80*	
11	*44.67*	
12	*45.23*	
13	*45.75*	
14	*49.00*	

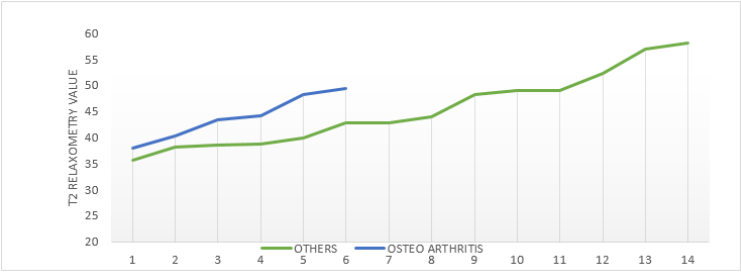

Figure 4: The graph shows the Comparison of T2 relaxometry values of the medial tibial Cartilage in osteoarthritis patients and in other symptoms

Table 5: Shows the T2 relaxometry values of the medial tibial Cartilage in osteoarthritis patients and in other symptoms

NO. OF PATIENTS	OTHERS	OSTEOARTHRITIS
1	35.54	37.98
2	38.23	40.34
3	38.51	43.40
4	38.79	44.19
5	39.81	48.25
6	42.80	49.38
7	42.86	
8	43.96	
9	48.25	
10	48.92	
11	49.06	
12	52.24	
13	57.00	
14	58.02	

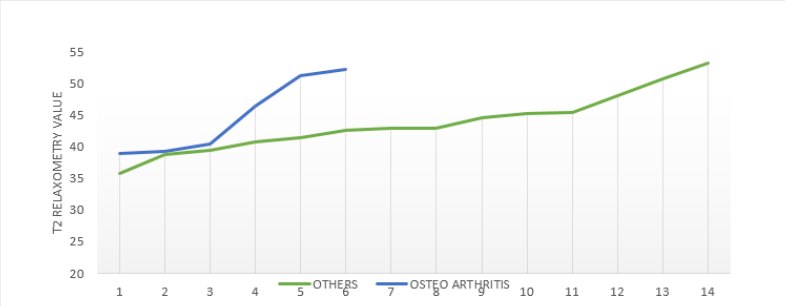

Figure 5: The graph shows the Comparison of T2 relaxometry values of the Lateral Femoral Cartilage in osteoarthritis patients and in other symptoms

Table 6: Shows the T2 relaxometry values of the lateral femoral Cartilage in osteoarthritis patients and in other symptoms

NO. OF PATIENTS	OTHERS	OSTEOARTHRITIS
1	35.74	38.96
2	38.75	39.21
3	39.41	40.38
4	40.73	46.38
5	41.47	51.20
6	42.61	52.12
7	42.83	
8	42.89	
9	44.50	
10	45.17	
11	45.30	
12	48.01	
13	50.77	
14	53.25	

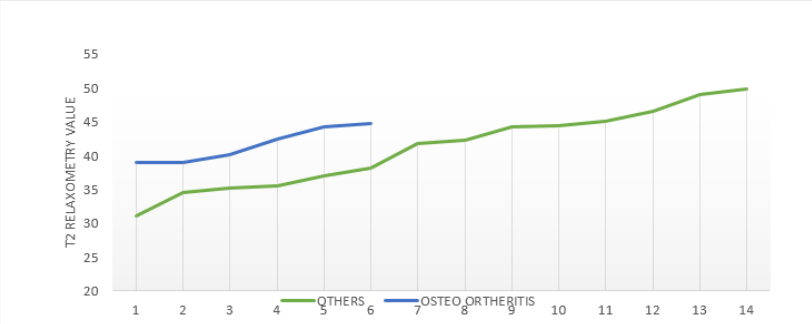

Figure 6: The graph shows the Comparison of T2 relaxometry values of the Lateral tibial Cartilage in osteoarthritis patients and in other symptoms

Table 7: Shows the T2 relaxometry values of the lateral tibial Cartilage in osteoarthritis patients and in other symptoms

NO. OF PATIENTS	OTHERS	OSTEOARTHRITIS
1	*31.08*	*42.44*
2	*34.54*	*39.02*
3	*35.28*	*39.04*
4	*35.61*	*40.20*
5	*37.01*	*44.33*
6	*38.21*	*44.74*
7	*41.83*	
8	*42.21*	
9	*44.31*	
10	*44.36*	
11	*45.01*	
12	*46.52*	
13	*49.03*	
14	*49.79*	

6 Result

The post processing of MR Cartigram (Sagittal) on the Functool reveals the following results.

- There was a significant increase in the T2 Relaxometry (more than 45) value of the knee joint cartilages for the following patients with the history of trauma / knee injury / instability / unknown knee pain.
- The comparison of T2 Relaxometry value of the patients with the history of Osteoarthritis and other causes shows that there was a significant increase in the T2 relaxation time of the knee joint cartilage with the history of osteoarthritis.

7 Discussion

The T2 relaxation time of articular cartilage is a function of both the water content and collagen ultra-structure of the tissue. Measurement of the spatial distribution of the T2 relaxation time reveals the areas of increased or decreased water content that correlate with cartilage damage.

Patients with symptoms of osteoarthritis can be diagnosed at an earlier stage by using MR Cartigram which is not possible in Conventional MR Imaging.

In osteoarthritis, there will be a thinning, breakdown and eventual loss of the articulating cartilage. Loss of collagen and proteoglycan in degenerating cartilage increases the mobility of water; subsequently sub condyle edema develops, thus increasing its signal intensity on T2-weighted images

The knee joint cartilage injury can also occur in case of trauma, which may or may not be very well appreciated by routine MR imaging sequences, in such conditions, MR Cartigram is used an effective tool to identify early degenerations and cartilage edema.

In this study we calculated the T2 relaxation times of the cartilages, and found that there is an increase in those values due to various reasons, and thus commercial MR imaging has been used to confirm the diagnosis.

It allows a subjective assessment of cartilage T2 changes, whereas quantitative T2 mapping provides objective data by generating either a color or a gray-scale map representing the variations in relaxation time within cartilage. A multiecho SE technique is used to measure T2 values. T2 Mapping acquires multiple scans at each location; each set of scans has a unique TE, resulting in a data set of images that represent different T2 weighting.

8 Conclusion

Cartilage edema following trauma (or) Due to osteoarthritis can be picked up early by MR Cartigram. Conventional MRI may not show early cartilage changes hence T2 Mapping is useful in patient management. T2 mapping can be implemented relatively on most clinical MR imaging systems for early detection of osteoarthritis.

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