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# **Synthetic MRI is not yet ready for morphologic and functional assessment of patellar cartilage at 1.5 Tesla**

Short title:

## **Synthetic MRI for cartilage assessment**

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## Abstract

**Purpose:** The purpose of this study was to compare morphologic assessment and relaxometry of patellar hyaline cartilage between conventional sequences (fast spin-echo [FSE] T2-weighted fat-saturated and T2 mapping) and synthetic T2 short-TI inversion recovery (STIR) and T2 maps at 1.5 T magnetic resonance imaging (MRI).

**Method:** The MRI examinations of the knee obtained at 1.5 T in 49 consecutive patients were retrospectively studied. There were 21 men and 28 women with a mean age of  $45 \pm 17.7$  (SD) years (range: 18 – 88 years). Conventional and synthetic acquisitions were performed, including T2-weighted fat-saturated and T2 mapping sequences. Two radiologists independently compared patellar cartilage T2 relaxation time on conventional T2 mapping and synthetic T2 mapping images. A third radiologist evaluated the patellar cartilage morphology on conventional and synthetic T2-weighted images. The presence of artifacts was also assessed. Interobserver agreement for quantitative variables was assessed using intraclass correlation coefficient (ICC).

**Results:** In vitro, conventional and synthetic T2 maps yielded similar mean T2 values  $58.5 \pm 2.3$  (SD) ms and  $58.8 \pm 2.6$  (SD) ms, respectively ( $P = 0.414$ ) and 6% lower than the expected experimental values ( $P = 0.038$ ). Synthetic images allowed for a 15% reduction in examination time compared to conventional images. On conventional sequences, patellar chondropathy was identified in 35 patients (35/49; 71%) with a mean chondropathy grade of  $4.8 \pm 4.8$  (SD). On synthetic images, 28 patients (28/49; 57%) were diagnosed with patellar chondropathy, with a significant 14% difference ( $P = 0.009$ ) and lower chondropathy scores ( $3.7 \pm 4.9$  [SD]) compared to conventional images. Motion artifacts were more frequently observed on synthetic images (18%) than on conventional ones (6%). The interobserver agreement was excellent for both conventional and synthetic T2 maps (ICC > 0.83). Mean cartilage T2 values were significantly greater on synthetic images ( $36.2 \pm 3.8$  [SD] ms; range : 29-46 ms ) relative to conventional T2 maps (  $31.8 \pm 4.1$  [SD] ms; range : 26-49 ms ) ( $P < 0.0001$ ).

**Conclusion:** Despite a reduction in examination duration, synthetic images convey lower diagnostic performance for chondropathy, greater prevalence of motion artifacts, and an overestimation of T2 values compared to conventional MRI sequences.

**Keywords:** Magnetic resonance imaging (MRI); Knee joint; T2 relaxation time; Cartilage diseases; Observer variation

## **Abbreviations**

FSE: fat spin-echo

ICC: intraclass correlation correlation

MDME : multiple-dynamic multiple-echo

MRI: magnetic resonance imaging

PD: proton density

ROI: region of interest

SD: standard deviation

STIR: short tau inversion recovery

TE: Echo time

TR: Repetition time

WORMS: Whole-Organ Magnetic Resonance Imaging Score

## **Introduction**

Classically, cartilage image assessment is based on morphologic criteria and intrasubstance signal variation on proton density (PD) or T2 weighted fat-saturated sequences [1,2]. Besides, T2 relaxometry (i.e., T2 mapping) has been shown to facilitate early detection of cartilage damage and allow a quantitative cartilage assessment, which can be used for the follow-up of patients treated with cartilage reconstruction procedures [3–7]. Conventional T2 mapping is prospectively acquired and requires an independent multi-echo acquisition, which increases examination time, which may hinder the application of this technique in clinical practice [6] .

Synthetic images refer to images generated/calculated from tissue properties measured by the analysis of one or various parameters acquired with a single acquisition. This is done by simulating different echo times (TE), repetition times (TR), and inversion times based on measurements of tissue relaxation characteristics (e.g., T1, T2, and PD values). In addition, these sequences also generate T1, T2, and PD relaxation maps. Synthetic sequences are commercially available, and although mostly used for brain imaging, a few studies have evaluated the use of synthetic sequences for hyaline cartilage assessment [8,9]. Thus, such sequences could allow simultaneous morphological and biochemical assessment of knee cartilage with a single acquisition, which could improve the workflow and increase the availability of cartilage relaxometry [9,10]. In a pilot study on 22 patients, Boudabbous et al. demonstrated that synthetic images of the knee acquired with magnetic resonance imaging (MRI) ( were of good quality in over 95% of patients [11]. There is, however, scarce information on the diagnostic performance of synthetic imaging and the evaluation of these sequences by comparison with conventional morphologic and functional acquisitions.

The purpose of this study was to compare the morphologic assessment and relaxometry of patellar hyaline cartilage between conventional sequences (fast spin-echo [FSE] T2-weighted fat-saturated and T2 mapping) and synthetic T2 short TI inversion recovery [STIR] and T2 maps acquired at 1.5 T.

## **Materials and methods**

### *Patients*

The MRI examinations of 51 consecutive patients referred for the evaluation of knee pain from September 2017 to November 2017 were retrospectively evaluated. These patients were referred for the evaluation of knee pain in a degenerative or traumatic setting. Patients with acute fractures around the knee and metallic surgical implants identified on MRI were not included. Two patients were excluded due to deviations in the acquisition protocol (no synthetic image acquisition and synthetic acquisition performed in a different plane). Thus, the final study population included 49 patients. There were 21 men (43%) and 28 women (57%) with a mean age of  $45 \pm 17.7$  (SD) years

(range: 18 - 88 years). Figure 1 shows the study flow chart. Do to the retrospective nature of the study, institutional review board exemption was obtained.

### *MRI protocol*

All acquisitions were performed using a 1.5T MRI scanner (Optima® MR450w, General Electric Healthcare) with 16 channel flexible coil (NeoCoil). Acquisition parameters are detailed in Table 1. Axial T1-weighted images, oblique sagittal and coronal T2-weighted fat-saturated fat spin-echo (FSE) images were also acquired but not considered in this study.

Acquisition time for each of the presented sequences was extracted directly from the estimated time given by the scanner console. Thus, we were able to compare the duration time between reference sequences and synthetic ones.

### *Phantom acquisition*

A phantom composed of agarose gel with different concentrations of nickel sulfate at 2.5 mmol/L, 0.8 mmol/L, and 0.31 mmol/L was used to evaluate T2 value measurement accuracy in synthetic and conventional T2 maps. The phantom was immersed in water a few minutes before acquisition. Water temperature was controlled and maintained at 18 ° C. Phantom image acquisitions were performed using the same MRI unit and acquisition protocol. The expected T2 relaxation times values for the different doses of nickel sulfate concentrations used are presented in Table 2.

### *Cartilage morphology assessment*

A musculoskeletal radiologist (P.T.) with 12 years of experience in musculoskeletal MRI performed cartilage evaluation on a picture archiving and communication system workstation (Synapse V4.1 Fujifilm Medical Systems). Patellar cartilage was divided into three zones [12]: medial facet, lateral facet, and ridge, which separates the broader lateral facet to the medial one. Patellar cartilage was assessed semi-quantitatively in each zone based on a modified Whole-Organ Magnetic Resonance Imaging Score (WORMS) [13,14] system on both axial synthetic and conventional T2 weighted fat-saturated images [14]. Several features were evaluated in each evaluated zone using a 3

or 4 point scale. They included : (i), cartilage signal and morphologic abnormalities (0-4 points; 0 - normal cartilage; 1 - signal hyperintensity with intact cartilage surface; 2 – loss of less than 50% of cartilage thickness; 3 – loss of more than 50% of cartilage thickness; 4 – full-thickness cartilage loss); (ii), subchondral bone signal abnormalities (0-3 points; 0 – normal bone signal; 1 – signal hyperintensity less than 25%; 2 – signal hyperintensity between 25 and 50%; 3 – signal hyperintensity more than 50%); and (iii), subchondral cysts and subchondral bone cortical abnormality (0-3 points; 0 – no cyst or cortical bone abnormality; 1 – slight flattening of the subchondral cortex; 2 – cortical bone abnormalities moderate with a slight concavity; 3 – severe abnormalities with marked concavity).

When all three evaluation zones were considered together, the cartilage score varied from 0 to 21 points (total score). Patellar chondropathy was diagnosed when the total modified WORMS was greater or equal to one. Besides, the same reader subjectively evaluated the presence of motion artifacts, fat suppression defects, and chemical shift artifacts on both standard and synthetic sequences.

## *T2 mapping post-processing and analysis*

T2 mapping post-processing was performed on a dedicated workstation. Conventional T2 maps were calculated and post-processed with the Readyview application (version 13.0-2.39, Discovery® 450w GEM GE Healthcare). Synthetic T2 maps were calculated and post-processed with the Magnetic Resonance Image Compilation application (CartiGram and Magnetic Resonance Image Compilation - MAGiC version 100.1.1).

Two readers (C.V., F.A.) with one year of clinical experience each in osteoarticular MRI independently measured the patellar cartilage T2 relaxation time of the patients included. Conventional and Synthetic T2 maps were evaluated separately in two readout sessions at least two weeks apart. Three square region of interest (ROI) were positioned on the patellar cartilage (medial facet, patellar ridge, lateral facet) in each patient on conventional and synthetic T2 maps sequences. The slice location tag and patellar morphology were used to assure measurement location was similar in conventional and synthetic images. The largest ROI possible was drawn within boundaries of the

articular cartilage, avoiding the inclusion of subchondral bone, adjacent soft tissue, or joint fluid (Fig. 2). Areas of full-thickness cartilage loss were not included in the analysis.

Reader one (PT) performed a second readout session two weeks after the first readout and measured T2 values at the patellar ridge in conventional and synthetic T2 maps to allow intraobserver agreement assessment.

Conventional T2 weighted fat-saturated images and T2 maps were considered as the standard of reference for chondral evaluation.

## *Statistical analysis*

Statistical analysis was performed with R software (version 3.0.0, R Foundation for Statistical Computing). Conventional T2 weighted fat-saturated images and T2 maps were considered as the standard of reference. Quantitative data were reported as mean  $\pm$  standard deviation and ranges, and categorical variables as raw numbers, proportions and percentages. Intraclass correlation coefficients (ICC) were calculated to assess intra and interobserver agreement. ICC values were also calculated to calculate the agreement between conventional and synthetic WORMS. They were graded as follows < 0 = poor; 0.01 – 0.2 = slight; 0.21 – 0.4 = fair; 0.41 – 0.6 = moderate; 0.61 – 0.8, substantial and 0.81 – 0.99, excellent [15]. Comparisons between conventional and synthetic T2 measurements in vivo and in vitro were performed by using Wilcoxon signed-rank test for paired data. Comparisons between T2 phantom values and in vivo T2 values were made using the student t test. Comparisons between T2 measurements for patients with and without patellar chondropathy were performed by using the Wilcoxon signed-rank test. A linear regression model was used to compare conventional and synthetic T2 values with the corresponding coefficient of determination R-squared ( $R^2$ ). *P*-values were two-sided, and significance was set at  $P = 0.05$ .

## **Results**

### *Acquisition time*

Conventional FSE weighted fat-saturated T2 axial sequences were acquired in 3 minutes and 18 seconds, conventional T2 mapping sequences in the axial plane in 3 minutes 4 seconds, and axial



T1-weighted sequence in 2 minutes 5 seconds with a total acquisition time of 8 minutes 27 seconds. Synthetic acquisitions were performed with multiple-dynamic multiple-echo (MDME) sequences acquired in 7 minutes 12 seconds. Thus, synthetic images allowed for a 15% reduction in examination time compared to conventional images.

### *Morphological analysis*

On conventional T2-weighted images, patellar chondropathy was diagnosed in 35 patients (35/49; 71%): In these patients, the mean chondropathy total score was  $4.8 \pm 4.8$  (SD) (range: 0 - 16) (Table 3). Fourteen patients (14/49; 29%) had normal patellar cartilage on conventional images.

On synthetic T2 weighted images, 28 patients (28/49; 57%) were diagnosed with patellar chondropathy, with a significant 14% difference by comparison with conventional T2-weighted images ( $P = 0.009$ ) (Fig. 3). These patients presented with relatively mild chondropathy on conventional images (mean chondropathy score of  $2.2 \pm 1.4$  [SD]; range : 1 - 5). Additionally, the individual score of each cartilage zone was less than two in all knees. In one patient, chondropathy was diagnosed on synthetic images, while conventional T2 images were interpreted as normal. In this patient, a patellar chondropathy grade one was diagnosed at the lateral facet, but motion artifacts were present in this study. The mean chondropathy total score with synthetic images was also lower than that found with conventional images ( $P= 0.001$ ) (Table 3). In 21 patients (15 men, six women; mean age,  $36.8 \pm 14.6$  [SD] years; age range: 17-63 years) patellar cartilage was deemed normal on synthetic images. When conventional T2 weighted images were considered as the standard of reference, the agreement of synthetic images was considered excellent (ICC = 0.87).

Motion artifacts were identified in nine patients (9/49; 18%) with synthetic images and three (3/49; 6%) with conventional images (Fig. 4). There were no fat-saturation or chemical-shift artifacts in the studied population.

## *T2 Relaxometry*

*In vitro*, no differences in T2 values were found between conventional and synthetic T2 maps and ( $P = 0.414$ ). With both conventional and synthetic sequences, these values were six percent lower than the expected experimental values ( $P = 0.038$  for both sequences) (Table 2).

*In vivo*, the interobserver agreement of patellar cartilage T2 values was considered excellent for both conventional and synthetic T2 maps (Table 4). The intraobserver agreement was considered excellent with conventional T2 maps and good with synthetic T2 maps (ICC = 0.87 and 0.79, respectively). Mean cartilage T2 values were significantly higher on synthetic with respect to conventional T2 maps ( $P < 0.0001$  for both readers) (Table 3). T2 value SDs were similar between conventional and synthetic maps ( $P = 0.237$  and 0.6 for Reader 1 and Reader 2).

T2 values were significantly higher in patients with patellar chondropathy compared to patients without chondropathy ( $P = 0.0009$ ) (Table 5). On conventional T2 maps, mean T2 values were 6% greater for Reader 1 and 7% greater for Reader 2 for patients with chondropathy versus patients with no chondropathy ( $P < 0.0001$ ). On synthetic T2 maps, mean T2 values were 4% greater for Reader 1 and 3% greater for Reader 2 for patients with chondropathy compared to patients with no chondropathy ( $P = 0.0063$ ).

On both conventional and synthetic T2 maps, a poor correlation was found between mean T2 values and total chondropathy scores for both readers ( $r = 0.37$  and  $r = 0.32$  on conventional T2 maps and 0.11 and 0.34 on synthetic T2 maps sequences respectively for Reader 1 and Reader 2).

## **Discussion**

In this study, we found that synthetic MRI conveys lower diagnostic performance for knee chondropathy, greater prevalence of motion artifacts and an overestimation of T2 values compared to conventional MRI sequences but results in a decreased examination time.

In our study, the slice thickness and gap of synthetic T2 images were larger than that of conventional ones, which could lead to partial volume effects. Additionally, since all synthetic images

were generated from a single sequence lasting over 7 minutes (as opposed to various smaller acquisitions with conventional images), motion artifacts were more frequent. Although the slice thickness and gap of synthetic images could be improved, the acquisition length would be increased as a result leading to a further increase in motion artifacts [13,14,16]. Thus, partial volume effects and increased motion artifacts could at least partially explain why 16% of the mild chondropathies (chondropathy score below two) were identified on conventional but not on synthetic T2 images. This impact in diagnostic performance of morphologic analysis had not yet been demonstrated. Additionally, motion artifacts were the likely explanation for a diagnosis of mild chondropathy with synthetic T2 images with no identifiable abnormality on conventional T2 images. Finally, a 15% reduction in acquisition time was obtained using synthetic acquisitions by comparison with conventional ones. However, if a standard knee study without T2 mapping is considered as reference, synthetic imaging would only represent 2.5% (12 sec) gain in acquisition duration. These findings suggest that in its current state, synthetic images cannot be recommended for the evaluation of the patellar cartilage on 1.5T MR scanners.

Our findings are discordant with those of Yi. et al., who reported a similar quality and performance of synthetic and conventional T2 images for the evaluation of knee chondropathy using arthroscopy as the gold standard [17]. However, these authors evaluated only 8 patients and considered lesions in all knee compartments [17]. These authors also used three-dimensional isotropic sequences in the conventional evaluation protocol while in our study two-dimensional sequences were evaluated. Differences in image reconstruction between these two types of acquisitions might also have led to changes in image contrast and sharpness. Further developments associating MDME acquisitions with novel image acceleration techniques such as compressed sensing, CAIPRINHA (controlled aliasing in parallel imaging results in higher acceleration) -type parallel imaging and deep learning reconstruction could help overcome these issues [18,19].

Although *in vitro* T2 relaxation times were similar between the synthetic sequences and the conventional T2 maps and comparable to literature, both synthetic and conventional T2 maps yielded T2 values 6% lower than reference values [19]. This slight variation could be related to differences in MR scanner model and acquisition protocol used for establishing phantom references. *In*

*in vivo*, regardless of the location, T2 values were significantly higher in synthetic T2 maps compared to conventional ones for both readers ( $P < 0.0001$ ). This is in agreement with previous studies [9]. We hypothesize that the smaller number of TE values in synthetic T2 maps compared to conventional maps (two versus eight) associated with the effects of the *in vivo* properties of hyaline cartilage (e.g., conductivity and permittivity) could explain these differences. Moreover, default TE values of the synthetic acquisition cannot be changed, and the higher TE value of 90.88ms may have been too high to evaluate the lower range of hyaline cartilage T2 values (30-40 ms in the superficial layers and as low as 1-2ms in the calcified layer) [20]. Despite these differences, both measurements remain within the normal range of patellar cartilage T2 values reported in the literature at 3T (from 27.6 to 37.8 ms) since transverse magnetization relaxation is independent of field-strength [20–22]. Finally, T2 value standard deviation was similar between conventional and synthetic maps showing a similar value distribution in the study population. This finding indicates that both conventional and synthetic maps can be used in clinical practice, but the T2 values obtained with these techniques are not comparable. The increased availability of cartilage T2 relaxometry provided by synthetic acquisitions could improve the detection of early chondral damage and provide means for a more accurate follow-up of patients with patellofemoral chondropathy [23].

Conventional and synthetic cartilage T2 values were weakly influenced by chondropathy grades using modified WOMBS. This apparent discordance might be related to the fact that T2 values are better correlated to pre structural cartilage lesions, whereas the modified WOMBS classification system focused on structural lesions [24,25]. Additionally, the population studied was relatively young (mean age of 45years), leading to lower modified WOMBS. Structural cartilage lesions may be associated with cartilage dehydration, tissue loss, and calcification, which may act as confounding factors for T2 value analysis.

Our study has some limitations. First, a limited number of patients were evaluated. The absence of an arthroscopic or surgical confirmation, which is the gold standard of chondral lesions, represents another limitation. However, the diagnostic performance of conventional T2-weighted fat-saturated images for the diagnosis of patellar chondropathy is well known, with reported sensitivity of

59% and specificity of 99% [26]. Thus, we believe that the presented results are valid despite the lack of surgical correlation. ROIs were positioned manually in synthetic and conventional T2 maps, which, despite a side-by-side image comparison and the consideration of the slice position for ROI placement, might have introduced variations in the measurements. The presence of motion artifacts on conventional and synthetic T2 maps was not assessed in this study. The potential of both subjective and texture-based (histogram, skewness level,) T2-relaxometry analysis in detecting mild chondral lesions was not evaluated. Larger studies with arthroscopic correlation would be necessary to clarify this point. All acquisitions were performed on a 1.5T MRI scanner, and higher field strengths could improve the diagnostic performance of synthetic images [27].

In conclusion, synthetic MRI can reduce acquisition time, but it lacks spatial resolution and is more frequently associated with motion artifacts, yielding a lower performance for the detection of early chondropathy. Although T2 relaxometry is readily available, T2 values systematically overestimated when compared with conventional T2 mapping despite a similar reproducibility, which is probably due to fewer and higher TE values in synthetic compared to conventional acquisitions. Hence, further improvements on the synthetic MRI acquisition sequence seem necessary before clinical application on 1.5T.

## **Human rights**

The authors declare that the work described has been carried out in accordance with the Declaration of Helsinki of the World Medical Association revised in 2013 for experiments involving humans.

## **Informed consent and patient details**

The authors declare that this report does not contain any personal information that could lead to the identification of the patient(s).

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## **Author contributions**

All authors attest that they meet the current International Committee of Medical Journal Editors (ICMJE) criteria for Authorship. Conflict of Interest: The authors declare that they have no conflict of interest in relation with this article.

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## Figures legends

**Fig. 1** – Study flow chart.

**Fig. 2** – Patellar cartilage T2 maps of a 60-year-old woman with right knee pain. Conventional and synthetic T2 color maps are shown in A and B, respectively. MRI T2-mapping image of the right knee in the axial plane. A region of interest (rectangle) is placed on the cartilage of the patellar ridge in both images. The T2-relaxation time was 55 ms on conventional T2 map (A) and 65 ms on synthetic T2 map (B).

**Fig. 3** – A 33-year-old man with non-traumatic right knee pain. A) Conventional T2-weighted fat-saturated image of the knee in the axial plan shows superficial erosion associated with a deep fissure (modified Whole-Organ Magnetic Resonance Imaging Score [WORMS] of 2) on the medial facet (arrowhead). B) Synthetic T2-weighted short TI Inversion Recovery (STIR) image at the same level. Even retrospectively, the previously described abnormalities are hardly seen (arrowhead). The modified WORMS of this study was 0.

**Fig. 4** – A 28-year-old man with recurrent knee pain after an anterior cruciate ligament tear treated conservatively. A) Conventional axial T2-weighted fat-saturated image of the knee shows some motion artifacts (arrows) with a normally appearing patellar cartilage. B) On synthetic T2-weighted short TI inversion recovery (STIR) image at the same level than in A shows more prominent motion artifacts than on (A) (arrows) with a hyperintense subchondral line appearing at the level of the subchondral bone plate (arrowhead) and artefactual foci of signal hyperintensity in the patellar cartilage (large arrows).

**Table 1.** Image acquisition parameters.

**Table 2.** Phantom T2 relaxation time (ms) analysis on synthetic T2 mapping MRI sequence and conventional T2 mapping MRI sequence with a temperature equal to 18°C compared to experimental T2 measurements at 1.5T.

**Table 3.** T2 relaxation time analysis in each sequence, compartment, and chondropathy grade with a modified WORMS (mWORMS) grading system with both conventional and synthetic T2 weighted sequences.

**Table 4.** Interobserver agreement in T2 relaxation time analysis.

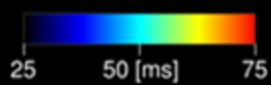
**Table 5.** T2 relaxation times for two different readers (reader 1 and reader 2) for patients with or without chondropathy.

51 patients assessed for eligibility between  
September 2017 and November 2017

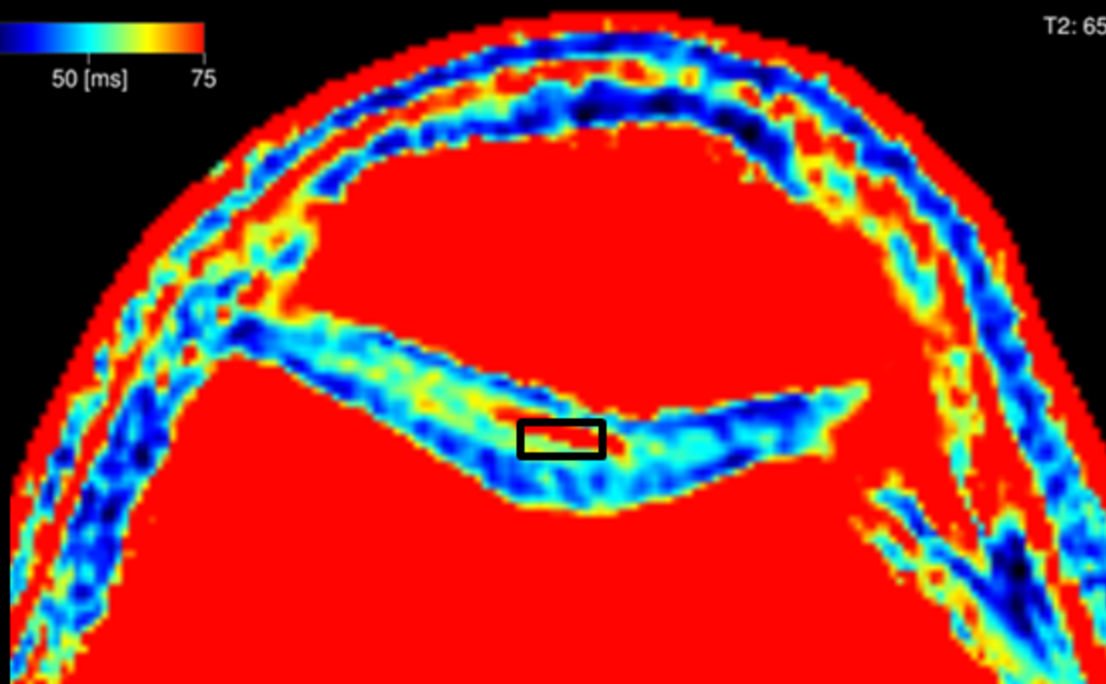
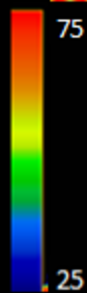
```
graph TD; A[51 patients assessed for eligibility between September 2017 and November 2017] --> B[49 patients ultimately included in the study]; A --> C[Excluded patients (n = 2)  
No synthetic acquisition (n = 1)  
Synthetic acquisition performed in the sagittal plane (n = 1)];
```

Excluded patients (n = 2)  
No synthetic acquisition (n = 1)  
Synthetic acquisition performed in the sagittal plane (n = 1)

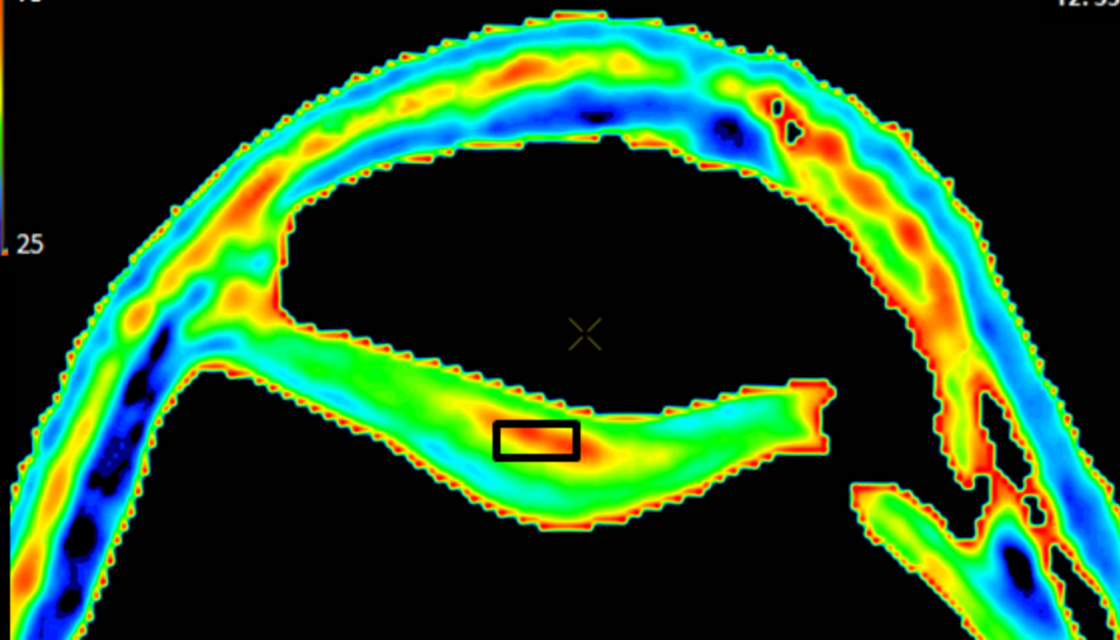
49 patients ultimately included in the  
study

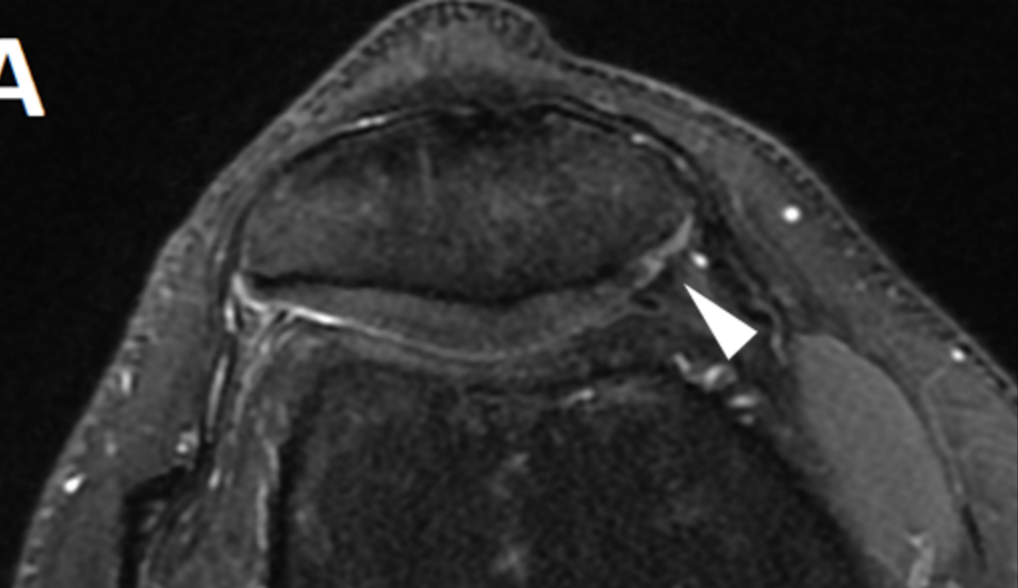
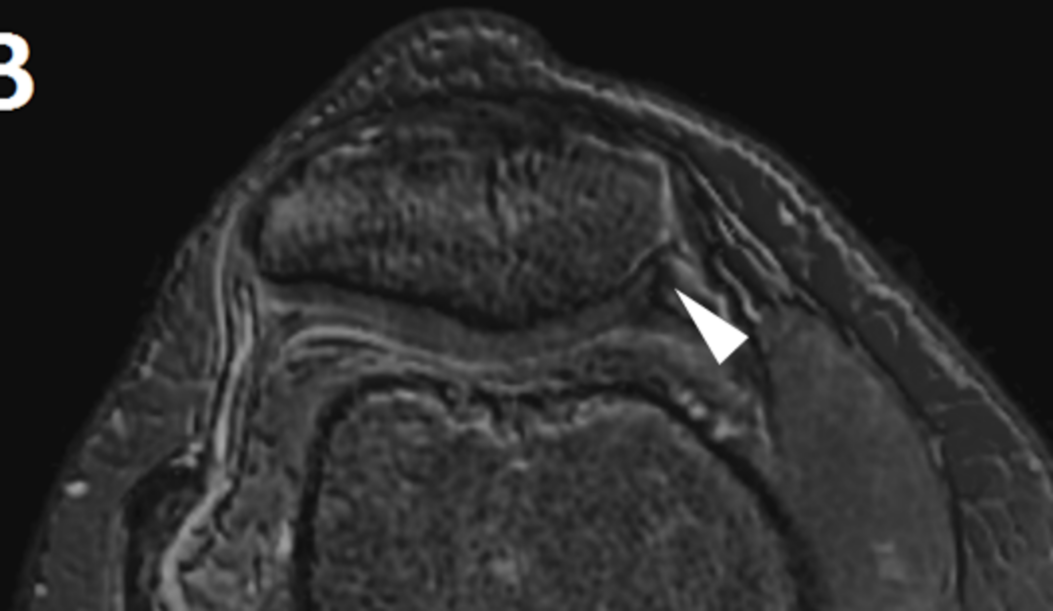
**A**

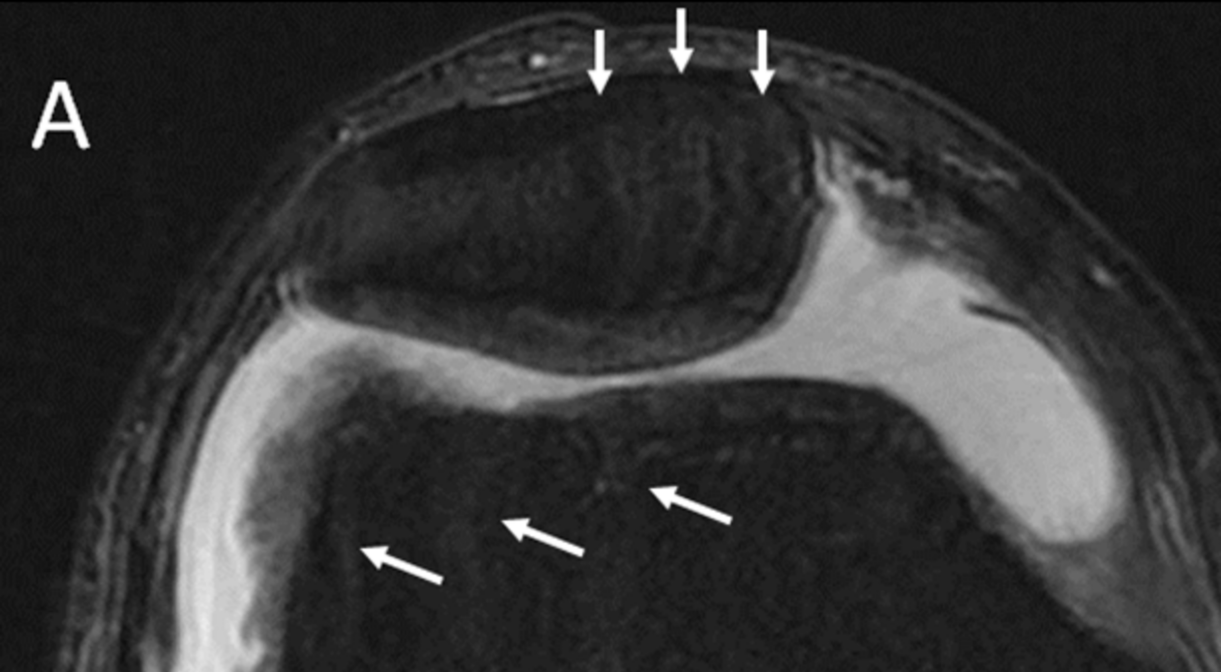
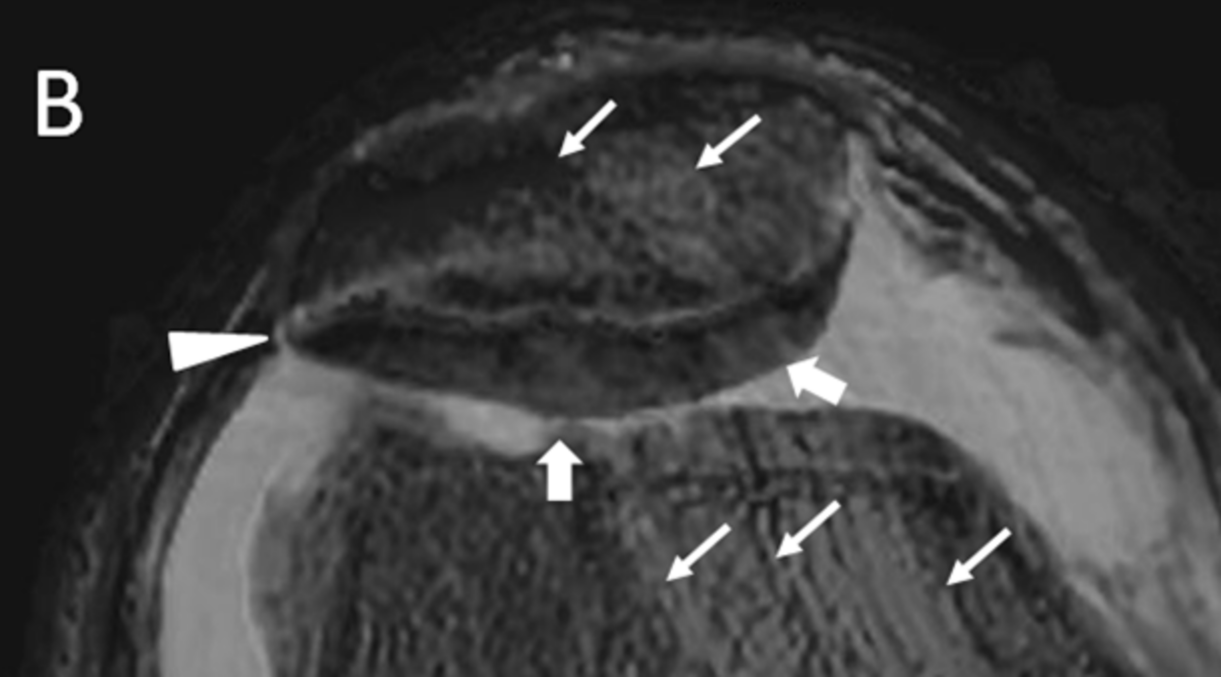
T2: 65 ms

**B**

T2: 55ms



**A****B**

**A****B**

	<b>TR</b> (ms)	<b>TE</b> (ms)	<b>FOV</b> (cm <sup>2</sup> )	<b>acquisition</b> <b>matrix</b>	<b>slice</b> <b>thickness</b> (mm)	<b>gap</b> (mm)	<b>flip</b> <b>angle</b> (°)	<b>ETL</b>	<b>number</b> <b>of slices</b>	<b>Acquisition</b> <b>time</b>
<b>Conventional</b>	3955	49.8	26.8 ×	188 × 352	3	3.3	160	10	31	3 min 18sec
<b>FSE</b>			16							
	900	9.70	33.5 ×	288 × 288	4	5	90	1	80	3min 4 sec
		19.39	20							
		29.09								
		38.78								
<b>T2 mapping</b>		48.48								
		58.18								
		67.87								
		77.57*								
<b>Synthetic</b>	4000	18.18	33.5 ×	352 × 352	4	5	90	10	80	7 min 12sec
<b>images</b>		and	20							
		90.88								

**FSE = Conventional fat-saturated T2 weighted fast spin echo axial images; ETL echo train length; Synthetic acquisitions were performed with a multiple-dynamic multiple-echo (MDME) sequences**

**\* Eight TE values were used for conventional T2 mapping according to vendor recommendations.**



Nitrate concentration of phantom (mmol/L)	T2 relaxation time (ms)		
	Synthetic T2 map sequence	Conventional T2 Map sequence	Phantom experimental T2 values
2.1	56	56	59
0.8	58	60	63
0.31	61	61	64
	58.5 ± 2.26 [ 56 - 61 ]	58.8 ± 2.64 [56 – 61]	62.2 ± 2.48 [59 – 64]

Data are expressed as means ± standard deviations; numbers in brackets are ranges.

	<b>Reader 1</b>	<b>Reader 2</b>	<b>mWORMS</b>
<b>Synthetic T2 map</b>			
Lateral facet	34.4 ± 4.7[26-51]	33 ± 4.3[25-48]	1.2± 1.8 [0-7]
Ridge	38.6 ± 5.2 [30-58]	37.8 ± 8.9[28-90]	1.4 ± 2 [0-6]
Medial facet	35.4 ± 5.8 [26-49]	34.7 ±5.2 [27-48]	1.1 ± 1.6 [0-5]
Mean	36.2 ± 3.8 [29-46]	35.2 ± 4.6[28-55]	3.7 ± 4.9 [0-19]
<b>Conventional T2 map</b>			
Lateral facet	30.4 ± 5.8 [22-57]	28.7 ± 3.8 [23-42]	1.5 ± 1.9 [0-7]
Ridge	33.9 ± 5.5 [25-57]	33.2 ± 6.0 [24-56]	1.6 ± 1.9 [0-6]
Medial facet	31.1 ± 5.9 [23-57]	30 ± 5.2 [23-49]	1.7 ±1.5 [0-5]
Mean	31.8 ± 4.1 [26-49]	30.6 ±3.9 [24-43]	4.8 ± 4.8 [0-16]

Data are expressed means ± standard deviations; numbers in brackets are ranges.

		Interobserver agreement (95% CI)
<b>Synthetic T2 map</b>	Lateral compartment	0.76 (0.61 – 0.86 )
	Ridge	0.71 (0.54 – 0.82)
	Medial compartment	0.79 (0.65 – 0.87)
	Mean	0.83 (0.72-0.92)
<b>Conventional T2 maps</b>	Lateral compartment	0.66 (0.47 – 0.79)
	Ridge	0.91 (0.85 – 0.95)
	Medial compartment	0.82 (0.71 – 0.90)
	Mean	0.87 (0.78 – 0.92)

CI = confidence interval

		Patients with chondropathy (n=35)	Patients with no chondropathy (n=14)	
<b>Reader 1</b>	<b>Synthetic T2 maps</b>			
	Lateral compartment	35.1 ± 5.1 [27-51]	32.8 ± 3.1 [26-38]	
	Ridge	38.7 ± 4.8 [30-54]	39.1 ± 6.7 [31-58]	
	Medial compartment	36.1 ± 5.2 [27-47]	33.8 ± 3.1 [26-49]	
	Mean	36.6 ± 3.5 [29-45]	35.2 ± 4.8 [30-16]	
	<b>Conventional T2 maps</b>			
	Lateral compartment	30.8 ± 6.2 [22-57]	29.5 ± 3.8 [25-39]	
	Ridge	34.5 ± 5.8 [26-57]	32.2 ± 3.4 [25-38]	
	Medial compartment	31.6 ± 6.7 [23-57]	29.9 ± 2.8 [26-36]	
	Mean	32.3 ± 4.7 [26-49]	30.5 ± 2.0 [27-33]	
	<b>Reader 2</b>	<b>Synthetic T2 maps</b>		
		Lateral compartment	33.7 ± 4.6 [28-48]	31.2 ± 3.2 [25-36]
Ridge		37.3 ± 5.2 [28-56]	39.3 ± 6.2 [30-90]	
Medial compartment		35.4 ± 5.2 [27-48]	33.4 ± 3.1 [28-45]	
Mean		35.5 ± 3.7 [28-45]	34.6 ± 6.5 [29-55]	
<b>Conventional T2 maps</b>				
Lateral compartment		29 ± 4.3 [23-42]	27.8 ± 3.1 [24-31]	
Ridge		34.2 ± 6.4 [24-56]	30.8 ± 2.2 [24-37]	
Medial compartment		30.6 ± 5.6 [23-49]	28.8 ± 2.8 [25-37]	
Mean		31.3 ± 4.3 [25-43]	29.2 ± 2.2 [24-33]	

Data are expressed as means ± standard deviations; numbers in brackets are ranges