International Journal of Radiology and Diagnostic Imaging

E-ISSN: 2664-4444
P-ISSN: 2664-4436
www.radiologypaper.com
IJRDI 2023; 6(1): 25-30
Received: 03-10-2022
Accepted: 08-11-2022

Dr. Mohanapriya A
PGJR3, Department of Radiodiagnosis, Mahatma Gandhi Medical College and Research Institute, Sri Balaji Vidyapeeth University, Puducherry, Puducherry Union Territory, India

Dr. Armel Arputha Sivarajan
Associate Professor, Department of Radiodiagnosis, Mahatma Gandhi Medical College and Research Institute, Sri Balaji Vidyapeeth University, Puducherry, Puducherry Union Territory

Dr. Raju
Assistant Professor, Department of Radiodiagnosis, Mahatma Gandhi Medical College and Research Institute, Sri Balaji Vidyapeeth University, Puducherry, Puducherry Union Territory, India

Dr. Col Sudhir Sachar
Professor and HOD, Department of Radiodiagnosis, Mahatma Gandhi Medical College and Research Institute, Sri Balaji Vidyapeeth University, Puducherry, Puducherry Union Territory, India

Corresponding Author:
Dr. Mohanapriya A
PGJR3, Department of Radiodiagnosis, Mahatma Gandhi Medical College and Research Institute, Sri Balaji Vidyapeeth University, Puducherry, Puducherry Union Territory, India

Comparison of 3D water selective excitation sequences versus conventional 2D fat suppressed sequences of MRI in evaluation of knee cartilage

Dr. Mohanapriya A, Dr. Armel Arputha Sivarajan, Dr. Raju and Dr. Col Sudhir Sachar

DOI: http://dx.doi.org/10.33545/26644436.2023.v6.i1a.301

Abstract
Background: To determine any difference between the efficacy of water excitation sequence in comparison with fat suppression sequence in evaluating knee cartilage.
Materials and Methods: This prospective study was conducted for a period of two years from January 2021 to June 2022 in Department of Radiodiagnosis, Mahatma Gandhi Medical College and Research Institute, Pondicherry.
Results: In this prospective study carried out on 40 persons who came for MRI knee, the inter-observer agreement for cartilage visibility was same and found to be better in both the sequences.
The inter-observer agreement for cartilage pathology was found to be same for MFC, LFC and MTP in both the sequences. However, the inter-observer agreement for cartilage pathology over Patella, Trochlea and LTP was found to be better in 3D water excitation sequence than 2D fat suppression sequence.
Conclusion: We observe a significant improvement in the inter-observer agreement when evaluating knee cartilage using 3D-WATS sequences than using conventional 2D PD SE sequences.

Keywords: Knee cartilage, 3D water excitation sequence MRI, 2D fat suppression sequence MRI

Introduction

MRI has emerged as the leading method of imaging soft-tissue structures around joints. One of the major advantages of MRI is its ability to manipulate contrast to highlight different tissue types. MRI, with its excellent soft-tissue contrast, is the best imaging technique currently available for the assessment of articular cartilage [1]. Magnetic resonance (MR) imaging is the most important imaging modality for the evaluation of traumatic or degenerative cartilaginous lesions in the knee. It is a powerful noninvasive tool for detecting such lesions and monitoring the effects of pharmacologic and surgical therapy [2]

Hyaline cartilage is an important intraarticular tissue that may be involved in traumatic injury to and degenerative change in the knee joint. Damaged cartilage rarely heals spontaneously, and its subsequent degeneration in association with degeneration of other articular tissues may lead to knee osteoarthritis, which is a cartilaginous disease [2].

Accurate detection of cartilage lesions within the knee and hip joints in clinical practice is essential to help identify patients who may benefit from early medical and surgical intervention [3].

MR imaging techniques for morphologic assessment of cartilage in the knee provide accurate information about processes such as fissuring and focal or diffuse cartilage loss [4].

Fat suppression is a fundamental technique in routine musculoskeletal magnetic resonance (MR) imaging that is used for three main purposes:

a) To emphasize water sensitivity when used in conjunction with intermediate- and T2-weighted fast spin-echo (SE) sequences,
b) To suppress the signal from normal adipose tissue to reduce chemical shift artifacts.
c) To improve dynamic range in water-containing structures such as cartilage when used in conjunction with T1-weighted sequences [5].

Fat suppression can be achieved with three methods: fat saturation, inversion- recovery imaging, and opposed-phase imaging [6].

An alternative to fat suppression method is water excitation with this technique, only water is excited by using section-selective composite pulses, while lipid spins are left in equilibrium, thereby producing no signal [5].
There are only few studies which show the comparison between fat suppression sequence and water selective sequences for musculoskeletal imaging and there is no study so far to our knowledge which specifically compares both types of sequences in the cartilage evaluation of knee.

Materials and Methods
This prospective study was conducted for a period of two years from January 2021 to June 2022 in Department of Radiodiagnosis, Mahatma Gandhi Medical College and Research Institute, Pondicherry.

Inclusion criteria
All patients referred to the Department of Radiodiagnosis, Mahatma Gandhi Medical College and Research Institute, Puducherry for MRI Knee with complaint of musculoskeletal pain in knee

Exclusion criteria
Patients having pacemaker, paramagnetic implants paramagnetic foreign bodies
Patients who are claustrophobic
Patients who cannot remain immobile within the MRI scanner.

Procedure
MRI knee imaging protocol
All scans will be performed on a 1.5T Philips Achieva machine.

Sequences
- 3D Water excitation sequence- T2-weighted GE,
- 2D Fat suppression sequence-Proton density weighted SPIR in all three planes.

MRI images (3D Water excitation- T2 weighted GE and 2D Fat Suppression-Proton density weighted SPIR) were evaluated by simple visual inspection and attention given to the presence or absence, visibility, margination and extension of lesion.
Images were reviewed by two radiologists blinded to each other along with the researcher.
The data was then recorded on proformas by the researcher as –
- Visibility of cartilage/contrast was graded as fair, good, excellent
- Based on the pathological characteristics, the visualised cartilage was graded by ICRS as grades 0 through 4
- Cartilage was assessed at
- Patella
- Medial femoral condyle
- Lateral femoral condyle
- Trochlea
- Medial tibial plateau and
- Lateral tibial plateau
- Inter-observer agreement was then calculated for each sequence separately and given a kappa value
- A kappa value of >0.8 indicated excellent correlation, 0.6-0.8 was considered as a good correlation, 0.4-0.6 fair correlation and values below that range denotes poor correlation between the readers.
- If the kappa value for one sequence was better than the other, that sequence is considered better and more reliable for cartilage injury grading.

Data collection
All data was entered into a Data Collection Proforma Sheet (Appendix 1) and was entered into Excel (MS Excel 2019). Other biographical details were also collected including age.

Statistical methods
Statistical analysis was carried out using SPSS version 19.0 (IBM SPSS, US) software with Regression Modules installed.

Results
The study results were expressed in frequencies and their respective percentages. All the study variables were analysed using chi square test which was done to measure the association between the 2D and 3D sequences. The inter observer agreement was expressed using kappa values.
Among the 40 study participants, 20% (n=8) of them were <30 years of age, 70% (n=28) of them belong to the age group of 31 to 50 years, 10% (n=4) of them were >51 years of age.

Inter-observer correlation analysis
The inter-observer agreement analysis was done, and kappa values was interpreted between two readers in both 2D fat suppression and 3D water excitation MRI. A kappa value of >0.8 indicated excellent correlation, 0.6-0.8 was considered as a good correlation, 0.4-0.6 fair correlation and values below that range has denotes poor correlation between the readers.
In 2D fat suppression MRI the correlation between two readers was excellent (kappa value=1) on examination of cartilage visibility or cartilage contrast, for ICRS grading of patella evaluation was excellent (kappa value= 0.883), the grading of medial femoral condyle and lateral femoral condyle was analysed to be excellent (kappa value=1) between the observers. On evaluation of trochlea ICRS grading the inter observer correlation was fair (kappa value=0.531), the medial tibial plateau between them was found to be excellent (kappa value=1), and lateral tibial plateau was good (kappa value=0.638) as shown in the table 1.

Table 1: Distribution of Inter-observer agreement between reader 1 and reader 2 for the 2D PD SE sequences

Variable			Total	Kappa value	P value
	1 Cartilage Visibility (Reader 2)				
1 Cartilage Visibility (Reader 1)	Poor/ fair	Good / excellent			
Poor/ fair	1	0	1	1	0.001*
Good / excellent	0	39	39		
Total	1	39	40		

	1 Patella (Reader 2)				
1 Patella (Reader 1)	ICRS GRADE ≤3	ICRS GRADE >3			
ICRS GRADE ≤3	26	0	26	0.886	0.001
ICRS GRADE >3	2	12	14		
Total	28	12	40		
	1. Medial Femoral Condyle (Reader 2)				
1 Medial Femoral Condyle (Reader 1)	ICRS GRADE ≤3	ICRS GRADE >3		1	0.001
ICRS GRADE ≤3	33	0	33		
ICRS GRADE >3	0	7	7		
Total	33	7	40		
	1 Lateral Femoral Condyle (Reader 2)				
1 Lateral Femoral Condyle (Reader 1)	ICRS GRADE ≤3	ICRS GRADE >3		1	0.001*
ICRS GRADE ≤3	33	0	33		
ICRS GRADE >3	0	7	7		
Total	33	7	40		
	1 Trochlea (Reader 2)				
1 Trochlea (Reader 1)	ICRS GRADE ≤3	ICRS GRADE >3		0.531	0.001*
ICRS GRADE ≤3	35	1	36		
ICRS GRADE >3	2	2	4		
Total	37	3	40		
	1 Medial Tibial Plateau (Reader 2)				
1 Medial Tibial Plateau (Reader 1)	ICRS GRADE ≤3	ICRS GRADE >3			
ICRS GRADE ≤3	34	0	34	1	0.001*
ICRS GRADE >3	0	6	6		
TOTAL	34	6	40		
	1 Lateral Tibial Plateau (Reader 2)				
1 Lateral Tibial Plateau (Reader 1)	ICRS GRADE ≤3	ICRS GRADE >3			
ICRS GRADE ≤3	37	2	39	0.638	0.001*
ICRS GRADE >3	0	1	1		
Total	37	3	40		

In 3D water excitation MRI, the correlation between two readers was seen to be good (kappa value= 0.677) for evaluation of cartilage visibility/ cartilage contrast. The inter-observer agreement for patella examination was found to be excellent (kappa value= 0.886), for medial femoral condyle was excellent (kappa value= 1), for lateral femoral condyle to be excellent (kappa value= 1). The inter-observer agreement between two readers for evaluation of ICRS grading of trochlea was analysed to be excellent (kappa value= 1), for medial tibial plateau was found to be excellent (kappa value=1), and lateral tibial plateau had been evaluated to be excellent (kappa value=1) between the readers as shown in table 2.

Table 2: Distribution of Inter-observer agreement between reader 1 and reader 2 for the 3D WATS sequence

Variable			**Total**	**Kappa value**	**P value**
	2 Cartilage Visibility (Reader 2)				
2 Cartilage Visibility (Reader 1)	Good	Excellent			
Good	8	3	11	0.677	0.001*
Excellent	2	27	29		
Total	10	30	30		
	2 Patella (Reader 2)				
2 Patella (Reader 1)	ICRS GRADE ≤3	ICRS GRADE >3			
ICRS GRADE ≤3	26	0	26	1	0.001*
ICRS GRADE >3	0	14	14		
Total	26	14	40		
	2 Medial Femoral Condyle (Reader 2)				
2 Medial Femoral Condyle (Reader 1)	ICRS GRADE ≤3	ICRS GRADE >3			
ICRS GRADE ≤3	33	0	33	1	0.001*
ICRS GRADE >3	0	7	7		
TOTAL	33	7	40		
	1 Lateral Femoral Condyle (Reader 2)				
1 Lateral Femoral Condyle (Reader 1)	ICRS GRADE ≤3	ICRS GRADE >3			
ICRS GRADE ≤3	33	0	33	1	0.001*
ICRS GRADE >3	0	7	7		
TOTAL	33	7	40		
	2 Trochlea (Reader 2)				
2 Trochlea (Reader 1)	ICRS GRADE ≤3	ICRS GRADE >3			
ICRS GRADE ≤3	35	0	35	1	0.001*
ICRS GRADE >3	0	5	5		

Total	35	5	40		
	1 Medial Tibial Plateau (Reader 2)				
1 Medial Tibial Plateau (Reader 1)	ICRS GRADE ≤3	ICRS GRADE >3			
ICRS GRADE ≤3	34	0	34	1	0.001*
ICRS GRADE >3	0	6	6		
Total	34	6	40		
	2 Lateral Tibial Plateau (Reader 2)				
2 Lateral Tibial Plateau (Reader 1)	ICRS GRADE ≤3	ICRS GRADE >3			
ICRS GRADE ≤3	37	0	37	1	0.001*
ICRS GRADE >3	0	3	3		
TOTAL	37	3	40		

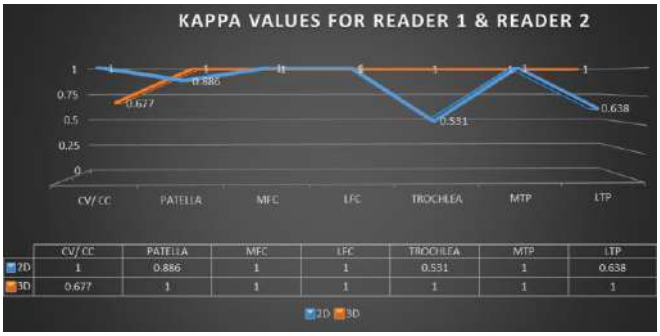

Fig 1: Comparison between 2D & 3D MRI kappa values of reader 1 and 2

Representative images

45-year-old female with history of knee pain

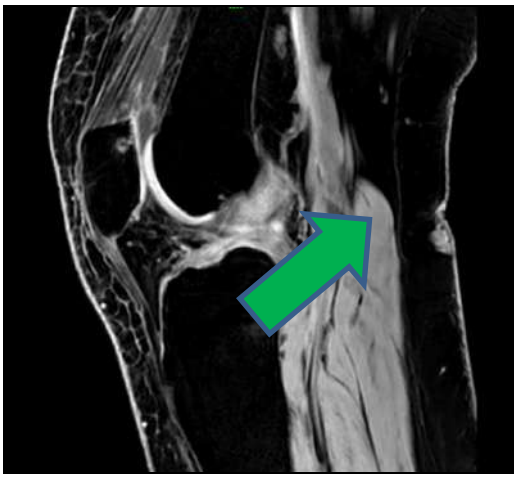

Fig 2: 3D WATS sequence showing Chondromalacia patella grade IV (green arrow)

Fig 3: 2D PDFS image of same patient showing Chondromalacia patella (green arrow)

23-year-old female

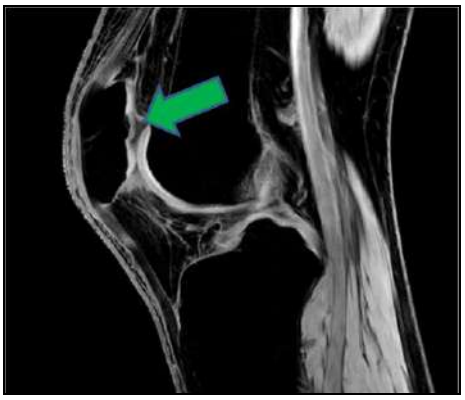

Fig 4: 3D WATS sequence showing the Focal cartilage defect over patella better.

Fig 5: 2D PDFS sequence showing focal cartilage defect in patella.

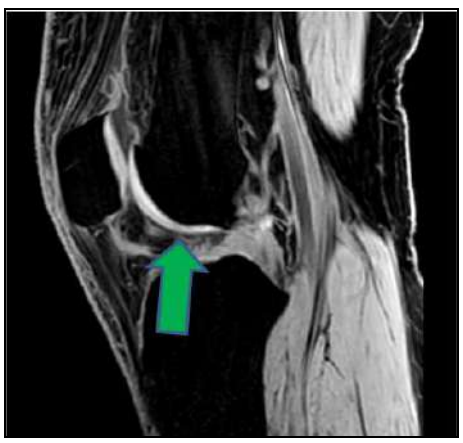

Fig 6: 3D WATS showing superficial articular cartilage surface irregularity along the medial condylar surface much better– ICRS grade 1

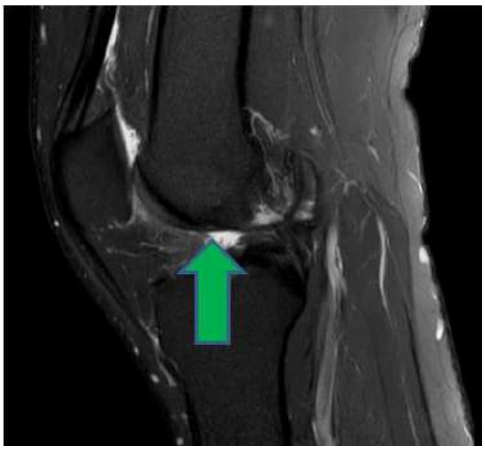

Fig 7: 2D PDFS showing superficial articular cartilage surface irregularity along the medial condylar surface – ICRS grade 1

Discussion

Cartilage visibility/contrast in 2D fat suppression sequence and 3D water excitation sequences

Cartilage visibility was graded as Good and Excellent for most of the cases by both the readers individually. Reader 1 had given excellent for 45% (n=18) and Reader 2 has given excellent of 42.5% (n=17) in 2D fat suppression sequence. Reader 1 gave excellent scoring to 72.5% (n=29) and Reader 2 has given excellent for 75% (n=30) in 3D water excitation sequences. In 2D fat suppression MRI the correlation between two readers was excellent (kappa value=1) on examination of cartilage visibility or cartilage contrast. In 3D water excitation MRI, the correlation between two readers was seen to be good (kappa value= 0.677) for evaluation of cartilage visibility/ cartilage contrast. The p value for both the sequences was found to be significant. Hence for cartilage visibility/ contrast, 2d fat suppression sequence was found to be better than 3D water excitation sequence.

Patella

Cartilage over patella was seen in both sequences and reviewed by two readers separately and graded according to ICRS. 45% has been given grade 0 by both readers which indicates no evidence of cartilage injury. 17.5% has been Graded as grade 3 and grade 4 by reader 1. 20% of the patients has been graded as grade 4 by and 10% as grade 3 by reader 2 in 2D fat suppression sequence. In 3D water excitation sequence, 12.5% and 22.5% was given as grade 3 and grade 4 by reader 1 and 15% and 20% as grade 3 and grade 4 by reader 2. Inter-observer agreement of patella evaluation was found to be excellent (kappa value= 0.883) in 2D fat suppression sequence with significant p value. However the Inter-observer agreement of patella in 3D water excitation sequence was found to be better than conventional 2D fat suppression sequence (kappa value = 1). Hence, 3D water excitation sequence was found to be better than 2D fat suppression sequence for cartilage over patella. However both was found to be excellent.

Medial femoral condyle

70% has been given grade 0 by both readers in both sequences. 2.5% and 15% has been graded as grade 3 and grade 4 by reader 1 and 5% of the patients has been graded as grade 3 and 12.5% as grade 4 by reader 2 in 2D fat suppression sequence. In 3D water excitation sequence, 2.5% and 15% was given as grade 3 and grade 4 by reader 1 and reader 2. Inter-observer agreement for medial femoral condyle was found to be excellent (kappa value= 1) in both the sequences with significant p value.

Lateral Femoral condyle

77.5% and 85% has been given grade 0 by both readers respectively. 5% and 12.5% has been graded as grade 3 and grade 4 by reader 1 and 5% of the patients has been graded as grade 3 and 5% as grade 4 by reader 2 in 2D fat suppression sequence. In 3D water excitation sequence, 77.5% and 75% was given as grade 0 by reader 1 and reader 2, 5% and 12.5% was given as grade 3 and grade 4 by reader 1 with 2.5% and 15% as grade 3 and grade 4 by reader 2 respectively. Inter-observer agreement for lateral femoral condyle had been analyzed to be excellent (kappa value= 1) in both the sequences with significant p value.

Trochlea

85% has been given grade 0 by both readers. 5% and 5% has been graded as grade 3 and grade 4 by reader 1 and 0% of the patients has been graded as grade 3 and 7.5% as grade 4 by reader 2 in 2D fat suppression sequence. In 3D water excitation sequence, 85% has been given grade 0 by both readers. 5% and 7.5% was given as grade 3 and grade 4 by reader 1 with 5% and 7.5% as grade 3 and grade 4 by reader 2 respectively. The inter-observer agreement between two readers for evaluation of trochlea was analyzed to be excellent (kappa value= 1) with significant p value in 3D water excitation sequence and the inter-observer agreement in 2D fat suppression sequence was found to be fair (0.536). Hence, 3D water excitation sequence was found to be better than 2D fat suppression sequence for cartilage over trochlea.

Medial tibial plateau

85% has been given grade 0 by both readers. 5% and 10% has been graded as grade 3 and grade 4 by reader 1 and 7.5% of the patients has been graded as grade 3 and 7.5% as grade 4 by reader 2 in 2D fat suppression sequence. In 3D water excitation sequence, 85% has been given grade 0 by both readers. 5% and 10% was given as grade 3 and grade 4 by reader 1 with 5% and 10% as grade 3 and grade 4 by reader 2 respectively. The inter-observer agreement between two readers for evaluation of ICRS grading for medial tibial plateau was found to be excellent (kappa value=1) in both the sequences with significant p value.

Lateral tibial plateau

92.5% has been given grade 0 by both readers. 0% and 2.5% has been graded as grade 3 and grade 4 by reader 1 and 0% of the patients has been graded as grade 3 and 7.5% as grade 4 by reader 2 in 2D fat suppression sequence. In 3D water excitation sequence, 92.5% has been given grade 0 by both readers. 0% and 7.5% was given as grade 3 and grade 4 by both reader 1 and reader 2 respectively. The inter-observer agreement between two readers for evaluation of ICRS grading lateral tibial plateau had been evaluated to be excellent (kappa value=1) in 3D water excitation sequence with significant p value and found to be fair in 2D fat suppression sequence. Hence, 3D water excitation sequence was found to be better than 2D fat suppression sequence for cartilage over lateral tibial plateau.

This study correlates well with the study done by Mokhtar Mars *et al*. in 2018 which showed 3D high resolution

sequences provide knee articular cartilage imaging with high image quality (SNR, contrast, artifacts) in relatively short acquisition time, minimum artifacts and more accurate cartilage thickness measurement [6].

Delaram Shakoor *et al*. in 2019 showed that the diagnostic performance of 3D MRI has statistically significantly improved and that current 3D MRI techniques provide comparable diagnostic performance to 2D MRI for depicting cartilage defects within the knee joint. Their results suggest that improvements in diagnostic performance of 3D MRI could be achieved with the use of 3.0-T field strength, 3D FSE sequences, and multiplanar reformation[7]. This study correlates well. However, Few studies showed 2D fat suppression was better than 3D water excitation sequence for cartilage.

Conclusion

Based on our study we observe a significant improvement in the inter-observer agreement when evaluating knee cartilage using 3D-WATS sequences than using conventional 2D PD SE sequences. Furthermore, there is also a decrease in the overall imaging time as the 3D sequence is isotropic and can be reconstructed into all 3 planes while the conventional sequence has to be acquired separately in all 3 planes to be equivalent. This study thus demonstrates the practical advantages the incorporation of the 3D WATS sequence would have in reducing subjectivity and decreasing overall scan times for a better workflow.

Acknowledgements

It gives me an immense pleasure to express my deepest gratitude and sincere thanks to my Guide, Dr. SIVARAJAN Associate Professor, Department of Radiodiagnosis, Mahatma Gandhi Medical College and Research Institute, Pondicherry for his constant support, encouragement and guidance which helped me to complete my dissertation work.

I express my heartfelt gratitude to Dr. MVS RAJU, Assistant Professor, Department of Radiodiagnosis for guiding me for this task by his valuable advice, unstinted support and encouragement which helped me finish my thesis.

I offer my sincere gratitude to Prof. Dr. Col. SUDHIR SACHAR, Professor and HOD,

for helping me with immense encouragement and guidance during the preparation of my thesis.

A special mention to Dr. G. EZHUMALAI, Senior Statistician and Research Consultant, Sri Balaji Vidyapeeth, for helping me with Statistics for my thesis. I extend my deep gratitude to all the faculty members of the department of Radiodiagnosis for their timely support during my postgraduation course. I cherish and remember all the experience with my fellow postgraduates who helped me with this study. My deep gratitude to all the patients who co-operated during my study, without whom, this study would not be possible.

My reverence to my beloved parents Mr. T.R. Anbazhagan, Mrs. Rathna Anbazhagan and my brother Dr. Arun Vijai Anandh. A for their immense sacrifices and guidance that has moulded me into the person I am today. A special mention to my Grandfather V.P. Pazhani who has been a constant support and Dr. Monish G.K, Dr. Thulasi Arumugam and Dr. Gowtham M who motivated me throughout the course.

Conflict of Interest

Not available

Financial Support

Not available

References

1. Gold GE, Chen CA, Koo S, Hargreaves BA, Bangerter NK. Recent Advances in MRI of Articular Cartilage. Am J Roentgenol. 2009;193(3):628-38.
2. Crema MD, Roemer FW, Marra MD, Burstein D, Gold GE, Eckstein F, *et al*. Articular Cartilage in the Knee: Current MR Imaging Techniques and Applications in Clinical Practice and Research. Radio Graphics. 2011;31(1):37-61.
3. Kijowski R. Clinical Cartilage Imaging of the Knee and Hip Joints. Am J Roentgenol. 2010;195(3):618-28.
4. Crema MD, Roemer FW, Marra MD, Burstein D, Gold GE, Eckstein F, *et al*. Articular Cartilage in the Knee: Current MR Imaging Techniques and Applications in Clinical Practice and Research <sup/>. Radio Graphics. 2011;31(1):37-61.
5. Hauger O, Dumont E, Chateil J-F, Moinard M, Diard F. Water Excitation as an Alternative to Fat Saturation in MR Imaging: Preliminary Results in Musculoskeletal Imaging. Radiology. 2002;224(3):657-63.
6. Mars M, Tbini Z, Chelli M, Ladeb F. Comparison of 3D MR imaging sequences in knee articular cartilage at 1.5 T. (14).
7. Diagnostic Performance of Three-dimensional MRI for Depicting Cartilage Defects in the Knee: A Meta-Analysis.https://pubs.rsna.org/doi/epdf/10.1148/radiol.2018180426.

How to Cite This Article

Mohanapriya A, Sivarajan AA, Raju, Sachar CS. Comparison of 3D water selective excitation sequences versus conventional 2D fat suppressed sequences of MRI in evaluation of knee cartilage. International Journal of Radiology and Diagnostic Imaging. 2023;6(1):25-30.