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ORIGINAL ARTICLE

Clinical Utility of DECT in Fat Fraction Assessment of Rotator Cuff Tears: A Comparative Analysis with MRI

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Abstract
Introduction: Rotator cuff tears are common musculoskeletal injuries, often associated with fatty degeneration (FD) of the rotator cuff muscles. While MRI has been the gold standard for assessing FD, dual-energy CT (DECT) shows promise in providing quantitative measurements. This study aims to compare FD quantification using DECT and MRI fat fraction values in patients with rotator cuff tears. **Materials and Methods:** Thirty patients diagnosed with rotator cuff tears underwent DECT and MRI scans for FD assessment. Imaging parameters and techniques were standardized for both modalities. Fat fraction values were obtained using region-of-interest (ROI) analysis. **Results:** The mean age of participants was 55.73 ± 10.16 years, with a majority classified as Goutallier stage 1. Significant differences were observed between fat fraction values measured by DECT and MRI. The ICC revealed moderate reliability (0.549, $p<0.001$), while the Pearson correlation coefficient indicated a strong positive correlation (0.808, $p<0.001$) between the two modalities. **Conclusion:** While DECT shows potential in preoperative assessment, MRI remains superior to DECT in assessing fat fraction in rotator cuff tears. Further research comparing DECT and MRI fat fraction performance is needed to determine their respective roles in clinical practice.

Keywords: Rotator cuff tears, fatty degeneration, dual-energy CT, MRI, fat fraction

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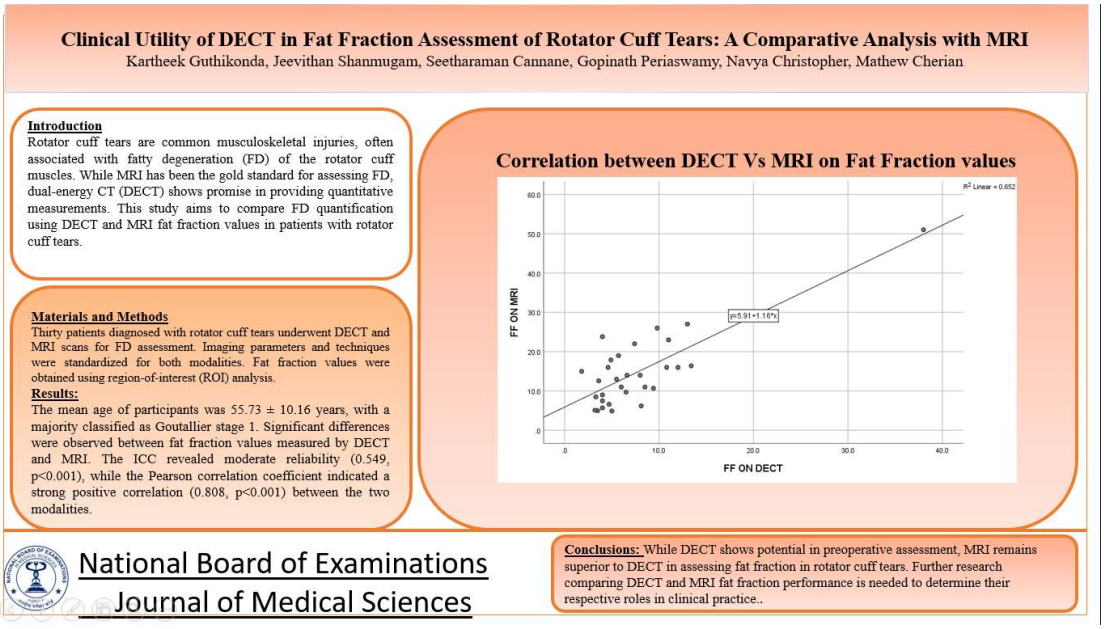
Graphical Abstract



Introduction

The rotator cuff constitutes the supraspinatus, infraspinatus, teres minor, and subscapularis muscles, playing a crucial role in shoulder mobility. Shoulder abduction initiation hinges significantly on the functional capacity and structural soundness of the supraspinatus muscle, in conjunction with the coordinated actions of the remaining rotator cuff muscles and their associated tendons [1].

Rotator cuff tendon disorders are classified into three categories: absence of tear, tendinopathy without tear, and tendinopathy with tear. Tears can be further classified as partial or complete. It's noteworthy that rotator cuff tears are found in up to 39% of individuals without symptoms. Moreover, the incidence of rotator cuff tears tends to rise with age [1,2]. Fatty degeneration (FD) occurring in the infraspinatus and subscapularis muscles has been linked to a heightened risk of recurrent tears in the supraspinatus tendon. This correlation may be attributed to reduced depressor capability, potentially leading to impingement of the supraspinatus tendon [3].

During the pre-operative assessment of rotator cuff tears, it is crucial to look for muscle abnormalities namely muscular atrophy and fatty degeneration. Fatty degeneration in the context of rotator cuff tears typically develops in muscles as a result of substantial and long-standing tendon tears. Studies have shown that the risk of rotator cuff retear is linked to the severity of fatty degeneration in the corresponding muscles before surgery.[3] Therefore, it is essential to assess the degree of fatty degeneration in rotator cuff muscles during pre-operative evaluations to determine surgical indications and anticipate the risk of recurrence.

Goutallier introduced a semi-quantitative grading system for fatty degeneration (FD). However, this system has faced inherent challenges. Studies indicate that the Goutallier score demonstrates moderate reproducibility, even among experienced observers. Qualitative assessments are further hindered by relatively high levels of inter-observer and intra-observer variability. To enhance assessment accuracy and reliability, a dependable quantitative

measurement method is necessary, as it helps minimize both inter and intra-observer variability. Presently, the Dixon method in MRI stands as the gold standard for quantifying fatty degeneration in rotator cuff muscles. Its superiority lies in its ease of reproducibility and accuracy in providing quantitative measurements [4].

Quantitative measurement of muscle density using computed tomography (CT) is recognized for its reliability and reproducibility. Dual-energy CT (DECT) emerges as a promising tool due to its capability to distinguish X-ray attenuation across different tissue types using various X-ray energy spectra. This unique ability enables the decomposition of materials and separation of fat, thereby improving the quantitative assessment of muscle density. DECT's potential for fat quantification presents a potentially stronger measure of fatty degeneration compared to MRI quantification using the Dixon method. The advantage of DECT lies in its ability to produce virtual mono-energetic images with reduced CT number variability compared to single-energy CT [4].

While individual studies have separately assessed CT and MRI quantification of fatty degeneration and correlated them with tendon severity, there remains a gap in data comparing DECT and MRI fat fractions. Therefore, this study has been planned to determine the amount of fatty degeneration of rotator cuff muscles using the DECT method and compare it with MRI fat fraction values in patients with rotator cuff tears. By comparing DECT and MRI fat fractions, the study aims to elucidate their potential roles in the clinical management of rotator cuff tears.

Materials and Methods

This cross-sectional study was conducted at a tertiary care teaching hospital in the western region of South India and received prior approval from the ethical committee. A consent waiver was granted by the ethical committee to utilize the MRI Picture Archiving and Communication System (PACS). After Institutional Ethics Committee approval and obtaining informed consent, all patients diagnosed with rotator cuff tears via MRI between February 2021 and August 2021 were considered for inclusion.

Participants under 18 years old or with a history of prior rotator cuff repair were excluded from the study. The primary investigator contacted eligible participants who met the inclusion and exclusion criteria. The study's objectives, necessity, participants' rights, and ethical considerations were thoroughly discussed. Patient information sheets were provided, allowing participants adequate time to review and comprehend the study's details. Upon expressing willingness to participate, written informed consent was obtained from each participant before undergoing DECT. The total number of patients included in the study was 30.

DECT Technique

- Imaging was conducted using a Siemens dual-energy 384 slice Computerised Tomography (CT) machine (Somatom Force, Siemens Healthcare, Erlangen, Germany).
- Parameters included tube voltage at 100/150 kV with a tin filter along with automatic exposure control settings of 415 mAs for low and 208 mAs for high quality reference x-ray tube energies respectively.
- Detector collimation of 192×0.6mm (with a z-flying focal spot) and a pitch of 0.6.
- The specified volume CT dose index (CTDIvol) was 24.1 mGy. Actual CTDIvol varied according to patient

size with the automatic exposure control (CAREDose4D, Siemens Healthcare).
- Images acquired at 100 kV and 150 kV were reconstructed in the parasagittal and axial planes of the shoulder using a soft-tissue smooth kernel (QR44) and an iterative reconstruction strength setting of 3 (ADMIRE; Siemens Healthcare).
- Slice thickness and interval were 1mm and 0.6 mm, respectively.
- Monochromatic images at 70 keV were generated using post-processing software (Syngo.via VB50).
- ROIs were drawn for each rotator cuff muscle in the parasagittal plane using Syngovia VB 50, Vnc application, which generated the fat fraction value for each muscle.

MRI Technique
- Imaging was performed on a Philips Ingenia 1.5T MRI scanner.
- The MRI protocol for diagnosing rotator cuff tears included PD fs sequence in oblique coronal, oblique sagittal, and axial planes; T2 TSE sequence in oblique coronal, oblique sagittal, and axial planes; a T1-weighted TSE sequence in oblique coronal, oblique sagittal planes; and mDixon method in the oblique sagittal plane for fat quantification.
- ROIs were drawn for each rotator cuff muscle in mDixon sequences using Philips ISP software, which generated fat fraction values for each muscle.

Free hand ROI was done along the outer margin of the cross section of the muscles in both the CT and MRI in the corresponding images.

Statistical analysis

The collected data were entered into Microsoft Excel and later exported for analysis using IBM SPSS version 27. Descriptive statistics was represented as mean and standard deviation, while categorical variables were expressed as frequency and percentages. t test was done to compare the association between Fat Fraction assessed by DECT and MRI. To assess the correlation between CT and MRI in fat fraction, intra-class correlation coefficients (ICC) were computed. Additionally, Pearson correlation coefficients were calculated to confirm the correlation between the two imaging modalities. A significance level of $p<0.05$ was deemed statistically significant.

Results

A total of 30 participants were enrolled in the study. The mean age of the study participants was 55.73 ± 10.16 with age ranging from 36-73. Females constituted 53.3% (16) and males 46.7% (14). 36.7% (11) had a normal BMI, another 60% (18) were overweight and the rest 3.3% (1) was obese. According to Goutallier classification, 76.7% (23) were stage 1, 20% (6) were stage 2 and the rest 3.3% (1) was stage 4. 36.7% (11) had supraspinatous tear, another 26.6% (8) had infraspinatous tear and the rest 36.7(11) had subscapularis tear. None had teres minor tear. According to tendon tear severity, 10% had full thickness tear, 73.3% had partial tear less than 25%. The rest 16.7% (5) had either 50% or 75% tear (Table 1).

The association between Fat Fraction measured with MRI and CT scan was measured. There was a significant difference between both. (Table 2)

The intraclass correlation coefficient was also 0.549($P<0.001$) indicating a moderate reliability (Table 3). The pearson correlation coefficient was 0.808 ($P < 0.001$) exhibiting a very high positive correlation (Fig. 1).

Table 1. Socio demographic characteristics of the study population

Parameter	Frequency	Percentage
Age		
35-45	5	16.7
46-55	9	30
56-65	10	33.3
66-75	6	20
Sex		
Male	14	46.7
Female	16	53.3
BMI		
Normal	11	36.7
Over weight	18	60
Obese	1	3.3
Goutallier Classification		
Stage 1	23	76.7
Stage 2	6	20
Stage 4	1	3.3
Position of Tear		
Supraspinatous tear	11	36.7
Infraspinatous tear	8	26.6
Subscapularis tear	11	36.7
Tear minor	0	0
Tear severity of Tendon		
Full thickness	3	10
Partilal < 25	22	73.3
Partial 25-50%	2	6.7
Partial high grade	3	10

Table 2. Mean comparison of Fat Fraction between DECT and MRI

MRI		DECT		Mean Diff	t value	p Value
Mean	SD	Mean	SD			
14.79	9.36	7.68	6.53	7.11	-6.938	<0.001

Table 3. ICC between DECT vs MRI on Fat Fraction values

Parameter measured	ICC	95% Confidence Interval		Significance	
		Lower limit	Upperlimit	F Value	P Value
Fat Fraction	0.549	-0.074	0.825	7.267	<0.001

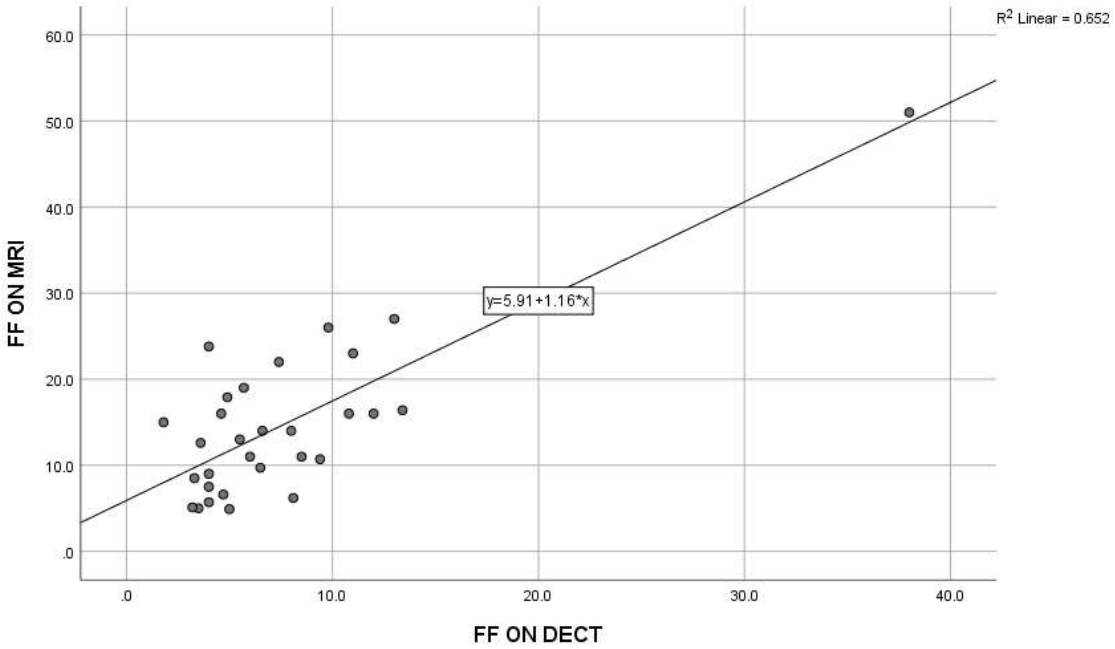


Fig 1. Correlation between DECT vs MRI on Fat Fraction values

Discussion

The cross-sectional study conducted on 30 participants aimed to understand the performance of Dual-energy computed tomography (DECT) in assessing Fat Fraction compared to routine Magnetic Resonance Imaging (MRI). The findings suggested a considerable statistically significant difference between the mean values, suggesting that MRI images outperformed DECT in detecting Fat Fraction. The Intraclass correlation coefficient of 0.549 indicated moderate reliability, while the Pearson correlation coefficient of 0.8 indicated a strong correlation between the two imaging modalities. However, despite the strong correlation, DECT was deemed inferior to MRI in Fat Fraction assessment.

DECT utilized material decomposition of iodine, fat, and soft tissue to assess Fat Fraction. This method was chosen due to limitations in MRI techniques. Qualitative assessment of fat on MRI using T1-weighted images was found to be limited in accuracy for fat quantification. Additionally, MR spectroscopy, while offering advantages, had drawbacks such as low spatial resolution and T2 bias [5,6].

Study by Muller et al. highlighted various aetiologies for fatty infiltration, including traction neuropathy and muscle tension loss, leading to architectural and physiological changes. They also demonstrated that the degree of tear retraction had a significant influence on the extent of fatty infiltration, as observed in a sheep model [7].

Dual-energy computed tomography (DECT) and magnetic resonance imaging (MRI) each have distinct strengths and limitations in identifying and quantifying fat fraction in rotator cuff tears [8-11].

1. Tissue Differentiation: MRI is superior to DECT in tissue differentiation, particularly in

distinguishing between adipose tissue and muscle due to its high soft tissue contrast resolution. This capability allows MRI to accurately identify and quantify fat fraction within the rotator cuff muscles.

2. Quantitative Accuracy: MRI using techniques such as the Dixon method provides highly accurate and reliable quantitative measurements of fat fraction in rotator cuff muscles. This method has been extensively validated in various studies, demonstrating its reliability in assessing fatty degeneration in rotator cuff tears.
3. Resolution and Detail: MRI typically offers higher spatial resolution and detailed anatomical visualization compared to DECT. This higher resolution allows for precise delineation of muscle boundaries and fat infiltration within the muscles, contributing to accurate fat fraction calculations.
4. Clinical Validation: MRI-based fat fraction measurements have been extensively validated in clinical studies and have become the standard method for assessing fatty degeneration in rotator cuff tears. Numerous research articles have demonstrated the clinical utility and reliability of MRI in evaluating fatty infiltration in rotator cuff muscles.

Despite the advantages of MRI-based fat quantification techniques, MRI is less readily available and more costly compared to CT. Non-contrast CT is routinely obtained in preoperative shoulder evaluations. However, the performance of DECT Fat Fraction against MRI Fat Fraction has not been extensively reported.

Conclusion

While DECT offers potential advantages in certain clinical scenarios, such as preoperative assessment, the study suggests that MRI remains superior to DECT in assessing Fat Fraction in rotator cuff tears. Further research comparing DECT and MRI Fat Fraction performance is warranted to provide more comprehensive insights into their respective roles in clinical practice.

Statements and Declarations

Conflicts of interest

The authors declares that they do not have conflict of interest.

Funding

No funding was received for conducting this study.

Ethics approval

Ethical approval obtained from all patients.

Human and animal rights

This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent

For this type of study formal consent is not required.

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