ISAKOS CONGRESS 2025 | MUNICH GERMANY June 8–11

Can fatty infiltration percentages on MRI predict irreparable cuff tears?

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Faculty Disclosure Information

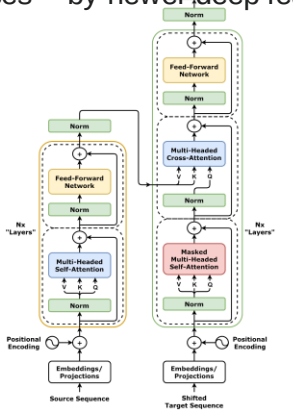
- My disclosures are;
  - Consultancies; Arthrex,
  - Depuy,
  - Smith and Nephew

  - Fellowship Support; Arthrex,
  - Depuy,
  - Smith and Nephew,
  - Stryker

The “New Age of Computing”; AI, CNN’s

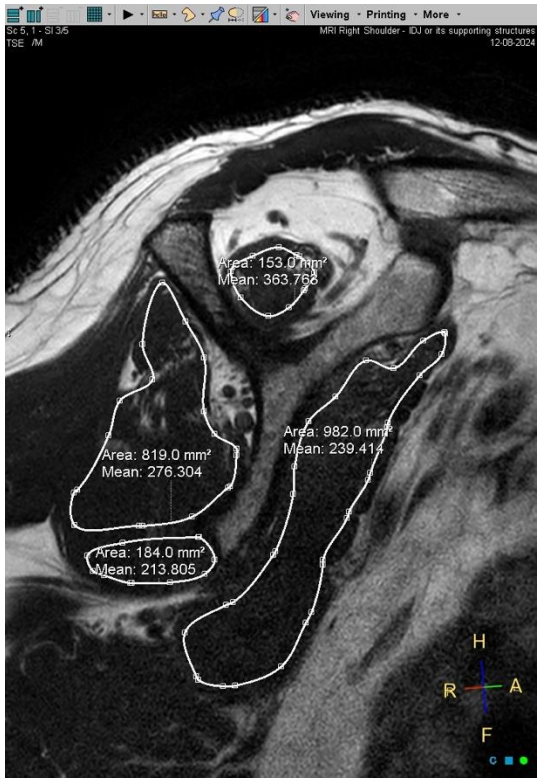
“Convolutional Neural Network”

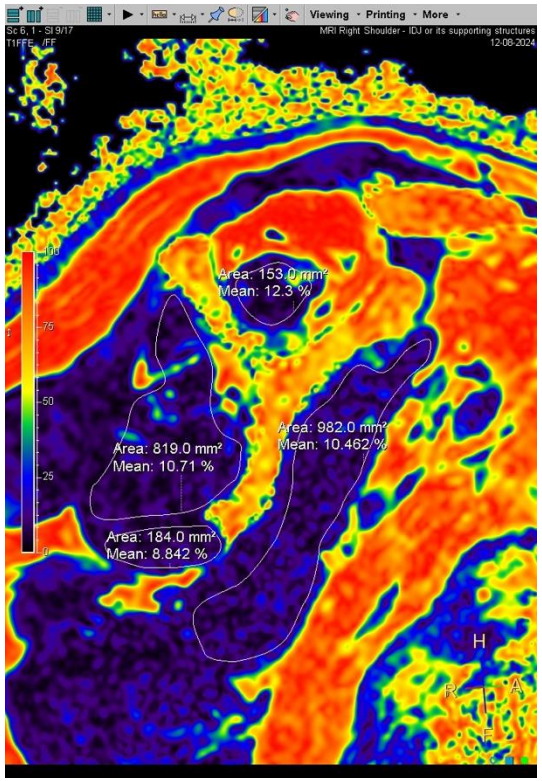
- learns features by itself via filter (or kernel) optimization. Type of deep learning network
- Followed on from RNN (Recurrent Neural Network)
- Convolution-based networks are the de-facto standard in deep learning-based approaches to computer vision and image processing, and have only recently have been replaced -- in some cases -- by newer deep learning architectures such as the transformer

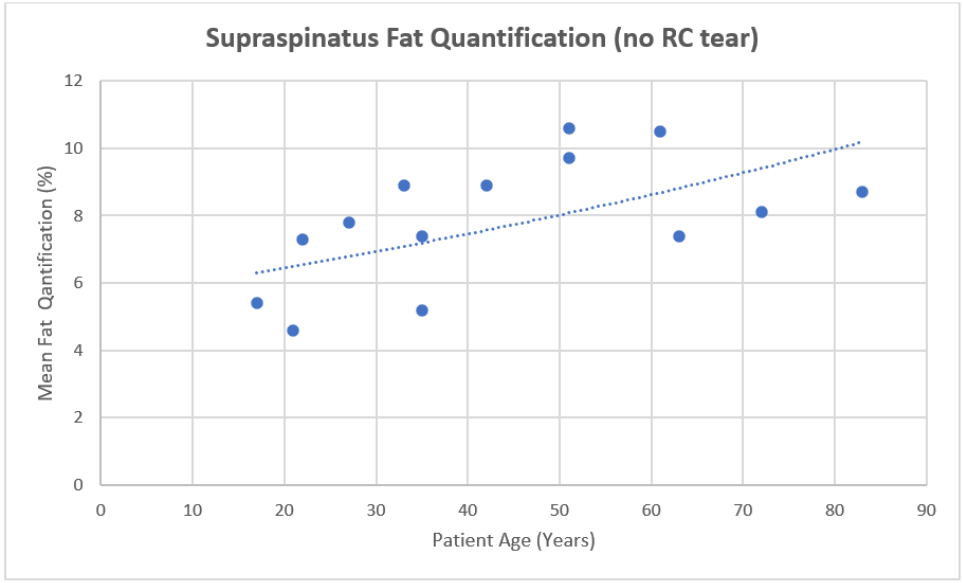


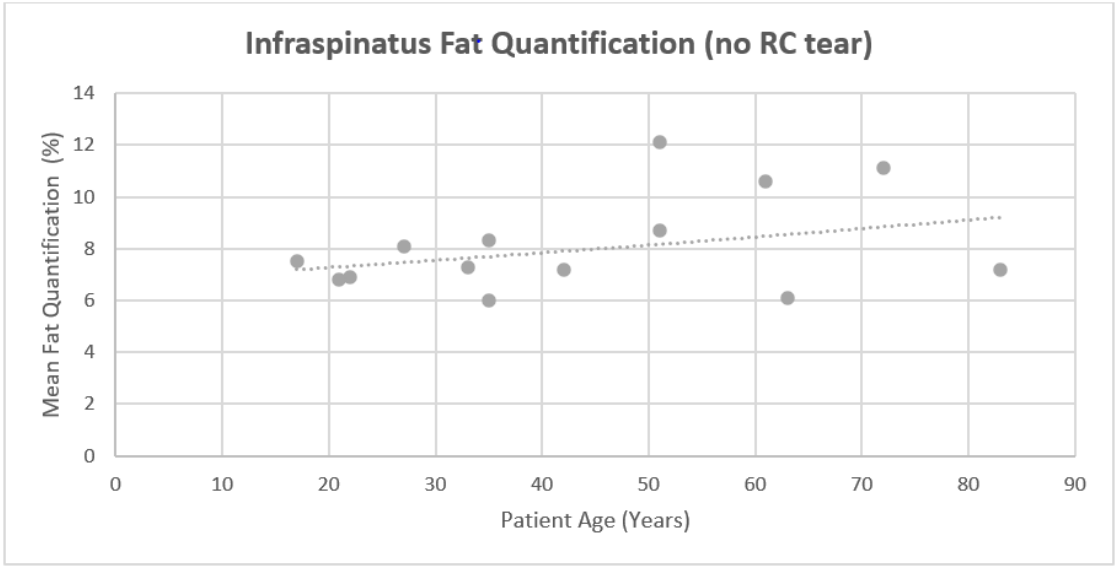
Chat GPT is a type of transformer

Modified Dixon Sequences for MRI



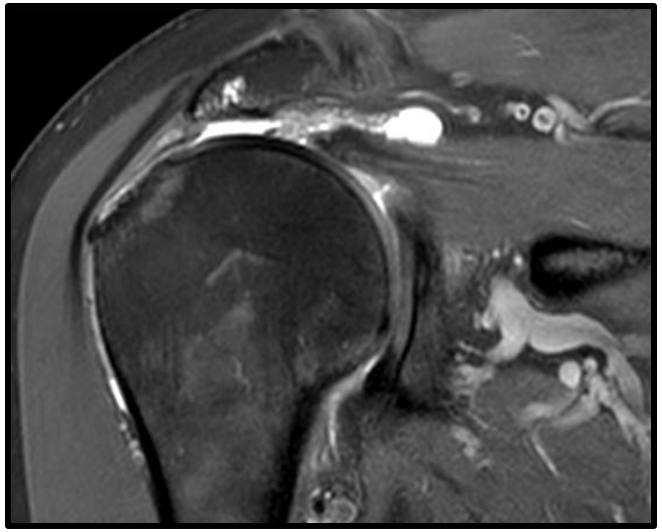


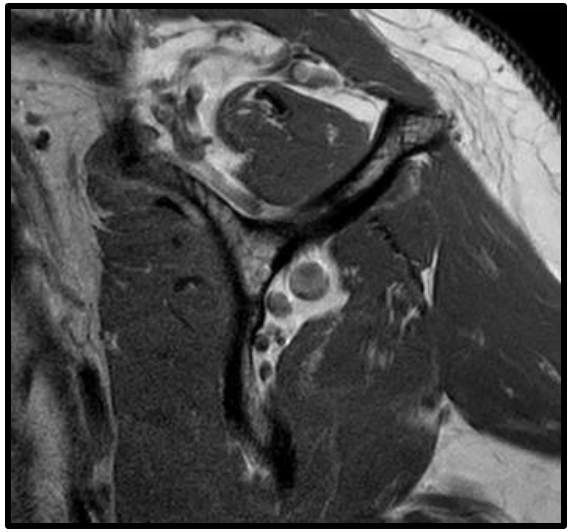


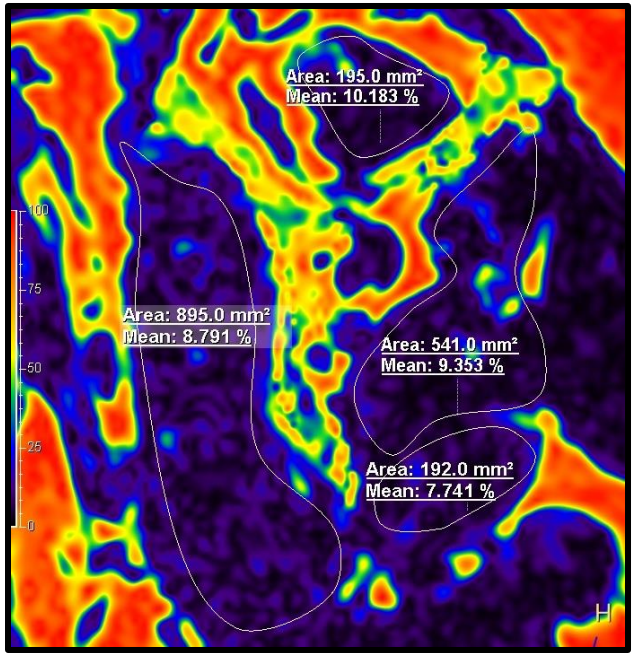


With age , there is a slow increase in intramuscular fat of the rotator cuff

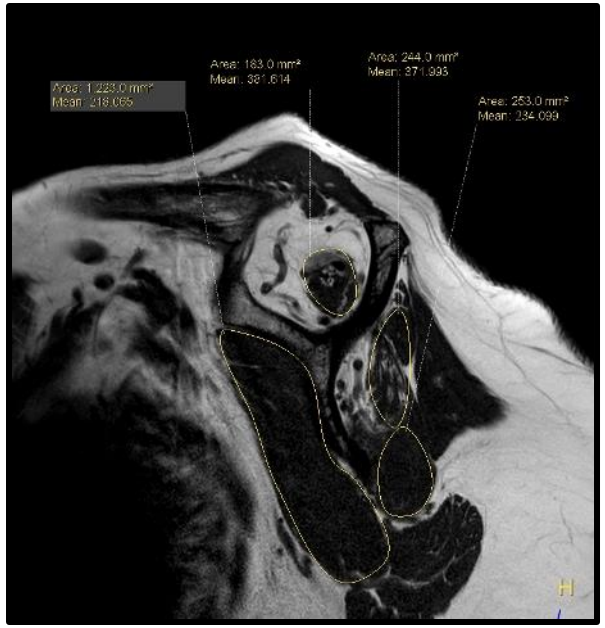
Supraspinatus Tendon Failure; Progression

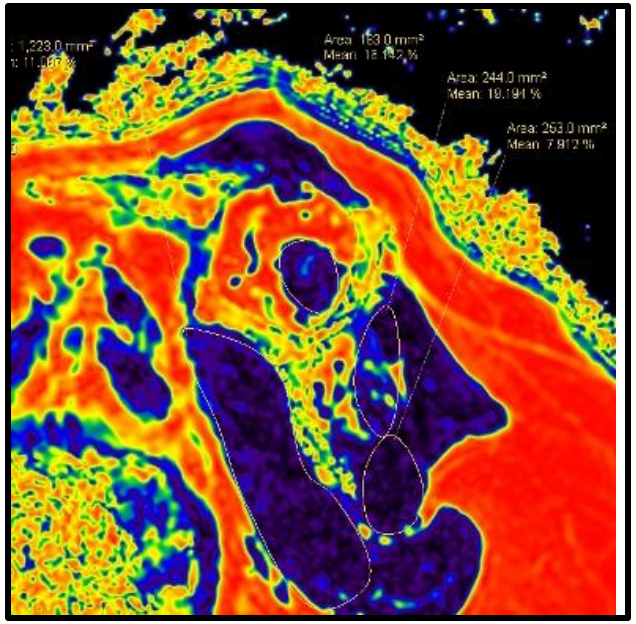






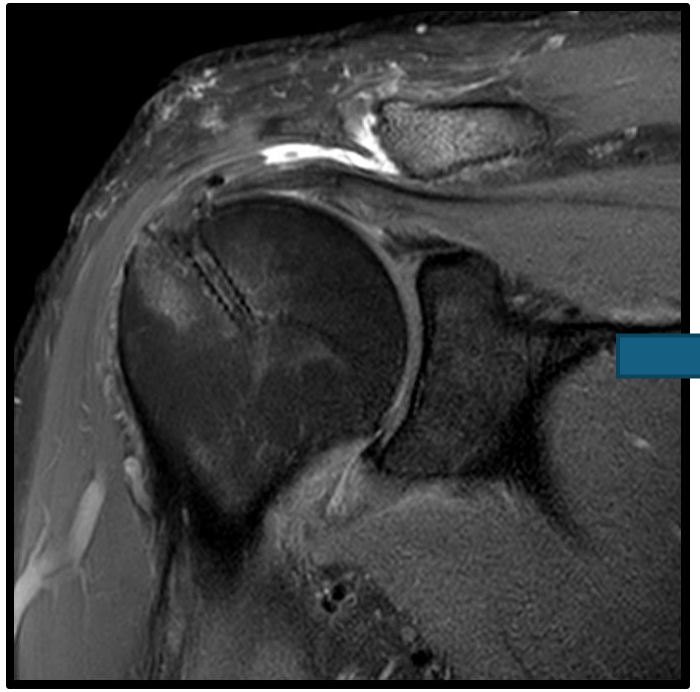
10 months later

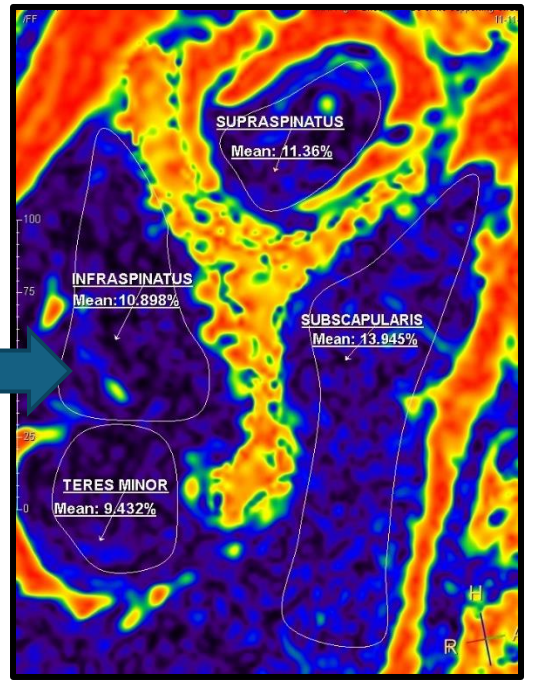




This has been confirmed in print by Eugene Ek and the Balgrist group;

Hochreiter B, Germann C, Feuerriegel GC, Sutter R, Selman F, Gressl M, Ek ET, Wieser K. Natural History of Quantitative Fatty Infiltration and 3D Muscle Volume After Nonoperative Treatment of Symptomatic Rotator Cuff Tears: A Prospective MRI Study of 79 Patients. J Bone Joint Surg Am 2024 Apr 17;106(8):690-699

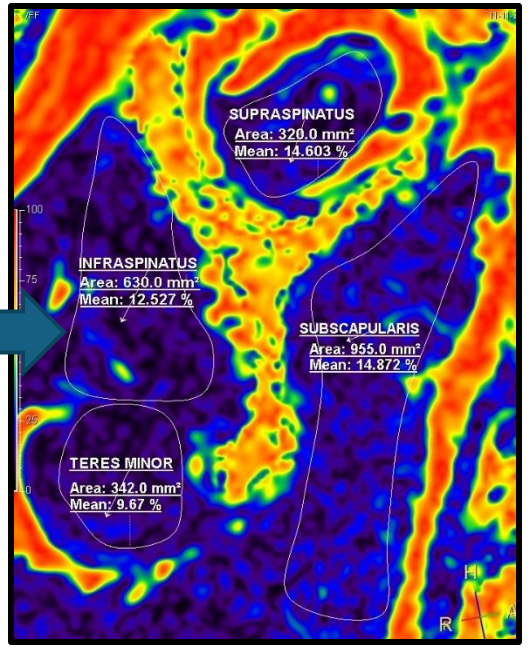




Case Study

A 66yo male with RC repair 6 years ago presents for assessment of the rotator cuff

11 months later



Xu, J. , Liu, B. , Qiao, Y. , Ye, Z. , Su, W. & Zhao, J. (2024). Longitudinal Changes in Overall 3D Supraspinatus Muscle Volume and Intramuscular Fatty Infiltration After Arthroscopic Rotator Cuff Repair. *The Journal of Bone and Joint Surgery, 106* (3), 218-226

Methods

- Olympic Park Imaging (Capital) Started measuring Fat Quant in most shoulders sent for shoulder MRI by me over a 3 year period
- We did a chart review of all patient details and operative details where appropriate
- We then assessed statistical patterns of both fat quant and volume at the scapular “y” position in relation to clinical and surgical pathology.

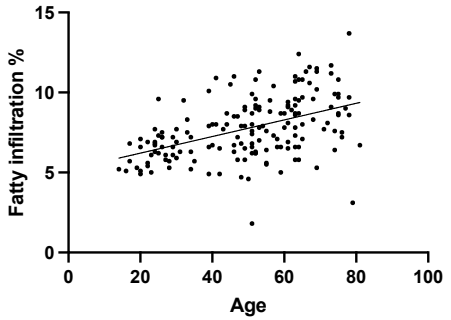
Results

Intact/Repairable cuff		Irreparable	
Rotator cuff tears	68	Massive cuff tears (non-op)	11
Osteoarthritis	54	Massive cuff tear (debridement)	7
Instability	42	Cuff tear arthropathy	12
Adhesive capsulitis	25	Failed repairs	5
Impingement	22	Recurrent tears	3
Cuff tendinopathy	8	Cuff failure post aTSA	1
Biceps tendinopathy	8		
AC joint pathology	6		
Others	16		
Total	249		40

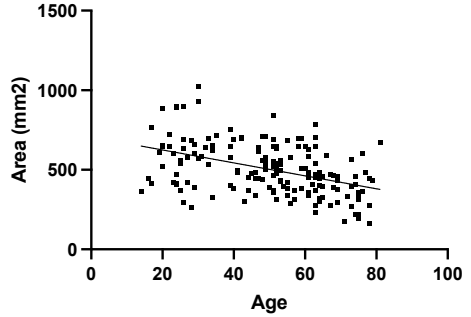
Cuff fatty infiltration and volume against age excluding both PT and FT RCT

Nonlin fit Table of results	A SSt %	B SSt Volume	C IS %	D IS Volume	E SubSc %	F SubSc Vol	G Tm %	H Tm Volume
	Y	Y	Y	Y	Y	Y	Y	Y
Line								
Best-fit values								
YIntercept	5.171	706.0	6.393	764.7	8.900	1898	6.571	416.1
Slope	0.05191	-4.067	0.03641	-1.912	0.03440	-10.19	0.03785	-1.611
95% CI (profile likelihood)								
YIntercept	4.377 to 5.965	638.6 to 773.5	5.564 to 7.222	645.0 to 884.3	7.784 to 10.02	1660 to 2135	5.225 to 7.918	354.8 to 477.3
Slope	0.03685 to 0.06696	-5.346 to -2.788	0.02068 to 0.05213	-4.187 to 0.3632	0.01316 to 0.05564	-14.69 to -5.691	0.01233 to 0.06338	-2.773 to -0.4477
Goodness of Fit								
Degrees of Freedom	166	166	166	165	165	166	166	165
R squared	0.2183	0.1918	0.1118	0.01641	0.05834	0.1074	0.04912	0.04336
Sum of Squares	489.1	3532259	533.8	10965862	951.7	43744051	1406	2894931
Sy.x	1.717	145.9	1.793	257.8	2.402	513.3	2.910	132.5
Number of points								
# of X values	168	168	168	168	168	168	168	168
# Y values analyzed	168	168	168	167	167	168	168	167

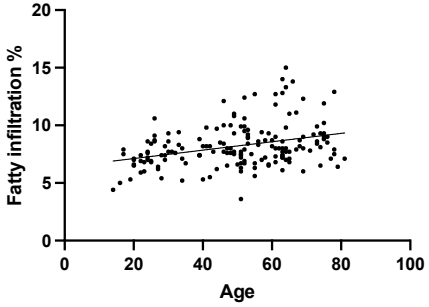
Supraspinatus fatty infiltration vs age (exc. all RCTs)



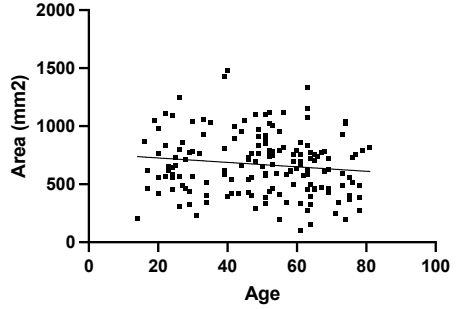
Supraspinatus Area vs age (exc all RCTs)



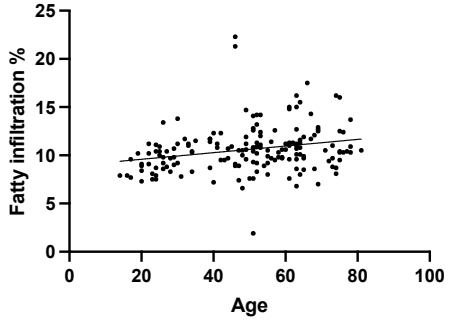
Infraspinatus fatty infiltration vs age (exc. all RCTs)



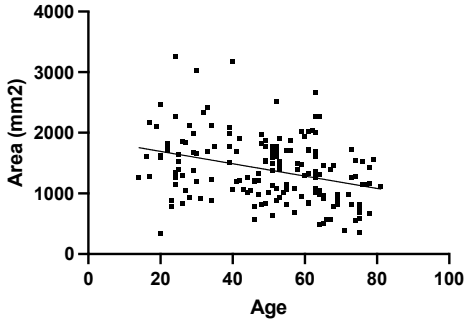
Infraspinatus Area vs age (exc all RCTs)



Subscapularis fatty infiltration vs age (exc. all RCTs)



Subscapularis Area vs age (exc all RCTs)



Results

	Intact/Repairable (n = 242)	Irreparable (n = 40)	p-value
Fatty Fraction %			
Supraspinatus $^{\alpha}$	9.1 ± 4.1	19.5 ± 8.9	<0.001*
Infraspinatus $^{\alpha}$	8.7 ± 2.4	18.8 ± 13.3	<0.001*
Subscapularis $^{\alpha}$	11.1 ± 2.9	15.3 ± 7.7	<0.001*
Teres minor $^{\alpha}$	8.7 ± 3.1	11.8 ± 7.5	<0.001*
Area (mm^2)			
Supraspinatus $^{\alpha}$	457 ± 170	228 ± 103	<0.001*
Infraspinatus $^{\alpha}$	641 ± 252	372 ± 216	<0.001*
Subscapularis $^{\alpha}$	1330 ± 548	965 ± 423	<0.001*
Teres minor $^{\alpha}$	334 ± 148	289 ± 129	0.16
Age $^{\alpha}$	53.9 ± 16.6	67.5 ± 10.4	<0.001*

$^{\alpha}$ Mann-Whitney U

(No age /sex adjustment)

Results

- **Adjusted for Age/Sex**
- Fatty infiltration and muscle area measurements, adjusted for age and sex of the Irreparable group and those supraspinatus tears which underwent a successful repair.

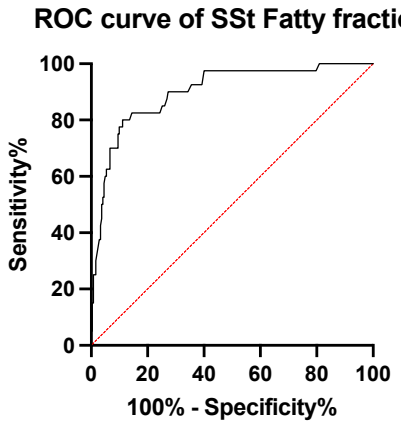
So Great for SSP and ISP,
NOT so good for SSC and TM
(and area appears to be almost
As good!)

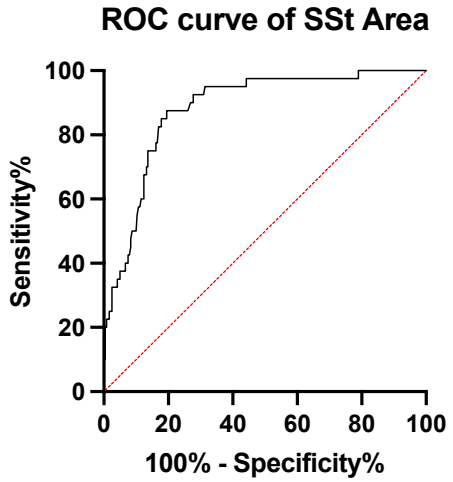
	SSt repaired (n=25)	Irreparable (n=40)	p-value
Fatty Fraction %			
Supraspinatus $^{\alpha}$	8.6 ± 4.8	16.2 ± 8.8	<0.001*
Infraspinatus $^{\alpha}$	7.6 ± 3.2	16.5 ± 13.4	0.003*
Subscapularis $^{\alpha}$	10.5 ± 3.5	13.5 ± 7.6	0.1
Teres minor $^{\alpha}$	5.8 ± 2.1	9.1 ± 7.5	0.03*
Area (mm^2)			
Supraspinatus $^{\beta}$	645 ± 136	535 ± 117	0.002*
Infraspinatus $^{\beta}$	731 ± 238	546 ± 218	0.002*
Subscapularis $^{\beta}$	1959 ± 624	1675 ± 428	0.03*
Teres minor $^{\alpha}$	486 ± 215	392 ± 116	0.10

Results

[α] Mann-Whitney U
[β] Two-tailed T-test

	PT/Repairable (n=67)	Irreparable (n=40)	p-value
Fatty Fraction %			
Supraspinatus [α]	11.4 ± 4.9	19.5 ± 8.9	<0.001*
Infraspinatus [α]	9.8 ± 3.1	18.8 ± 13.3	<0.001*
Subscapularis [α]	11.7 ± 2.8	15.3 ± 7.7	0.004*
Teres minor [α]	8.7 ± 2.8	11.8 ± 7.5	0.004*
Area (mm^2)			
Supraspinatus [β]	360 ± 142	228 ± 103	<0.001*
Infraspinatus [α]	580 ± 230	372 ± 216	<0.001*
Subscapularis	1219 ± 563	965 ± 423	0.02*
Teres minor [α]	338 ± 179	289 ± 129	0.34
Age [α]	62.7 ± 9.51	67.5 ± 10.4	0.009*





	SSt repaired (n=25)	Irreparable (n=40)	p-value
Fatty Fraction %			
Supraspinatus [α]	11.7 ± 4.9	19.5 ± 8.9	<0.001*
Infraspinatus [α]	9.7 ± 3.3	18.8 ± 13.3	<0.001*
Subscapularis [α]	12.2 ± 3.64	15.3 ± 7.7	0.08
Teres minor [α]	8.3 ± 2.0	11.8 ± 7.5	0.007*
Area (mm^2)			
Supraspinatus [β]	373 ± 147	228 ± 103	<0.001*
Infraspinatus [β]	582 ± 244	372 ± 216	<0.001*
Subscapularis [β]	1339 ± 650	965 ± 423	0.007*
Teres minor [α]	398 ± 234	289 ± 129	0.08
Age [α]	61.2 ± 8.6	67.5 ± 10.4	0.006*

So we can differentiate critical values of Fat Quant For the likely irreparable and the likely reparable cuff tear

And very recent publications exploding now

Journal Pre-proof

Qualitative analysis of the Supraspinatus muscle fatty infiltration on MRI - Correlation of the Tangent sign with Goutallier grade at the Y view and Medial Scapular border in large retracted rotator cuff tears

Shaoyu Xu, MPhil, Freek Hollman, MD, PhD, Romat C. Stewart, PhD, Ruth Delaney, MD, Mohammad N. Jomaa, MD, Helen Ingoe, MD, Roberto Pareyon, MD, Ryan Shulman, MD, Dr. Sanjay Dhupelia, MD, Acrane Y. Li, MD, Sarah Whitehouse, PhD, Jashint Maharaj, MD, Cameron Brown, PhD, Peter Pivonka, PhD, Ashish Gupta, MD

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muscles

MDPI

Systematic Review

The Use of Dixon Magnetic Resonance Imaging Methods for the Quantification of Rotator Cuff Fatty Infiltration: A Systematic Review

Andrew J. Nasr [1], Joshua Harris [2], Jijia Wang [1], Michael Khazzam [3], Nitin B. Jain [3,4], Yi-Ting Tzen [1,3,5] and Yen-Sheng Lin [3,5,*]

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Abstract: Fatty infiltration of the rotator cuff muscles is very common following rotator cuff tears and is one of the most important factors in determining treatment. Current clinical practice relies on subjective evaluation of fatty infiltration through categorical scoring based on the Goutallier classification system. The Dixon magnetic resonance imaging (MRI) sequence provides flexibility in selecting echo times for water–fat separation. The Dixon method, therefore, has the potential to provide robust and high-quality fat quantification that allows for more accurate calculation of fat fraction (%Fat) of the rotator cuff muscles than the Goutallier classification system. However, significant variance exists in sequencing and post-processing methodology within the recent application of Dixon sequences to quantify rotator cuff fatty infiltration. In this paper, we conducted a systematic review to synthesize the relevant literature utilizing Dixon sequencing for the quantification of rotator cuff fatty infiltration. The literature search was extracted from 1094 articles, with 12 studies included in the final review. Regardless of the varying sequencing pattern and post-processing techniques among studies, the findings suggest the Dixon method is reliable for quantitatively calculating the fat fraction of the rotator cuff muscles, even at very low levels of fatty infiltration. In addition, a quantitative difference in fat fraction was observed between participants with different degrees of tear vs. those without any shoulder pathologies. Multi-point Dixon imaging has the potential to be utilized clinically to objectively quantify fatty infiltration and may lead to improved clinical decision making for patients with rotator cuff tears.

Keywords: Dixon MRI; rotator cuff; shoulder; fatty infiltration; atrophy; muscle degeneration

check for updates

Citation: Nasr, A.J.; Harris, J.; Wang, J.; Khazzam, M.; Jain, N.B.; Tzen, Y.-T.; Lin, Y.-S. The Use of Dixon Magnetic Resonance Imaging Methods for the Quantification of Rotator Cuff Fatty Infiltration: A Systematic Review. *Muscles* **2024**, *3*, 133–152. https://doi.org/10.3390/muscles3020013

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1. Introduction

Rotator cuff disease is a highly prevalent musculoskeletal condition with more than 250,000 rotator cuff repairs performed annually in the United States [1–3]. In untreated rotator cuff tears, progressive and irreversible fatty infiltration and atrophy occur over time [4]. Fatty infiltration is influenced by the size of the tear and the number of involved tendons and leads to a loss of muscle strength and function, and a higher degree of fatty infiltration is associated with poor surgical and non-surgical outcomes [5]. The natural history of fatty infiltration remains poorly understood; however, animal models show fatty infiltration and muscle atrophy progress steadily during the initial four months after tendon detachment [6]. Additionally, patients with a higher degree of fatty infiltration are often considered poor surgical candidates due to concerns over tendon healing. Despite the clinical importance of fatty infiltration, current clinical standards to evaluate fatty

Original Article

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Preoperative Shoulder MRI Findings to Predict Subscapularis Tendon Tear Requiring Surgical Repair

수술이 필요한 견갑하건 파열을 예측하기 위한 어깨 MRI 소견

Ji-hoon Jung, MD[1], Young-Hoon Jo, MD[2], Yeo Ju Kim, MD[1], Seunghun Lee, MD[1], JeongAh Ryu, MD[1,*]

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Purpose This study aimed to investigate which indirect parameters on preoperative MRI were the principal predictors of subscapularis tendon tears (STTs) requiring surgical repair.

Materials and Methods Preoperative MRI scans of 86 patients were retrospectively reviewed for visual assessment of the STT, pathology of the long head of the biceps tendon (LHBT), posterior decentering (PD) of the humeral head, humeral rotation, fatty degeneration, and subscapularis muscle atrophy. To evaluate atrophy, visual grading using the anatomical line connecting the coracoid tip to the glenoid base, designated as the base-to-tip line (BTL), and thickness measurements were performed in the en-face view.

Results Arthroscopically, 31 patients (36%) exhibited Lafosse type II or IV STT and underwent surgical repair. LHBT pathology ($p = 0.002$), PD of the humeral head ($p = 0.012$), fatty degeneration ($p < 0.001$), and BTL grade ($p = 0.003$) significantly correlated with STT. In the multivariate analysis, PD of the humeral head ($p = 0.011$, odds ratio [OR] = 5.14) and fatty degeneration ($p = 0.046$, OR = 2.81) were independent predictors of STT.

Conclusion PD of the humeral head and fatty degeneration of the subscapularis can help to diagnose clinically significant STT. Interpretation of these findings may contribute to the planning of an optimal surgical strategy.

Index terms Subscapularis; Rotator Cuff Tear; Magnetic Resonance Imaging; Posterior Decentering; Fatty Degeneration

A commentary by Grant E. Garrigues, MD, is linked to the online version of this article.

Natural History of Quantitative Fatty Infiltration and 3D Muscle Volume After Nonoperative Treatment of Symptomatic Rotator Cuff Tears

A Prospective MRI Study of 79 Patients

Bettina Hochreiter, MD, Christoph Germann, MD, Georg C. Feuerriegel, MD, Reto Sutter, MD, Farah Selman, MD, Maximilian Gressl, Eugene T. Ek, MBBS, PhD, FRACS, and Karl Wieser, MD

Investigation performed at the Department of Orthopaedics, Balgrist University Hospital, University of Zurich, Zurich, Switzerland

Background: The severity of fatty infiltration (FI) predicts the treatment outcome of rotator cuff tears. The purpose of this investigation was to quantitatively analyze supraspinatus (SSP) muscle FI and volume at the initial presentation and after a 3-month minimum of conservative management. We hypothesized that progression of FI could be predicted with initial tear size, FI, and muscle volume.

Methods: Seventy-nine shoulders with rotator cuff tears were prospectively enrolled, and 2 magnetic resonance imaging (MRI) scans with 6-point Dixon sequences were acquired. The fat fraction within the SSP muscle was measured on 3 sagittal slices, and the arithmetic mean was calculated (FI^{SSP}). Advanced FI^{SSP} was defined as ≥8%, pathological FI^{SSP} was defined as ≥13.5%, and relevant progression was defined as a ≥4.5% increase in FI^{SSP}. Furthermore, muscle volume, tear location, size, and Goutallier grade were evaluated.

Results: Fifty-seven shoulders (72.2%) had normal FI^{SSP}, 13 (16.5%) had advanced FI^{SSP}, and 9 (11.4%) had pathological FI^{SSP} at the initial MRI scan. Eleven shoulders (13.9%) showed a ≥4.5% increase in FI^{SSP} at 19.5 ± 14.7 months, and 17 shoulders (21.5%) showed a ≥5-mm^3 loss of volume at 17.8 ± 15.3 months. Five tears (7.1%) with initially normal or advanced FI^{SSP} turned pathological. These tears, compared with tears that were not pathological, had significantly higher initial mediolateral tear size (24.8 compared with 14.3 mm; $p = 0.05$), less volume (23.5 compared with 34.2 mm^3; $p = 0.024$), more FI^{SSP} (9.6% compared with 5.6%; $p = 0.026$), and increased progression of FI^{SSP} (8.6% compared with 0.5%; $p < 0.001$). An initial mediolateral tear size of ≥20 mm yielded a relevant FI^{SSP} progression rate of 81.8% (odds ratio [OR], 19.0; $p < 0.001$). Progression rates of 72.7% were found for both initial FI^{SSP} of ≥9.9% (OR, 17.5; $p < 0.001$) and an initial anteroposterior tear size of ≥17 mm (OR, 8.0; $p = 0.003$). Combining these parameters in a logistic regression analysis led to an area under the receiver operating characteristic curve (AUC) of 0.913. The correlation between FI^{SSP} progression and the time between MRI scans was weak positive ($ρ = 0.31$).

Conclusions: Three risk factors for relevant FI progression, quantifiable on the initial MRI, were identified: ≥20-mm mediolateral tear size, ≥9.9% FI^{SSP}, and ≥17-mm anteroposterior tear size. These thresholds were associated with a higher risk of tear progression: 19 times higher for ≥20-mm mediolateral tear size, 17.5 times higher for ≥9.9% FI^{SSP}, and 8 times higher for ≥17-mm anteroposterior tear size. The presence of all 3 yielded a 91% chance of ≥4.5% progression of FI^{SSP} within a mean of 19.5 months.

Level of Evidence: Diagnostic Level II. See Instructions for Authors for a complete description of levels of evidence.

Nonoperatively treated rotator cuff tears run the risk of developing progressive fatty muscle infiltration (FI) over time. Successful rotator cuff repair has been shown to halt, but not reverse, FI[1-5]. It is known that tears do enlarge over time[6-11] and that enlargement is associated with the progression of FI in both a clinical setting[1,6,7,10,12] and an experimental setting[13].

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Conclusion

Newer techniques of assessing both muscle volume AND percentage of fatty infiltration in rotator cuff muscles

DO

Show us a predictability of reparable vs irreparable cuff tears of SSP and ISP

- Much more work on the nuances of
  - “reparability with adjuvant devices” and
  - Retears of high level fatty infiltration repairs

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