

Ultrasound Diagnosis of Rotator Cuff Tears: The Necessity for Technical and Qualification Upgrades

Yaqun Tang^{1,2,3}, Junguo Zhang⁴, Weiwen Chen³, Wenhong Yi^{1,2}, Jingjiao Xu^{1,2}, Hongmei Liu^{1,2*}

¹Department of Ultrasound, Institute of Ultrasound in Musculoskeletal Sports Medicine, The Affiliated Guangdong Second Provincial General Hospital of Jinan University, Guangzhou, China, ²GuangDong Engineering Technology Research Center of Emergency Medicine, Guangzhou, China, ³Department of Ultrasound, Zhuhai People's Hospital (Zhuhai Clinical Medical College of Jinan University), Zhuhai, China, ⁴Department of Epidemiology, School of Public Health, Sun Yat-Sen University, Guangzhou, China

Abstract

Background: The dependence of each subtype of rotator cuff tears (RCTs) on ultrasound (US) experience and technique is unknown. The aims of this study were to investigate the necessity of physician qualification and US technical upgrades – possible further diagnostic triage strategies when certain sites of involvement are not clear, by analyzing the degree of dependence of symptomatic rotator cuff on qualifications and techniques. **Methods:** Two-dimensional US and contrast-enhanced US (CEUS) images of 84 patients who had undergone arthroscopy from 2014 to 2022 were retrospectively analyzed by two senior and two junior radiologists, using a randomized blinded method. A multivariable logistic model was established with the probability of correct diagnosis to investigate the extent to which qualifications, techniques, and subtypes affect the accurate diagnosis of RCTs. **Results:** Qualification, mode, and subtype were statistically different ($P < 0.05$), where CEUS was 10.48 times more likely to be diagnosed correctly than US and 2.43 times by senior than by junior physicians overall ($P < 0.05$). CEUS was 19.89, 5.15, and 10.48 times more likely than US to be diagnosed correctly when the subtypes were bursal-side partial-thickness tear ($P < 0.05$), articular-side partial-thickness tear, and small full-thickness tear, respectively ($P < 0.05$). **Conclusion:** In clinical practice, when bursal-side tendon involvement is suspected on US, it is more practical to recommend CEUS than to improve seniority, whereas for articular-side tendon involvement, qualification upgrade is recommended first.

Keywords: Arthroscope, contrast media, observer variation, rotator cuff injuries, ultrasonography

INTRODUCTION

Precise staging of rotator cuff tears (RCTs) directly influences clinical decision-making, and surgical treatment is usually recommended for large-thickness partial tears and full-thickness tears.^[1] Tear tendon is difficult to heal spontaneously, and the above tear types are prone to secondary muscle atrophy and traumatic arthritis in later stages.^[2] Furthermore, a precise preoperative diagnosis facilitates rational intraoperative exploration to avoid omission, especially in intratendinous partial-thickness tears.

Numerous factors influence ultrasound (US) staging of RCTs,^[3-8] with diagnostic modality and physician qualifications being the most significant. Although studies have shown that contrast-enhanced US (CEUS) can substantially increase the diagnostic detection rate of many subtypes compared

to conventional US^[9-12] and can significantly reduce interobserver experience dependence.^[13] Since in our practical US application scenario, physicians are randomly qualified and conventional US is the initial diagnostic technique, upgrading of qualification or technology will inevitably lead to an increase in time or cost, especially since the latter will increase both while bringing the potential risk of minimally invasive examinations. Therefore, it is necessary to explore the necessity and applicability of upgrading.

Therefore, the purpose of this study is to investigate the necessity of physician qualification and US technical upgrades – possible further diagnostic triage strategies when

Address for correspondence: Prof. Hongmei Liu,

Department of Ultrasound, Institute of Ultrasound in Musculoskeletal Sports Medicine, The Affiliated Guangdong Second Provincial General Hospital of Jinan University, Guangzhou 510317, China.
E-mail: hongmeiliu3@163.com

Received: 13-06-2024 Revised: 27-07-2024 Accepted: 11-08-2024 Available Online: 10-03-2025

Access this article online

Quick Response Code:



Website:
<https://journals.lww.com/jmut>

DOI:
10.4103/jmu.jmu_68_24

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: WKHLRPMedknow_reprints@wolterskluwer.com

How to cite this article: Tang Y, Zhang J, Chen W, Yi W, Xu J, Liu H. Ultrasound diagnosis of rotator cuff tears: The necessity for technical and qualification upgrades. J Med Ultrasound 2025;33:228-35.

certain sites of involvement are not clear, by analyzing the degree of dependence of symptomatic rotator cuff on qualifications and techniques. The hypothesis of the present study is that qualification, technique, and subtype may be independent influences on the correct diagnosis of RCT, whereas bursal and articular lateral tendon involvement may be differentially dependent on qualification and technique.

PATIENTS AND METHODS

Patients

Four hundred and sixty-one consecutive patients (461 shoulders) with suspected RCTs were recruited by orthopedic surgeons, among which 118 were referred for US and CEUS and followed arthroscopy of the shoulders at the hospital between January 2014 and January 2022.

Inclusion criteria were as follows: (i) concurrent ultrasonography (US and CEUS) and arthroscopy and (ii) surgery completed within 2 weeks after ultrasonography (indications for surgery: (1) imaging diagnosis of full-thickness tear and (2) conservative treatment of a partial tear for more than 3 months without adequate relief of symptoms such as shoulder pain or dysfunction). Thirty-four cases were excluded: (i) 1 intact cuff was identified during arthroscopy but diagnosed as an intrasubstance partial-thickness tear on CEUS, as intrasubstance partial-thickness tears could not be verified surgically. (ii) Twenty-three cases lacked percutaneous US-guided tendon lesionography (PUTL) images needed by one of the radiologists. CEUS includes single percutaneous US-guided subacromial bursography (PUSB) or joint PUTL procedure.^[11] The PUSB procedure was performed on all patients first, but only the cuffs that were suspected of being torn on US that were not detected on PUSB needed to undergo the followed PUTL procedure. In a retrospective review of images, some of the cases who had been correctly diagnosed through PUSB without PUTL read were asked to provide PUTL images for further diagnosis by an inexperienced physician were excluded from the study. (iii) Ten cases, including two larger full-thickness tears (1F), small full-thickness tears (sF), bursal-side partial-thickness tears (bP), articular-side partial-thickness tears (aP), and intact cuffs (NT), respectively, were also excluded for junior radiologists training on CEUS. Ultimately, 84 patients were recruited [Figure 1].

The study was conducted in accordance with the Declaration of Helsinki. The institutional review board of the Affiliated Guangdong Second Provincial General Hospital of Jinan University approved the study (No. 2023-KY-KZ-307-02), and all participants provided written informed consent.

Ultrasonography examination and imaging analysis

Equipment and materials

A Logiq S8 US system (General Electric Medical Systems, Fairfield, CT, USA) was used during ultrasonography examinations. The US and CEUS examinations were performed using an ML 6–15 matrix and a 9 L linear transducer, respectively.

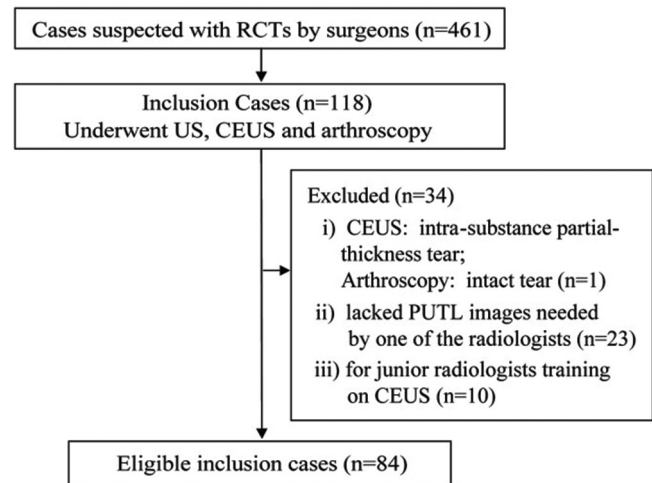


Figure 1: Flow diagram of the included patients. RCTs: Rotator cuff tears, US: 2D ultrasound, CEUS: Contrast-enhanced ultrasound, PUTL: Percutaneous ultrasound-guided tendon lesionography

SonoVue (Bracco, Italy) solution was used for CEUS contrast. 1.5 mL of SonoVue solution was diluted to 15 mL with 13.5 mL of 0.9% NaCl. Two percent lidocaine solution was used as an anesthetic agent during CEUS.

Procedure

Shoulder examinations were performed according to the guidelines for shoulder US techniques recommended by the European Society of Skeletal Radiology.^[14] The steps are as follows: first, US and PUSB are performed in all patients^[6,7] and PUTL is necessary (only the cuffs suspected of being torn on US and not detected on PUSB needed to undergo the followed PUTL procedure).^[11]

Ultrasound

US was continuously scanned for longitudinal and transverse views of the long-head biceps tendon, subscapularis tendon, supraspinatus tendon, infraspinatus tendon, and teres minor tendon on the affected side and compared with the contralateral side to document the RCT subtype.^[15]

Contrast-enhanced ultrasound (percutaneous ultrasound-guided subacromial bursography ± PUTL)^[11]

All patients underwent PUSB after an initial US examination. First, the thickest and toughest area of the subacromial-subdeltoid (SASD) bursa was identified to determine the optimal injection site and method. Then, after disinfecting the skin in the target area, lidocaine was injected subcutaneously into all patients to anesthetize the local tissue and ensure that the 22 G injection needle reached the target area. Once the tip of the needle is visible in the SASD bursa, a contrast pulse sequence is initiated and 10–12 mL of contrast is gently injected into the SASD bursa under US guidance. We observed contrast leakage in real time during the injection process and again through video after completion of the CEUS examination to visualize the contrast distribution.

The patient underwent PUTL immediately following the PUSB procedure. The criteria for PUTL were (i) suspicion of a

rotator cuff lesion based on the initial US examination and (ii) confirmation of an intact upper surface of the rotator cuff during the PUSB procedure and evidence that the contrast agent was dispersed exclusively in the bursa. The PUTL procedure was similar to the PUSB procedure except that the contrast agent was injected directly into the area of suspected tendon lesion, with an average total volume of 4–6 mL of contrast agent.

Image analysis

Radiologists' qualifications

Two senior and two junior radiologists joined the image analysis. The radiologists were physicians with 12, 9, 2, and 1 years of experience in musculoskeletal contrast-enhanced ultrasonography, respectively.

Imaging interpretation design

Four musculoskeletal radiologists read US and CEUS images blinded independently, where both stills and video data were available with the basic information obscured. US imagings were read and noted first, and then followed by PUSB, and finally PUTL imagings necessarily.

Diagnostic criteria

Ultrasound

FT: (i) Tendon retraction, bare humeral head only in the footprint area; (ii) hypoechoic defect throughout the tendon; (iii) local thinning of the tendon with no continuity. With at least one of these characteristics and a short-axis view showing ≤ 1 cm/ >1 cm of involvement is considered sF/IF.^[3,15,16]

PT: (i) Obvious hypoechoic defect or mixed echogenic area, involving only part of the tendon; (ii) local flattening or depression of the bursa-surface of the tendon. bP: If the abovementioned features are met (i) and only the bursal side of the tendon is involved, or if met (ii); iP: if met (i) and the involved area is only within the tendon; aP: if met (i) and only the articular side of the tendon is involved.^[3,15,16]

Contrast-enhanced ultrasound

FT: (i) PUSB shows the contrast agent from the SASD bursa into the shoulder joint cavity; (ii) PUTL shows the contrast agent from the lesioned area into the SASD bursa and shoulder joint cavity.

PT: PUSB or PUSB + PUTL shows the contrast agent confined to part of the tendon. bP: the contrast agent from the SASD bursa into the tendon on the side of the bursa and the joint cavity was never visualized; iP: contrast agent confined to the tendon only and not visualized in the SASD bursa and joint cavity; aP: the contrast agent from the lesion area into the joint cavity and the SASD bursa is never visualized.

Arthroscopy

All arthroscopic procedures were performed by two experienced orthopedic surgeons in shoulder arthroscopy. Based on Codman's and Cofield's classification systems, RCTs are classified into seven subtypes.^[17,18] We defined the width of full-thickness tears > 1 cm as "larger."

Statistical analyses

All analyses were conducted using R software 4.1.1 (R Development Core Team, Vienna, Austria). The variables were presented as median (interquartile range) for continuous variables and frequencies (percentages) for categorical variables. Comparisons between the groups of intact cuffs and tears were performed using the Mann–Whitney *U*-test or Chi-square test. The detection rates of diagnosing RCTs through US and CEUS interpreted by both junior and senior groups for all subtypes were evaluated. The multivariable logistic model was established to determine the influence factors of the probability of correct diagnosis. The model was adjusted by diagnostic modes, physician qualifications, tear subtypes, and the multiplicative interaction between modes and subtypes. Subgroup analysis was performed to analyze the relationships between subtypes under different models and qualifications and the interaction combination of models and qualifications. All statistical tests were two-tailed, and $P < 0.05$ was considered statistically significant.

RESULTS

Patient characteristics

Arthroscopy was performed on a total of 84 shoulders. All tears were surgically proved to be tears of the supraspinatus tendon except 15 which simultaneously involved the infraspinatus tendon. Among patients with no tears, there were 2 with low elastic tendons (who had diabetes mellitus or hyperlipidemia), 1 with superior labrum anterior-to-posterior lesions, 8 with supraspinatus tendinopathy, and 9 with SASD bursitis. The ages ranged from 17 to 64 years, with a median age of 53 (20) years in 84 cases. Fifty-three patients had a history of trauma, and others may be associated with degeneration, hypovascularity, or impingement. There were no significant differences between the tear and intact cuff groups concerning age, gender, history of trauma, and course of disease [Tables 1 and 2].

Main influence factors

Model reliability analysis

The probabilistic logistic model was correctly diagnosed. The area under the curve of this model is 0.8041, which indicates that the model is relatively accurate [Figure 2].

Analysis of model effects

1. Main effects ($P < 0.05$) [Table 3]

The model explained the main effects (physician qualification, diagnostic mode, and subtype) as follows: the experienced radiologists were 2.43 times more likely to make the correct diagnosis than inexperienced radiologists (coefficient: 0.89); CEUS was 10.48 times more likely to make a correct diagnosis than US (coefficient: 2.35); compared with sF, NT was 3.53 times more and bP was 5.26 times less.

2. Interaction effects ($P < 0.05$) [Table 3]

There is a multiplicative interaction effect of diagnostic mode and subtype in this model. When the reference is CEUS * sF, using CEUS to diagnose NT, the two have an antagonistic

Table 1: 2D ultrasound and contrast-enhanced ultrasound image interpretation by radiologists in senior and junior groups for diagnosis of rotator cuff tears

	Arthroscopy	NT	bP	aP	sF	IF	Total	Reader	Arthroscopy	NT	bP	aP	sF	IF	Total
R1	NT	18 (18)	9 (1)	0	0	0	27 (19)	R2	NT	17 (18)	7 (1)	0	0	0	24 (19)
	bP	0 (2)	4 (15)	1 (0)	0	0	5 (17)		bP	1 (2)	6 (14)	1 (0)	1 (0)	0	9 (16)
	iP	0	0	0	0	0	0		iP	0	0	1 (1)	1 (0)	0	2 (1)
	aP	0	0	17 (21)	3 (0)	0	20 (21)		aP	0	0	17 (20)	2 (0)	0	19 (20)
	sF	2 (0)	3 (0)	3 (0)	9 (12)	0	17 (12)		sF	2 (0)	3 (1)	2 (0)	8 (12)	0	15 (13)
	IF	0	0	0	0	15 (15)	15 (15)		IF	0	0	0	0	15 (15)	15 (15)
R3	NT	16 (18)	9 (2)	0	2 (1)	0	27 (21)	R4	NT	16 (18)	10 (3)	0	2 (2)	0	28 (23)
	bP	4 (2)	3 (13)	2 (0)	1 (0)	0	10 (15)		bP	3 (2)	2 (12)	1 (0)	2 (0)	0	8 (14)
	iP	0	0	3 (2)	0	0	3 (2)		iP	1 (0)	0	5 (4)	0	0	6 (4)
	aP	0	0	13 (19)	3 (0)	0	16 (19)		aP	0	0	12 (17)	2 (0)	0	14 (17)
	sF	0	4 (1)	3 (0)	6 (11)	0	13 (12)		sF	0	4 (1)	3 (0)	6 (10)	0	13 (11)
	IF	0	0	0	0	15 (15)	15 (15)		IF	0	0	0	0	15 (15)	15 (15)
Total		20	16	21	12	15	84	Total		20	16	21	12	15	84

n^l(n²): n^{us} (n^{ceus}), US: 2D ultrasound, CEUS: Contrast-enhanced ultrasound, RCTs: Rotator cuff tears, R: Radiologist, NT: No tear, bP: Bursal-side partial-thickness tear, iP: Intra-substance partial-thickness tear, aP: Articular-side partial-thickness tear, sF: Small full-thickness tear, IF: Larger full-thickness tear

Table 2: Baseline data of tear and intact cuff groups

Arthroscopy (n=84)	Tears (n=64)	Intact cuffs (n=20)	P
Age (years)	53.0 (21.5)	48.0 (21.75)	0.267
Male (%)	43 (67)	12 (60)	0.555
Trauma (%)	44 (69)	9 (45)	0.055
Course of disease (mo)	5.0 (5.75)	8.5 (10.0)	0.151

*Values of $P < 0.05$ indicate significance

effect – the correct rate is not as good as the main effect of the two alone (the effect of CEUS or NT on the correct rate).

3. Subgroup analysis ($P < 0.05$).

1. Physician qualifications [Figure 3]

- Between physician qualifications under different subtypes: when the subtype was aP and sF, respectively, the probability of correct diagnosis was 3.58 and 3.06 times higher among senior physicians than among junior physicians
- When junior radiologists were involved, among different subtypes: the probability of correct diagnosis of NT was 9.19, 2.36, and 2.95 times higher than that of bP, aP, and sF, respectively
- When senior radiologists were involved, the probability of correct diagnosis was 6.42, 6.81, and 4.65 times higher for NT, aP, and sF than that for bP between different subtypes.

2. Diagnostic modes ($P < 0.05$) [Figure 4].

- Between diagnostic modes under different subtypes: When the subtypes were bP, aP, and sF, respectively, the probability of correct diagnosis was 19.89, 5.15, and 10.48 times higher for CEUS than US
- On US, between different subtypes: When US was used, the probability of correct diagnosis of no tear was 18.96, 2.38, and 3.53 times higher than that of the bP, aP, and sF, respectively

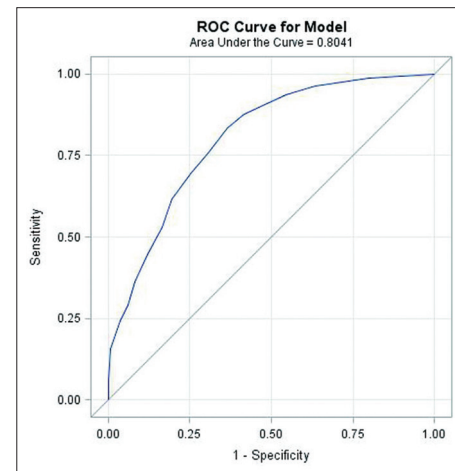


Figure 2: Area under the curve of the logistic model of the probability of correct diagnosis. ROC: Receiver operating characteristic

- On CEUS, no statistically significant was detected between different subtypes ($P > 0.05$).

Accuracy and differences between groups

There were four groups, including US junior, US senior, CEUS junior, and CEUS senior. The detection rates were 61.9%–95.2% for all subtypes. Detection rates were 100.0% for IF, 50.0%–100.0% for sF, 59.5%–97.6% for aP, 15.6%–90.6% for bP, and 80.0%–90.0% for NT, respectively [Table 4].

For the diagnosis of IF and NT, there was no statistically significant difference in the detection rates between all groups. For the diagnosis of sF, there was no statistically significant difference in detection rates between US senior and US junior groups, and there was a statistically significant difference in detection rates between US senior group and CEUS senior group. For the diagnosis of aP, the differences in detection rates between each of these two

Table 3: Main effects of the correct diagnosis prediction model

Parameter	Estimated value	SEx	OR	P
Model (reference: US)	2.35	0.67	10.48	<0.01
Qualification (reference: Junior)	0.89	0.24	2.43	<0.01
Subtype (reference: sF)				
NT	1.26	0.43	3.53	<0.01
bP	-1.68	0.43	0.19	<0.01
aP	0.40	0.39	1.49	0.30
Model * subtype (multiplicative interaction) (reference: CEUS * sF)				
CEUS * NT	-1.78	0.83	0.17	0.03
CEUS * bP	0.64	0.81	1.90	0.43
CEUS * aP	-0.71	0.82	0.49	0.38
Qualification * subtype (multiplicative interaction) (reference: junior * sF)				
Junior * NT	-0.76	0.74	1.07	0.30
Junior * bP	-0.40	0.68	0.35	0.55
Junior * aP	0.16	0.71	0.05	0.82

*Values of $P < 0.05$ indicate significance. US: 2D ultrasound, sF: Small full-thickness tear, NT: No tear, bP: Bursal-side partial-thickness tear, aP: Articular-side partial-thickness tear, CEUS: Contrast-enhanced ultrasound, OR: Odds ratio, SEx: standard error

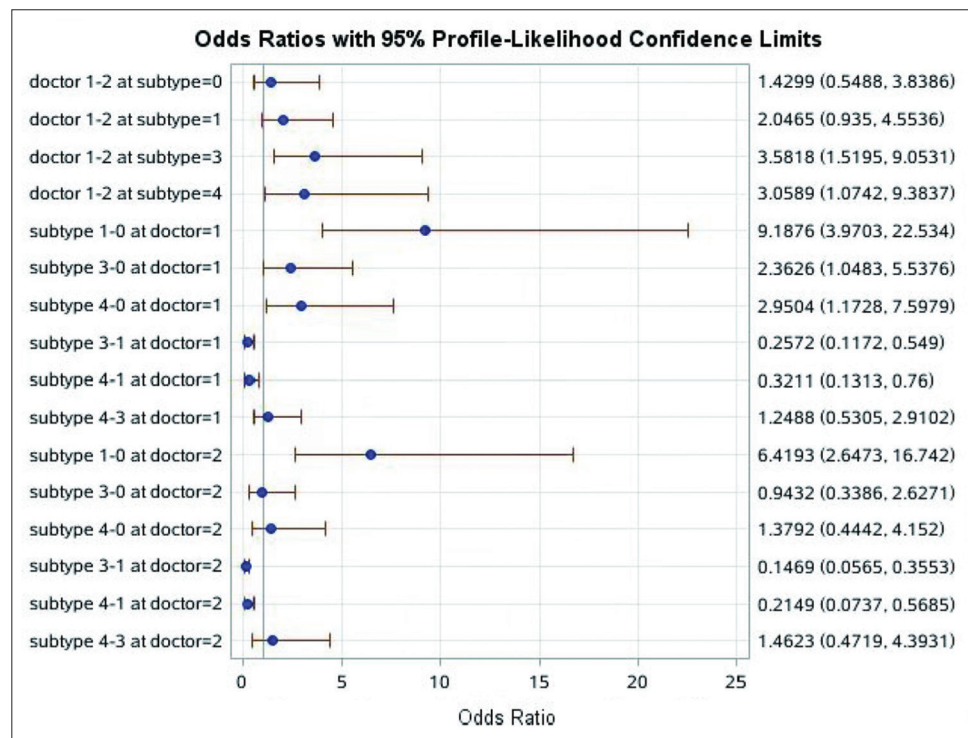


Figure 3: Subgroup analysis of the logistic model of correct diagnostic probability (physician qualification). Doctor 1, 2: senior, junior physicians; Subtype 0, 1, 3, 4 = no tear, bursal-side partial-thickness tear, articular-side partial-thickness tear, small full-thickness tear, respectively

groups were statistically significant. For the diagnosis of bP, the differences in detection rates between senior and junior groups in US and CEUS were not statistically significant, and that between the remaining each of these two groups were statistically significant [Table 5].

DISCUSSION

This study shows that physician qualification, US mode, and tear subtype are all independent factors influencing the accurate diagnosis of RCTs. Both the upgrade of US mode and

physician's qualification improved the diagnostic accuracy of the RCTs to varying degrees, with the former being greater.

In terms of diagnostic modality, the present model showed that CEUS improved the diagnostic accuracy of bP, aP, and sF compared with the US, which was consistent with previous studies.^[10-12] In contrast, the difference was not significant in the diagnosis of NT. In terms of physician qualification, the present model showed that the difference between senior and junior physicians was only reflected in aP and sF, but not in bP and NT. The overall diagnostic difficulty of US for the

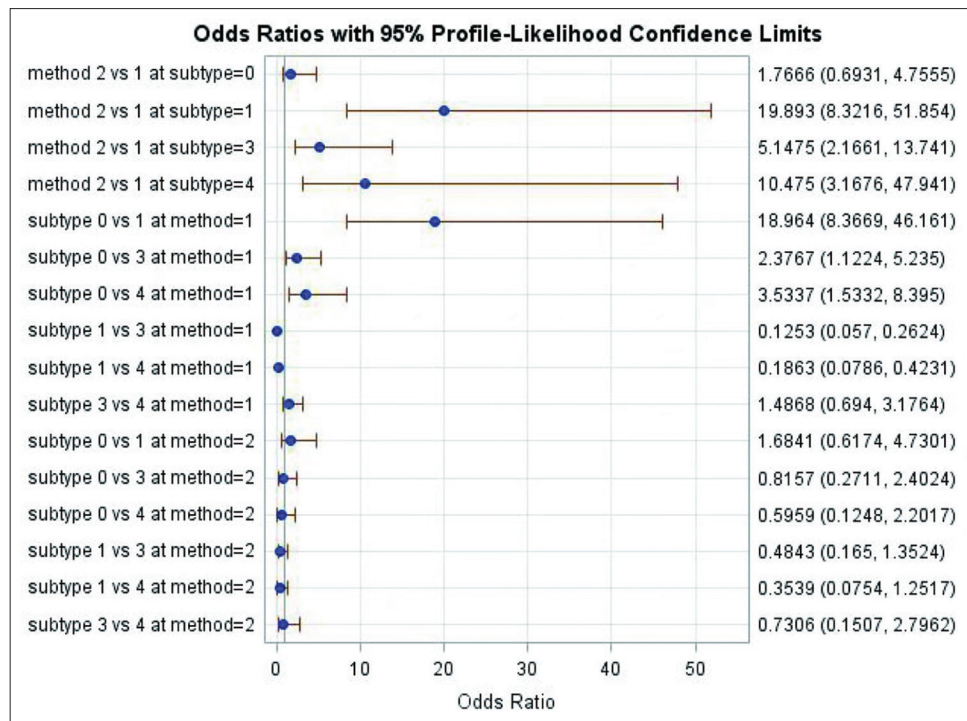


Figure 4: Subgroup analysis of the logistic model of the probability of correct diagnosis (diagnostic modality). Method 1, 2: Ultrasound, contrast-enhanced ultrasound; Subtype 0, 1, 3, 4 = no tear, bursal-side partial-thickness tear, articular-side partial-thickness tear, small full-thickness tear, respectively

Table 4: The detection rates for diagnostic modality interaction combination physician qualification groups in the detection of rotator cuff tears

RCTs	US (n/N)		CEUS (n/N)	
	Junior group	Senior group	Junior group	Senior group
ALL	61.9% (104/168)	75.0% (126/168)	88.1% (148/168)	95.2% (160/168)
IF	100.0% (30/30)	100.0% (30/30)	100.0% (30/30)	100.0% (30/30)
sF	50.0% (12/24)	70.8% (17/24)	87.5% (21/24)	100.0% (24/24)
aP	59.5% (25/42)	81.0% (34/42)	85.7% (36/42)	97.6% (41/42)
bP	15.6% (5/32)	31.3% (10/32)	78.1% (25/32)	90.6% (29/32)
NT	80.0% (32/40)	87.5% (35/40)	90.0% (36/40)	90.0% (36/40)

RCTs: Rotator cuff tears, US: 2D ultrasound, CEUS: Contrast-enhanced ultrasound, ALL: All subtypes, IF: Larger full-thickness tear, sF: Small full-thickness tear, aP: articular-side partial-thickness tear, bP: Bursal-side partial-thickness tear, NT: No tear

Table 5: Comparison of differences between different groups with diagnostic model interaction physician qualification in the detection of rotator cuff tear subtypes

RCTs	USju and USse		USju and CEUSju		USse and CEUSse		USse and CEUSju		CEUSju and CEUSse	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
IF	-	-	-	-	-	-	-	-	-	-
SF	0.412	0.120–1.326	<0.001	-.0243	0.143	0.028–0.553	<0.001	-.0096	<0.001	-.0835
AP	0.346	0.124–0.906	0.104	0.005–0.605	0.245	0.079–0.679	0.036	0.002–0.191	0.146	0.008–0.912
BP	0.407	0.113–1.325	0.047	0.010–0.170	0.052	0.013–0.171	0.019	0.003–0.077	0.369	0.074–1.482
NT	0.571	0.158–1.890	0.778	0.180–3.172	0.444	0.110–1.553	0.444	0.110–1.553	1.000	0.221–4.524

USju: 2D ultrasound junior radiologists, USse: 2D ultrasound senior radiologists, CEUSju: Contrast-enhanced ultrasound junior radiologists, CEUSse: Contrast-enhanced ultrasound senior radiologists, IF: Larger full-thickness tear, sF: Small full-thickness tear, aP: Articular-side partial-thickness tear, bP: Bursal-side partial-thickness tear, NT: No tear, OR: Odds ratio, CI: Confidence interval, RCTs: Rotator cuff tears

subtypes was bP, sF/aP, NT, and IF in descending order of difficulty, and when US modalities and physician qualifications were differentiated, the order of difficulty was only applicable

to junior physicians or US. Only the bP is more difficult to diagnose than the other subtypes when the senior physician is involved, and there is no significant difference in the difficulty

of diagnosis between the remaining subtypes. However, there was no significant difference between the subtypes in CEUS.

Therefore, CEUS can significantly improve the diagnostic accuracy of subtypes, whereas the improvement of physician qualification can only eliminate the heterogeneity between some subtypes (sF, aP, and NT, respectively) and is not as good as that of CEUS, especially for bP, the most difficult subtype to diagnose, which could not be accurately diagnosed by qualification improvement, and the diagnostic accuracy of which can be significantly improved by CEUS. Therefore, when there is a high suspicion of bursal tendon involvement, CEUS can be used to screen for it when necessary.

Different subtypes exhibited varying degrees of dependence on qualifications and technology.

In the present study, for IF and NT, there was no experience or method dependence. IF is a subtype that is recognized as easy to diagnose, and previous studies have shown that the diagnostic accuracy of IF was high.^[4,10,11] For NT, the accuracy rate was 80%–90% in this study, and neither increasing the seniority nor the method could improve the diagnostic rates. Analyzing the reasons, the most important is that NT is mostly tendinopathy and subacromial-deltoid bursitis, and the former has no obvious continuity interruption of tendon texture and mainly shows focal uneven echogenicity, lacking specificity on echogenicity;^[16] the latter may be easily misdiagnosed as bP due to obvious synovial hyperplasia resulting in less regular tendon contour on the bursal-side tendon. There was also a special type of tendon due to long-term diabetes mellitus or hyperlipidemia that could easily lead to overdiagnosis as a tear, and because of the decreased denseness of the tendon, a small amount of contrast agent penetrated the tendon when CEUS was used for diagnosis, resulting in false positive, which reflected the antagonistic effect of the interaction between CEUS and NT. Previous studies have also shown that diabetes mellitus and hyperlipidemia are independent risk factors for RCTs.^[19] Besides, the accuracy rate was relatively high and difficult to improve. Therefore, it is difficult to break through only from the features of images, and it is necessary to start from the mechanism of development of the disease, pathology, and clinically relevant information, including risk factors, underlying disease, meticulous history taking and physical examination, and other comprehensive specialized management to further improve the accuracy.

When diagnosing bP, there was no dependence on experience but technology. Moreover, the use of CEUS for RCT diagnosis by junior physicians was even superior to the use of US by senior physicians [Figure 5]. Therefore, as the most difficult subtype to diagnose, upgrading technology may be the only way to optimize diagnostics. To analyze the reasons, the chronic course of most bP cases resulting in lacking typical signs such as hypoechoic areas in the acute phase may play a vital role. Instead, they were more likely to be misdiagnosed as tendinopathy due to the heterogeneous echogenicity exhibited by scar repair.^[16] Second, if combined with severe bursitis,

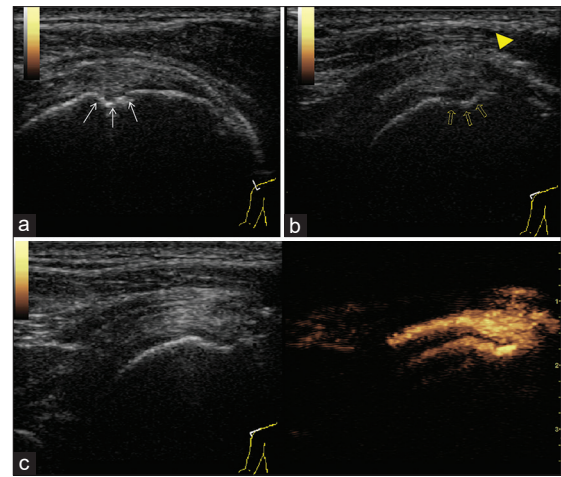


Figure 5: Small full-thickness tear sonograms of supraspinatus tendon with chronic course in a 54-year-old male. (a) The junior physician found a bony irregularity (arrows) adjacent to the articular-side tendon with no obvious abnormality. (b) The senior physician found a hypoechoic area in the articular-side tendon (empty arrows) by careful comparison of multiple views, but it was difficult to identify whether it was due to a tear or bursitis because of an unsmooth bursal surface (triangle). (c) The percutaneous ultrasound-guided subacromial bursography showed that the contrast agent entered the tendon from the bursa and flowed into the joint cavity immediately. PUSB: Percutaneous ultrasound-guided subacromial bursography

the small tear near the side of the bursa is easily obscured by the hyperplastic synovium and could not be easily identified. However, the lesioned areas were easily revealed through contrast agent.

For aP, there was dependence both on experience and technology. In this study, junior physicians were prone to misdiagnose aP. This may be due to the deep location of the articular-side tendon and its larger travel curvature, which is susceptible to a lack of penetration and anisotropic artifacts, which can usually be adjusted by experienced physicians with the aid of machines and techniques [Figure 5]. The experienced physician can usually adjust the machine and technique to achieve a better definition, thus showing the suspected lesion area better and avoiding misdiagnosis. The distribution of the contrast agent in CEUS, confined to the articular-side tendon and without bursa, made it easier to identify this type.

There was no experience dependence on US diagnosis, and only upgrading the diagnostic mode for higher seniority could increase the diagnostic confidence in the detection of sF. Some of the sF are easily misdiagnosed due to repeated repair tears under chronic course resulting in tortuous laceration alignment, which is difficult to show completely in one section, and the method upgrade while ensuring the overlay of experience may break through this type of cases. In addition, large bP was easily misdiagnosed as sF, where the contrast agent was visualized in articular-side tendon in CEUS but never flowed into the joint cavity, and only a layer of tendon tissue on the articular side was found intraoperatively, which could only be accurately diagnosed by upgrading modality.

By retrospectively analyzing the diagnostic difficulty of each subtype and its dependence on qualifications and different techniques, as well as the possible sonographic manifestations and difficulties under each qualification and technical configuration, we can fully recognize the possible diagnostic pitfalls and corresponding sonographic confusion points of each subtype under different influencing factors, which can help improve the radiologist's alertness to subtype identification, and then supplemented by clinical data. For example, in clinical practice, when bursal tendon involvement is suspected on US, it is more practical to recommend CEUS than to improve seniority. However, for suspected articular-side tendon involvement, it is recommended to ask for a consultation first, which is likely to clarify the aP through the enhancement of experience.

Limitations

The present study has some limitations. First, the CEUS is invasive with well-recognized risks, such as infection, despite our lack of complications. Another possible limitation of the study is an operator bias in diagnostic decisions because all static and dynamic images were acquired by a senior physician to reduce misdiagnosis due to missing images. In addition, this was a retrospective study with a relatively small sample. Although it is sometimes not possible to specify the subtype of tear in clinical practice, one or two tear subtypes are ultimately favored based on the available US signs. While this study suggests a technical upgrade for patients with suspected involvement of the lateral bursa, there is still a need for a prospective, large-sample study to test the above suggestions for better decision-making on further diagnostic US triage.

CONCLUSION

Qualification, technology, and subtype were all independent influence factors on the correct diagnosis of RCTs, with modality upgrade having a greater impact than qualification. The subtype bP is the most difficult to diagnose, followed by sF, with modality upgrades significantly improving accuracies. Therefore, in clinical practice, when bursal tendon involvement is suspected on US, it is more practical to recommend CEUS than to improve seniority, whereas for articular-side tendon involvement, qualification upgrade is recommended first.

Financial support and sponsorship

This research has received funding from Tianhe Science and Technology Project 201604 KW031, Guangzhou, Guangdong, China; Featured Clinical Technique of Guangzhou (Grant No. 2023P-TS40), Guangzhou, Guangdong, China.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Donohue NK, Nickel BT, Grindel SI. High-grade articular, bursal, and intratendinous partial-thickness rotator cuff tears: A retrospective study comparing functional outcomes after completion and repair. *Am J Orthop (Belle Mead NJ)* 2016;45:E254-60.
2. Kim HM, Dahiya N, Teefey SA, Keener JD, Galatz LM, Yamaguchi K. Relationship of tear size and location to fatty degeneration of the rotator cuff. *J Bone Joint Surg Am* 2010;92:829-39.
3. Jacobson JA, Lancaster S, Prasad A, van Holsbeeck MT, Craig JG, Kolowich P. Full-thickness and partial-thickness supraspinatus tendon tears: Value of US signs in diagnosis. *Radiology* 2004;230:234-42.
4. Lenza M, Buchbinder R, Takwoingi Y, Johnston RV, Hanchard NC, Faloppa F. Magnetic resonance imaging, magnetic resonance arthrography and ultrasonography for assessing rotator cuff tears in people with shoulder pain for whom surgery is being considered. *Cochrane Database Syst Rev* 2013;2013:CD009020.
5. Lee K, Kim JY, Lee MH, Choi CH, Hwang JY. Imbalanced loss-integrated deep-learning-based ultrasound image analysis for diagnosis of rotator-cuff tear. *Sensors (Basel)* 2021;21:2214.
6. Wu WT, Lin CY, Shu YC, Chen LR, Özçakar L, Chang KV. Subacromial motion metrics in painful shoulder impingement: A dynamic quantitative ultrasonography analysis. *Arch Phys Med Rehabil* 2023;104:260-9.
7. Shu YC, Lo YC, Chiu HC, Chen LR, Lin CY, Wu WT, *et al.* Deep learning algorithm for predicting subacromial motion trajectory: Dynamic shoulder ultrasound analysis. *Ultrasonics* 2023;134:107057.
8. Chang RF, Lee CC, Lo CM. Computer-aided diagnosis of different rotator cuff lesions using shoulder musculoskeletal ultrasound. *Ultrasound Med Biol* 2016;42:2315-22.
9. Chang KV, Lew HL, Wang TG, Chen WS. Use of contrast-enhanced ultrasonography in musculoskeletal medicine. *Am J Phys Med Rehabil* 2012;91:449-57.
10. Cheng X, Lu M, Yang X, Guo X, He F, Chen Q, *et al.* The effect of percutaneous ultrasound-guided subacromial bursography using microbubbles in the assessment of subacromial impingement syndrome: Initial experience. *Eur Radiol* 2015;25:2412-8.
11. Tang YQ, Zeng C, Su XT, Li SS, Yi WH, Xu JJ, *et al.* The value of percutaneous shoulder puncture with contrast-enhanced ultrasound in differentiation of rotator cuff tear subtypes: A preliminary prospective study. *Ultrasound Med Biol* 2019;45:660-71.
12. Wang Y, Zhu Y, Zhang F, Chen X, Chen J, Jiang W, *et al.* The value of combined ultrasound contrast arthrography and subacromial-subdeltoid bursography for detecting and differentiating the rotator cuff tear subtypes in patients with the uncertain rotator cuff tear. *Eur Radiol* 2024;34:3503-12.
13. Tang Y, Chen W, Yi W, Zhang J, Li S, Xu J, *et al.* Consistency of diagnosing rotator cuff tear based on contrast-enhanced ultrasound through percutaneous shoulder puncture. *Chin J Med Imaging Technol* 2022;38:1545-50.
14. Daenen B, Houben G, Bauduin E, Lu KV, Meulemans JL. Ultrasound of the shoulder. *JBR-BTR* 2007;90:325-37.
15. Tang Y, Zeng C, Su X, Li S, Yi W, Xu J, *et al.* Ultrasound in diagnosis of rotator cuff tears. *Chin J Med Imaging Technol* 2017;33:1864-8.
16. Ellman H. Diagnosis and treatment of incomplete rotator cuff tears. *Clin Orthop Relat Res* 1990;64-74.
17. Codman EA. *The Shoulder*. Boston: Thomas Todd; 1934.
18. Cofield RH. Rotator cuff disease of the shoulder. *J Bone Joint Surg Am* 1985;67:974-9.
19. Lin TT, Lin CH, Chang CL, Chi CH, Chang ST, Sheu WH. The effect of diabetes, hyperlipidemia, and statins on the development of rotator cuff disease: A nationwide, 11-year, longitudinal, population-based follow-up study. *Am J Sports Med* 2015;43:2126-32.