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Diagnostic sensitivity of ultrasound of the supraspinatus tendon when compared to magnetic resonance imaging prior to arthroscopy: A retrospective study

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ORIGINAL ARTICLE

Diagnostic sensitivity of ultrasound of the supraspinatus tendon when compared to magnetic resonance imaging prior to arthroscopy: A retrospective study

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Abstract

Introduction: Ultrasound (USS) and magnetic resonance imaging (MRI) have been used as screening tools for rotator cuff tears with MRI reported as superior. When comparing USS and MRI for supraspinatus tears, less data is available.

Aim: Compare the diagnostic sensitivity of USS and MRI in the pre-operative diagnosis of partial thickness tears (PTT) and full thickness tears (FTT) of supraspinatus tendons compared to gold-standard shoulder arthroscopy to assess if differences in detection rates exist.

Method: Retrospective study of deidentified electronic medical records including post-operative surgical notes and pre-operative imaging USS and MRI results.

Results: $N = 103$ participants, male: female ratio of 63:40, mean age 64 years. FTT were diagnosed by arthroscopy in 63/103 (61.2%), PTT <5 mm in 18/103 (17.5%), PTT >5 mm in 22/103 (21.4%). USS and MRI sensitivity were both 95.2% for FTT. PTT <5 mm sensitivity for USS and MRI were 83.3% and 77.7%, and PTT >5 mm sensitivity were 73.3% and 86.4% respectively. Overall supraspinatus tears USS sensitivity was 88.4% and MRI 90.3%.

Discussion: Comparable sensitivity was demonstrated for FTT for USS and MRI. USS had better sensitivity than MRI for PTT <5 mm, MRI performed better for PTT >5 mm. Pre-operative evaluation of suspected supraspinatus tears could include USS as a first line imaging modality, due to its low cost and easier availability.

Conclusion: USS has high diagnostic accuracy for diagnosing supraspinatus FTT and PTT. MRI may be used where significant glenohumeral joint osteoarthritis needs to be assessed. Further studies with larger numbers are needed to verify these results.

KEYWORDS

magnetic resonance imaging, sensitivity, supraspinatus, ultrasound

1 | INTRODUCTION

Rotator cuff pathologies are a significant cause of shoulder pain.¹⁻³ Within the group of rotator cuff tendons, supraspinatus tendon tears represent the majority of injuries.¹⁻⁴ The shoulder's complexity of function with multidirectional movements makes it vulnerable to damage.⁴ The supraspinatus tendon can tear partially or fully in thickness, tear size has a significant influence over reparability. Primary repair of a supraspinatus tendon may not be possible if the tendon is very large and has retracted.

This differentiation in diagnosis is important to illustrate for the surgeon, as the path of treatment is different based on tear size and retraction.⁴ A partial tear with less than 25% of the tendon involved will generally only have the damaged tissue removed. This process is called debridement. Partial tears greater than 25% of the tendon width and full thickness tears (FTT) will have the tendon reattached to the bone.⁴⁻⁹

The two main diagnostic tools used to assess tendon tears prior to surgery are high resolution ultrasound (USS) and magnetic resonance imaging (MRI).^{4,6} The advantages of USS include lower cost, higher accessibility, real time evaluation allowing for observation of tendon movement whilst performing the scan and in general better patient compliance as there is no confined space or limitations with movement.¹⁻³ Assessment and comparison of the opposite shoulder is also a distinct advantage with USS.^{1,4-6}

The benefits of MRI include better tissue delineation, anatomy definition and the ability to interrogate bony degenerative changes and or fractures.¹⁻³ However, increased cost, time and patient intolerance are limitations to MRI's use.^{1-3,7,10}

USS and MRI have been used as screening tools for rotator cuff tears since 1984.⁸ Subsequent research compared the accuracy of these two imaging modalities in the diagnosis of rotator cuff pathology, with the majority reporting MRI to be superior to USS.^{2,6-8,11} However, when the clinical question is focussed on the supraspinatus tendon, the argument to replace USS with the more expensive MRI is less persuasive as most recent literature demonstrates that there is little difference in the diagnostic superiority of MRI.^{1,3,7,11}

To date there is an abundance of data that has been published on rotator cuff tears. However, there is a paucity of concise information detailing USS role as a stand-alone diagnostic tool specifically for supraspinatus tears. Despite a comparative accuracy of 100% for FTT all studies were inconclusive in establishing the value of USS replacing MRI as the preferred pre-operative imaging tool when diagnosing partial thickness tears (PTT).^{1-3,7,11}

2 | AIM

This study aims to investigate the sensitivity of USS compared to MRI in the pre-operative diagnosis of partial and full thickness supraspinatus tendon tears using shoulder arthroscopy as the gold standard. The study will assess if there is a difference in detection rates between the two imaging modalities. We hypothesised that USS can be used as a pre-operative screening tool for FTT and PTT without the need for MRI.

3 | METHOD

This project was a retrospective, quantitative study with data collected from participants' medical records. The information was collected over a period from 01/08/2020–01/08/2021. Data collected involved a number of general radiology practices. Ultrasounds were performed by general sonographers. Ultrasound machines involved in the study included Philips Epiq5, Canon Aplio 500, and General Electric Logiq E9. These machines are equipped with high frequency linear probes in the range of 10–15 MHz appropriate for musculoskeletal scanning.

The MRI machines in this study included a Philips Ingenia 1.5 T, Philips Ingenia 3.T and a Siemens Magnetom 1.5 T. One orthopaedic practice was used to collate the data where there are two orthopaedic surgeons. The relevant Medicare numbers for arthroscopic repair, MRI and USS were used to capture relevant participants.

The participants included had a shoulder arthroscopic repair performed within 3 months of a positive supraspinatus tear diagnosed by both MRI and USS. The post-operative notes from the surgeon and pre-operative imaging results from MRI and USS were used to detail findings. The surgeon's findings along with the work up imaging tests were stored as electronic data. The de-identified electronic medical records of the participants USS, MRI and arthroscope were accessed. Comparisons were tabulated between the USS and MRI diagnostic sensitivity, with that of the gold standard finding of arthroscope assessing the results of full and partial supraspinatus thickness tears.

We detailed findings according to sensitivity using this formula; Sensitivity = $[\text{TP}/\text{TP} + \text{FN}] \times 100$ (TP = true positive and TP = false negative) categorising average sensitivity for FTT, average sensitivity for PTT and overall sensitivity for all tears (both PTT and FTT).¹²⁻¹⁴

Tear sizes were classified using the Ellman classification system.¹⁵ There was only one orthopaedic practice involved in this study and all MRI and ultrasound machines used were of similar standard, this endeavours to reflect the general imaging community.

3.1 | Variables and demographics

Data collected included patient age reported as mean (standard deviation) (m (SD)), gender as a ratio of male: female and degree of supraspinatus tear.¹²⁻¹⁴ Data were analysed reporting on number of supraspinatus tears reported as sensitivity (true positive case) for USS and MRI and categorised into

1. number and sensitivity of partial thickness tears <than 5 mm
2. number and sensitivity of partial thickness tears >than 5 mm
3. number and sensitivity of full thickness tears

Exclusion criteria were those who had a longer than 3-month period between diagnosis and arthroscopy, and whose pathology was unrelated to the supraspinatus tendon and participants aged less than 18 years.

Participants signed a consent for de-identified data to be used for research purposes. This consent was provided to each participant by the surgeon as part of a non-obligatory pre-surgery protocol.

TABLE 1 Number of cases and partial and full thickness tear sensitivity and overall sensitivity of USS and MRI compared to arthroscopy.

	Full thickness tear		Partial thickness tear <5 mm		Partial thickness tear >5 mm		Average sensitivity PTT and FTT		Overall sensitivity
	60/63	95.2%	15/18	83.3%	16/22	73.3%	83.9%	91/103	
Ultrasound	60/63	95.2%	15/18	83.3%	16/22	73.3%	83.9%	91/103	88.4%
MRI	60/63	95.2%	14/18	77.7%	19/22	86.4%	86.4%	93/103	90.3%
Arthroscope	63	100%	18	100%	22	100%	100%	103	100%

All participants in this study were recruited and identified using Medicare numbers, this allowed the capture of only those participants who had an USS, MRI and arthroscopic repair. Central Queensland Ethics Committee provided ethics approval (ethics number 2021-010).¹⁶

4 | RESULTS

One hundred and three participants who had arthroscopic shoulder repair had their data reviewed comparing the diagnostic accuracy of pre-operative USS and MRI with arthroscopy used as gold standard. Overall, there were 63 FTT and 40 PTT diagnosed by arthroscopy.

The ratio of male: female participants were 63:40 with a mean age of 64 (10.8) years. Data reporting sensitivity for USS and MRI for FTT and PTT and overall sensitivity for all tears is listed in Table 1. Specificity could not be calculated as people with negative results did not present for surgery.

Comparable sensitivities were seen with the two modalities of USS and MRI with MRI having slightly higher sensitivity overall.

The sensitivity of MRI and USS was the same for FTT. For PTT greater than 5 mm, MRI had a 13.1% improvement in diagnosis compared to USS. For PTT less than 5 mm USS had a 5% improvement in diagnosis compared to MRI.

5 | DISCUSSION

This study demonstrates pre-operative evaluation of suspected supraspinatus tears comparing USS and MRI show similar diagnostic sensitivity with FTT reported by MRI and USS having the same detection rate (sensitivity of 95.2%). Three out of 60 participants in this study had their FTT incorrectly reported in both MRI and USS. In the PTT of greater than 5 mm, MRI had greater sensitivity (86.4% for MRI and 73.3% for USS) whilst PTT of 5 mm or less demonstrated USS to be more diagnostically sensitive (83.3% for USS and 77.7% for MRI). Six participants were under reported on USS where the tear size was greater than 5 mm on arthroscopy, however in tear sizes smaller than 5 mm, USS and MRI results were similar. However, due to the small sample size, it is difficult to conclude whether this is clinically significant. Overall, the sensitivity of USS and MRI were similar.

Our results demonstrate the sensitivity of USS and MRI are comparable in diagnosing full thickness and partial thickness supraspinatus tears. Since USS is less expensive and more available, it could be

considered as the screening tool of choice when supraspinatus tendon integrity is the only question.^{1-3,7,11}

The incidence of rotator cuff tears increases with age.^{17,18} FTT are reported in 25% of individuals over the age of 60 and 50% of individuals over 80 years of age.¹⁹ The age and gender demographics in our study are consistent with the literature that indicates older age and male gender are associated with a higher number of supraspinatus tears.^{1-3,19} Supraspinatus PTT and FTT may be part of a degenerative process where the tendon progressively wears out due to repetitive stress or due to an acute injury.^{1-3,12,13}

A PTT is defined as focal discontinuation without continuation of the tear to the opposing tendon surface.^{4,12} These tears are often treated conservatively; sometimes with physiotherapy or corticosteroid injections. In cases where this treatment fails to help, debridement under arthroscope is used.^{6,8} Partial tears can be described as bursal, articular surface tears and intrasubstance tears.^{4,20-22}

The articular side of the supraspinatus tendon is commonly torn with a critical hypo vascular zone existing 10–15 mm proximal to the supraspinatus tendon insertion onto the humeral head making it vulnerable to damage.^{4,20-22} The bursal sided tears are more likely due to subacromial impingement and are less common than articular and intrasubstance tears.^{4,20-22} USS is useful for detection of impingement due to the ability to scan dynamically which has advantage over the stationary nature of MRI.

The intrasubstance tear is confined to the interstitial layers of the tendon, they are also known as concealed interstitial delamination tears. Previous studies indicate that PTT's on the articular surface are the most common supraspinatus pathology diagnosed.^{1-4,23} However in these studies the participants were from a broader cohort, including those that did not require surgical intervention. In our study there was a higher number of FTT ($n = 63$) than PTT ($n = 40$). The captured participants in our study all needed surgical intervention giving a higher prevalence of significant tears that could not be managed conservatively. It is important to correctly diagnose the location and thickness of tears as it directly impacts on management.^{4,8,11,17} Our study shows good correlation between MRI and USS giving confidence in USS ability to correctly define tendon tear location and size.

Arthroscopic repair for a FTT involves reattachment of the torn tendon onto the bone and may involve acromioplasty, where the underside of the acromion is shaved to allow for better tendon sliding due to an increase in the subacromial space.^{4,6,8,17} Management decisions are influenced by identifying the extent of tendon retraction and the condition of the ruptured edges, as well as quality of the muscle.^{4,6,8} If tendon pathology is detected early, then management is less

invasive with better patient outcomes.²⁴ In our study USS and MRI both had a sensitivity rate of 95.2%. These results suggest USS could replace MRI as a stand-alone imaging modality for FTT detection.

Supraspinatus tendon thicknesses can vary substantially between individuals. According to Ruotolo, et al.²³ the mean anteroposterior dimension of the supraspinatus insertion is 25 mm.

The mean superior to inferior dimension (longitudinal) of the supraspinatus tendon thickness at the rotator interval is 11.6 mm, 12.1 mm at mid tendon and 12 mm at the posterior edge.⁴

Using the Ellman classification system,¹⁵ tendon tears can be classified as:

grade 1: <3 mm or < 25%.

grade 2: 3–6 mm or 25%–50%.

grade 3: >6 mm or > 50%.

In our study a cut off of 5 mm was chosen to delineate a minor PTT (grouping grade 1 and 2 together) from a significant PTT.¹⁵ Using this cut-off allows conformity to previous studies and ease of replication for future studies.

Advantages of USS over MRI include greater patient tolerance due to better patient comfort, dynamic scanning using real time imaging (which is useful to demonstrate tendon or bursal impingement) better patient accessibility, and cost savings. The cost benefit of USS alone makes for a compelling argument to replace MRI as the preferred imaging tool whenever possible. Shoulder USS fee, as determined by the Australian Government Department of Health, is \$43.05 by contrast a shoulder MRI fee is \$403.20,²⁵ making USS significantly less expensive.

MRI, although more expensive and less well tolerated, still remains the preferred imaging choice prior to surgery, as it is generally considered to have a higher sensitivity overall when diagnosing PTT.^{1–3} Our study involved a group of generalist sonographers using differing USS machines intending to reflect a less specialised group. Therefore, our results may be more indicative of a broader cross section of examinations available to the general community. According to Cole et al.²⁶ rotator cuff tear sensitivity using USS is operator and machine dependant.²⁶ USS performed by experienced specialised sonographers improves tear detection rates.²⁶ Sensitivity rate using USS will continue to further improve with better sonography training and continued improvement of spatial resolution, ultimately allowing greater confidence in the use of USS as a stand-alone diagnostic tool for supraspinatus tears.^{1–4}

Shoulder arthroscope is the gold standard for diagnosis of intra-articular pathologies.³ However, because arthroscopy involves an anaesthetic and a surgical procedure, it is not appropriate to be used as the first line of assessment.⁹ Although MRI remains the preferred imaging modality for shoulder assessment,^{1–3} USS is emerging as a cost-effective, reliable, and convenient alternative due to continued improvement in transducer resolution and consistent education.^{24,26,27} While the results of our research may impact on the diagnostic imaging choices prior to supraspinatus arthroscopy with USS being used as an alternative to MRI, our study suggests, practices should audit USS to see if these results concur generally.

Arthroscopic technological advances have allowed for better surgical intervention. Arthroscope has become less invasive and less expensive. Intervention for moderate PTT is therefore now more

likely.^{6,8,17,28,29} The evolution of surgical intervention makes it important for USS to detect a small partial thickness tear because these tears are now more likely in the future to be referred to surgery rather than being treated conservatively.^{6,8,28} PTT, if left untreated can enlarge and propagate into FTT, early intervention prevents tear progression and protects cuff elasticity.²⁴

Lower grade tears do well with arthroscopic debridement alone while large tears need a repair.^{4,23,24} As USS resolution and user proficiency continues to improve in detecting PTTs USS role will become more important for early intervention diagnosis, perhaps in the future replacing MRI.

Recent meta-analysis published in 2020 and 2021,^{27,30} found good correlation between MRI and USS for FTT though a lower sensitivity for both modalities compared to arthroscope for characterising PTT.^{27,30}

These results appear to be broadly consistent with earlier systematic reviews. With advances in technologies, MRI and USS have together shown significant improvements in the detection of both PTT and FTT.^{31,32}

Our study also reported an improvement in USS sensitivity when compared with reports of detection of PTT.²⁹ Our study did not assess accuracy though Malik et al.¹ in 2020 found a 94% accuracy for detection of partial thickness supraspinatus tears, compared to that of the earlier study by Teefey et al. in 2004²⁹ which found an accuracy rate of 84%. A study conducted in 1996–1997 by Goldberg et al.³³ cautioned against the diagnostic powers of ultrasound; suggesting a sensitivity rate of only 49% for the detection of rotator cuff tears. This steady improvement in USS sensitivity highlights that significant improvement due to improved spatial resolution, technological advances and user proficiency over time will make USS more likely to be used as a stand-alone diagnostic tool in the future.^{1–3,26,34,35} However, in cases where underlying significant glenohumeral joint osteoarthritis is present, MRI will always have superior diagnostic capabilities compared to USS.

6 | STRENGTHS AND LIMITATIONS

The retrospective study was chosen as an efficient way to report on data with no inconvenience to participants and eliminating loss to follow up. Retrospective research analyses in this study used pre-existing results in the form of a written report. This allowed for less risk of data manipulation and misclassification bias as all measurements were taken prior to the research.^{12,13}

Researcher bias was also reduced due to the quantitative rather than a qualitative nature of this study, allowing for less observer interpretation.¹²

Several limitations of this study were identified. Small sample-size number reduced the power of the study, future studies should endeavour to increase the sample size to allow for better verification and validation of results. The use of arthroscopic repair as a selection criterion may have created a selection bias as arthroscopic evaluation only occurs when pathology is significant. More inclusions such as

participant weight and dominant handedness could be beneficial for predicting the aetiology of supraspinatus tears.

While it is clear age and gender influence likelihood of tears, it remains unclear whether there are other influencing factors. For example, having a detailed smoking history would have added interest to this study, as smoking negatively affects vascularity of tendons.^{4,35} Broader data collection would have benefited this study, providing statistics on specificity so that accuracy could have been included and assessed. This would have allowed for more effective comparisons with other past and future studies.

7 | CONCLUSION

Advances in USS shoulder imaging due to increased spatial resolution has revolutionised shoulder imaging over the last 20 years. This study indicates substantial agreement for supraspinatus tear diagnosis when comparing MRI to USS performed in general imaging departments. Given USS is less expensive and more available, it could be considered as a first line screening tool when the main question is one of tendon integrity. However, where the patient has significant underlying osteoarthritis, MRI should be included in the imaging workup prior to surgery.

As technology continues to improve with ultra-high frequency ultrasound probes, further studies to assess accuracy of supraspinatus tear detection should be evaluated, the assumption is that in future, USS will have the capacity to serve as a stand-alone diagnostic tool in accurately assessing supraspinatus tears prior to arthroscopy.

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CONFLICT OF INTEREST STATEMENT

Ann Quinton is an editorial board member for Sonography and a co-author on this article. Other declare no conflict of interest.

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QUESTIONNAIRE
A21(25) Part 1 of 2

Diagnostic sensitivity of ultrasound of the supraspinatus tendon when compared to magnetic resonance imaging prior to arthroscopy: A retrospective study

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- **Some questions may have more than one correct answer;** in which case you must mark **all** the correct answers.

Introduction

Question 1: A partial tear with of the tendon involved will generally only have the damaged tissue removed?

- A:** Less than 25%
- B:** Greater than 25%

Question 2: What are the two main diagnostic tools used to assess tendon tears prior to surgery?

- A:** CT scan and X-ray
- B:** Magnetic resonance imaging (MRI) and X-ray
- C:** High-resolution ultrasound (USS) and magnetic resonance imaging (MRI)
- D:** Ultrasound and CT scan
- E:** Electromyography and arthroscopy

Question 3: Which of the following are advantages of USS over MRI for tendon evaluation?

- A:** Better tissue delineation
- B:** Better patient compliance because of no confined spaces or limitation in movement
- C:** Anatomy definition
- D:** Higher accessibility and real-time evaluation
- E:** Assessment and comparison of opposite shoulder

Question 4: What are the limitations of MRI?

- A:** Patient intolerance
- B:** Worse tissue delineation
- C:** Increased cost and time
- D:** The inability to interrogate bony degenerative changes

Question 5: Is it **TRUE** that all studies were conclusive in establishing the value of USS replacing MRI as the preferred pre-operative imaging tool when diagnosing partial thickness tears (PTT)?

- A:** YES
- B:** NO

Question 6: What was the ratio of male to female participants in the study?

- A:** 40:63
- B:** 63:40
- C:** 100:3
- D:** 50:50

Discussion

Question 7: What was the detection rate (sensitivity percentage) of both USS and MRI for full-thickness tears (FTT) in this study?

- A:** 86.4%
- B:** 83.3%
- C:** 73.3%
- D:** 95.2%

Question 8: For partial thickness tears (PTT) greater than 5 mm, which imaging modality had higher sensitivity?

- A:** USS with 86.4% sensitivity
- B:** USS with 73.3% sensitivity
- C:** MRI with 86.4% sensitivity
- D:** Both had equal sensitivity of 80%

Question 9: For partial thickness tears less than 5 mm, which imaging modality demonstrated higher sensitivity?

- A:** USS with 83.3% sensitivity
- B:** MRI with 83.3% sensitivity
- C:** USS with 77.7% sensitivity
- D:** MRI with 77.7% sensitivity

Question 10: According to the article, what was the reported incidence of individuals over the age of 60 with full-thickness tears (FTT)?

- A:** 10%
- B:** 25%
- C:** 50%
- D:** 75%

THE END

QUESTIONNAIRE
A21(25) Part 2 of 2

Diagnostic sensitivity of ultrasound of the supraspinatus tendon when compared to magnetic resonance imaging prior to arthroscopy: A retrospective study

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- **Some questions may have more than one correct answer;** in which case you must mark **all** the correct answers.

Question 1: How is a partial thickness tear (PTT) defined?

- A:** Continuous tear from one tendon surface to the other
- B:** Focal discontinuation with continuation of the tear to the opposing tendon surface
- C:** Focal discontinuation without continuation of the tear to the opposing tendon surface
- D:** Tendon inflammation without structural damage

Question 2: Which conservative treatment options are often chosen for PTT?

- A:** Corticosteroid injections
- B:** Debridement under arthroscope
- C:** Surgical intervention
- D:** Physiotherapy

Question 3: Which side of the supraspinatus tendon is most commonly torn?

- A:** Bursal side
- B:** Articular side
- C:** Intrasubstance
- D:** Mid-substance

Question 4: In this study, which had the higher number?

- A:** PTT with 60
- B:** FTT with 40
- C:** FTT and PTT had the same number
- D:** PTT with 40
- E:** FTT with 63

Question 5: According to the Ellman classification system, a tendon tear size of 3-6 mm or 25% - 50% is classified as which of the following?

- A:** Grade 1
- B:** Grade 2
- C:** Grade 3

Question 6: Is it **TRUE** or **FALSE** that although MRI is more expensive and less tolerated, it remains the preferred imaging choice prior to surgery, as it is generally considered to have a higher sensitivity overall when diagnosing PTT?

- A:** TRUE
- B:** FALSE

Question 7: According to *Cole et al.* what factors affect rotator cuff tear sensitivity when using USS?

- A:** Patient age and gender
- B:** Patient positioning and operator
- C:** Operator and machine dependant
- D:** Patient age and patient positioning

Question 8: What is considered the gold standard for the diagnosis of intra-articular pathologies of the shoulder?

- A:** Ultrasound
- B:** MRI
- C:** Arthroscopy
- D:** CT scan

Question 9: In which circumstance would MRI always have superior diagnostic capabilities compared to USS?

- A:** When evaluating tendon thickness
- B:** When underlying significant glenohumeral joint osteoarthritis is present
- C:** When assessing bursal inflammation
- D:** When evaluating tendon movement

Question 10: This study indicates agreement for supraspinatus tear diagnosis when comparing MRI to USS performed in general imaging departments

- A:** Inadequate
- B:** No
- C:** Moderate
- D:** Substantial

THE END



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ANSWER SHEET

A21(25)

Diagnostic sensitivity of ultrasound of the supraspinatus tendon when compared to magnetic resonance imaging prior to arthroscopy: A retrospective study

	*Time spent on activity						hour					min				
	A	B	C	D	E		A	B	C	D	E	A	B	C	D	E
1						1										
2						2										
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Not at all	Somewhat	Mostly	Extremely

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