

Do Magnetic Resonance Imaging Characteristics of Full-Thickness Rotator Cuff Tears Correlate With Sleep Disturbance?

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Background: Many patients with rotator cuff tears suffer from nocturnal shoulder pain, resulting in sleep disturbance.

Purpose: To determine whether rotator cuff tear size correlated with sleep disturbance in patients with full-thickness rotator cuff tears.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: Patients with a diagnosis of unilateral full-thickness rotator cuff tears (diagnosed via magnetic resonance imaging [MRI]) completed the Pittsburgh Sleep Quality Index (PSQI), a visual analog scale (VAS) quantifying their shoulder pain, and the American Shoulder and Elbow Surgeons (ASES) questionnaire. Shoulder MRI scans were analyzed for anterior-posterior tear size (mm), tendon retraction (mm), Goutallier grade (0-4), number of tendons involved (1-4), muscle atrophy (none, mild, moderate, or severe), and humeral head rise (present or absent). Bivariate correlations were calculated between the MRI characteristics and baseline survey results.

Results: A total of 209 patients with unilateral full-thickness rotator cuff tears were included in this study: 112 (54%) female and 97 (46%) male (mean age, 64.1 years). On average, shoulder pain had been present for 24 months. The mean PSQI score was 9.8, and the mean VAS score was 5.0. No significant correlations were found between any of the rotator cuff tear characteristics and sleep quality. Only tendon retraction had a significant correlation with pain.

Conclusion: Although rotator cuff tears are frequently associated with nocturnal pain and sleep disruption, this study demonstrated that morphological characteristics of full-thickness rotator cuff tears, such as size and tendon retraction, do not correlate with sleep disturbance and have little to no correlation with pain levels.

Keywords: rotator cuff tear; sleep quality; MRI; shoulder pain; rotator cuff tear pattern; patient-reported outcome measures

The recent literature has emphasized the negative effects that orthopaedic abnormalities have on sleep quality.[‡]

Associations have been made between sleep disturbance and chronic neck and back pain,^{1,12,14} knee pain,¹⁷ carpal tunnel syndrome,^{18,19} long-bone fractures,²² and shoulder abnormalities,^{6,16} including shoulder impingement syndrome²³ and rotator cuff tears.^{3,16} To our knowledge, there has only been one study to find that pain levels in patients with shoulder impingement syndrome directly correlated with sleep quality.²³ However, others have demonstrated that sleep disturbance is more strongly associated with poor emotional status and ineffective coping strategies and less dependent on symptom intensity or functional status.^{20,22} While sleep disturbance is accepted as a classic symptom of rotator cuff tears, these studies illustrate the complexity of the association between shoulder pain and sleep.

A seemingly more straightforward relationship is that between rotator cuff tear severity and pain perception. However, previous studies examining this association have produced inconsistent results. Three recent studies^{11,13,15} prospectively followed patients with asymptomatic rotator

[‡]References 1-3, 6, 12, 14, 16-20, 22, 23, 27.

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cuff tears and found that pain development is associated with an increase in tear size. However, 2 recent cross-sectional studies^{7,8} have demonstrated the lack of association between morphological characteristics of full-thickness rotator cuff tears and pain. Additionally, Wylie et al²⁶ demonstrated that shoulder pain and function in patients with rotator cuff tears are more strongly associated with mental health status than tear severity. Similar to our understanding of sleep disturbance, the interconnection between rotator cuff tear severity and pain perception is complex, and further studies are needed to better understand the intricacies.

To our knowledge, no studies have examined the relationship between rotator cuff tear characteristics and sleep quality. The purpose of this study was to determine whether rotator cuff tear morphology, based on magnetic resonance imaging (MRI) findings in patients with full-thickness rotator cuff tears, correlated with sleep disturbance. We hypothesized that there would be no correlation between rotator cuff tear severity and sleep quality.

METHODS

Patients presenting with unilateral shoulder pain and diagnosed with a symptomatic full-thickness rotator cuff tear on MRI were prospectively enrolled in this study. Institutional review board approval was obtained before the commencement of patient enrollment. The data included in this study were obtained from a prospectively collected database examining the effects of shoulder abnormalities on sleep quality, as previously described by Mulligan et al.¹⁶ All patients were enrolled by a single surgeon (M.S.K.) between September 2013 and July 2016. Baseline data were collected for enrolled patients and were used for analysis before any treatment intervention.

Inclusion criteria were all patients aged 18 to 100 years with a unilateral symptomatic full-thickness rotator cuff tear confirmed by MRI (magnet strength, minimum 1.5 T). Exclusion criteria included age younger than 18 years, bilateral shoulder symptoms, rotator cuff tear arthropathies, isolated subscapularis tears, bilateral full-thickness rotator cuff tears, partial-thickness rotator cuff tears, prior shoulder surgery, shoulder injections either within the subacromial space or glenohumeral joint in the previous 6 months, acute shoulder fractures or dislocations (within the previous 6 months), history of psychotic or mood disorders, dementia, a current problem with substance abuse, or a current diagnosis of a sleep disorder. Additionally, patients were excluded if they did not complete the outcome survey.

At the time of the initial visit, before being seen by the treating physician, the patients were asked to complete a survey regarding demographic information, current medical health history, shoulder symptoms, and impact of their symptoms on activities of daily living and quality of sleep. Additionally, patients were asked the following to assess the chronicity of symptoms: "How long has your shoulder been bothering you?" The patients were asked to choose from the following options: <1 month, 1-3 months, 4-6 months, 7-12 months, and >12 months; they were also

asked to provide a specific number of days, months, and/or years. This survey contained standardized self-reported outcome tools, including the Pittsburgh Sleep Quality Index (PSQI), American Shoulder and Elbow Surgeons (ASES) questionnaire, visual analog scale (VAS) for pain, Single Assessment Numeric Evaluation (SANE) of the affected shoulder, and Self-Administered Comorbidity Questionnaire (SCQ).²¹ All patients consented to enrollment by voluntarily completing the survey and were given no specific instruction or prompts on how to respond. Sleep quality was assessed by the PSQI.

The PSQI⁵ is a validated outcome tool used to assess sleep quality. It is a self-reported questionnaire with 19 questions subdivided into 7 subcategories including sleep quality, latency, duration, and disturbance; habitual sleep efficiency; use of sleeping medications; and daytime dysfunction. Questions are scored from 0 to 3, where 0 represents no current issues and 3 represents the worst quality of sleep. The sum of the scores from all 7 subcategories yield a global PSQI score, ranging from 0 to 21, with higher scores indicating worse sleep. A global score of ≥ 5 indicates "poor" sleep based on prior studies, with a sensitivity of 0.90, specificity of 0.87, and kappa value of 0.75.^{4,5}

All shoulder MRI scans were reviewed by the senior author (M.S.K.), a shoulder fellowship-trained board-certified orthopaedic surgeon. Information gathered from MRI included the number of tendons involved (1-4; supraspinatus, infraspinatus, subscapularis, teres minor), measurements of medial retraction of the tear edges and anterior-posterior (AP) dimension of the tear (mm) at the site of maximum tendon retraction, graded level of retraction (midhumeral, glenohumeral, or glenoid), Goutallier grade (0-4), subjective atrophy (none, mild, moderate, or severe), and presence or absence of humeral head rise assessed by AP shoulder radiographs, taken with the patient either standing or seated (proximal humeral head migration was dichotomous as a yes/no answer). Rotator cuff muscle atrophy and fatty infiltration were assessed on the T1-weighted sagittal MRI cut, which included both the coracoid and the scapular spine. Atrophy was assessed (none, mild, moderate, severe) using the tangent sign, as described by Thomazeau et al.²⁵ Muscle fatty infiltration was assessed according to the modified Goutallier classification.⁹ A tear of >2.5 cm for the AP width was considered to involve the supraspinatus and the infraspinatus.²⁶ The number of torn tendons was defined by adding each tendon that was involved in the full-thickness aspect of the tear (supraspinatus, infraspinatus, and/or subscapularis).

Statistical Analysis

Based on an expected correlation coefficient of 0.20 with an alpha probability of a type I error of 0.05 and power of 0.80, a sample size of 194 participants was required. Bivariate correlations were calculated between each of the MRI characteristics of the rotator cuff tears and sleep quality (determined by PSQI scores), pain level (determined by VAS scores), ASES scores, and SANE scores. The Pearson correlation coefficient was utilized when both variables were continuous. The Spearman rank-order correlation

coefficient was utilized when one variable was continuous and the other was ordinal. The point biserial correlation coefficient was utilized when one variable was dichotomous and the other was continuous. This analysis was performed using an online calculation program at www.vassarstats.net. Analysis of variance was used to calculate differences in ordinal chronicity values and PSQI scores. The coefficient of determination, which represents the proportion of the variance in the dependent variable attributable to the independent variable, was calculated by computing the square of the correlation coefficient value. Linear regression was performed to determine the relationship of the 7 rotator cuff tear characteristics and sleep quality, pain, and ASES score using the Excel 2010 Data Analysis package (Microsoft).

RESULTS

The study included 209 patients with unilateral full-thickness rotator cuff tears. Included were 112 (54%) female and 97 (46%) male patients, with a mean age of 64.1 years (range, 38-91 years). On average, shoulder pain had been present for 1.99 ± 4.0 years (range, 1 day to 25 years; only available for 206 involved shoulders). The mean PSQI score was 9.8 ± 4.8 (range, 0-21). The mean VAS score for pain was 5.0 ± 2.6 (range, 0-10). The mean ASES score was 45.7 ± 19.0 (range, 3-93). None of the demographic variables including age, sex, chronicity of symptoms, side dominance, or smoking significantly correlated with VAS or ASES scores (Table 1). The chronicity of symptoms did significantly correlate with sleep quality ($r = 0.22$, $P = .002$) when assessed on a continuous scale (Table 2). A further examination to assess chronicity and tear characteristics on an ordinal scale demonstrated no significant correlations (Table 3). The mean PSQI score for those reporting symptoms <1 month was 7.9, 1-3 months was 9.3, 4-6 months was 10.2, 7-12 months was 10.9, and >12 months was 11.0. There was no significant difference between these groups ($P > .05$) except when comparing <1 month and >12 months, which did demonstrate a difference ($P = .05$). Pain levels based on chronicity were 5.3, 5.0, 5.2, 5.5, and 4.8 for <1 month through >12 months, respectively, and there were no significant differences between any groups ($P = .82$).

We looked at the 7 independent variables that describe a rotator cuff tear and conducted a correlation analysis on each of these factors independently to the dependent variable of sleep (PSQI), pain (VAS), function (ASES), and self-perception (SANE). These correlation (and significance) values for each rotator cuff parameter are detailed in Tables 4 to 7. No statistically significant correlations were found between any of the rotator cuff tear characteristics and sleep quality (Table 4). Similarly, only medial retraction significantly correlated with the VAS for pain score, and this positive correlation was small (Table 5). This difference, although statistically significant, was so small that it is likely of minimal clinical importance. The more meaningful data point would be the correlation of determination value, which was 0.02 (meaning that the amount of retraction only explains 2% of the multiple factors that contribute

TABLE 1
Patient Demographics and
Rotator Cuff Tear Characteristics^a

Demographic/Characteristic	Value
No. of patients	209
Age, y	64.1 ± 9.9 (38-91)
Sex, n (%)	
Female	112 (54)
Male	97 (46)
Body mass index, kg/m ²	30.2 ± 6.5 (18-57)
Involved side	
Right, n (%)	136 (65)
Left, n (%)	73 (35)
Dominant, n	133
Nondominant, n	67
Missing data, n	9
PSQI score	9.8 ± 4.8 (0-21)
VAS for pain score	5.0 ± 2.6 (0-10)
ASES score	45.7 ± 19.0 (3-93)
SCQ score	5.7 ± 4.9 (0-20)
Chronicity, n	
<1 mo	37
1-3 mo	65
4-6 mo	28
7-12 mo	24
>12 mo	55
No. of torn tendons	
1 (supraspinatus)	102
2 (supraspinatus and infraspinatus)	69
3 (supraspinatus, infraspinatus, and subscapularis)	37
4 (supraspinatus, infraspinatus, subscapularis, teres minor)	1
Retraction, mm	29.8 ± 12.2 (6.0-65.6)
Anterior-posterior dimension, mm	24.7 ± 12.1 (6.0-58.8)
Level of retraction, n	
Mild	58
Glenohumeral joint	44
Humeral head	21
Midhumeral head	66
Glenoid	20
Goutallier grade, n	
Grade 0	78
Grade 1	69
Grade 2	32
Grade 3	21
Grade 4	9
Atrophy, n	
None	65
Mild	74
Moderate	41
Severe	29
Humeral head rise, n	
No	184
Yes	25

^aData are presented as mean \pm SD (range) unless otherwise indicated. ASES, American Shoulder and Elbow Surgeons; PSQI, Pittsburgh Sleep Quality Index; SCQ, Self-Administered Comorbidity Questionnaire; VAS, visual analog scale.

to the pain score). Several rotator cuff tear characteristics, namely, number of tendons involved, medial retraction, AP

TABLE 2
Demographic Correlations to Outcome Scores^a

Demographic	PSQI		VAS		ASES	
	Correlation (<i>r</i>)	Significance (<i>P</i>)	Correlation (<i>r</i>)	Significance (<i>P</i>)	Correlation (<i>r</i>)	Significance (<i>P</i>)
Age	0.004 ^b	.95	0.06 ^b	.37	0.05 ^b	.47
Sex (male vs female)	-0.13 ^c	.06	0.12 ^c	.09	-0.01 ^c	.90
Chronicity (categorical)	0.22 ^d	.002	0.03 ^d	.66	0.03 ^d	.68
Smoker (yes vs no)	0.09 ^c	.19	0.07 ^c	.35	-0.06 ^c	.36
Side dominance	-0.01 ^c	.93	0.02 ^c	.73	-0.06 ^c	.43

^aBolded data indicate statistically significant value ($P < .05$). ASES, American Shoulder and Elbow Surgeons; PSQI, Pittsburgh Sleep Quality Index; VAS, visual analog scale.

^bPearson correlation coefficient (both variables are continuous).

^cPoint biserial correlation coefficient (one variable is dichotomous [nominal: yes or no], and the other is continuous).

^dSpearman rank-order correlation coefficient (one variable is continuous, and the other is ordinal [ranked]).

TABLE 3
Correlations Between Rotator Cuff Tear
Characteristics and Chronicity^a

Characteristic	Correlation (<i>r</i>)	Significance (<i>P</i>)
No. of torn tendons	0.04	.55
Level of retraction	0.00	.94
Atrophy	0.00	.93
Goutallier grade	0.03	.69
Humeral head rise	0.04	.53
Retraction	0.03	.68
Anterior-posterior dimension	0.13	.07

^aChronicity: <1 months, 1-3 months, 4-6 months, 7-12 months, and >12 months.

TABLE 4
Correlations Between Rotator Cuff Tear
Characteristics and PSQI Score^a

Characteristic	Correlation (<i>r</i>)	Significance (<i>P</i>)
Retraction	-0.01 ^b	.84
Anterior-posterior dimension	0.00 ^b	.99
Atrophy	0.13 ^c	.06
Goutallier grade	0.07 ^c	.29
Level of retraction	-0.04 ^c	.60
No. of torn tendons	0.01 ^c	.91
Humeral head rise	0.11 ^d	.10

^a $P < .05$. PSQI, Pittsburgh Sleep Quality Index.

^bPearson correlation coefficient (both variables are continuous).

^cSpearman rank-order correlation coefficient (one variable is continuous, and the other is ordinal [ranked]).

^dPoint biserial correlation coefficient (one variable is dichotomous [nominal: yes or no], and the other is continuous).

dimension, and presence of humeral head rise, had small but significant inverse correlations with the ASES score (Table 6). The most statistically significant correlations were found between rotator cuff characteristics and the SANE score (Table 7).

The mean SCQ score was 5.7 ± 4.9 (range could be 0-36, with 0 representing no comorbidities). The PSQI score was

TABLE 5
Correlations Between Rotator Cuff Tear
Characteristics and VAS Score^a

Characteristic	Correlation (<i>r</i>)	Significance (<i>P</i>)
Retraction	0.15 ^b	.03
Anterior-posterior dimension	0.11 ^b	.13
Atrophy	0.01 ^c	.87
Goutallier grade	0.05 ^c	.48
Level of retraction	0.04 ^c	.52
No. of torn tendons	0.13 ^c	.07
Humeral head rise	0.09 ^d	.18

^aBolded data indicate statistically significant value ($P < .05$). VAS, visual analog scale.

^bPearson correlation coefficient (both variables are continuous).

^cSpearman rank-order correlation coefficient (one variable is continuous, and the other is ordinal [ranked]).

^dPoint biserial correlation coefficient (one variable is dichotomous [nominal: yes or no], and the other is continuous).

TABLE 6
Correlations Between Rotator Cuff Tear
Characteristics and ASES Score^a

Characteristic	Correlation (<i>r</i>)	Significance (<i>P</i>)
Retraction	-0.20 ^b	.001
Anterior-posterior dimension	-0.14 ^b	.04
Atrophy	-0.03 ^c	.65
Goutallier grade	-0.10 ^c	.14
Level of retraction	-0.08 ^c	.25
No. of torn tendons	-0.18 ^c	.001
Humeral head rise	-0.20 ^d	.002

^aBolded data indicate statistically significant values ($P < .05$). ASES, American Shoulder and Elbow Surgeons.

^bPearson correlation coefficient (both variables are continuous).

^cSpearman rank-order correlation coefficient (one variable is continuous, and the other is ordinal [ranked]).

^dPoint biserial correlation coefficient (one variable is dichotomous [nominal: yes or no], and the other is continuous).

TABLE 7
Correlations Between Rotator Cuff Tear
Characteristics and SANE Score^a

Characteristic	Correlation (<i>r</i>)	Significance (<i>P</i>)
Retraction	-0.29 ^b	<.0001
Anterior-posterior dimension	-0.28 ^b	<.0001
Atrophy	-0.25 ^c	.0002
Goutallier grade	-0.24 ^c	.0001
Level of retraction	-0.08 ^c	.26
No. of torn tendons	-0.25 ^c	.0003
Humeral head rise	-0.27 ^d	<.0001

^aBolded data indicate statistically significant values ($P < .05$). SANE, Single Assessment Numeric Evaluation.

^bPearson correlation coefficient (both variables are continuous).

^cSpearman rank-order correlation coefficient (one variable is continuous, and the other is ordinal [ranked]).

^dPoint biserial correlation coefficient (one variable is dichotomous [nominal: yes or no], and the other is continuous).

TABLE 8
Correlations Between Rotator Cuff Tear
Characteristics and PSQI Score^a

Characteristic	Correlation (<i>r</i>)	Significance (<i>P</i>)
No. of torn tendons	0.02	.83
Level of retraction	0.01	.83
Atrophy	0.13	.06
Goutallier grade	0.11	.10
Humeral head rise	0.10	.24
Retraction	0.03	.68
Anterior-posterior dimension	0.03	.68

^aPittsburgh Sleep Quality Index (PSQI) score: >5 (poor sleep) and ≤5 ("normal" sleep).

significantly correlated ($P < .0001$) at 0.33 with the SCQ and ASES scores ($r = 0.15$, $P = .03$) but not with the VAS score ($r = 0.06$, $P = .36$).

Linear regression analysis using the 7 rotator cuff morphological variables (retraction, AP diameter, atrophy, Goutallier grade, retraction level, number of tendons, and humeral head rise) demonstrated multiple correlation coefficients of 0.19 for sleep quality, 0.24 for the VAS, and 0.31 for the ASES. Additionally, there was no significant relationship between rotator cuff tear characteristics and sleep quality (Table 8). The coefficient of determination was 0.04 for sleep, 0.06 for pain, and 0.09 for function. In other words, 4% of the sleep score, 6% of the pain score, and 9% of the function score can be explained by the rotator cuff tear characteristics.

DISCUSSION

The results of our study reveal no correlation between full-thickness rotator cuff tear characteristics (ie, retraction, AP tear size, number of tendons involved, muscle atrophy, Goutallier grade, retraction level, and proximal humeral

head migration) and sleep quality. While there are no previous studies with which to directly compare our results, a loose correlation existed in our pilot study, which demonstrated no significant differences in sleep disturbance or pain levels between patients with subacromial impingement and rotator cuff tears.¹⁶ On the other hand, our results do reveal a small level of correlation between the SANE score and several morphological characteristics of a tear. The patients had significantly worsened subjective function of the shoulder with larger rotator cuff tears and worsening atrophy of the rotator cuff musculature.

Additionally, all but one of the rotator cuff tear characteristics (medial retraction) had no correlation with pain levels. This difference, although statistically significant, was so small that it is likely of minimal clinical importance. The more meaningful data point would be the correlation of determination value, which was 0.02 (meaning that the amount of retraction only explains 2% of the multiple factors that contribute to the pain score).

Our findings with regard to pain are similar to previous reports.^{7,8} Dunn et al⁸ reported on a large cohort of 393 patients with atraumatic symptomatic full-thickness rotator cuff tears. In their study, no measure of rotator cuff tear severity based on MRI findings correlated with pain. Additionally, the only significant factors associated with pain were increased comorbidities, education level, and race. In a similar study, Curry et al⁷ concluded that rotator cuff tear size, fatty infiltration, and muscle atrophy were not associated with pain levels. However, poor mental health and advanced age were found to be significantly associated with pain.

Similar to pain perception, sleep disturbance associated with rotator cuff tears seems to have a significant overlap with psychiatric issues. In our pilot study, we found a moderate relationship between the presence of depression and reduced sleep quality in patients with rotator cuff tears. Cho et al⁶ similarly found a correlation between poor sleep quality and depression in patients with chronic shoulder pain. Additionally, Peters et al²⁰ examined sleep disturbance in a cohort of patients with a wide variety of upper extremity conditions. They found that sleep disturbance was more strongly associated with poor coping strategies as opposed to symptom intensity or amount of disability.

Finally, recent basic science studies have contributed to our evolving understanding of pain and sleep disturbance associated with rotator cuff tears. Ha et al¹⁰ found that melatonin levels, which fluctuate in accordance with the circadian rhythm, may play a role in increasing the inflammatory response in the shoulder at night. Terabayashi et al²⁴ demonstrated that patients with rotator cuff tears and night pain had increased blood flow in the anterior humeral circumflex artery. Clearly, sleep disturbance and pain perception associated with rotator cuff tears are complex multifactorial symptoms, which are only beginning to be understood. It is becoming increasingly clear that other factors, possibly some yet to be identified, significantly influence pain symptoms and sleep quality in patients with rotator cuff disorders.

There are some limitations to our study. While the patients were collected from a prospectively gathered

cohort, this study was a cross-sectional analysis. Additionally, only patients with shoulder MRI scans and unilateral symptoms were included in the study. Therefore, some bias was introduced by excluding all patients with full-thickness rotator cuff tears not confirmed by advanced imaging. Additional limitations of our study include only a single surgeon evaluating the MRI scans, and no collection of data on mental health. Finally, we excluded patients with partial-thickness rotator cuff tears, and although these patients also report night pain and sleep disturbance; as investigators, we felt that this was beyond the scope of our current hypothesis and a topic for future investigation.

In conclusion, the morphological characteristics of rotator cuff tears did not predict pain levels or sleep quality in this study. Conversely, rotator cuff tear size and morphology did seem to inversely correlate with self-reported function and “normality” of the shoulder. Clinicians should develop intervention plans to address pain and sleep deprivation and possibly give less consideration regarding the size or nature/characteristics of a rotator cuff tear. Given these findings, it may be of more importance to place a greater emphasis on the patient’s concern regarding his or her level of function when determining which patients should be treated conservatively versus surgically.

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