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Association of Preoperative Shoulder Osteoarthritis Severity Score With Change in American Shoulder and Elbow Surgeons Score at 2 Years After Rotator Cuff Repair

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Background: The impact of early glenohumeral osteoarthritis (GHOA) on clinical outcomes after rotator cuff repair (RCR) remains unclear. The magnetic resonance imaging (MRI)-based Shoulder Osteoarthritis Severity (SOAS) score is a comprehensive approach to quantifying glenohumeral degeneration.

Purpose: To investigate the association between SOAS scores and changes in American Shoulder and Elbow Surgeons (ASES) scores in patients who underwent RCR.

Study Design: Cohort study; Level of evidence, 3.

Methods: Two reviewers independently analyzed the preoperative MRI scans of 116 shoulders and assigned SOAS scores. Spearman correlation was used to calculate the association of mean SOAS scores with patient demographic characteristics and change in ASES scores over the 2-year follow-up period (Δ ASES). Multivariate regression analysis was performed between the independent variables of patient age, sex, body mass index, and significant SOAS score components as determined by univariate analysis, with the dependent variable being Δ ASES. Significance was defined as $P < .05$ for univariate analysis and $P < .0125$ after application of the Bonferroni correction for multivariate analysis.

Results: The mean ASES scores were 55.8 ± 18.6 preoperatively and 92.1 ± 12.1 at 2 years postoperatively. The mean preoperative SOAS score was 15.2 ± 7.1 . On univariate analysis, the total SOAS score was positively correlated with patient age ($r_s = 0.41$; $P < .001$), whereas Δ ASES was negatively correlated with patient age ($r_s = -0.27$; $P = .0032$). Increasing SOAS subscores for supraspinatus/infraspinatus tear size ($r_s = -0.28$; $P = .024$), tendon retraction ($r_s = -0.23$; $P = .015$), muscle atrophy ($r_s = -0.20$; $P = .034$), paralabral ganglia ($r_s = -0.23$; $P = .015$), and cartilage degeneration ($r_s = -0.21$; $P = .024$) were negatively correlated with Δ ASES. A negative correlation was found between increasing total SOAS score and Δ ASES ($r_s = -0.22$; $P = .016$). On multivariate analysis, increasing supraspinatus/infraspinatus tear size was significantly and negatively correlated with Δ ASES ($\beta = -3.3$; $P = .010$).

Conclusion: Increasing the total SOAS score was predictive of less improvement in ASES scores at 2 years postoperatively. On univariate analysis, SOAS subscores with the strongest negative correlations with Δ ASES scores included tear size, muscle atrophy, tendon retraction, paralabral ganglia, and cartilage wear. On multivariate analysis, only tear size was significantly associated with a lower change in the ASES score.

Keywords: SOAS score; ASES score; rotator cuff; shoulder arthritis

repairs (RCRs) performed in the United States has increased as the population ages alongside advancements in arthroscopic surgical technique and diagnostic imaging.^{18,33} As more patients undergo RCR, studies have sought to identify factors associated with poor outcomes after surgery. It has been shown that worse patient-reported outcomes after RCR are associated with older age,^{15,31} increased body mass index (BMI),^{10,35} female sex,^{1,10} smoking,^{2,3} increased tear size,⁴ fatty infiltration,¹¹ and any concomitant biceps tendon or acromial joint procedures.¹⁴

Glenohumeral osteoarthritis (GHOA) may coexist with rotator cuff tears in as many as 28% of patients, with a greater prevalence of OA in older patients and patients with larger tear sizes.^{23,27} However, the effects of GHOA on RCR postoperative outcomes have been controversial. Although some studies have shown moderate association between GHOA and rates of rotator cuff retear,²¹ others have found no significant differences between patients with or without GHOA in rates of retear, range of motion, and patient-reported outcomes.^{19,28} Kim et al²¹ found that although there were no differences in postoperative outcomes between patients with and without GHOA and small to medium rotator cuff tears, GHOA was associated with significantly decreased range of motion and worse patient-reported outcome scores in patients with large to massive rotator cuff tears.

GHOA is evaluated radiographically in most studies by classifications such as the Samilson and Prieto, Walch, Guyette, and Kellgren and Lawrence systems. These classification systems are widely used due to their excellent interobserver and intraobserver reliabilities. However, these radiographic systems characterize GHOA by hallmarks of more advanced disease such as joint space narrowing, osteophyte size, humeral head subluxation, and sclerosis; thus, they pose a challenge for the identification of early arthritis.²⁹ Magnetic resonance imaging (MRI)-based scoring systems such as the Shoulder Osteoarthritis Severity (SOAS) score therefore represent potential alternatives in identifying and characterizing changes to soft tissue and inflammation associated with GHOA. The SOAS score ranges from 0 to 100, with 100 representing more severe pathology; there are 20 subscores of individual structures measuring severity of arthritic degeneration in 6 areas: rotator cuff, labral-bicipital complex, cartilage, osseous findings, joint capsule, and acromion.²⁰ This semi-quantitative whole-joint system has been shown to

correlate strongly with established radiographic scoring systems and have excellent intra- and interobserver agreement.²⁰ Recently, increasing SOAS scores were found to predict lower postoperative PROMIS-UE (Patient-Reported Outcomes Measurement Information System—Upper Extremity) scores in patients undergoing RCR.⁵

The purpose of this study was to use the American Shoulder and Elbow Surgeons (ASES) score to investigate the association between the degree of preoperative GHOA assessed by SOAS scores and changes in patient-reported outcomes among patients who underwent RCR. Because RCR is a joint-preserving procedure, we hypothesized that patients with more severe joint degeneration and higher SOAS scores before RCR would experience a smaller increase in ASES scores after surgery compared with patients who had lower preoperative SOAS scores.

METHODS

Study Design and Participants

This was a retrospective cohort study from a prospectively collected database of patients who underwent arthroscopic RCR between 2018 and 2020. All patients were evaluated using the ASES score preoperatively and at 3 months, 1 year, and 2 years postoperatively. We included patients who underwent arthroscopic RCR with a preoperative MRI scan and at least 24 months of follow-up ($n = 124$). Patients with an MRI scan that was insufficient to calculate the SOAS score were excluded ($n = 7$), leading to a total of 116 shoulders from 116 patients that were included. This study was deemed exempt from institutional review board approval.

Study Variables

Demographic characteristics of study participants (age, sex, and body mass index [BMI]) were recorded as well as preoperative ASES scores and ASES scores at 2 years postoperatively. MRI scans were scored by 2 independent reviewers (D.M., M.R.D.) using the SOAS criteria as described by Jungmann et al.²⁰ The structures of the rotator cuff, labral-bicipital complex, cartilage, joint capsule, acromion, and osseous findings were individually scored to make up the overall total SOAS score (range, 0-100; higher scores indicate more severe degenerative changes).

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Ethical approval for this study was waived by the University of California San Francisco (ref No. 281634).

TABLE 1
Characteristics of the Study Patients (N = 116)^a

Characteristic	Value
Age, y	60.2 ± 10.3 (36-79)
Sex, n	
Male	72
Female	44
Body mass index, kg/m ²	27.3 ± 4.8 (18.8-39.6)
ASES score	
Preoperative	55.8 ± 18.6 (16.7-93.3)
2-year follow-up	92.1 ± 12.1 (31.7-100)

^aData are presented as mean ± SD (range) unless otherwise indicated. ASES, American Shoulder and Elbow Surgeons.

The interobserver reliability between the reviewers was calculated for total SOAS score as well as for each subscore.

Statistical Analysis

Descriptive statistics including mean and standard deviation were calculated. Interobserver reliability of SOAS scoring was calculated using the intraclass correlation

coefficient (ICC). The Spearman correlation was used to evaluate the association of mean SOAS scores (total score as well as each constituent subscore) with patient characteristics and change in ASES scores over the 2-year follow-up period (Δ ASES scores). Multivariate regression analysis was performed between the independent variables of patient age, sex, BMI, and significant SOAS score components as determined by univariate analysis, with the dependent variable being Δ ASES scores.

All statistical analysis was performed with Stata (Version 16.1; StataCorp). Significance was defined as $P < .05$ for univariate analysis and $P < .0125$ for multivariate analysis ($m = 4$) using the Bonferroni correction.

RESULTS

The study included 72 men and 44 women, with an overall mean age of 60.2 ± 10.3 years. The mean BMI of study patients was 27.3 ± 4.8 kg/m². The mean preoperative ASES score was 55.8 ± 18.6, whereas scores at 2 years postoperatively were 92.1 ± 12.1 (Table 1). All patients had at least 24 months of follow-up. The mean preoperative SOAS score was 15.2 ± 7.1 (Table 2). The ICC for total SOAS score was 0.87 (Table 2).

TABLE 2
Total SOAS Scores, Subscores, and ICC Values^a

SOAS Score Parameter	Score Range	Score, Mean ± SD	ICC ^b
Total SOAS score	0-100	15.23 ± 7.14	0.87
Rotator cuff		7.44 ± 4.37	
Supraspinatus/infraspinatus tear size	0-6	2.75 ± 1.38	0.84
Subscapularis tear size	0-5	1.83 ± 1.02	0.89
Retraction	0-3	0.94 ± 1.0	0.89
Fatty infiltration	0-4	1.48 ± 1.43	0.99
Atrophy	0-3	0.43 ± 0.89	0.97
Labral-bicipital complex		1.97 ± 1.29	
Labrum	0-2	0.91 ± 0.69	0.83
Long head of biceps	0-3	0.98 ± 0.85	0.98
Paralabral ganglia	0-3	0.026 ± 0.17	0.16
Glenohumeral ligaments	0-2	0.056 ± 0.22	0.0
Cartilage		1.22 ± 1.76	
Glenohumeral articular cartilage	0-6	1.22 ± 1.76	0.94
Osseous findings		1.60 ± 1.42	
Bone marrow edema	0-3	0.98 ± 0.96	0.68
Subchondral cysts	0-3	0.39 ± 0.70	0.92
Osteophytes	0-3	0.21 ± 0.41	0.37
Bone deformity	0-3	0.017 ± 0.11	0.0
Joint capsule		1.09 ± 1.03	
Synovitis	0-2	0.60 ± 0.63	0.79
Joint effusion	0-3	0.46 ± 0.57	0.54
Loose bodies	0-2	0.026 ± 0.15	0.24
Acromion		1.93 ± 0.91	
Subacromial bursitis	0-3	0.53 ± 0.42	0.085
Acromioclavicular joint degeneration	0-3	1.40 ± 0.75	0.89
Acromion deformity	0-2	0 ± 0	—

^aICC, intraclass correlation coefficient; SOAS, Shoulder Osteoarthritis Severity.

^b $P < .05$ for all ICC values.

TABLE 3
Summary of Correlations^a

Comparison	r_S	P
Patient characteristics		
Age vs total SOAS	0.41	<.001
Age vs Δ ASES	-0.27	.0032
Sex vs total SOAS	-0.059	.53
Sex vs Δ ASES	0.0082	.93
BMI vs total SOAS	0.13	.18
BMI vs Δ ASES	0.094	.32
Total SOAS score vs Δ ASES	-0.22	.016
Rotator cuff		
Supraspinatus/infraspinatus tear size vs Δ ASES	-0.28	.0024
Subscapularis tear size vs Δ ASES	-0.021	.82
Retraction vs Δ ASES	-0.23	.015
Fatty infiltration vs Δ ASES	-0.084	.37
Atrophy vs Δ ASES	-0.20	.034
Labral-bicipital complex		
Labrum vs Δ ASES	-0.17	.075
Long head of the biceps vs Δ ASES	-0.17	.068
Paralabral ganglia vs Δ ASES	-0.23	.015
Glenohumeral ligaments vs Δ ASES	0.085	.37
Cartilage		
Cartilage vs Δ ASES	-0.21	.024
Osseous findings		
Bone marrow edema vs Δ ASES	-0.078	.41
Joint capsule		
Joint effusion vs Δ ASES	0.015	.87
Loose bodies vs Δ ASES	-0.030	.75
Acromion		
Subacromial bursitis vs Δ ASES	-0.028	.76
Acromioclavicular joint degeneration vs Δ ASES	-0.0064	.95

^aBoldface P values indicate statistical significance ($P < .05$). Δ ASES, American Shoulder Elbow Surgeons score 2-year follow-up period; BMI, body mass index; SOAS, Shoulder Osteoarthritis Severity score.

Correlation analysis indicated that total SOAS score was positively correlated with patient age ($r_S = 0.41$; $P < .001$), whereas Δ ASES was negatively correlated with patient age ($r_S = -0.27$; $P = .0032$). A negative correlation was found between increasing preoperative SOAS score and Δ ASES ($r_S = -0.22$; $P = .015$) (Table 3). Increasing supraspinatus/infraspinatus tear size, tendon retraction, muscle atrophy, paralabral ganglia, and cartilage degeneration were all negatively correlated with Δ ASES (Table 3).

In the multivariate linear regression analysis of significant SOAS variables with patient characteristics to predict Δ ASES, only increasing supraspinatus/infraspinatus tear size was found to be significantly negatively correlated with Δ ASES ($\beta = -3.3$; $P = .010$) (Table 4).

DISCUSSION

The results of this study in patients who underwent RCR indicated that higher preoperative SOAS scores were negatively correlated with change in ASES scores at 2 years

TABLE 4
Multivariate Regression of SOAS Variables to Predict Δ ASES^a

	β	SE	P
Univariate			
Age	-0.31	0.18	.088
Sex ^b	-0.83	3.54	.82
BMI	0.42	0.36	.25
Total SOAS	-0.40	0.26	.13
Multivariate			
Age	-0.36	0.17	.031
Sex ^b	-2.23	3.52	.53
BMI	0.45	0.35	.21
Supraspinatus/infraspinatus tear size	-3.30	1.25	.010
Tendon retraction			
Age	-0.35	0.17	.042
Sex ^b	-1.99	3.54	.58
BMI	0.50	0.36	.17
Tendon retraction	-4.08	1.78	.024
Paralabral ganglia			
Age	-0.31	0.18	.077
Sex ^b	-0.63	3.52	.86
BMI	0.43	0.36	.24
Atrophy	-3.99	2.01	.050
Cartilage			
Age	-0.39	0.17	.021
Sex ^b	-0.27	3.51	.94
BMI	0.20	0.36	.59
Paralabral ganglia	-21.52	10.11	.036
Cartilage			
Age	-0.39	0.18	.033
Sex ^b	-0.47	3.59	.90
BMI	0.33	0.36	.36
Cartilage	-0.60	1.05	.57

^aBoldface P value indicates statistical significance ($P < .0125$ after Bonferroni correction for multiple comparisons). Δ ASES, American Shoulder Elbow Surgeons score 2-year follow-up period; BMI, body mass index; SOAS, Shoulder Osteoarthritis Severity score.

^bFemale = 0; male = 1.

after surgery. The SOAS subscores with the strongest negative correlations with Δ ASES in univariate analysis were tear size, muscle atrophy, tendon retraction, paralabral ganglia, and cartilage wear. In a multivariate analysis with patient demographic characteristics, only supraspinatus/infraspinatus tear size maintained a significant negative correlation with change in ASES scores. These findings support the hypothesis that more severe preoperative degeneration of the shoulder joint is associated with lower patient-reported outcome scores after RCR.

Many other studies have demonstrated that the quality of muscle is an integral factor in predicting outcomes after RCR.^{12,13,24} We found that atrophy of the rotator cuff as well as degree of tendon retraction and tear size were both negatively associated with lower Δ ASES after RCR. However, preoperative fatty infiltration on MRI scan was not negatively correlated with Δ ASES on multivariate regression in this particular cohort. Fatty infiltration is a degenerative process that occurs in conjunction with other chronic changes of the rotator cuff after tear.^{12,25} In this study, the mean score for fatty infiltration was

1.48, indicating a low overall level of fatty infiltration in this cohort of patients. It is possible, therefore, that factors such as tear size, retraction, and muscle atrophy may be poor prognostic signs for RCR that present earlier in patients compared with fatty infiltration and may be more relevant in patients who are clearly indicated for a joint-preserving procedure such as RCR.

Interestingly, degeneration of the cartilage demonstrated significant negative correlation with change in ASES scores after RCR. Tears of the rotator cuff can lead to destabilization of the glenohumeral joint and subsequent degeneration of the cartilage and cuff tear arthropathy, especially in larger and chronic cuff tears.^{8,17,26} However, the effects of cartilage degeneration on patient-reported outcomes have been conflicting. In a prospective study with 33 patients, Klinger et al²² found that preoperative arthrosis before arthroscopic debridement of rotator cuff tears was prognostic of poor outcomes. A previous study with 45 patients found no significant differences in outcomes between patients who underwent RCR with and without cartilage degeneration.²⁰ Notably, these studies used arthroscopic and radiographic methods to classify cartilage degeneration. Use of MRI to evaluate osteoarthritis via the SOAS classification may offer an improved method for assessing degenerative changes of cartilage as well as other bony and soft tissue changes that commonly occur in osteoarthritis compared with radiography and arthroscopy and may help guide clinical decisions and post-operative expectations after RCR in patients with damaged cartilage.

Prior work has demonstrated that more severe preoperative GHOA as classified by the SOAS system is associated with functional improvement after total shoulder arthroplasty.⁶ In contrast, the current study found that worse preoperative GHOA as quantified by MRI was associated with poorer patient-reported outcomes after a joint-sparing procedure. Reverse total shoulder arthroscopy is indicated in patients with rotator cuff arthropathy as well as patients with pseudoparalysis.⁷ Arthroplasty is rarely a first-line treatment option given the higher risk of complications and increased costs relative to nonoperative management and joint-sparing procedures^{9,30,32}; however, when to perform a joint-sparing procedure versus a joint replacement in a patient with mild to moderate GHOA remains under debate. Radiographic classifications such as the Hamada classification continue to help inform these clinical decisions¹⁶; however, it may be possible to leverage the subtler findings on MRI to identify which patients would be better served with a joint replacement versus a joint-sparing procedure.

Although the SOAS score considers the different joint structures and periarticular structures, it is worth noting that rotator cuff characteristics make up one-third of the total score, and the rotator cuff subscores contributed largely to the overall SOAS scores of the patients included in this study with known rotator cuff pathology. Although cartilage degeneration was associated with decreased change in ASES score on univariate analysis, we found no correlation on multivariate analysis between change in ASES score and cartilage findings. Osseous findings

and acromion structures similarly were not associated with change in ASES score on multivariate analysis. Therefore, although this study demonstrates a correlation between total SOAS score and change in ASES score 2 years after RCR, a direct correlation between change in ASES score and GHOA may be less clear.

The complete clinical picture including patient age, muscle quality, and joint degeneration should be considered when discussing treatment options, and use of MRI-based tools such as the SOAS score may prove useful in guiding these clinical decisions.


Limitations

This study has several limitations. Although the interobserver reliability for total SOAS score (ICC = 0.87) demonstrated good agreement, the ICCs for several subscores demonstrated low reliability. It is likely that this was due to certain parameters of the SOAS score, such as bony deformity of the humerus or glenoid, being exceedingly rare findings in this cohort of patients. Additionally, the strength of the correlations between SOAS score components and Δ ASES scores was most frequently in the weak to moderate range. This may reflect the fact that the overall magnitude of joint pathology in this cohort of patients indicated for a joint-sparing surgery was low; on the SOAS scale from 0 to 100, the mean score for patients was 15.2. The utility of the SOAS score in predicting outcomes for patients with more severe osteoarthritis is uncertain, and future studies should focus on patients with more significant degenerative changes for which indications for joint-sparing versus joint-replacing procedures are less clear. Finally, the application of the Bonferroni correction to the multivariate analysis increases the risk of a type 2 error, which may limit the conclusions drawn from that analysis.

CONCLUSION

In this prospective cohort of patients undergoing RCR, increasing preoperative total SOAS score was predictive of less improvement in ASES scores at 2 years after surgery. On univariate analysis, SOAS subscores with the strongest negative correlations with Δ ASES scores included tear size, muscle atrophy, tendon retraction, paralabral ganglia, and cartilage wear. Tear size alone was found to be significantly associated with a lower Δ ASES in multivariate linear regression analysis.

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REFERENCES

1. Abate M, Schiavone C, Di Carlo L, Salini V. Prevalence of and risk factors for asymptomatic rotator cuff tears in postmenopausal women. *Menopause*. 2014;21(3):275-280. doi:10.1097/GME.0b013e31829638e3

2. Bishop JY, Santiago-Torres JE, Rimmke N, Flanigan DC. Smoking predisposes to rotator cuff pathology and shoulder dysfunction: a systematic review. *Arthroscopy*. 2015;31(8):1598-1605. doi:10.1016/j.arthro.2015.01.026
3. Carbone S, Gumina S, Arceri V, Campagna V, Fagnani C, Postacchini F. The impact of preoperative smoking habit on rotator cuff tear: cigarette smoking influences rotator cuff tear sizes. *J Shoulder Elbow Surg*. 2012;21(1):56-60. doi:10.1016/j.jse.2011.01.039
4. Chalmers PN, Granger E, Nelson R, Yoo M, Tashjian RZ. Factors affecting cost, outcomes, and tendon healing after arthroscopic rotator cuff repair. *Arthroscopy*. 2018;34(5):1393-1400. doi:10.1016/j.arthro.2017.11.015
5. Davies MR, Kucirek N, Motamedi D, Ma CB, Feeley BT, Lansdown D. Relationship between preoperative shoulder osteoarthritis severity score and postoperative PROMIS-UE score after rotator cuff repair. *Orthop J Sports Med*. 2023;11(1):23259671221143801. doi:10.1177/23259671221143801
6. Davies MR, Tang A, Motamedi D, Ma CB, Feeley BT, Lansdown D. MRI-based shoulder osteoarthritis severity score (SOAS) is predictive of functional improvement following total shoulder arthroplasty. *Semin Arthroplasty*. 2022;32(1):74-81. doi:10.1053/j.sart.2021.06.007
7. Drake GN, O'Connor DP, Edwards TB. Indications for reverse total shoulder arthroplasty in rotator cuff disease. *Clin Orthop Relat Res*. 2010;468(6):1526-1533. doi:10.1007/s11999-009-1188-9
8. Feeley BT, Gallo RA, Craig EV. Cuff tear arthropathy: current trends in diagnosis and surgical management. *J Shoulder Elbow Surg*. 2009;18(3):484-494. doi:10.1016/j.jse.2008.11.003
9. Frankle M, Levy JC, Pupello D, et al. The reverse shoulder prosthesis for glenohumeral arthritis associated with severe rotator cuff deficiency. a minimum two-year follow-up study of sixty patients surgical technique. *J Bone Joint Surg Am*. 2006;88(suppl 1, pt 2):178-190. doi:10.2106/JBJS.F.00123
10. Gilat R, Haunschild ED, Williams BT, et al. Patient factors associated with clinical failure following arthroscopic superior capsular reconstruction. *Arthroscopy*. 2021;37(2):460-467. doi:10.1016/j.arthro.2020.09.038
11. Gladstone JN, Bishop JY, Lo IKY, Flatow EL. Fatty infiltration and atrophy of the rotator cuff do not improve after rotator cuff repair and correlate with poor functional outcome. *Am J Sports Med*. 2007;35(5):719-728. doi:10.1177/0363546506297539
12. Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures: pre- and postoperative evaluation by CT scan. *Clin Orthop Relat Res*. 1994;304:78.
13. Goutallier D, Postel JM, Gleyze P, Leguilloux P, Van Driessche S. Influence of cuff muscle fatty degeneration on anatomic and functional outcomes after simple suture of full-thickness tears. *J Shoulder Elbow Surg*. 2003;12(6):550-554. doi:10.1016/s1058-2746(03)00211-8
14. Gulotta LV, Nho SJ, Dodson CC, et al. Prospective evaluation of arthroscopic rotator cuff repairs at 5 years, part II: prognostic factors for clinical and radiographic outcomes. *J Shoulder Elbow Surg*. 2011;20(6):941-946. doi:10.1016/j.jse.2011.03.028
15. Gumina S, Carbone S, Campagna V, Candela V, Sacchetti FM, Gianicola G. The impact of aging on rotator cuff tear size. *Musculoskeletal Surg*. 2013;97(suppl 1):69-72. doi:10.1007/s12306-013-0263-2
16. Hamada K, Yamanaka K, Uchiyama Y, Mikasa T, Mikasa M. A radiographic classification of massive rotator cuff tear arthritis. *Clin Orthop Relat Res*. 2011;469(9):2452-2460. doi:10.1007/s11999-011-1896-9
17. Herve A, Thomazeau H, Favard L, et al. Clinical and radiological outcomes of osteoarthritis twenty years after rotator cuff repair. *Orthop Traumatol Surg Res*. 2019;105(5):813-818. doi:10.1016/j.otsr.2019.02.013
18. Jain NB, Higgins LD, Losina E, Collins J, Blazar PE, Katz JN. Epidemiology of musculoskeletal upper extremity ambulatory surgery in the United States. *BMC Musculoskelet Disord*. 2014;15:4. doi:10.1186/1471-2474-15-4
19. Jeong HY, Jeon YS, Lee DK, Rhee YG. Rotator cuff tear with early osteoarthritis: how does it affect clinical outcome after large to massive rotator cuff repair? *J Shoulder Elbow Surg*. 2019;28(2):237-243. doi:10.1016/j.jse.2018.07.022
20. Jungmann PM, Gersing AS, Woertler K, et al. Reliable semiquantitative whole-joint MRI score for the shoulder joint: the shoulder osteoarthritis severity (SOAS) score. *J Magn Reson Imaging*. 2019;49(7):e152-e163. doi:10.1002/jmri.26251
21. Kim DH, Min SG, Lee HS, et al. Clinical outcome of rotator cuff repair in patients with mild to moderate glenohumeral osteoarthritis. *Knee Surg Sports Traumatol Arthrosc*. 2021;29(3):998-1005. doi:10.1007/s00167-020-06307-8
22. Klinger HM, Steckel H, Ernstberger T, Baums MH. Arthroscopic debridement of massive rotator cuff tears: negative prognostic factors. *Arch Orthop Trauma Surg*. 2005;125(4):261-266. doi:10.1007/s00402-004-0738-6
23. Kukkonen J, Äärilä V, Joukainen A, Lehtinen J. The effect of glenohumeral osteoarthritis on the outcome of isolated operatively treated supraspinatus tears. *J Orthop Sci*. 2013;18(3):405-409. doi:10.1007/s00776-013-0369-2
24. Kuptniratsaikul V, Laohathaimongkol T, Umprai V, Yeekian C, Prasathaporn N. Pre-operative factors correlated with arthroscopic reparability of large-to-massive rotator cuff tears. *BMC Musculoskelet Disord*. 2019;20(1):111. doi:10.1186/s12891-019-2485-4
25. Meyer DC, Farshad M, Amacker NA, Gerber C, Wieser K. Quantitative analysis of muscle and tendon retraction in chronic rotator cuff tears. *Am J Sports Med*. 2012;40(3):606-610. doi:10.1177/0363546511429778
26. Neer CS, Craig EV, Fukuda H. Cuff-tear arthropathy. *J Bone Joint Surg Am*. 1983;65(9):1232-1244.
27. Oh JH, Chung SW, Oh CH, et al. The prevalence of shoulder osteoarthritis in the elderly Korean population: association with risk factors and function. *J Shoulder Elbow Surg*. 2011;20(5):756-763. doi:10.1016/j.jse.2011.01.021
28. Reddy RP, Solomon DA, Hughes JD, Lesniak BP, Lin A. Clinical outcomes of rotator cuff repair in patients with concomitant glenohumeral osteoarthritis. *J Shoulder Elbow Surg*. 2022;31(6S):S25-S33. doi:10.1016/j.jse.2021.11.010
29. Schumaier A, Abboud J, Grawe B, et al. Evaluating glenohumeral osteoarthritis: the relative impact of patient age, activity level, symptoms, and Kellgren-Lawrence grade on treatment. *Arch Bone Jt Surg*. 2019;7(2):151-160.
30. Sirveaux F, Favard L, Oudet D, Huquet D, Walch G, Molé D. Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive rupture of the cuff: results of a multicentre study of 80 shoulders. *J Bone Joint Surg Br*. 2004;86(3):388-395. doi:10.1302/0301-620x.86b3.14024
31. Tempelhof S, Rupp S, Seil R. Age-related prevalence of rotator cuff tears in asymptomatic shoulders. *J Shoulder Elbow Surg*. 1999;8(4):296-299. doi:10.1016/s1058-2746(99)90148-9
32. Thomas M, Bidwai A, Rangan A, et al. Glenohumeral osteoarthritis. *Shoulder Elbow*. 2016;8(3):203-214. doi:10.1177/1758573216644183
33. Yanik EL, Chamberlain AM, Keener JD. Trends in rotator cuff repair rates and comorbidity burden among commercially insured patients younger than the age of 65 years, United States 2007-2016. *JSES Rev Rep Tech*. 2021;1(4):309-316. doi:10.1016/j.xrtr.2021.06.009
34. Yelin E, Weinstein S, King T. The burden of musculoskeletal diseases in the United States. *Semin Arthritis Rheum*. 2016;46(3):259-260. doi:10.1016/j.semarthrit.2016.07.013
35. Zhao J, Luo M, Liang G, et al. What factors are associated with symptomatic rotator cuff tears: a meta-analysis. *Clin Orthop Relat Res*. 2022;480(1):96-105. doi:10.1097/CORR.0000000000001949