Original Article

Patient-Determined Outcomes After Arthroscopic Margin Convergence Rotator Cuff Repair

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Purpose: To determine whether patients who require margin convergence would have equivalent postsurgical patient-determined scores compared with patients with standard rotator cuff repair. The secondary purpose of this study was to determine whether the short-term results found for patients with margin convergence repairs would be durable through medium-term follow-up. **Methods:** A retrospective analysis of patients undergoing arthroscopic rotator cuff repair was performed to examine the effects of marginal convergence on patient-determined outcomes (Western Ontario Rotator Cuff Index, American Shoulder and Elbow Surgeons score, Simple Shoulder Test, Single Assessment Numeric Evaluation, and Shoulder Activity Level). Patient-determined outcomes in patients who had margin convergence repairs were compared with patients who had standard rotator cuff repair. Prospective follow-up of patients that had margin convergence repairs was performed to determine whether patient-determined outcomes deteriorated over time. **Results:** Two-hundred-seventy-two patients had standard rotator cuff repairs and 9 patients had margin convergence rotator cuff repair (3.2%). All patients had significant improvements in their Western Ontario Rotator Cuff Index, American Shoulder and Elbow Surgeons score, Simple Shoulder Test, and Single Assessment Numeric Evaluation. Patients requiring margin convergence rotator cuff repair had similar preoperative and postoperative scores compared with patients with a standard rotator cuff repair. At a mean follow-up of 7.5 years, there was no change in outcome scores compared with the early follow-up time point (mean 3.3 years) for patients undergoing margin convergence. **Conclusions:** Arthroscopic margin convergence repair techniques along with the treatment of concomitant pathologies result in similar patient-determined outcomes compared with standard rotator cuff repair techniques. These results appear to be durable and do not deteriorate from short-term to medium-term follow-up. **Level of evidence:** III: Retrospective comparative study

Arthroscopic rotator cuff repair has become a commonly performed procedure. Most rotator cuff tears are transverse or crescent-shaped and often can be repaired directly to bone.[1] U-shaped and L-shaped tears may be difficult to reduce directly to the greater tuberosity with medial-to-lateral translation. If the surgeon is capable of reducing and fixing these types of tears to the greater tuberosity, they are often under tension and may be at risk for failure to heal. In 1992, Dr Burkhart initiated a technique called margin convergence to treat these U- and L-shaped rotator cuff tear patterns.[2] The principle of margin convergence rotator cuff repair is achieved by side-to-side suturing of the cuff tear in the anterior—posterior direction to converge the free margin of the cuff toward its bone bed.[3] In 1995, suture anchors were first used to repair the tendon to bone once margin convergence was completed, and this technique was published in 1996.[2,4] Margin convergence creates a lateral shift of the free margin of the tendon edge toward the greater tuberosity (converting a U-shaped tear into a crescent shaped tear), resulting in a decrease in both the gap size of the rotator cuff tear and the strain across the repair site, making it easier to successfully anchor the tendon edge to bone (Fig 1).[3,5-7]

Although this technique was developed and reported more than 20 years ago, there are minimal clinical data that demonstrate the efficacy of margin convergence on improving patient-determined outcomes when used for arthroscopic rotator cuff repair.[2,8] Thus, there is little to guide the clinician in how to counsel patients who require

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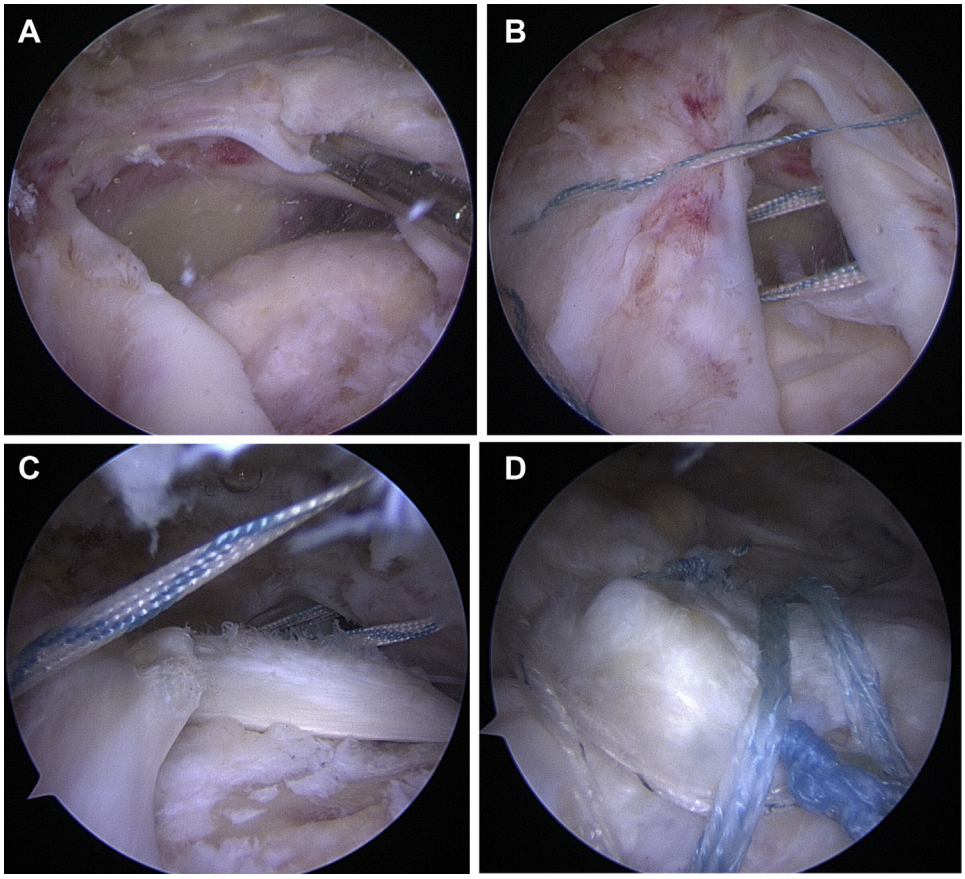

Fig 1. (A) Arthroscopic image of a right shoulder with a large U-shaped tear with minimal medial to lateral excursion. (B) U-shaped tear with 2 anterior-to-posterior margin convergence sutures before arthroscopic knot tying. (C) Conversion of the U-shaped tear pattern to a crescent-shape tear pattern with arthroscopic tying of the margin convergence sutures. (D) Final tendon-to-bone repair.

margin convergence rotator cuff repair as what to expect after surgery both in the short and long term. The aim of this study was to determine whether patients who required margin convergence repairs had similar success rates compared with patients who had standard rotator cuff repair techniques. The primary purpose of this study was to determine whether patients who require margin convergence would have equivalent postsurgical patient-determined scores compared with patients with standard rotator cuff repair. The secondary purpose of this study was to determine whether the short-term results found for patients with margin convergence repairs would be durable through medium-term follow-up.

The primary hypothesis of this study was that patients who require margin convergence would have equivalent postsurgical patient-determined outcome scores compared with patients without margin convergence. The secondary hypothesis was that the short-term results found for patients with margin convergence repairs would be durable through medium-term follow-up.

Methods

Prospective collection of preoperative patient-determined outcomes scores on patients undergoing arthroscopic rotator cuff repair by a single surgeon was begun in December 2008. Quality-of-life outcome scores that were collected include the Western Ontario Rotator Cuff Index (WORC)[9-11] (a disease-specific outcome score that has been recommended for assessing the results of rotator cuff repair treatment[12]), the American Shoulder and Elbow Surgeons (ASES) score,[13-15] the Simple Shoulder Test (SST),[15,16] (joint-specific outcome scores), and the Single Assessment Numeric Evaluation (SANE)[17,18] (a general health measure). In addition, the Shoulder Activity Level was the primary activity level score outcome examined in this study since it is a validated, patient-determined outcome score that can be used to measure a patient's activity level.[19-21]

Patients who underwent primary arthroscopic rotator cuff repair with a concomitant subacromial decompression and had completed preoperative patient outcome forms had the potential for inclusion in this study. Patients who underwent concomitant acromioclavicular joint resection, biceps tenodesis, and/or labral repair were included to increase the generalizability of the study since they are often performed clinically along with rotator cuff repairs. Exclusion criteria were patients with radiographically apparent osteoarthritis, patients with less than 2 years' follow-up, patients undergoing revision rotator cuff repair, patients with rotator cuff

arthropathy or irreparable rotator cuff tears, patients who were deceased before postoperative outcomes measures could be obtained, non—English-speaking patients, and patients with concomitant cervical radiculopathy, adhesive capsulitis, proximal humerus fracture, or a diagnosis of inflammatory arthritis.

In 2014, institutional review board approval was obtained (University of South Dakota 2014:115 and 2019:039.), and patients were mailed the identical outcomes measures that were taken preoperatively by U.S. mail to determine the effect of arthroscopic rotator cuff repair on their scores 2 to 6 years after surgery. To examine hypothesis #1, patients who had margin convergence rotator cuff repair techniques were identified and compared with patients that did not require margin convergence. To answer hypothesis #2, in 2019, patients who had margin convergence repairs were mailed the identical patient outcome forms by U.S. mail to determine whether their postsurgical outcomes remained durable from the initial short-term follow-up period or if there was deterioration of their scores.

To determine clinically meaningful improvements from arthroscopic rotator cuff repair, the percentage of shoulders that had improvements equal to or greater than the minimal clinically important difference (MCID) of the WORC, the ASES score, and the SANE was reported.[12,18,22,23] These studies suggested the MCID of the WORC was 11.7%, the SANE was 15%, and the MCID of the ASES ranged from 6.4 to 17.

Statistical analysis was performed using Microsoft Excel 2010 (Microsoft, Inc., Redmond, WA) and an open-source statistical calculator.[24] A paired samples *t* test was conducted, on pre- and post-test scores to determine statistically significant improvements in quality of life scales and the Shoulder Activity Level. χ^2 testing was used to analyze discrete variables. The level of significance was determined to be .05. To try to accommodate the biases of small sample sizes (margin convergence group) on the findings and conclusions of this study, 95% confidence intervals were calculated.[25] To further examine the clinical significance of the findings, effect sizes (Cohens d) were determined.[26] Small effect sizes were defined as $0.2 \leq d < 0.5$, medium effect sizes were defined as $0.5 \leq d < 0.8$, and large effect sizes were defined as $d \geq 0.8$.[27]

Results

From January 1, 2008, to December 31, 2012, the author (K.M.B.) identified 307 shoulders that met the inclusion criteria. Twenty-seven shoulders (8.8%) were lost to follow-up and were unable to provide postoperative patient-determined outcome scores. None of the patients who were lost to follow-up underwent margin convergence repair. Therefore, 281 shoulders were included from 273 patients who completed their postoperative patient-determined outcome scores at a mean follow-up of 3.7 years after surgery (range 2.01-7.47 years). Of the 281 shoulders enrolled in our rotator cuff repair database, 9 (3.2%) required margin convergence techniques for rotator cuff repair. Six patients had U-shaped tears (66.7%) and 3 patients had L-shaped tears (33.3%). The remaining 272 shoulders had standard rotator cuff repair techniques performed in a transosseous-equivalent repair fashion using both medial and lateral suture anchors without side-to-side suturing of the rotator cuff.

Patients with margin convergence repairs had similar ages compared with patients without margin convergence repairs (57.4 vs 58.9 years; $P = .57$). There were fewer women in the margin convergence group (1 woman; 11%) compared with the group that did not require margin convergence (96 females; 35%; $P = .06$). The length of initial follow up was statistically different between groups with a slightly shorter follow-up in the margin convergence group (3.3 vs 3.7 years; $P = .05$). There was no difference in the percentage of shoulders undergoing concomitant labral repair (0% vs 11%; $P = .27$), biceps tenodesis (33% vs 47%; $P = .43$), or acromioclavicular joint resection (44% vs 57%; $P = .44$) in the margin convergence group compared with the standard repair group.

There were statistically significant improvements in postoperative scores in all quality-of-life scores (WORC, ASES, SST, and SANE) for both the standard rotator cuff repair group and the margin convergence repair group ($P \leq .002$). However, there was no change in SAL for the margin convergence group (12.6 ± 3.8 vs 12.6 ± 5.1; $P = 1.00$) and a deterioration of the SAL in the non-margin convergence group (11.6 ± 4.5 vs 10.3 ± 4.8; $P < .0001$). Patients requiring margin convergence rotator cuff repair had similar preoperative and postoperative scores compared with patients without margin convergence repair (Table 1).

There were no clinical differences between the groups in the percentage of shoulders achieving at least the MCID in postoperative improvement in any of the patient outcome scores (Table 2). Although there was a statistical difference between the percentages of patients achieving the MCID of the WORC, this is likely an effect of the small sample size of patients requiring margin convergence.

There was no difference between patients requiring margin convergence and those who did not have margin convergence in the percentage of patients requiring supraspinatus repair (100% vs 92%; $P = .36$), infraspinatus repair (0% vs 13%; $P = .26$), and subscapularis repair (22% vs 38%; $P = .35$). The margin convergence group had a similar number of tendons requiring repair as the non-margin convergence group (1.2 vs 1.4; $P = .23$).

Shoulders that required margin convergence repair had larger supraspinatus and/or infraspinatus tears (coronal

Table 1. Preoperative and Initial Postoperative Patient-Determined Outcome Scores

	Preoperative Scores					Postoperative Scores				
	Margin Convergence Repair	Standard Rotator Cuff Repair	*P* Value	95% Confidence Intervals	Effect Size	Margin Convergence Repair	Standard Rotator Cuff Repair	*P* Value	95% Confidence Intervals	Effect Size
WORC	44 ± 14	42 ± 15	.75	(−11, 15)	0.11	86 ± 17	88 ± 16	.65	(−16, 10)	0.16
ASES	48 ± 16	41 ± 16	.23	(−5, 20)	0.43	86 ± 20	88 ± 17	.73	(−18, 13)	0.14
SST	5 ± 3	5 ± 3	.40	(−1, 3)	0.30	11 ± 2	10 ± 3	.22	(−1, 2)	0.29
SANE	47 ± 31	37 ± 21	.34	(−13, 35)	0.50	91 ± 11	88 ± 16	.61	(−7, 11)	0.13
SAL	12.6 ± 3.8	11.6 ± 4.5	.48	(−2, 4)	0.21	12.6 ± 5.1	10.3 ± 4.8	.22	(−2, 6)	0.48

ASES, American Shoulder and Elbow Surgeons; SAL, Shoulder Activity Level; SANE, Single Assessment Numeric Evaluation; SST, Simple Shoulder Test; WORC, Western Ontario Rotator Cuff Index.

plane = 38 ± 13 vs 21 ± 11 mm [*P* = .005; d = 1.6], sagittal plane = 27 ± 10 vs 19 ± 9 mm [*P* = .04; d = 0.97], area = 1147 ± 630 vs 467 ± 450 mm^2 [*P* = .01; d = 1.6]) compared with shoulders without margin convergence repair. Shoulders undergoing margin convergence were more likely to have atrophy (Goutallier stage 1-4) found in the supraspinatus, infraspinatus, and/or subscapularis (89% vs 29%; *P* = .0002), and the average Goutallier scores were greater in the margin convergence group (supraspinatus = 1.4 ± 0.9 vs 0.3 ± 0.7 [*P* = .005; d = 1.7], infraspinatus 0.9 ± 1.2 vs 0.3 ± 0.7 [*P* = .17; d = 0.85], subscapularis 0.4 ± 1.0 vs 0.2 ± 0.7 [*P* = .54; d = 0.32]).

Shoulders requiring margin convergence had a similar risk of having arthroscopically identified chondromalacia intraoperatively (33% vs 32%; *P* = .93) and had a similar mean severity of chondromalacia as defined by the Outerbridge grading scale compared to patients that did not require margin convergence (1 ± 1.6 vs 0.7 ± 1.2; *P* = .61).

Mid-term follow-up was obtained on all patients undergoing margin convergence repair to determine whether the early follow up results were durable. At a mean follow-up of 7.5 years (range 5.9-9.3), there was no change in outcome scores compared with the early follow-up time point (Table 3).

There were no complications in the margin convergence group and 2 complications in the standard rotator cuff repair group (2/271; 0.7%) that required revision surgery. One patient had a recurrent/persistent supraspinatus tear 5.5 months after supraspinatus repair and underwent revision rotator cuff repair. Her final follow-up scores were WORC = 94; ASES = 86.7; SST = 7; and SANE = 75. Another patient, a smoker (48 pack-years), had persistent pain and stiffness 8 months after supraspinatus repair and underwent a revision arthroscopy with lysis of adhesions. His rotator cuff was healed at the time of second-look surgery. His final follow-up scores were WORC = 46; ASES = 55; SST = 6; and SANE = 50.

Discussion

This study demonstrated that patients undergoing margin convergence repairs had similar patient-determined outcomes compared with patients who did not require margin convergence techniques, thus supporting our primary hypothesis. In addition, our secondary hypothesis was supported by this study since there was no deterioration of patient-determined outcome scores from a short-term follow-up of 3.3 years to a mid-term follow up of 7.5 years.

For a surgical technique that was published in 1996, there is not an abundance of studies that examine margin convergence rotator cuff repair, with most of the literature published by the author and institution that popularized the technique.[2-4,6,8-30] Biomechanical studies have shown that margin convergence techniques

Table 2. Percentage of Patients Achieving at Least the MCID in Postoperative Improvement After Rotator Cuff Repair With and Without Margin Convergence

	Margin Convergence	No Margin Convergence	*P* Value
WORC (MCID 11.7%)	100%	89%	.0002
ASES (MCID 6.4)	89%	94%	.56
ASES (MCID 17)	78%	89%	.28
SANE (MCID 15)	89%	90%	.96

ASES, American Shoulder and Elbow Surgeons; MCID, minimal clinically important difference; SANE, Single Assessment Numeric Evaluation; WORC, Western Ontario Rotator Cuff Index.

decrease gap formation and may provide a better mechanical environment for rotator cuff healing.[5-7] Mazzocca et al.[5] demonstrated that margin convergence may decrease strain across the rotator cuff by up to 58%. When reviewing the literature that examined clinical outcomes after margin convergence rotator cuff repair techniques that incorporated tendon to bone repair similar to our study, we could only identify 2 studies. In 2001 Burkhart et al.[2] demonstrated comparable clinical outcomes (UCLA scores) in patients requiring margin convergence repair to patients who did not require margin convergence repair. Like our study, they had only a small sample size of patients who underwent margin convergence repair to bone (10 patients) and their follow-up (mean 3.5 years) was similar to our short-term follow-up period. In 2010, Kim et al.[8] published a non-comparative study of 15 patients undergoing margin convergence repair that showed improvements in visual analog scales and Constant scores. This study was limited by a short-term follow-up of 18 months (range 12-25 months).

Limitations

Our study was limited by the small sample size, since only 3.2% of shoulders in our cohort required margin convergence. The small effect sizes found in this study suggest that it is less likely that increasing sample size of the margin convergence group would demonstrate clinically relevant differences. An additional limitation was the inclusion of a large number of patients who underwent procedures concomitant to the rotator cuff repair (biceps tenodesis, acromioclavicular joint resection, etc.). Inclusion of these procedures does not allow us to determine whether the satisfactory outcomes found in this study was due to rotator cuff repair alone or due to the concomitant procedures or a combination of both. However, since there were similar percentages of concomitant procedures between the groups, the inclusion of concomitant procedures should not confound the interpretation of the data and the conclusions of this study. Another limitation of this study was that patients did not return to clinic at final follow-up for a physical examination or radiologic assessment of rotator cuff healing. Whereas this would have made the study more comprehensive, it did not prevent this study from exploring the hypotheses that (1) margin convergence repairs would have comparable patient-determined outcomes to standard rotator cuff repair and (2) these results would be durable from short- to medium-term follow-up.

Table 3. Comparison of Initial Postoperative Follow-up Compared to Final Follow-up for Patients Requiring Margin Convergence Repair

	Initial Follow-up (Mean 3.3 Years)	Final Follow-up (Mean 7.5 Years)	*P* Value
WORC	86 ± 17	88 ± 12	.50
ASES	86 ± 20	92 ± 8	.34
SST	10.9 ± 1.7	10.2 ± 1.8	.36
SANE	91 ± 11	89 ± 14	.75
SAL	12.6 ± 5.1	11.8 ± 4.9	.51

ASES, American Shoulder and Elbow Surgeons; SAL, Shoulder Activity Level; SANE, Single Assessment Numeric Evaluation; SST, Simple Shoulder Test; WORC, Western Ontario Rotator Cuff Index.

Conclusions

Arthroscopic margin convergence repair techniques along with the treatment of concomitant pathologies result in similar patient-determined outcomes compared with standard rotator cuff repair techniques. These results appear to be durable and do not deteriorate from short-term to medium-term follow-up.

References

1. Sallay PI, Hunker PJ, Lim JK. Frequency of various tear patterns in full-thickness tears of the rotator cuff. *Arthroscopy* 2007;23:1052-1059.
2. Burkhart SS, Danaceau SM, Pearce CE Jr. Arthroscopic rotator cuff repair: Analysis of results by tear size and by repair technique-margin convergence versus direct tendon-to-bone repair. *Arthroscopy* 2001;17:905-912.
3. Burkhart SS. The principle of margin convergence in rotator cuff repair as a means of strain reduction at the tear margin. *Ann Biomed Eng* 2004;32:166-170.
4. Burkhart SS, Athanasiou KA, Wirth MA. Margin convergence: A method of reducing strain in massive rotator cuff tears. *Arthroscopy* 1996;12:335-338.
5. Mazzocca AD, Bollier M, Fehsenfeld D, et al. Biomechanical evaluation of margin convergence. *Arthroscopy* 2011;27:330-338.
6. Nguyen ML, Quigley RJ, Galle SE, et al. Margin convergence anchorage to bone for reconstruction of the anterior attachment of the rotator cable. *Arthroscopy* 2012;28:1237-1245.
7. Oh JH, McGarry MH, Jun BJ, et al. Restoration of shoulder biomechanics according to degree of repair completion in a cadaveric model of massive rotator cuff tear: Importance of margin convergence and posterior cuff fixation. *Am J Sports Med* 2012;40:2448-2453.

8. Kim KC, Rhee KJ, Shin HD, et al. Modified margin convergence technique using suture anchors for footprint reconstruction of rotator cuff tears. *Orthopedics* 2010;33:26-29.
9. Kirkley A, Alvarez C, Griffin S. The development and evaluation of a disease-specific quality-of-life questionnaire for disorders of the rotator cuff: The Western Ontario Rotator Cuff Index. *Clin J Sport Med* 2003;13:84-92.
10. Wessel RN, Wolterbeek N, Fermont AJM, Lavrijsen L, van Mameren H, de Bie RA. Responsiveness and disease specificity of the Western Ontario Rotator Cuff index. *J Orthop* 2018;15:337-342.
11. Razmjou H, Bean A, van Osnabrugge V, MacDermid JC, Holtby R. Cross-sectional and longitudinal construct validity of two rotator cuff disease-specific outcome measures. *BMC Musculoskelet Disord* 2006;7:26.
12. Wright RW, Baumgarten KM. Shoulder outcomes measures. *J Am Acad Orthop Surg* 2010;18:436-444.
13. Richards RR, An KN, Bigliani LU, et al. A standardized method for the assessment of shoulder function. *J Shoulder Elbow Surg* 1994;3:347-352.
14. St-Pierre C, Desmeules F, Dionne CE, Fremont P, MacDermid JC, Roy JS. Psychometric properties of self-reported questionnaires for the evaluation of symptoms and functional limitations in individuals with rotator cuff disorders: A systematic review. *Disabil Rehabil* 2016;38:103-122.
15. Schmidt S, Ferrer M, Gonzalez M, et al. Evaluation of shoulder-specific patient-reported outcome measures: A systematic and standardized comparison of available evidence. *J Shoulder Elbow Surg* 2014;23:434-444.
16. Matsen FA 3rd, Ziegler DW, DeBartolo SE. Patient self-assessment of health status and function in glenohumeral degenerative joint disease. *J Shoulder Elbow Surg* 1995;4:345-351.
17. Williams GN, Gangel TJ, Arciero RA, Uhorchak JM, Taylor DC. Comparison of the Single Assessment Numeric Evaluation method and two shoulder rating scales. Outcomes measures after shoulder surgery. *Am J Sports Med* 1999;27:214-221.
18. Thigpen CA, Shanley E, Momaya AM, et al. Validity and responsiveness of the Single Alpha-numeric Evaluation for shoulder patients. *Am J Sports Med* 2018;46:3480-3485.
19. Brophy RH, Beauvais RL, Jones EC, Cordasco FA, Marx RG. Measurement of shoulder activity level. *Clin Orthop Relat Res* 2005;439:101-108.
20. Ryliskis S, Brophy RH, Kocius M, Marx RG. Shoulder activity level in the preoperative assessment of patients with rotator cuff tears. *Knee Surg Sports Traumatol Arthrosc* 2009;17:1522-1528.
21. Baumgarten KM, Chang PS, Dannenbring TM, Foley EK. Does arthroscopic rotator cuff repair improve patients' activity levels? *J Shoulder Elbow Surg* 2018;27:2167-2174.
22. Michener LA, McClure PW, Sennett BJ. American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form, patient self-report section: Reliability, validity, and responsiveness. *J Shoulder Elbow Surg* 2002;11:587-594.
23. Tashjian RZ, Deloach J, Green A, Porucznik CA, Powell AP. Minimal clinically important differences in ASES and simple shoulder test scores after nonoperative treatment of rotator cuff disease. *J Bone Joint Surg Am* 2010;92:296-303.
24. Usable Stats. 2-sample t-test calculator, https://www.usablestats.com/calcs/2samplet&sample=1. Accessed January 5, 2020.
25. Sauro J. Best practices for using statistics on small sample sizes, https://measuringu.com/small-n/ 2013. Accessed April 6, 2020.
26. Coe R. It's the Effect Size, Stupid. What effect size is and why it is important, *Annual Conference of the British Educational Research Association*. England: University of Exeter, 2002.
27. Cohen J. *Statistical power analysis for the behavioral sciences*, 2d ed. New York: Lawrence Erlbaum, 1988.
28. Burkhart SS. A stepwise approach to arthroscopic rotator cuff repair based on biomechanical principles. *Arthroscopy* 2000;16:82-90.
29. Burkhart SS, Hartzler RU. Arthroscopic rotator cuff repair: How to avoid retear. *Arthroscopy* 2019;35:12-13.
30. Richards DP, Burkhart SS. Margin convergence of the posterior rotator cuff to the biceps tendon. *Arthroscopy* 2004;20:771-775.