Shoulder-specific outcomes 1 year after nontraumatic full-thickness rotator cuff repair: a systematic literature review and meta-analysis

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Abstract

Background: Nontraumatic full-thickness rotator cuff tears are commonly initially treated conservatively. If conservative treatment fails, rotator cuff repair is a viable subsequent option. The objective of the present meta-analysis is to evaluate the shoulder-specific outcomes one year after arthroscopic or mini-open rotator cuff repair of nontraumatic rotator cuff tears.

Methods: A literature search was conducted in PubMed and EMBASE within the period January 2000 to January 2017. All studies measuring the clinical outcome at 12 months after nontraumatic rotator cuff repair of full-thickness rotator cuff tears were listed.

Results: We included 16 randomized controlled trials that met our inclusion criteria with a total of 1,221 shoulders. At 12 months after rotator cuff repair, the mean Constant score had increased 29.5 points; the mean American Shoulder and Elbow Score score increased by 38.6 points; mean Simple Shoulder Test score was 5.6 points; mean University of California Los Angeles score improved by 13.0 points; and finally, mean Visual Analogue Scale score decreased by 4.1 points.

Conclusions: Based on this meta-analysis, significant improvements in the shoulder-specific indices are observed 12 months after nontraumatic arthroscopic or mini-open rotator cuff repair.

Keywords

quality of life, shoulder-specific outcome, rotator cuff repair, rotator cuff tear

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Introduction

Nontraumatic rotator cuff tears (RCTs) are commonly seen in patients with persistent pain of the shoulder and can be accompanied by disability, decreased range of motion and strength.¹ It is suggested that shoulder dysfunction and rotator cuff pathology are associated with a compromise in the patients health status.² This is similar to diabetes mellitus, clinical depression and other major diseases, such as congestive heart failure or acute myocardial infarction.³ Dysfunction and pain as a result of RCTs can be improved reliably and significantly with medical treatment.⁴

In the working population, RCTs may cause the inability to work, whereas in the older population

RCTs may contribute to the loss of functional independence.³ Our understanding of the natural history of full-thickness RCTs is evolving. It is clear that a full-thickness tear has little inherent capacity to heal without operative management.⁵ It is also accepted that the size of untreated tears mostly increases over time, with subsequent tendon retraction and irreversible

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atrophy with fatty infiltration.⁵ Treatment options for the symptomatic RCT include both non-operative and operative interventions. Many individuals with RCTs find symptomatic relief with physiotherapy with or without an infiltration, whereas others require operative repair for improvement of the pain and weakness.^{6–10} The number of successful arthroscopic rotator cuff repairs is reported to have increased thanks to improvements in technology and the ability to achieve robust repairs in a minimally invasive fashion.¹¹

The objective of this meta-analysis was to evaluate the improvement of the shoulder-specific outcomes after one year following nontraumatic arthroscopic or mini-open repair of a full-thickness rotator cuff tear.

We hypothesized a clinically relevant improvement of the shoulder-specific outcomes, 1 year after full-thickness nontraumatic rotator cuff repair. This was achieved by conducting a meta-analysis of randomized controlled trials.

Materials and methods

Data sources and searches

A literature search was performed using PubMed and EMBASE databases from January 2000 to January 2017. This period was chosen to include the most recent operative techniques. In total, 1238 unique articles were found using the search terms listed in Appendix 1 (supplementary material, online). This search was developed and performed with the assistance of medical research librarians. To be as inclusive as possible, a large number of terms were included in the search string, including Medical Subject Headings (MeSH), outcomes of interest, and study design. In addition, review articles and book chapters related to rotator cuff repair were identified within the search results, and all references from these sources were manually evaluated for potential inclusion. All references of articles meeting the inclusion criteria were similarly examined.

Study selection

To evaluate the highest quality of the available literature, only randomized controlled trials were included. Only trials studying interventions according to current consensus that do not influence the clinical results were included. This aimed to prevent the inclusion of those patients who were treated with an inferior cuff repair. We included one study that compared arthroscopic with mini-open full-thickness rotator cuff repair.¹² Some studies have compared rotator cuff repair with additional treatments in the shoulder region, such as acromioplasty or augmentation with platelet rich plasma.^{6,9,13–20} Others have compared treatment with

or without acromioplasty^{21,22} or single-row to the double-row fixation method for RCTs.^{8,23} Finally, postoperative rehabilitation programmes are compared.²⁴ This was conducted to increase the focus on the common treatment of rotator cuff repair.

Inclusion criteria for articles identified by the search were: (i) inclusion of patients who underwent nontraumatic full-thickness primary rotator cuff repair performed arthroscopically or with a mini-open procedure. Because of the increasing tendency of performing arthroscopic or mini-open cuff repair, we did not include studies reporting outcomes after open rotator cuff repair; (ii) surgical indication specified with a pre-operative full-thickness rotator cuff tear without glenohumeral arthritis; (iii) comparative studies were included (with or without acromioplasty, with or without augmentation with platelet rich plasma, single-row or double-row fixation technique and arthroscopic or mini-open procedure); (iv) reported at least one of the following shoulder-specific outcome indices pre- and postoperatively; Constant score,²⁵ American Shoulder and Elbow Score (ASES),²⁶ Simple Shoulder Test (SST),²⁵ Visual Analogue Scale (VAS)²⁶ or University of California Los Angeles (UCLA) score,²⁸ (5) studies reporting their outcomes at 12 months of follow-up with the mean (SD). No studies were excluded on the basis of patient characteristics, including age, sex, race/ethnicity, socio-economic status, tear size if repairable or comorbidity.

Studies were excluded if (i) there were 10 or fewer patients; (ii) it contained irreparable or partial thickness rotator cuff tears; (iii) traumatic cuff tears; (iv) 12-month follow-up outcome indices not reported; (v) data presented were duplicative with those of previous publication; or the report was not in the English language.

All inclusion and exclusion criteria were reviewed by two orthopaedic surgeons specialized in shoulders. All articles identified with the search strategy were evaluated for inclusion by the lead author.

Data extraction and evidence assessment

Information from each study, including publication year, study location and method of patient selection, was assessed. Number of patients, attrition, pre-operative and postoperative shoulder-specific outcome indices with the mean (SD), pre-operative diagnosis of a full-thickness rotator cuff repair, average follow-up, patient demographics and funding source were abstracted. The significance of any study findings was reported, as were any references of surgical techniques used. Sources of potential bias with patient selection were recorded. In many cases, the studies did not detail complications according to the specific patient group, and so it was not possible to accurately

Table 1. Study characteristics.

Author(s)	Study	Number of patients	Follow-up (months)	Outcome
Jo (2015) ²⁰	Arthroscopic cuff repair; full-thickness, PRP versus no PRP	37 PRP 37 No PRP	12	Constant Score, SST, ASES, UCLA, VAS
Malavolta (2014) ¹⁹	Arthroscopic cuff repair; full-thickness, PRP versus no PRP	27 PRP 27 No PRP	12	Constant Score, UCLA, VAS
Abrams (2014) ⁶	Arthroscopic cuff repair; full-thickness with or without Acromioplasty	43 Nonacromioplasty 52 Acromioplasty	12	Constant Score, SST, ASES, UCLA
Kukkonen (2014) ²²	Physiotherapy versus acromioplasty versus cuff repair for full-thickness rotator cuff tears	55 Cuff repair	12	Constant Score
Keener (2014) ²⁴	Arthroscopic cuff repair; full-thickness, early mobilization versus delayed	61 Early 53 Delayed	12	SST, ASES, VAS
Jo (2013) ¹⁵	Arthroscopic cuff repair; full-thickness, PRP versus no PRP	24 PRP 24 No PRP	12	Constant Score, SST, ASES, UCLA
Van der Zwaal (2013) ¹²	Arthroscopic versus mini open rotator cuff repair; full-thickness	47 Arthroscopic repair 48 Mini open	12	Constant Score, VAS
Lapner (2012) ²³	Arthroscopic cuff repair; Full thickness, single-row versus double-row	48 Single-row 42 Double-row	12	Constant Score, ASES
Shin (2012) ²¹	Arthroscopic cuff repair; full-thickness, with or without Acromioplasty	60 Nonacromioplasty 60 Acromioplasty	12	Constant Score, ASES, UCLA, VAS
Gumina (2012) ¹⁴	Arthroscopic cuff repair; full-thickness, with or without leukocyte platelet membrane	40 PRP membrane 40 No PRP membrane	12	Constant score, SST
Rodeo (2012) ¹⁸	Arthroscopic cuff repair; full-thickness, with or without PRP	40 PRP 39 No PRP	12	ASES
Castricini (2011) ⁹	Arthroscopic cuff repair; full-thickness with or without platelet rich plasma	43 PRP 45 No PRP	16	Constant score
Dezaly (2011) ¹³	Arthroscopic cuff repair versus acromioplasty, full-thickness tears	68 Cuff repair	12	Constant score

(continued)

Table 1. Continued

Author(s)	Study	Number of patients	Follow-up (months)	Outcome
MacDonald (2011)¹⁶	Arthroscopic cuff repair, Full thickness, with or without Acromioplasty	36 Nonacromioplasty 32 Acromioplasty	12	ASES
Randelli (2011)¹⁷	Arthroscopic cuff repair, full-thickness, PRP versus not PRP	26 PRP 27 No PRP	12	Constant, SST, UCLA
Burks (2009)⁸	Arthroscopic cuff repair, full-thickness, single-row versus double-row	20 Single-row 20 Double-row	12	Constant Score, ASES, UCLA

PRP: Platelet Rich Plasma

characterize complications beyond their effect on aggregate shoulder-specific outcome indices as reported for each patient group.

Data synthesis and analysis

All analyses were performed with use of meta-analysis software (Review Manager, version 5.1; Cochrane Collaboration, London, UK). The number of included shoulders was used as the group size (n) for each study because the number of patients was less frequently reported for the specific treatment groups. All shoulder-specific indices were treated with continuous variables, and Cohen's d was used to estimate effect size from individual studies. For each index, the chi-squared test statistic for heterogeneity was calculated. Random effects models were used for this meta-analysis because of the observed heterogeneity in the collected data. Forest plots were generated for each outcome index, displaying individual mean differences (MD) and corresponding 95% confidence intervals (CIs), individual study weights and overall summary effect size and 95% CI. $p < 0.05$ was considered statistically significant.

Results

Data source and selection

Of the initial 1238 selected studies, 16 studies met the inclusion criteria with 1221 shoulders (Table 1) were included, (Figure 1). Although the period of our search started in 2000, the first published study that met our inclusion criteria is dated 2009.⁸ In seven studies comprising 476 shoulders, shoulder-specific indices were reported after rotator cuff repair with or without augmentation with platelet-rich plasma.^{9,14,15,17–20} Four studies with 351 shoulders comparing rotator cuff repair with or without acromioplasty;^{6,13,16,21} one study with 55 shoulders comparing physiotherapy alone, acromioplasty and physiotherapy, or rotator cuff repair with acromioplasty and physiotherapy;²² two with 130 shoulders comparing the single-row and double-row fixation techniques;^{8,23} one with 95 shoulders comparing the mini-open with arthroscopic cuff repair;¹² and one with 114 shoulders comparing the early with delayed rehabilitation procedure.²⁴

Baseline characteristics (age, sex, quality of life outcome indices) did not differ between the two or three comparative groups in each included study.

All of the included studies found no clinical significant difference at final follow-up between the compared rotator cuff repair groups.

We extracted the shoulder-specific indices reported at 12 months after rotator cuff repair. We also included 1 article with a mean follow-up of 16 months.⁹

Figure 1. Summary of systematic review process.

Table 2. Results.

Shoulder-specific outcome	Included studies	Shoulders	Mean difference	p-value	95 % CI
Constant score	13	912	29.5	<0.001	25.7 to 33.3
ASES	9	734	38.6	<0.001	36.4 to 40.9
SST	6	474	5.6	<0.001	5.1 to 6.2
UCLA score	6	436	13.0	<0.001	10.3 to 15.6
VAS	6	386	-4.1	<0.001	-4.6 to -3.5

ASES, American Shoulder and Elbow score; SST, Simple Shoulder Test; UCLA, University of California of Los Angeles; VAS, Visual Analogue Score; SMD, standardized mean difference; CI, confidence interval.

Shoulder-specific indices (Table 2)

In 13 studies on a total of 912 shoulders, the outcome was reported using the Constant score (Figure 2). A significant increase of 29.5 points ($p < 0.001$, 95% CI = 25.7 to 33.3) at 12 months after rotator cuff repair was observed. Nine studies with a total of 734 shoulders reported outcomes using the ASES score (Figure 3). Significant improvements were observed after rotator cuff repair with a mean increase of 38.6 points ($p < 0.001$, 95% CI = 36.4 to 40.9). In six articles, the SST score was reported for 474 shoulders (Figure 4), which also showed a significant increase of 5.6 points ($p < 0.001$, 95% CI = 5.1 to 6.2). Six studies reported outcome using the UCLA score for 436 shoulders (Figure 5), revealing a significant mean increase

of 13.0 points ($p < 0.001$, 95% CI = 10.3 to 15.6). Finally, the VAS score was reported in six studies on 386 shoulders. The mean decrease of 4.1 points (standardized mean difference = $p < 0.001$, 95% CI -4.6 to -3.5) was significant (Figure 6).

Discussion

The objective of this meta-analysis was to evaluate the improvement of the shoulder-specific quality of life after 1 year following nontraumatic arthroscopic or mini-open repair of a full-thickness rotator tear. Based on this study, a repair of a nontraumatic full-thickness RCT was shown to be a highly effective intervention in all the shoulder-specific indices.

Figure 2. Meta-analysis Constant score.

The strong points of the present study according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines are the inclusion of only randomized studies based on a strictly defined systematic search of the literature in the commonly used databases. This thorough search was developed and performed with the assistance of medical research librarians.

Limitations of current meta-analysis are that several randomized controlled trials did not report a SD but instead only confidence intervals, and so these trials could not be included in current meta-analysis. Assessment was performed focusing on the indices 12 months after repair. Some studies also or only reported the indices at 6 months or at 2-year follow-up. Only data reported at 12 months were extracted and used

in the present study. Because shoulder outcome can still increase 6 months after rotator cuff repair and mostly stabilizes after 12 months, we did not include studies if not reporting the indices at 12 months in the current analysis.

As a result of the heterogeneity of the included trials, the conclusions of this meta-analysis are not generalizable to the whole population.

A potential limitation in generalizing these results to all mini-open and arthroscopic cuff repair procedures is that hospital volume and surgeon volume and experience have an effect on outcome. Although the results of this analysis show good results of rotator cuff repair after 1 year, it remains unclear whether the positive effect carries through on the long-term (>1 year).

Figure 3. Meta-analysis American Shoulder and Elbow Score (ASES).

Figure 4. Meta-analysis Simple Shoulder Test (SST) score.

Figure 5. Meta-analysis University of California Los Angeles (UCLA) score.

Figure 6. Meta-analysis Visual Analogue Scale (VAS) score.

According to the title, this meta-analysis focuses on the shoulder-specific indices, and the pooling of more general outcome measures such as as Short-Form (SF)-12, SF-36 and EuroQoL was not possible because of poor reporting.

The ASES score has been reported to be reliable, valid and responsive, with a minimal clinically important difference of 6.4 points.²⁹ The mean improvement in the ASES score found in this meta-analysis was 38.6 points, which is a major improvement. The SST has

been shown to have discriminant construct validity, to be reproducible, and to be responsive to changes in shoulder function after intervention.^{29,30} In non-operative treatment of rotator cuff disease, a minimal clinically important difference was seen of 2 points,³¹ whereas we found a mean increase of 5.6 points. Although we did not find any specific validation and reliability of the UCLA score for rotator cuff disease, it is widely used in studies to determine shoulder outcome. More than 50% of the scale is based on pain relief, passive motion and patient satisfaction and designed for shoulder arthroplasty,²⁸ although a fair correlation between the UCLA score and Constant score is observed in rotator cuff repair.

Despite the Constant score being one of the widest used scoring system for shoulder pathology, there still exists concern about validity. Current evidence indicates an excellent responsiveness for different shoulder pathologies except for shoulder instability.³¹ Standardization of the range of motion and strength of the Constant score might increase reliability.^{31,33} The minimal clinically important difference for the Constant score is 10 points,³⁴ whereas an increase of 29.5 points was observed in the current analysis. One included study reported the relative constant score, which is a Constant score standardized for age and sex, these data were excluded because the other studies only reported an absolute score. Finally, the VAS score is also used widely in rotator cuff diseases and has a minimal clinically important difference of 1.4 in non-operated shoulders.³⁵ Other outcome indices were not analyzed as a result of an insufficient amount of studied shoulders that met our inclusion criteria.

Although with ranging postoperative follow-up, repair of full-thickness rotator cuff tears have been reported to show failure rates between 25% and 90%.¹ Interestingly, several studies have reported shoulder-specific outcomes in re-tears after rotator cuff repair showing no difference in clinical outcome.^{1,36} Full-thickness rotator cuff tears can also be managed non-operatively with physiotherapy, resulting in good clinical outcomes as well.⁷ This is supported by results of a multicentre prospective cohort study including 452 shoulders, reporting improvement in the outcomes studied with physiotherapy alone.³⁷ However, 25% were eventually indicated to undergo surgery after 2-year follow-up. Another randomized controlled trial ($n = 167$) comparing the outcomes after (i) physiotherapy, (ii) acromioplasty and physiotherapy or (iii) cuff repair, acromioplasty and physiotherapy reported no significant differences in constant score at final follow-up.²² The risk of treating a rotator cuff tear non-operatively is the possible enlargement of the tear and the development of cuff tear arthropathy on the long term. Although the treatment of choice

for full-thickness rotator cuff tears remains controversial, our results show that operative management results in significant improvement of shoulder-specific outcomes.

A recent large multicentre randomized controlled trial in the UK compared the effectiveness of arthroscopic with open repair of the rotator cuff.³⁸ The study included 273 patients (136 arthroscopic and 137 open) being treated for degenerative tears of the rotator cuff. The Oxford Shoulder Score (OSS) was analyzed with a 2-year follow-up and the integrity of the cuff repair was assessed. The OSS is poorly reported in the current literature for rotator cuff tears, although its uptake is increasing in a number of countries.³⁹ The OSS did not differ between both groups, nor did the re-tear rate. However, a significant improvement in the OSS, Shoulder Pain and Disability Index (SPADI), EuroQol and Mental Health Inventory (MHI-5) was reported if the rotator cuff was repaired. Although the outcome measures in our meta-analysis are different, our findings of increased shoulder function and decreased pain are similar to that study.

Conclusions

The findings of this meta-analysis show a significant increase of all the analyzed shoulder-specific indices at 12 months after nontraumatic full-thickness rotator cuff repair. Patients with a rotator cuff tear have high pain scores and might have a reduced quality of life with an increased dependency on their caregivers. Rotator cuff repair appears to be an effective intervention in patients with tears. Based on the results of the present study, we recommend repair in nontraumatic rotator cuff repair if conservative treatment failed. The relative value of surgical treatment in relation to non-operative treatment with, for example physiotherapy, cannot be determined based on the present study. This comparison is still open for debate for several subgroups and larger multicentre randomized controlled trials, with quality of life and patient-reported outcome measures.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Ethical Review and Patient Consent

Not required for this article.

References

- Xu C, Zhao J and Li D. Meta-analysis comparing single-row and double-row repair techniques in the arthroscopic treatment of rotator cuff tears. *J Shoulder Elbow Surg* 2014; 23: 182–188.
- Mascarenhas R, Chalmers PN, Sayegh ET, et al. Is double-row rotator cuff repair clinically superior to single-row rotator cuff repair: a systematic review of overlapping meta-analyses. *Arthroscopy* 2014; 30: 1156–1165.
- Downie BK and Miller BS. Treatment of rotator cuff tears in older individuals: a systematic review. *J Shoulder Elbow Surg* 2012; 21: 1255–1261.
- McKee MD and Yoo DJ. The effect of surgery for rotator cuff disease on general health status. Results of a prospective trial. *J Bone Joint Surg Am* 2000; 82A: 970–979.
- Yamaguchi K, Tetro AM, Blam O, Evanoff BA, Teefey SA and Middleton WD. Natural history of asymptomatic rotator cuff tears: a longitudinal analysis of asymptomatic tears detected sonographically. *J Shoulder Elbow Surg* 2001; 10: 199–203.
- Abrams GD, Gupta AK, Hussey KE, et al. Arthroscopic repair of full-thickness rotator cuff tears with and without acromioplasty: randomized prospective trial with 2-year follow-up. *Am J Sports Med* 2014; 42: 1296–1303.
- Ainsworth R and Lewis JS. Exercise therapy for the conservative management of full thickness tears of the rotator cuff: a systematic review. *Br J Sports Med* 2007; 41: 200–210.
- Burks RT, Crim J, Brown N, Fink B and Greis PE. A prospective randomized clinical trial comparing arthroscopic single- and double-row rotator cuff repair: magnetic resonance imaging and early clinical evaluation. *Am J Sports Med* 2009; 37: 674–682.
- Castricini R, Longo UG, De Benedetto M, et al. Platelet-rich plasma augmentation for arthroscopic rotator cuff repair: a randomized controlled trial. *Am J Sports Med* 2011; 39: 258–265.
- Kijima H, Minagawa H, Nishi T, Kikuchi K and Shimada Y. Long-term follow-up of cases of rotator cuff tear treated conservatively. *J Shoulder Elbow Surg* 2012; 21: 491–494.
- Sheibani-Rad S, Giveans MR, Arnoczky SP and Bedi A. Arthroscopic single-row versus double-row rotator cuff repair: a meta-analysis of the randomized clinical trials. *Arthroscopy* 2013; 29: 343–348.
- Van der Zwaal P, Thomassen BJ, Nieuwenhuijse MJ, et al. Clinical outcome in all-arthroscopic versus mini-open rotator cuff repair in small to medium-sized tears: a randomized controlled trial in 100 patients with 1-year follow-up. *Arthroscopy* 2013; 29: 266–273.
- Dezaly C, Sirveaux F, Philippe R, et al. Arthroscopic treatment of rotator cuff tear in the over-60s: repair is preferable to isolated acromioplasty-tenotomy in the short term. *Orthop Traumatol Surg Res* 2011; 97(6 Suppl): S125–S130.
- Gumina S, Campagna V, Ferrazza G, et al. Use of platelet-leukocyte membrane in arthroscopic repair of large rotator cuff tears: a prospective randomized study. *J Bone Joint Surg Am* 2012; 94: 1345–1352.
- Jo CH, Shin JS, Lee YG, et al. Platelet-rich plasma for arthroscopic repair of large to massive rotator cuff tears: a randomized, single-blind, parallel-group trial. *Am J Sports Med* 2013; 41: 2240–2248.
- MacDonald P, McRae S, Leiter J, Mascarenhas R and Lapner P. Arthroscopic rotator cuff repair with and without acromioplasty in the treatment of full-thickness rotator cuff tears: a multicenter, randomized controlled trial. *J Bone Joint Surg Am* 2011; 93: 1953–1960.
- Randelli P, Arrigoni P, Ragone V, Aliprandi A and Cabitza P. Platelet rich plasma in arthroscopic rotator cuff repair: a prospective RCT study, 2-year follow-up. *J Shoulder Elbow Surg* 2011; 20: 518–528.
- Rodeo SA, Delos D, Williams RJ, Adler RS, Pearle A and Warren RF. The effect of platelet-rich fibrin matrix on rotator cuff tendon healing: a prospective, randomized clinical study. *Am J Sports Med* 2012; 40: 1234–1241.
- Malavolta EA, Gracitelli MEC, Ferreira Neto AA, et al. Platelet-rich plasma in rotator cuff repair: a prospective randomized study. *Am J Sports Med* 2014; 42: 2446–2454.
- Jo CH, Shin JS, Shin WH, Lee SY, Yoon KS and Shin S. Platelet-rich plasma for arthroscopic repair of medium to large rotator cuff tears: a randomized controlled trial. *Am J Sports Med* 2015; 43: 2102–2110.
- Shin SJ, Oh JH, Chung SW and Song MH. The efficacy of acromioplasty in the arthroscopic pair of small- to medium-sized rotator cuff tears without acromial spur: prospective comparative study. *Arthroscopy* 2013; 28: 628–635.
- Kukkonen J, Joukainen A, Lehtinen J, et al. Treatment of non-traumatic rotator cuff tears: a randomised controlled trial with one-year clinical results. *Bone Joint J* 2014; 96B: 75–81.
- Lapner PL, Sabri E, Rakhra K, McRae S, Leiter J, Bell K and Macdonald P. A multicenter randomized controlled trial comparing single-row with double-row fixation in arthroscopic rotator cuff repair. *J Bone Joint Surg Am* 2012; 94: 1249–1257.
- Keener JD, Galatz LM, Stobbs-Cucchi G, Patton R and Yamaguchi K. Rehabilitation following arthroscopic rotator cuff repair: a prospective randomized trial of immobilization compared with early motion. *J Bone Joint Surg Am* 2014; 96: 11–19.
- Constant CR and Murley AH. A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res* 1987; 214: 160–164.
- Richards RR, An K-N, Bigliani LU, et al. A standardized method for the assessment of shoulder function. *J Shoulder Elbow Surg* 1994; 3: 347–352.
- Lippitt SB, Harryman DT 2nd and Matsen FA III. A practical tool for evaluating function: the Simple Shoulder Test. In: Matsen FA III, Fu FH and Hawkins RJ (eds) *The shoulder: a balance of mobility and stability*. Rosemont, IL: American Academy of Orthopaedic Surgeons, 1993, pp.501–518.
- Amstutz HC, Sew Hoy AL and Clarke IC. UCLA anatomic total shoulder arthroplasty. *Clin Orthop Relat Res* 1981; 155: 7–20.

29. Roy JS, MacDermid JC and Woodhouse LJ. Measuring shoulder function: a systematic review of four questionnaires. *Arthritis Rheum* 2009; 61: 623–632.
30. Godfrey J, Hamman R, Lowenstein S, Briggs K and Kocher M. Reliability, validity, and responsiveness of the simple shoulder test: psychometric properties by age and injury type. *J Shoulder Elbow Surg* 2007; 16: 260–267.
31. Tashjian RZ, Deloach J, Green A, Porucznik CA and 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.
32. Blonna D, Scelsi M, Marini E, et al. Can we improve the reliability of the Constant-Murley score? *J Shoulder Elbow Surg* 2012; 21: 4–12.
33. Roy JS, MacDermid JC and Woodhouse LJ. A systematic review of the psychometric properties of the Constant-Murley score. *J Shoulder Elbow Surg* 2010; 19: 157–164.
34. Kukkonen J, Kauko T, Vahlberg T, Joukainen A and Aärimala V. Investigating minimal clinically important difference for Constant score in patients undergoing rotator cuff surgery. *J Shoulder Elbow Surg* 2013; 22: 1650–1655.
35. Tashjian RZ, Deloach J, Porucznik CA and Powell AP. Minimal clinically important differences (MCID) and patient acceptable symptomatic state (PASS) for visual analog scales (VAS) measuring pain in patients treated for rotator cuff disease. *J Shoulder Elbow Surg* 2009; 18: 927–932.
36. Millett PJ, Warth RJ, Dornan GJ, Lee JT and Spiegl UJ. Clinical and structural outcomes after arthroscopic single-row versus double-row rotator cuff repair: a systematic review and meta-analysis of level I randomized clinical trials. *J Shoulder Elbow Surg* 2014; 23: 586–597.
37. Kuhn JE, Dunn WR, Sanders R, et al. for the MOON Shoulder Group. Effectiveness of physical therapy in treating atraumatic full-thickness rotator cuff tears: a multicenter prospective cohort study. *J Shoulder Elbow Surg* 2013; 22: 1371–1379.
38. Carr A, Cooper C, Campbell MK, et al. Effectiveness of open and arthroscopic rotator cuff repair (UKUFF): a randomised controlled trial. *Bone Joint J* 2017; 99B: 107–115.
39. Dawson J, Rogers K, Fitzpatrick R and Carr A. The Oxford Shoulder Score revisited. *Arch Orthop Trauma Surg* 2009; 129: 119–123.