



# Do partial glenohumeral degenerative changes in patients undergoing arthroscopic rotator cuff repair influence clinical outcomes?

Karam Al-Tawil<sup>1</sup>, Joseph Casey<sup>2</sup>, Prashant Thayaparan<sup>1</sup>, Adel Tavakkolizadeh<sup>1</sup>, Joydeep Sinha<sup>1</sup>, Toby Colegate-Stone<sup>1,2</sup>

<sup>1</sup>Department of Orthopaedic Surgery, King's College Hospital, London, UK

<sup>2</sup>King's Health Partners, London, UK

**Background:** The prognostic factors for patients with full-thickness rotator cuff tears (RCTs) include tear size, muscle atrophy and fatty infiltration. However, the influence of early coexisting degenerative changes on RCT outcomes is unappreciated. The purpose of this study was to calculate the impact that pre-existing partial glenohumeral cartilaginous changes have on patients undergoing arthroscopic RCT repair.

**Methods:** A study of 54 patients undergoing arthroscopic RCT repair was undertaken. The presence of co-existing patches of glenohumeral degenerative cartilaginous changes and RCT size was recorded at surgery. Pre- and postoperative outcomes were assessed using traditional (Oxford Shoulder Score [OSS], 5-level EuroQol-5D [EQ-5D-5L] questionnaire and EuroQol visual analog scale [EQ-VAS]) and patient-centric re-formatted prisms. Outcomes were assessed as an entire dataset, and sub-group analysis was performed according to the grade of co-existing arthritis and tear size.

**Results:** Significant improvements ( $p < 0.05$ ) in clinical outcomes were recognized when assessed using either the traditional or reformatted prisms (average % improvements in OSS, EQ-5D-5L and EQ-VAS were 47%, 33% and 43%, respectively; average improvements in pain, function, and psychological well-being were 48%, 33% and 29%, respectively). Positive gain was noted in all sub-groups of arthritic grading and tear size.

**Conclusions:** Good clinical outcomes can be achieved following RCT repair even in the presence of local partial degenerative cartilage changes and advancing tear size. These benefits are patient-centered but require RCT reparability.

**Keywords:** Rotator cuff repair; Osteoarthritis; Outcomes

## INTRODUCTION

Shoulder pain accounts for > 2% of primary care consultations in the UK [1,2]. Full-thickness rotator cuff tears (RCTs) are the

most frequent causes of shoulder pain and dysfunction, [3-5] accounting for 30%–70% of shoulder presentations. Non-traumatic RCTs become more common with age, with magnetic resonance imaging incidences of  $\leq 13\%$  in those aged < 60 years and 28%–

Received: October 29, 2021    Revised: February 3, 2022    Accepted: February 9, 2022

Correspondence to: Toby Colegate-Stone

Department of Orthopaedic Surgery, King's College Hospital, Denmark Hill, London SE5 9RS, UK

Tel: +44-79-77531559, E-mail: [tobycolegate-stone@nhs.net](mailto:tobycolegate-stone@nhs.net)

Financial support: None.

Conflict of interest: None.

Copyright© 2022 Korean Shoulder and Elbow Society.

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/4.0/>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

51% in those aged >60 years [6,7]. Most symptomatic RCTs when left untreated may progress in size, which can lead to rotator cuff arthropathy [8,9]. Numerous studies have reported surgical repair of full-thickness RCTs to be a highly effective treatment, providing significant clinical improvement with symptom and condition reversibility [10-14]. The management of end-stage rotator cuff arthropathy is more complex than that of a simple RCT when measured by any prism. Arthroplasty surgery carries a higher morbidity profile with less optimal outcomes compared to rotator cuff repair (RCR) as well as a notably higher fiscal cost of care [14,15]. Prevention is often preferred as a course of action over cure, and, with respect to the shoulder, if patients could be successfully diverted away from developing symptomatic end-stage glenohumeral arthritis, this would offer benefits to all from both population and socio-economic perspectives. However, the clinical burden that RCTs pose is likely to evolve inextricably and as a consequence of our aging population demographics [6,7].

Multiple patient and surgical factors concerning those with full-thickness RCTs already exist that provide accepted prognostic power. These include tendon tear size, muscle atrophy and fatty infiltration [8,9,16,17]. The prognostic impact of the presence of partial patches of degenerative arthritic and cartilaginous change is less appreciated. Osteoarthritis is not a binary disease; rather, it exists initially in progressive states [18]. It is not uncommon to note such partial degenerative changes in the glenohumeral joint at arthroscopy, and these findings are more common in patients as their age increases. In the presence of bone-on-bone end-stage arthritis, the surgical management of an RCT alone is not expected to offer an appropriate clinical benefit. What is less clear is the influence of early co-existing patches of degenerative change on RCR outcomes.

The purpose of the study was to calculate the impact that pre-existing glenohumeral cartilaginous change may have on patients undergoing arthroscopic repair of full-thickness RCTs. The working hypothesis was that such degenerative changes may inhibit end-outcomes.

## METHODS

The study followed the requisite institutional requirements and advice and was approved by the Institutional Review Board. And, despite the retrospective design of this study, patient consent was attained. A retrospective analysis of consecutive patients undergoing arthroscopic RCR by consultant surgeons was performed over a 4-year period. Inclusion criteria were patients with symptomatic full-thickness RCTs who had failed conservative treat-

ment. Patients were excluded if they had a prior history of shoulder surgery, obvious bone-on-bone glenohumeral changes on plain radiographs, an acute traumatic RCT, lacked suitable biology for healing, required additional subscapularis repair, required additional biceps tenodesis, had undergone previous cervical spine surgery or had a history of regional infection or a complex medical history with an American Society of Anesthesiologists classification of  $\geq 4$  [19]. Additionally, if patients had patches of bone on bone progressive cartilaginous degenerative changes measuring >1 cm by >1 cm at arthroscopy, they were also excluded. All patients underwent clinical cervical spine review. If patients had active and concomitant cervical symptoms with radicular symptoms, they were also excluded.

Arthroscopic surgical repair was performed under a general anesthetic with the patient in the beach chair position. All patients underwent surgery at the same orthopedic elective center, undergoing preoperative work-up performed by the same teams, surgery from the same surgeons and the same postoperative physiotherapy regimes. All RCTs were repaired using an all-arthroscopic technique.

At arthroscopy, the size of RCT and the presence of any co-existing patches of glenohumeral degenerative cartilaginous change were recorded. Cartilage changes were graded using the Outerbridge classification [18], which is based on direct visualization of the joint and was developed to be a reproducible methodology to grade changes to articular cartilage. The system assigns a grade of 0-4 to the chondral area of interest, where grade 0 suggests normal cartilage, grade 1 suggests cartilage with softening and swelling, grade 2 suggests a partial-thickness defect with fissures on the surface that do not reach subchondral bone, grade 3 suggests full-thickness fissuring to the level of subchondral bone and grade 4 suggests exposed fully subchondral bone.

Additional findings recorded at surgery included the RCT size, the number of anchors used in repair and the stability of the repair during range-of-movement examination and additional procedures (e.g., arthroscopic acromioclavicular joint decompression). The footprint of the greater tuberosity was prepared prior to repair. A complete repair of the full-thickness RCT was conducted, which returned the tendon to cover the entirety of the greater tuberosity footprint with a double-row repair technique utilizing triple loaded 5.5-mm Healix anchors (Depuy Mitek, Raynham, MA, USA) in a double-row repair approach. Those patients with cuff tears >2 cm required two anchors to achieve this, whilst those with smaller tear patterns only required one anchor. In the latter group, two more medially placed mattress sutures were initially tied and a subsequent lateral simple suture was completed. In those with two anchor repairs, two to three

more medially placed mattress sutures were secured initially, followed by two simple sutures, to a more laterally placed anchor. Following surgery, patients were immobilized in a sling for 4 weeks before commencing full range of movement and a structured active assisted exercise program.

**Outcomes**

Clinical outcomes were measured using standard patient-reported outcome measures, including the Oxford Shoulder Score (OSS), the 5-level EuroQol-5D (EQ-5D-5L) questionnaire and the EuroQol visual analog scale (EQ-VAS) [20,21]. The OSS is a subjective patient-based questionnaire used to assess shoulder pain. It asks 12 questions, each with five potential answers, covering pain and functional disability. The OSS was specifically designed as a research tool to assess outcomes following shoulder surgery; however, it does not provide more holistic information. The EQ-5D-5L and EQ-VAS are also subjective scoring systems assessing some of these more holistic aspects of care, including treatment expectations, patient perception, satisfaction and anxiety and depression.

Outcome assessments were performed preoperatively and ≥6 months postoperatively. To translate the data into a more patient-centered format, a validated matrix formula was applied [14,22]. The three outcomes tools were converted to have a uniform scale, where positive and negative findings shared the same polarity. In total, the outcome score included values added from 20 questions that formed the basis of the tier two outcomes

[23,24]. These questions were re-formatted into questions relating to the three domains of pain, function and psychological and secondary health markers, which were mathematically converted to a uniform score out of 100 points, where 0 points represented the worst outcome possible and 100 points represented the best. The scores for each of the three domains could then be summed to form an aggregate score out of 300 points. The percentage change between a patient’s preoperative and postoperative outcomes was then compared across each separate domain to determine the summed score percentage change. Outcomes were assessed as an entire dataset and sub-group analysis by grade of co-existing arthritis and tear size.

**Statistical Analysis**

Chi-square testing was used to assess the relationship between nominal categorical variables. Mann-Whitney-Wilcoxon testing was performed to assess the relationship between continuous non-parametric data (OES, EQ-5D-5L and EQ-VAS scores). A p-value of 0.05 or less was considered statistically significant.

**RESULTS**

This study included 54 patients (20 men and 34 women) with an average age of 61 years (range, 41–81 years). A variation in tear sizes was noted in the cohort, with less massive tears dominating; however, there was no significant imbalance between the groups (Table 1). The observed spectrum of rotator cuff pathology in

**Table 1.** Summary of arthroscopic findings and events at surgery

Variable	Number of patient	p-value
RCT size (cm)		0.19
0–2	20	
2–4	20	
>4	14	
OA grade		0.70
0	12 (22)	
1	11 (20)	
2	19 (35)	
3	9 (17)	
4	3 (6)	
Additional procedure undertaken at arthroscopy	LHB tenotomy, 5; ACJ decompression, 3; LHB tenotomy & ACJ decompression, 1; glenohumeral debridement, 3	-
Procedures per consultant	Consultant 1, 34; consultant 2, 15; consultant 3, 5	-
Complication	Postoperative glenohumeral capsulitis, 2	-
Further procedure	Postoperative US-guided glenohumeral joint hydrodilatation, 2	-

Values are presented as number or number (%).

RCT: rotator cuff tear, OA: osteoarthritis (grade by Outerbridge classification), LHB: long head of biceps, ACJ: acromioclavicular joint, US: ultrasound.

this study was in keeping with most general shoulder practices. Similarly, there was variation in coexisting patches of glenohumeral degenerative cartilaginous changes (Table 1). When the size of the tear was compared against the grade of pre-existing degenerative change, it was noted that the smaller tears (< 2 cm) more frequently had less progressive cartilaginous changes (grade 0 or 1) compared to those with larger RCTs (Table 2). Conversely, those with the greatest RCT size (> 4 cm) had significantly more progressive cartilaginous changes (grade 3 or 4) compared to those with smaller RCTs ( $p=0.03$ ).

The average duration for follow-up was 19 months (range, 6–27 months). The average range of movement at discharge regarding forward flexion was 166° (range, 80°–180°) and abduction was 162° (range 70°–180°), respectively. A low rate of com-

plications was observed ( $n=2/54$ , 3%), and both complications related to postoperative capsulitis and both patients had a successful outcome following ultrasound-guided glenohumeral joint hydrodilatation (Table 1). No other subsequent procedures were performed on the operated shoulders.

When the whole-cohort clinical outcomes were assessed using the OSS, EQ-5D-5L questionnaire, and EQ-VAS, a significant improvement ( $p<0.05$ ) were recognized (Tables 3 and 4). This was noted when values were analyzed by either the traditional or re-formatted scoring measures (Table 5). When the outcome measures were reorganized to assess the domains of pain, function and psychological well-being, there were significant improvements recorded; however, this was accompanied by some variation at the patient level, with not all patients uniformly see-

**Table 2.** Patients categorized following comparison of arthroscopic findings (grade of pre-existing cartilaginous degenerative change against the size of RCT)

RCT size	OA grade 0 (n = 12)	OA grade 1 (n = 11)	OA grade 2 (n = 19)	OA grade 3 (n = 9)	OA grade 4 (n = 3)
0–2 cm (n = 20)	5	6	6	3	0
2–4 cm (n = 20)	7	2	7	2	2
> 4 cm (n = 14)	0	3	6	4	1

Those RCT size of over 4 cm had significantly more progressive cartilaginous changes (grade 3 or 4), as against those with smaller RCTs ( $p=0.03$ ). RCT: rotator cuff tear, OA: osteoarthritis (grade by Outerbridge classification).

**Table 3.** Pre- and postoperative outcomes following arthroscopic rotator cuff repair

Variable	Mean preoperative value	Mean postoperative value	MWU*
Entire cohort			
OSS	21.6	44.2	U = 69.5, Z = -8.53, $p < 0.01$
EQ-5D	0.34	0.86	U = 122.5, Z = -8.20, $p < 0.01$
EQ-VAS	45.4	88.0	U = 177.5, Z = -7.86, $p < 0.01$
OA grade			
G0 OSS	23.6	44.9	U = 2.5, Z = -3.98, $p < 0.01$
G0 EQ-5D	0.47	0.85	U = 12.5, Z = -3.41, $p < 0.01$
G0 EQ-VAS	53.3	91.3	U = 6, Z = -3.78, $p < 0.01$
G1 OSS	26.5	45.5	U = 5.5, Z = -3.58, $p < 0.01$
G1 EQ-5D	0.47	0.91	U = 0.5, Z = -3.91, $p < 0.01$
G1 EQ-VAS	51.8	90.9	U = 7, Z = -3.48, $p < 0.01$
G2 OSS	19.4	42.4	U = 1, Z = -5.23, $p < 0.01$
G2 EQ-5D	0.22	0.81	U = 4, Z = -5.14, $p < 0.01$
G2 EQ-VAS	43.7	82.6	U = 18, Z = -4.73, $p < 0.01$
G3 OSS	18.2	44.9	U = 0, Z = 3.53, $p < 0.01$
G3 EQ-5D	0.23	0.87	U = 2.5, Z = -3.31, $p < 0.01$
G3 EQ-VAS	32.9	89.1	U = 3.5, Z = -3.22, $p < 0.01$
G4 OSS	20.3	46.0	U = 0.5, Z = -2.72, $p < 0.01$
G4 EQ-5D	0.37	0.97	U = 0, Z = -2.80, $p < 0.01$
G4 EQ-VAS	38.3	91.6	U = 2.5, Z = -2.75, $p < 0.01$

MWU: Mann-Whitney U-test, OSS: Oxford Shoulder Score, EQ-5D: EuroQol-5D, EQ-VAS: EuroQol visual analog scale, OA: osteoarthritis (grade by Outerbridge classification).

\*A p-value of 0.05 or less was considered statistically significant.

**Table 4.** Pre- and postoperative outcomes following arthroscopic rotator cuff repair charted by size of RCT

RCT size	Mean preoperative value	Mean postoperative value	MWU*
0–2 cm OSS	21.8	44.7	U = 3.5, Z = -5.45, p < 0.01
0–2 cm EQ-5D	0.31	0.87	U = 24.5, Z = -4.92, p < 0.01
0–2 cm EQ-VAS	44.8	89.6	U = 22, Z = -4.98, p < 0.01
2–4 cm OSS	20.5	44.4	U = 2.5, Z = -5.32, p < 0.01
2–4 cm EQ-5D	0.35	0.87	U = 10, Z = -5.13, p < 0.01
2–4 cm EQ-VAS	45	88	U = 19, Z = -4.88, p < 0.01
> 4 cm OSS	23.2	43.2	U = 12.5, Z = -3.66, p < 0.01
> 4 cm EQ-5D	0.38	0.81	U = 7.7, Z = -3.92, p < 0.01
> 4 cm EQ-VAS	46.9	85.0	U = 15, Z = -3.54, p < 0.01

RCT: rotator cuff tear, MWU: Mann-Whitney U-test, OSS: Oxford Shoulder Score, EQ-5D: EuroQol-5D, EQ-VAS: EuroQol visual analog scale, OA: osteoarthritis (grade by Outerbridge classification).

\*A p-value of 0.05 or less was considered statistically significant.

**Table 5.** Outcomes by traditional and patient centric re-formatted frameworks

Outcome methodology	Outcome assessment	Positive change (%)
Traditional outcomes	OSS	47
	5-Level EQ-5D	33
	EQ-VAS	43
Patient centric reformatted prisms	Pain	48
	Function	33
	Psychological well-being	29

OSS: Oxford Shoulder Score, EQ-5D: EuroQol-5D, EQ-VAS: Euroqol visual analog scale.

ing improvement in all domains (Figs. 1 and 2).

A sub-group analysis of outcomes by pre-existing degenerative changes indicated that preoperative scores were not significantly different independent of the grade of degenerative change. There was a significant improvement within individual sub-groups compared to between pre- and postoperative scores ( $p < 0.05$ ). However, there was no notable difference in end-outcome scores amongst the different grades of cartilaginous degenerative changes ( $p > 0.05$ ). Patients were additionally assessed from the perspective of whether their end-outcomes were better or worse than their presenting position, and their relative changes, being either positive or negative, were individually plotted on a line of best fit (Fig. 2); ultimately, almost all results were on the positive side of the line of fit, indicating an improvement in their condition. However, there was an element of variance in outcomes, with not all patients having the same experience.

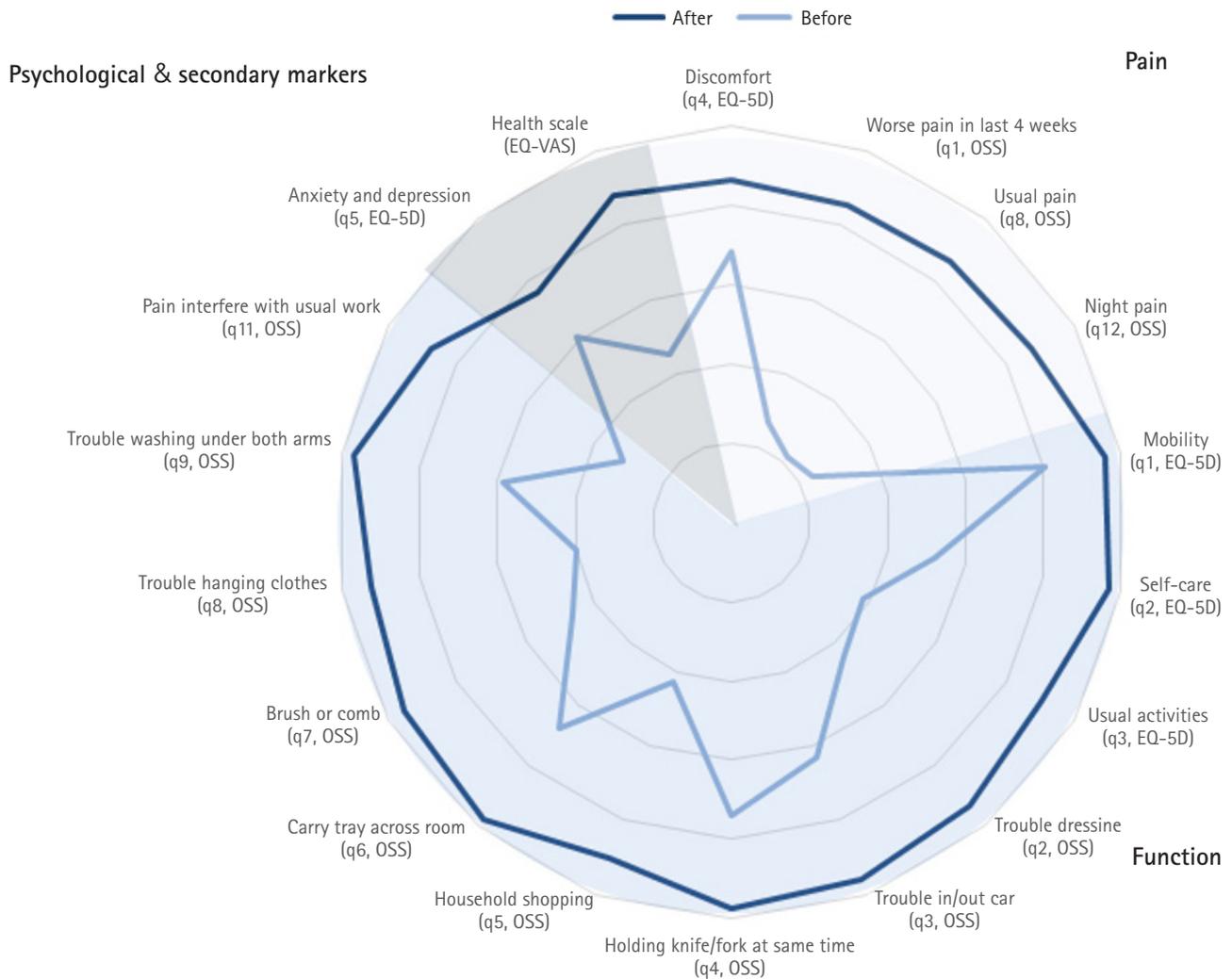
Sub-group analysis of outcomes by RCT size indicated that preoperative scores were not significantly different independent of RCT size ( $p > 0.05$ ). There was a significant improvement within individual sub-groups compared to between pre- and postoperative scores ( $p < 0.05$ ). However, there was no significant

difference in end-outcome scores amongst the different classes of RCT size assessed.

## DISCUSSION

This study has demonstrated that good clinical outcomes can be achieved following RCT repair even in the presence of local partial degenerative cartilaginous changes and advancing RCT size. As such, the hypothesis that pre-existing degenerative changes would inhibit end-outcomes has not been proved. The described clinical outcome benefits are patient-centered but require RCT repairability. The data presented indicate a positive gain independent of the grade of partial degenerative cartilaginous changes. However, the achieved improvements in outcomes were not universal and did not routinely return the individual to complete normality (Table 3 and Fig. 2). Rather, RCR surgery led to a significant positive change in outcomes that had meaning to the patients with respect to the domains of pain, function and psychological well-being (Table 5).

It is accepted that the surgical management of symptomatic RCTs is a high-value care intervention [14]. Previous randomized controlled trials assessing the management of patients with surgical repair of RCTs versus non-surgical care strategies had to be halted and adapted because of high cross-over rates for those in the non-surgical arms subsequently requiring surgical fixation [11]. If those with symptomatic RCTs are neglected, the scenario can deteriorate and increase the risk of progression toward a classical rotator cuff arthropathy picture [8,9,16,17,25]. Such a situation is more complex to manage and is associated with less favorable end-results compared to the management of a simple RCT. Many would agree that avoiding the potential morbidity of arthroplasty if possible is an attractive goal. National guidelines suggest arthroplasty is rarely the first-line treatment option [26].

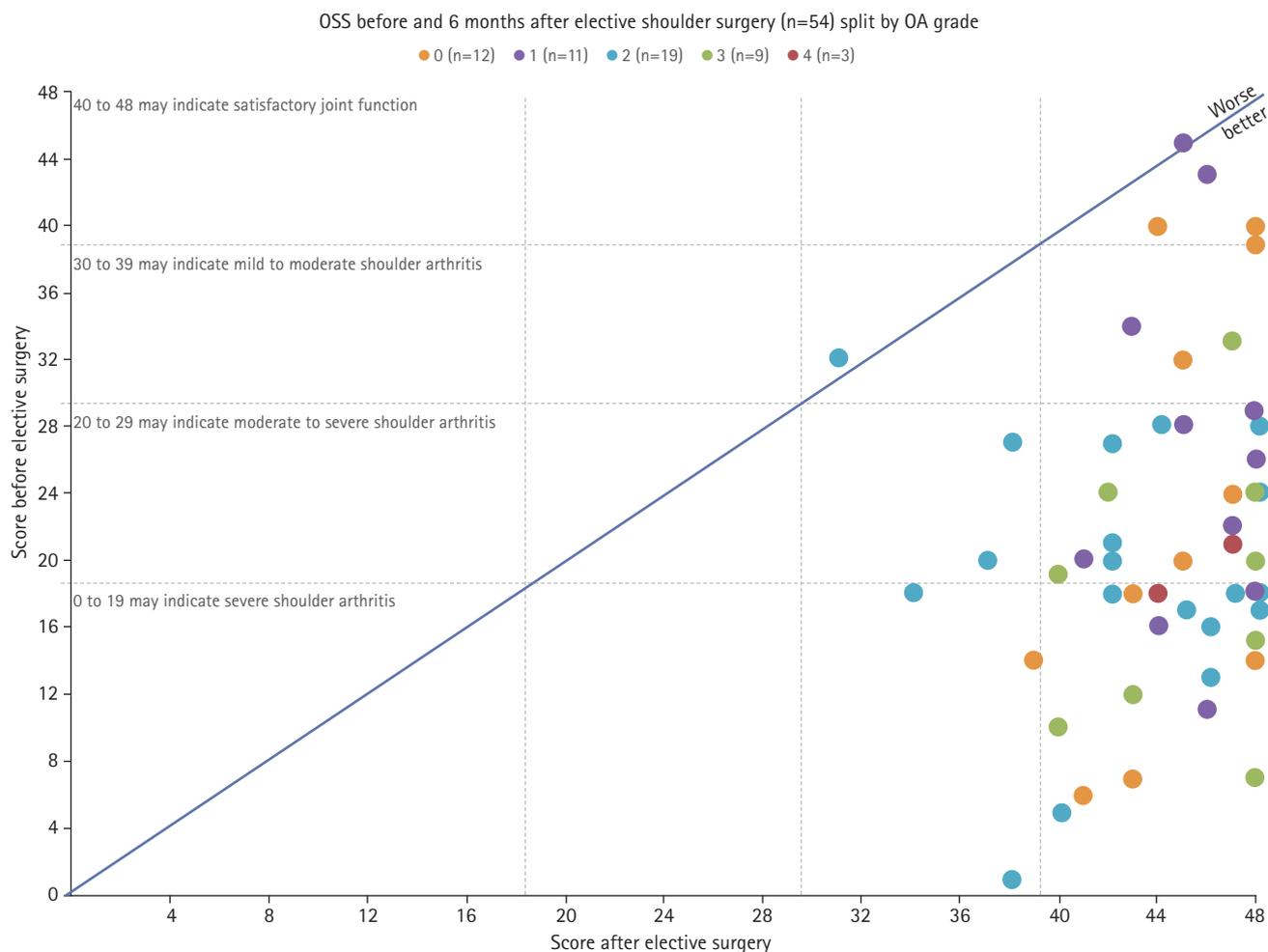


**Fig. 1.** Radar graph displaying the changes in response to individual patient-related outcome measure (PROM) questions before and after surgery. The Oxford Shoulder Score (OSS), 5-level EuroQol-5D (EQ-5D) questionnaire, and EuroQol visual analog scale (EQ-VAS) values were re-formatted to present a patient-centric representation of PROMs before and after rotator cuff repair surgery. q: question.

The financial costs of arthroplasty are also high compared to arthroscopic RCR [14,15].

Whilst the presentations of a conventional uncomplicated RCT and that of a rotator cuff arthropathy are markedly different, they are on the same continuum of disease. Generally, the concept of delaying or reversing disease progression is attractive if possible, and such logic is accepted when offering RCR to patients. In turn, RCR is noted to be a high-value intervention [14]. The demographic of patients with symptomatic RCT is similar to those that may be developing partial degenerative cartilaginous changes. Local partial progressive cartilage changes are often noted at arthroscopy. A reasonable working hypothesis could be that the end-outcomes of RCR may be less optimal in the presence of florid progressive degenerative changes; however, the impact of limited patches of change are less well appreciated.

The results in this study have demonstrated positive alterations in all groups of partial degenerative changes, although there were a limited number of patients enrolled with patches of grade 4 cartilaginous changes, so the data should be interpreted judiciously. It must be noted that those who did exhibit grade 4 changes had small discrete patches of change only. The presence of such progressive changes was not expected prior to surgery, and the patches themselves were very limited. As such, these patients did not represent a classical rotator cuff arthropathy picture. Patients with florid grade 4 changes were not considered. Arthroscopic RCR is not the advocated treatment in those with gross widespread bone-on-bone glenohumeral degenerative changes, and such presentations were excluded in this study [26,27]. Interestingly, however, the data showed similar levels of improvement following RCR in patients with other grades of



**Fig. 2.** Change in outcome following rotator cuff repair surgery from a better versus worse perspective compared to the individual patient’s preoperative state as measured by the Oxford Shoulder Score (OSS). OA: osteoarthritis (graded by the Outerbridge classification).

partial cartilaginous changes. The data also indicated a correlation regarding the presence of more advanced grades of cartilage changes in those with larger RCTs. This finding is in keeping with existing experiences. The notable benefit of RCR to such patients is likely linked to the reactivation of the rotator cuff couple and biomechanical axis of action [28,29]. This in turn promotes stabilization of glenohumeral movement whilst attenuating eccentric high-energy glenohumeral loading. This theoretically could inhibit further cartilage misloading or injury. The evidence for this in the glenohumeral joint is limited, but the concept of restoring the mechanical axis to protect the joint is well established in other joints, with osteotomy surgery being an example of how this theory is clinically enacted [30]. Following RCR, patients enjoy heightened success if they have factors in favor of reparability [16]. As such, a nuanced surgical decision-making process is crucial, and offering RCR to patients in the absence of such positive characteristics may not lead to such

a successful outcome.

Analyzing the degree of failure or success following an intervention can be challenging. Objective classical scoring measures, such as OSS, offer potential solutions with absolute scores. Such scores in isolation fail to express the degree of change delivered by the treatment and may lack real-world relevance to the patient. The current study assessed outcomes using traditional and re-formatted measures that can be readily interchanged. Previous works have highlighted the patient-centered benefits when using outcomes that are easily intelligible and relevant to patients [14,22]. Within this study, this approach helped to highlight the notable improvements in those who had more progressive cartilaginous change or larger-sized RCTs. This may reflect the fact that they enjoyed a greater potential uplift from a poorer starting point and, in turn, this considerable improvement in their biomechanical action triggered a meaningful change in their symptoms.

This study has several obvious limitations, which include the limited number of patients in the study and the fact that the patient sub-groups were unmatched in number or demographics. There is no long-term follow-up data of this group currently available, and it is possible that some of the patients may experience disease progression, requiring additional treatment. Given that the patients assessed had demonstrable cartilaginous changes, it is possible that, over time, some of these patients may require arthroplasty. This study can provide no estimation of the number or sub-groups that might trend to this point. The enrolled patients did not undergo routine postoperative imaging to evaluate the RCR. This is not part of the unit's standard practice and, as such, this present study cannot conclusively report on cuff integrity; however, outcomes were assessed clinically in keeping with accepted national practice. This study was undertaken at a single center by a limited number of surgeons. However, there was a shared management philosophy and surgical technique amongst the surgeons that enhanced the standardization of the treatment pathway. The re-formatted outcome prisms were unequally weighted, specifically regarding the assessment of psychological well-being. We would expect that future revisions would require this domain of analysis to be expanded and directed by patient-derived measures.

In conclusion, this study provides evidence that good clinical outcomes can be achieved following RCT repair, even in the presence of local partial degenerative cartilage changes and advancing tear size. These benefits are patient-centered but require RCT reparability. We advise that patients undergo careful selection, especially if more advanced patches of degenerative change are suspected in combination with larger-sized RCTs. Repairing the symptomatic RCT patient before they convert to a rotator cuff arthropathy can offer potential salvage and, as such, is a high-value intervention. We recommend that RCR should be considered following appropriate review in those with biological reparability, even in the presence of partial glenohumeral degenerative changes.

## REFERENCES

1. Linsell L, Dawson J, Zondervan K, et al. Prevalence and incidence of adults consulting for shoulder conditions in UK primary care; patterns of diagnosis and referral. *Rheumatology (Oxford)* 2006;45:215-21.
2. Beard DJ, Rees JL, Cook JA, et al. Arthroscopic subacromial decompression for subacromial shoulder pain (CSAW): a multi-centre, pragmatic, parallel group, placebo-controlled, three-group, randomised surgical trial. *Lancet* 2018;391:329-38.
3. Bunker T. Rotator cuff disease. *Current Orthopaedics* 2002;16:223-33.
4. Oliva F, Osti L, Padulo J, Maffulli N. Epidemiology of the rotator cuff tears: a new incidence related to thyroid disease. *Muscles Ligaments Tendons J* 2014;4:309-14.
5. Matthews TJ, Hand GC, Rees JL, Athanasou NA, Carr AJ. Pathology of the torn rotator cuff tendon: reduction in potential for repair as tear size increases. *J Bone Joint Surg Br* 2006;88:489-95.
6. Tempelhof S, Rupp S, Seil R. Age-related prevalence of rotator cuff tears in asymptomatic shoulders. *J Shoulder Elbow Surg* 1999;8:296-9.
7. Sher JS, Uribe JW, Posada A, Murphy BJ, Zlatkin MB. Abnormal findings on magnetic resonance images of asymptomatic shoulders. *J Bone Joint Surg Am* 1995;77:10-5.
8. Moosmayer S, Gärtner AV, Tariq R. The natural course of non-operatively treated rotator cuff tears: an 8.8-year follow-up of tear anatomy and clinical outcome in 49 patients. *J Shoulder Elbow Surg* 2017;26:627-634.
9. Ranebo MC, Björnsson Hallgren HC, Norlin R, Adolphsson LE. Clinical and structural outcome 22 years after acromioplasty without tendon repair in patients with subacromial pain and cuff tears. *J Shoulder Elbow Surg* 2017;26:1262-70.
10. Gurnani N, van Deurzen DE, van den Bekerom MP. Shoulder-specific outcomes 1 year after nontraumatic full-thickness rotator cuff repair: a systematic literature review and meta-analysis. *Shoulder Elbow* 2017;9:247-57.
11. Carr AJ, Cooper CD, Campbell MK, et al. Clinical effectiveness and cost-effectiveness of open and arthroscopic rotator cuff repair (the UK Rotator Cuff Surgery (UKUFF) randomised trial). *Health Technol Assess* 2015;19:1-218.
12. van Deurzen DE, Scholtes VA, Willems WJ, et al. Long-term results of arthroscopic and mini-open repair of small- to medium-size full-thickness rotator cuff tears. *Shoulder Elbow* 2019;11(1 Suppl):68-76.
13. Nicholson JA, Searle HK, MacDonald D, McBirnie J. Cost-effectiveness and satisfaction following arthroscopic rotator cuff repair: does age matter. *Bone Joint J* 2019;101:860-6.
14. Holzer-Fleming C, Tavakkolizadeh A, Sinha J, Casey J, Moxham J, Colegate-Stone TJ. Value-based healthcare analysis of shoulder surgery for patients with symptomatic rotator cuff tears: calculating the impact of arthroscopic cuff repair. *Shoulder Elbow* 2020 Jul 2 [Epub]. <https://doi.org/10.1177/1758573220928258>.
15. Steen BM, Cabezas AF, Santoni BG, et al. Outcome and value of reverse shoulder arthroplasty for treatment of glenohumeral osteoarthritis: a matched cohort. *J Shoulder Elbow Surg* 2015;

- 24:1433-41.
16. Kim SJ, Park JS, Lee KH, Lee BG. The development of a quantitative scoring system to predict whether a large-to-massive rotator cuff tear can be arthroscopically repaired. *Bone Joint J* 2016;98:1656-61.
  17. Tse AK, Lam PH, Walton JR, Hackett L, Murrell GA. Ultrasound determination of rotator cuff tear reparability. *Shoulder Elbow* 2016;8:14-21.
  18. Outerbridge RE. The etiology of chondromalacia patellae. *J Bone Joint Surg Br* 1961;43:752-7.
  19. American Society of Anesthesiologists. ASA physical status classification system [Internet]. Schaumburg, IL: American Society of Anesthesiologists; 2020 [cited 2022 Jan 30]. Available from: <https://www.asahq.org/standards-and-guidelines/asa-physical-status-classification-system>.
  20. Dawson J, Fitzpatrick R, Carr A. Questionnaire on the perceptions of patients about shoulder surgery. *J Bone Joint Surg Br* 1996;78:593-600.
  21. EuroQol Group. EQ-5D-5L user guide: basic information on how to use the EQ-5D-5L instrument [Internet] Rotterdam: EuroQol Research Foundation; 2009 [cited 2022 Jan 30]. Available from: <https://euroqol.org/eq-5d-instruments/eq-5d-5l-about/>.
  22. Gabriel L, Casey J, Gee M, et al. Value-based healthcare analysis of joint replacement surgery for patients with primary hip osteoarthritis. *BMJ Open Qual* 2019;8:e000549.
  23. Porter M, Lee TH. The strategy that will fix health care. Boston, MA: Harvard Business Review; 2013.
  24. Porter ME. What is value in health care. *N Engl J Med* 2010; 363:2477-81.
  25. Yamaguchi K, Tetro AM, Blam O, Evanoff BA, Teefey SA, 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.
  26. Thomas M, Bidwai A, Rangan A, et al. Glenohumeral osteoarthritis. *Shoulder Elbow* 2016;8:203-14.
  27. British Elbow and Shoulder Society. BESS Patient Care Pathways (PCPs). Standardising referral guidelines and optimising outcomes for shoulder patients. Shoulder pain, diagnosis, treatment and referral guidelines for primary, community and intermediate care: a BESS/BOA guideline summary to support the NHS EBI programme [Internet]. London: British Elbow and Shoulder Society; 2020 [cited 2022 Jan 30]. Available from: [https://bess.ac.uk/national-guidelines/#all\\_0-1421-wpfd-primary-intermediate-care-guidelines](https://bess.ac.uk/national-guidelines/#all_0-1421-wpfd-primary-intermediate-care-guidelines).
  28. Hansen ML, Otis JC, Johnson JS, Cordasco FA, Craig EV, Warren RF. Biomechanics of massive rotator cuff tears: implications for treatment. *J Bone Joint Surg Am* 2008;90:316-26.
  29. Thompson WO, Debski RE, Boardman ND 3rd, et al. A biomechanical analysis of rotator cuff deficiency in a cadaveric model. *Am J Sports Med* 1996;24:286-92.
  30. Laprade RF, Spiridonov SI, Nystrom LM, Jansson KS. Prospective outcomes of young and middle-aged adults with medial compartment osteoarthritis treated with a proximal tibial opening wedge osteotomy. *Arthroscopy* 2012;28:354-64.