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Incidence and risk factors for shoulder stiffness after open and arthroscopic rotator cuff repair

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Abstract

Introduction The aim of this study was to estimate the incidence of stiffness during the first 6 months after rotator cuff repair and to evaluate postoperative stiffness with respect to its risk factors and its influence on the outcome at 6 months postoperatively.

Methods In a prospective cohort of 117 patients (69 women, 48 men; average age 59) from our institutional rotator cuff registry, who underwent either arthroscopic ($n=77$) or open ($n=40$) rotator cuff repair, we measured shoulder range of motion (ROM) at 3 and 6 months post-surgery. We evaluated the incidence of stiffness and analyzed functional outcomes, comparing various preoperative and intraoperative factors in patients with stiffness to those without at the 6-month mark.

Results Shoulder stiffness was observed in 31% of patients (36/117) at 3 months postoperatively, decreasing to 20% (23/117) at 6 months. No significant link was found between stiffness at 6 months and demographic factors, preoperative stiffness, tear characteristics, or the type of repair. Notably, patients undergoing arthroscopic repair exhibited a 4.3-fold higher risk (OR 4.3; 95% CI 1.2–15.6, $p=0.02$) of developing stiffness at 6 months compared to those with mini-open repair. Despite these differences in stiffness rates, no significant variation was seen in the American Shoulder and Elbow Surgeons (ASES) score, Single Assessment Numeric Evaluation (SANE) score, or Visual Analog Scale (VAS) scores at 6 months between the groups.

Conclusion The incidence of postoperative shoulder stiffness following rotator cuff repair was substantial at 31% at 3 months, reducing to 20% by 6 months. Mini-open repair was associated with a lower 6-month stiffness incidence than arthroscopic repair, likely due to variations in rehabilitation protocols. However, the presence of stiffness at 6 months post-surgery did not significantly affect functional outcomes or pain levels.

Keywords Rotator Cuff Repair · Shoulder stiffness · Arthroscopic surgery · Mini-open Repair · Postoperative outcomes

Introduction

The prevalence of rotator cuff tears has risen in tandem with an aging global population and increased physical activity among adults ([1, 2]. Over recent years, there has been a notable rise in the incidence of rotator cuff surgeries worldwide [3, 4], with arthroscopic surgery emerging as the preferred method for addressing rotator cuff issues [5]. Despite its generally positive outcomes, rotator cuff repair can entail several complications, such as infections, repair failures, retears, deep vein thrombosis, and notably, postoperative shoulder stiffness [6, 7].

Postoperative shoulder stiffness stands out as a predominant complication after rotator cuff repair [6]. Stiffness manifests as shoulder discomfort and diminished ROM, thereby impeding patients' routine daily activities. The reported incidence of this complication varies significantly—between

This study was approved by our Institutional Review Board.

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4.9–39%—largely due to the absence of a universally accepted definition for stiffness [8–14]. Current definitions predominantly rely on clinical judgment, rather than empirical evidence [6].

Various risk factors are associated with shoulder stiffness following rotator cuff repair. These include being younger than 50 years of age, having type I diabetes mellitus or hypothyroidism, a history of calcific tendonitis or capsulitis, the size and type of the tear, undergoing concurrent labral procedures, the presence of glenohumeral synovitis, inconsistent adherence to physical therapy, and cases involving workers' compensation [10–12, 15–19]. Nevertheless, the available research presents a degree of variability and inconsistency, with only a handful of risk factors consistently cited [19].

This study aims to determine the incidence of stiffness within the initial 6 months following both open and arthroscopic rotator cuff repairs. Additionally, we seek to assess the potential risk factors for postoperative stiffness and its subsequent impact on outcomes at the 6-month postoperative mark.

Materials and methods

Patient selection

Between January 2017 and July 2020, patients treated with either open or arthroscopic rotator cuff repair, and who were subsequently enrolled in our rotator cuff repair registry, were retrospectively studied. The study obtained approval from our institutional review board. Eligible participants were those aged over 18 years who underwent either open or arthroscopic rotator cuff repair and had complete passive and active ROM records at 6 months post-surgery. On the other hand, patients were excluded if they had an isolated subscapularis tear, a postoperative surgical site infection, partial rotator cuff repair or massive irreparable tears, or required revision or reoperation within the first 6 months post-surgery. Additionally, patients with glenohumeral osteoarthritis, cuff arthropathy, a history of prior rotator cuff repair, or those who underwent concomitant procedures during repair such as superior capsule reconstruction, subacromial balloon placement, or labral repair were also excluded.

During the specified study period, two surgeons performed 325 rotator cuff repairs (205 arthroscopic, 120 mini-open). After exclusions (Fig. 1), the final study cohort comprised 117 repairs: 40 mini-open and 77 arthroscopic.

Patient demographics showed a mean age of 59 ± 10 years, with 59% being females. Furthermore, 67% of the cases involved degenerative tears. The average tear size, as measured intraoperatively, was 21.7 mm x 20.7 mm. Detailed demographic and intraoperative data are presented in Table 1.

Surgical technique and rehabilitation

The two surgical approaches, mini-open and arthroscopic, were respectively performed by two distinct surgeons: JCG and GFP. Each procedure had its specific nuances in terms of patient positioning, incision strategy, and surgical techniques. The choice of anchor numbers and repair configurations depended on the nature and size of the tear, with the double-row repair being the predominant method, used in 63% of cases. Post-operatively, patients followed a rehabilitation program based on our Rotator Cuff Clinical Care Center's five-phase protocol, detailed in the Appendix. It's worth noting that the start of the rehabilitation varied between the two surgical methods: patients who underwent the mini-open repair began rehabilitation 2 weeks post-surgery, whereas those who had arthroscopic repair started 4 weeks post-surgery.

Patient assessment

ROM evaluations were performed at baseline and then again at 12- and 24-weeks post-operation. Other collected data included patient demographics, comorbidities such as hypothyroidism, diabetes, and obesity, and the origin of the tear, whether degenerative or traumatic. Further evaluations utilized the Zanetti system to assess supraspinatus atrophy and the Goutallier classification for fatty infiltration. Lastly, postoperative evaluations included the American Shoulder and Elbow Surgeons (ASES) score and the Single Assessment Numeric Evaluation (SANE) at both the 12- and 24-week intervals.

Statistical methods

For the purposes of our analysis, shoulders were classified into two distinct groups based on the presence or absence of stiffness at the 6-month postoperative mark. Recognizing the absence of a universally accepted definition for shoulder stiffness following rotator cuff repair, we adopted a distribution-centric criterion. Specifically, individuals with shoulder flexion and/or external rotation at or below the 15th percentile, according to the distribution of each motion at every evaluation interval, were categorized under the "stiff" group. Conversely, those surpassing the 15th percentile threshold for each movement were placed in the "non-stiff" group.

Our analysis set out to compare a variety of factors between these two groups. These included demographic data, preoperative stiffness indicators, tear specifics, the

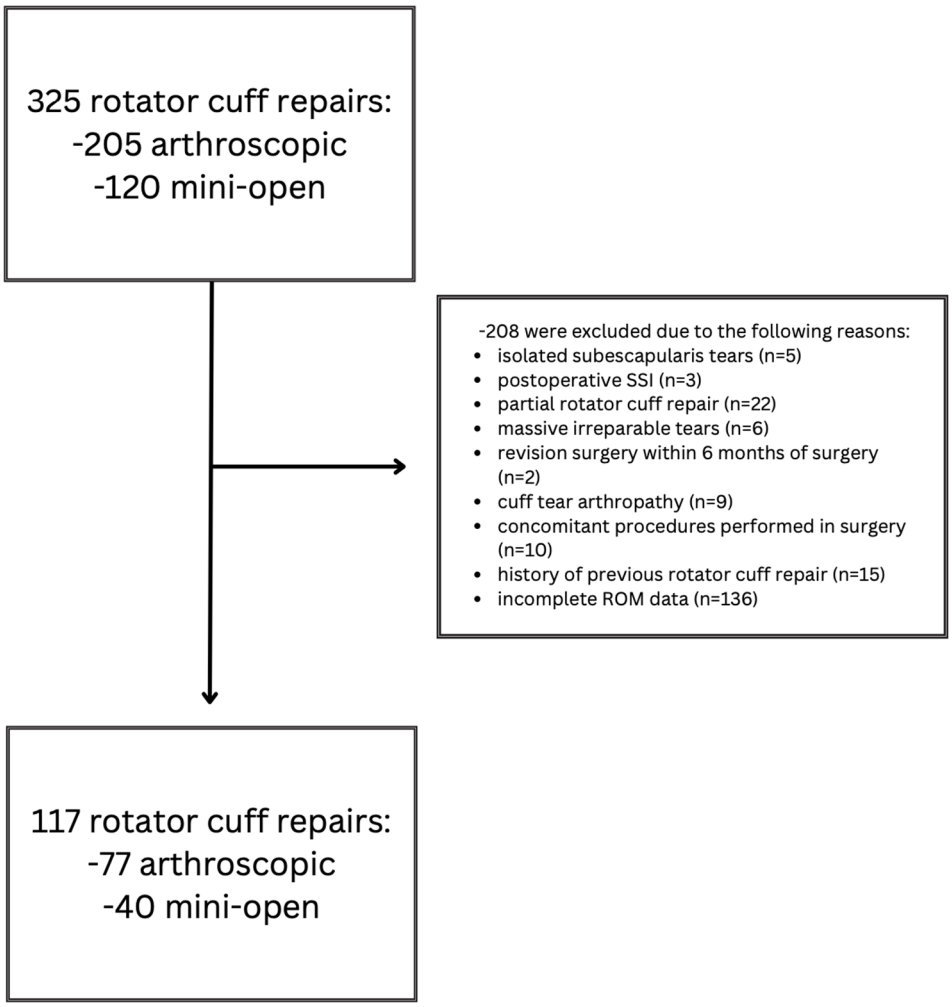

Fig. 1 Patient selection flowchart

chosen repair method (either open or arthroscopic), repair design, other intraoperative determinants, as well as the 6-month ASES and SANE scores. To discern differences in continuous variables, we employed independent t-tests, while Fisher's exact tests were utilized for categorical variables. The established threshold for statistical significance was a *P* value below 0.05.

To identify potential risk determinants for shoulder stiffness at the 6-months, a multiple logistic regression analysis was executed using the Firth technique. Variables that achieved a *P* value less than 0.25 in the univariate examination were considered suitable for the multivariate investigation. Variables deemed non-significant and not acting as confounders were systematically excluded from the model. We determined significance at an α level of 0.1. Furthermore, any alteration in a parameter estimate exceeding 15% in comparison to the comprehensive model was identified as confounding.

Results

Within the first 6 months post-operatively, 31% (36 out of 117) of the patients fulfilled our definition of stiffness at the 3-month evaluation, decreasing to 20% (23 out of 117) by 6 months. Of these 23 patients with stiffness at 6 months, 18 (78%) were already identified as stiff at 3 months. The remaining 5 (22%) were included in the stiffness category at 6 months not due to the development of new stiffness, but because their shoulder motion improvement was slower relative to the rest of the cohort, placing them below the 15th percentile for range of motion improvement.

Looking at the type of repair, those who underwent arthroscopic repair had a higher rate of stiffness than those with mini-open repair at both 3 months (40% vs. 12.5%, $p=0.002$) and 6 months (26% vs. 7.5%, $p=0.017$). Patient age, sex, or BMI showed no notable differences between the stiff and non-stiff groups (Table 2). The type of tear, whether degenerative or traumatic, did not significantly influence stiffness outcomes ($p=0.511$). Preoperative use

Table 1 Demographic, preoperative MRI and intraoperative variable for the entire cohort of patients

Characteristic	Total	Characteristic	Total
	(N = 117)		**(N = 117)**
Demografic variables		Intraoperative variables	
Age-yrs.		**Rotator cuff repair - no. (%)**	
Mean	58.7	Arthroscopic	77 (65.8)
Range	27–80	Mini-open	40 (34.2)
Sex – no. (%)		**Supra and infraspinatus medio-lateral tear size ******	
Male	48 (41)	Mean	20.7 mm
Female	69 (59)	Range	2–50 mm
Hand dominance – no. (%)		**Supra and infraspinatus anterior-posterior tear size ******	
Right	107 (91.5)	Mean	21.7 mm
Left	8 (6.8)	Range	2–55 mm
Ambidextrous	2 (1.7)	**Subscapularis tear - no. (%)**	
Comorbidities – no. (%)	30 (25.6)	No	74 (73.2)
Hypothyroidism	21 (70) (17.9)	Yes, but not repair	16 (13.7)
Diabetes mellitus type 2	9 (30) (7.7)	Yes, and repair	27 (23.1)
Etiology – no. (%)		**Subscapularis tendon medio-lateral tear size *****	
Degenerative	78 (66.7)	Mean	13.1
Traumatic	39 (33.3)	Range	1–40 mm
Shoulder operated – no. (%)		**Subscapularis tendon cefalo-caudal tear size ******	
Right	81 (69.2)	Type 1	11 (45.8)
Left	36 (30.8)	Type 2	2 (8.3)
Preoperative MRI variable		Type 3	7 (29.2)
		Type 4	4 (16.7)
Supra and infraspinatus medio-lateral tear size **		**Biceps tenotomy - no. (%)**	87 (74.4)
		Biceps tenodesis - no. (%)	52 (44.4)
Mean	16.2 mm	**Distal clavicle excision - no. (%)**	16 (13.7)
Range	3–55 mm	**Cuff interval release - no. (%)**	72 (61.5)
Supra and infraspinatus anterior- posterior tear size ***		**Posterior capsulotomy - no. (%)**	
Mean	16.4 mm	Yes	35 (29.9)
Range	3–57 mm	Yes, open release up to tear	25 (21.4)
Subscapularis tendon medio-lateral tear size *		No	57 (48.7)
Mean	13.5	**Anchor sutures - no. (%)**	
Range	10–17 mm	One	50 (42.7)
Subscapularis tendon cefalo-caudal tear size **		Two	44 (37.6)
T ype 1	5 (83.3)	Three	16 (13.7)
Type 2	1 (16.7)	Four	7 (6)
Muscle atrophy (Zanetti) – no. (%) **		**Rows - no. (%)**	
Without muscle atrophy	87 (77)	Single row repair	42 (36.2)
With muscle atrophy	26 (23)	Convergence - double dependent row repair	74 (63.8)
Fatty infiltration (Goutallier) – no. (%) *		**Convergence - no. (%) ***	

Table 1 (continued)

Characteristic	Total (N = 117)	Characteristic	Total (N = 117)
Demografic variables		Intraoperative variables	
Type 0	46 (40)	Yes	36 (31.3)
Type 1	65 (56.5)	No	70 (68.7)
Type 2	4 (3.5)	**Tear morphology - no (%)**	
		Crescent	60 (52.1)
		Longitudinal	25 (21.7)
		Massive	30 (26.1)

* Data in this variable at baseline was missing for two patients

** Data in this variable at baseline was missing for four patients

*** Data in this domain at baseline was missing for five patients

*** Data in this domain at baseline was missing for seven patients

+ Only two patients had Subscapularis tendon medio_lateral tear size

++ Only six patients had Subscapularis tendon cefalo-caudal tear size

+++ Only twelve patients had Subscapularis tendon medio_lateral tear size

++++ Only ttwenty four patients had Subscapularis tendon cefalo-caudal tear size

of anti-inflammatory drugs or opioids was not associated to 6-month stiffness (Table 2).

Preoperative pain levels, shoulder function scores, and tear size also did not differ significantly between the stiff and non-stiff groups (Table 2). A key finding was the significant association between the repair technique (arthroscopic vs. mini-open) and 6-month stiffness ($p = 0.017$; Table 2). Other procedures like biceps tenodesis, rotator interval release, or posterior capsule release weren't linked to stiffness at 6 months (Table 2).

In multivariate analysis, the repair technique emerged as the main factor associated with stiffness at 6 months. Patients who had arthroscopic repair were 4.3 times more likely (OR 4.3, 95% CI 1.2–15.6, $p = 0.02$) to experience stiffness at 6 months than those with mini-open repair.

Lastly, postoperative pain levels and shoulder function scores at 6 months showed no significant differences between the stiff and non-stiff groups (Table 2).

Discussion

Our study, which involved mini-open and arthroscopic rotator cuff repairs performed by two surgeons, revealed a post-operative shoulder stiffness rate of 30% at 3 months, decreasing to 20% at 6 months. Significantly, patients who underwent arthroscopic repairs were more prone to stiffness compared to those receiving mini-open repairs, with the repair method emerging as a key factor; arthroscopic patients had a fourfold higher stiffness risk at 6 months.

The variation in stiffness rates reported in literature (3–25%) could stem from different definitions of stiffness, varying study sizes, and diverse patient demographics [6, 20]. Various researchers have anchored their stiffness definitions either on specific motion thresholds, distribution-based percentile rankings, or patient-reported outcomes based on movement satisfaction [6, 8, 10–13, 16–18]. Huberty et al. classified it based on patients' satisfaction with their motion and found a 4.5% incidence in 489 arthroscopic repairs [12]. Parson et al. defined it by specific motion ranges (flexion < 100° and passive external rotation < 30° at 3 months postoperatively), noting a 23% incidence in 43 arthroscopic repairs [21]. Schneider et al. used combined flexion and rotation measures (sum of passive flexion and passive external rotation at 90° of abduction ≤ 220°), reporting rates of 7.3% at 12 weeks and dropping to 1.6% by 1 year in 150 patients [13]. Meanwhile, Chung et al. set thresholds for specific movements (limited flexion, external rotation, or internal rotation of < 120°, 30°, or L3, respectively) and observed incidences of 18.6% at 3 months, 2.8% at 6 months, and 6.6% at their final check in 228 patients [11].

Table 2 Patient characteristics and surgical variables between shoulders with and without stiffness 6 months after rotator cuff repair

	Total	Stiffness at 6 mo (%)		*P* value
		Yes	No	
No. shoulders	117	23	94	
Age (yr)	59 ± 10	60 ± 7	58 ± 11	0.471
Sex				
Male	48	9 (39)	39 (41)	0.837
Female	69	14 (61)	55 (59)	
BMI (kg/m^2)	24.8 ± 6.7	23.9 ± 8.1	25.1 ± 6.3	0.432
Etiology of the tear				
Degenerative	78	14 (61)	64 (68)	0.511
Traumatic	39	9 (39)	30 (32)	
Preoperative NAIDs (≥ 1 more pills per week)				
No	90	7 (32)	19 (20)	0.240
Yes	26	15 (68)	75 (80)	
Preoperative Opioids (≥ 1 more pills per week)				
No	114	23 (100)	91 (97)	0.385
Yes	3	0 (0)	3 (3)	
Hypothyroidism				
No	98	20 (87)	78 (83)	0.643
Yes	19	3 (13)	16 (17)	
Diabetes				
No	108	22 (96)	86 (91)	0.686
Yes	9	1 (4)	8 (9)	
Preoperative VAS pain (points)	6.7 ± 2.3	6.3 ± 2.3	6.7 ± 2.3	0.494
Preoperative ASES score (points)	39 ± 18	40 ± 21	39 ± 17	0.494
Preoperative SANE score (points)	51 ± 23	50 ± 23	51 ± 23	0.867
Preoperative passive flexion (degrees)	162 ± 19	163 ± 11	162 ± 19	0.799
Preoperative passive external rotation (degrees)	63 ± 15	62 ± 14	64 ± 15	0.686
Anteroposterior Tear size (mm)	22 ± 11	24 ± 12	21 ± 11	0.385
Repair technique				
Mini-open	40	3 (13)	37 (39)	0.017*
Arthroscopic	77	20 (87)	57 (61)	
Biceps tenodesis				
No	45	15 (65)	50 (53)	0.298
Yes	72	8 (35)	44 (47)	
Rotator interval release				
No	65	5 (22)	40 (43)	0.07
Yes	52	18 (78)	54 (57)	
Posterior capsular release				
No	57	10 (43)	47 (50)	0.575
Yes	60	13 (57)	47 (50)	
VAS pain at 6 months (points)	2.4 ± 2.3	2.4 ± 2.2	2.4 ± 2.4	0.996
ASES score at 6 months (points)	75 ± 16	73 ± 17	75 ± 14	0.456
SANE score at 6 months (points)	76 ± 14	73 ± 14	77 ± 13	0.343

Our study's relatively higher incidence may be attributable to our unique distribution-based stiffness definition, focusing on those below the 15th percentile for motion. Although differing from other studies, this criterion effectively identifies the lower-performing segment in our cohort's motion recovery, aligning closely with thresholds by Chung et al. [11].

We noted the typical reduction in post-operative shoulder stiffness over time, as supported by existing research [9, 10, 12, 18]. Unlike previous studies that have identified various potential risk factors for post-rotator cuff repair stiffness — such as age and comorbidities — [10–12, 16–19], our study did not find any significant associations with these factors However, the low prevalence of certain variables in our study might have obscured potential associations.

Guo et al. conducted a systematic review focusing on rotator cuff tears and stiffness. Their analysis encompassed seven studies primarily examining stiffness and retear rates.

Among these, four studies indicated that patients experiencing preoperative and early postoperative stiffness exhibited lower retear rates compared to those without stiffness. However, other studies failed to identify a significant distinction in retear rates between groups developing postoperative stiffness and those who did not, albeit with several noted limitations [22].

The influence of repair technique on stiffness has been debated in literature. In a comparative analysis between arthroscopic and mini-open rotator cuff repair, where both groups followed the same rehabilitation protocol, Severud et al. observed a 14% incidence of postoperative stiffness in the mini-open group, in contrast to none in the arthroscopic group [23]. Echoing this, Chung et al. found that mini-open cuff repair was associated with an increased risk of late-onset postoperative stiffness [11]. However, our findings diverge from these studies, indicating that mini-open repair actually resulted in lower stiffness rates. A pivotal distinction in our research was the timing of post-surgical movement initiation. Patients who underwent mini-open repair commenced their shoulder exercises two weeks earlier compared to those who had arthroscopic surgery. This earlier initiation of physical activity may be a critical factor in reducing stiffness. Additionally, the heterogeneity in arthroscopic and mini open repair techniques between different studies, could also help explain the variance in stiffness outcomes.

Interestingly, our study diverges from some findings in the literature that associate post-operative stiffness with pain and reduced function. We observed no significant differences in pain or functionality, as measured by patient-reported outcomes, between stiff and non-stiff groups.

This study has certain limitations. While a standardized rehabilitation protocol was recommended for all patients, patient compliance to the protocol was not measured and we do not know whether all the patients followed the recommended rehabilitation program. However, this is a frequent limitation in retrospective studies on this topic published in the literature. The sample size and the number of events (i.e., stiffness) was small and thus most of the associations evaluated in the study may be underpowered. A considerable number of patients were excluded of the study due to incomplete ROM data and this may have resulted in a selection bias. However, the baseline characteristics of these patients in terms of demographics, motion and tear size were not significantly different from those of the included cases. Finally, our study presents results only up to 6 months postoperatively and the incidence and risk factors for stiffness may be different at a longer-term follow-up.

Conclusion

The overall incidence of stiffens after open and arthroscopic rotator cuff repair was 31% at 3 months and significantly decreased to 20% at 6 months. In this cohort of patients, mini-open repair was associated with a lower incidence of stiffness at 6 months than arthroscopic repair probably due to a difference in the rehabilitation protocol between techniques. However, the presence of stiffness at 6 months did not influence functional outcomes or postoperative pain.

Appendix

Postoperative rehabilitation was performed by different physicians. However, the rehabilitation protocol is standardized and divided into 5 phases. In order to proceed to the following phase, the patient must accomplish the objectives of the previous stage with minimal pain.

Phase 1- immobilization phase (Week 0–4)

Patients were immobilized for 1 month, restricting shoulder movement, and instructed to perform exercises for the cervical spine, protraction and retraction of the scapula, and flexion and extension of the elbow, wrist, and fingers.

Phase 2- Passive Range of Motion Phase (Week 4–6)

Patients were referred to physiotherapist sessions to initiate pendulum exercises with gentle circular movements of no more than 20 centimeters in diameter (to avoid significant isometric contraction of the supraspinatus) and passive movements of the operated shoulder with the patient in the supine position (maximum flexion of 120 ° and external rotation of 30 °).

Phase 3- active Movement Phase (Week 6–12)

: Beginning at week 6, patient began active assisted exercises such as: scapula protraction and retraction both seated and in the supine position, flexion in the scapular plane and external rotation in the supine position, and progressive internal rotation exercises (without weight) in the lateral decubitus position. Moreover, extension and adduction of the shoulder plus isometric exercises of glenohumeral stabilizers were performed. From week 8 to 12, all active

movements of the shoulder in supine and lateral decubitus position were performed. Scapular stabilizer strengthening exercises and proprioceptive neuromuscular exercises were progressively introduced. Starting at week 10, active exercises assisted with a weight bar, starting with one pound, was initiated.

Phase 4 - strength phase (Week 12 - Month 5)

After three months, the following exercises were started: rotator cuff and deltoid strengthening exercises with bands and weights, proprioceptive reeducation exercises, and plyometric exercises.

Phase 5 - advance strength phase

The advanced strengthening phase is focused on patients whose work or recreational demands require loads or positions not reached in phases 3 and 4. It consisted of continuing the exercises in phase four while progressively increasing resistance.

Return to work

Patients returned to work around 6 to 8 weeks postoperative depending on the type of work activity and surgeon discretion.

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Declarations

Disclaimer None.

References

1. Milgrom C, Schaffler M, Gilbert S, van Holsbeeck M (1995) Rotator-cuff changes in asymptomatic adults. The effect of age, hand dominance and gender. J Bone Joint Surg Br 77:296–298
2. Tempelhof S, Rupp S, Seil R (1999) Age-related prevalence of rotator cuff tears in asymptomatic shoulders. J Shoulder Elb Surg 8:296–299. https://doi.org/10.1016/S1058-2746(99)90148-9
3. Thorpe A, Hurworth M, O'Sullivan P et al (2016) Rising trends in surgery for rotator cuff disease in Western Australia. ANZ J Surg 86:801–804. https://doi.org/10.1111/ans.13691
4. Vidal C, Lira MJ, de Marinis R et al (2021) Increasing incidence of rotator cuff surgery: a nationwide registry study in Chile. BMC Musculoskelet Disord 22:1052. https://doi.org/10.1186/s12891-021-04938-7
5. Kelly BC, Constantinescu DS, Vap AR (2019) Arthroscopic and open or Mini-open Rotator Cuff Repair trends and Complication Rates among American Board of Orthopaedic surgeons Part II examinees (2007–2017). Arthroscopy: J Arthroscopic Relat Surg 35:3019–3024. https://doi.org/10.1016/j.arthro.2019.06.022
6. Audigé L, Blum R, Müller AM et al (2015) Complications following arthroscopic rotator cuff tear repair. Orthop J Sports Med 3:232596711558786. https://doi.org/10.1177/2325967115587861
7. DiPompeo CM, Inabathula A, Kay K et al (2023) Complications and Retears following arthroscopic repair of full thickness rotator cuff tears. SN Compr Clin Med 5:62. https://doi.org/10.1007/s42399-023-01400-8
8. Baumann AN, Oleson C, Curtis DP et al (2023) The incidence of postoperative shoulder stiffness after arthroscopic rotator cuff repair: a systematic review. https://doi.org/10.7759/cureus.37199. Cureus
9. Baumann A, Oleson C, Curtis D et al (2023) Incidence of postoperative shoulder stiffness after arthroscopic rotator cuff repair. Arch Phys Med Rehabil 104:e4. https://doi.org/10.1016/j.apmr.2022.12.009
10. Cho C-H, Bae K-C, Kim D-H (2022) Incidence and risk factors for early postoperative stiffness after arthroscopic rotator cuff repair in patients without preoperative stiffness. Sci Rep 12:3132. https://doi.org/10.1038/s41598-022-07123-5
11. Chung SW, Huong CB, Kim SH, Oh JH (2013) Shoulder stiffness after Rotator Cuff Repair: risk factors and influence on Outcome. Arthroscopy: J Arthroscopic Relat Surg 29:290–300. https://doi.org/10.1016/j.arthro.2012.08.023
12. Huberty DP, Schoolfield JD, Brady PC et al (2009) Incidence and treatment of postoperative stiffness following arthroscopic rotator cuff repair. Arthroscopy: J Arthroscopic Relat Surg 25:880–890. https://doi.org/10.1016/j.arthro.2009.01.018
13. Schneider WR, Trasolini RG, Riker JJ et al (2021) Stiffness after arthroscopic rotator cuff repair: a rehabilitation problem or a surgical indication? JSES Int 5:88–92. https://doi.org/10.1016/j.jseint.2020.09.001
14. Seo S-S, Choi J-S, An K-C et al (2012) The factors affecting stiffness occurring with rotator cuff tear. J Shoulder Elb Surg 21:304–309. https://doi.org/10.1016/j.jse.2011.04.011
15. Audigé L, Aghlmandi S, Grobet C et al (2021) Prediction of shoulder stiffness after arthroscopic rotator cuff repair. Am J Sports Med 49:3030–3039. https://doi.org/10.1177/03635465211028980
16. Blonna D, Fissore F, Bellato E et al (2017) Subclinical hypothyroidism and diabetes as risk factors for postoperative stiff shoulder. Knee Surg Sports Traumatol Arthrosc 25:2208–2216. https://doi.org/10.1007/s00167-015-3906-z
17. Burrus MT, Diduch DR, Werner BC (2019) Patient-related risk factors for postoperative stiffness requiring Surgical intervention after arthroscopic rotator cuff repair. J Am Acad Orthop Surg 27:e319–e323. https://doi.org/10.5435/JAAOS-D-16-00929
18. Koo SS, Parsley BK, Burkhart SS, Schoolfield JD (2011) Reduction of postoperative stiffness after arthroscopic rotator cuff repair: results of a customized physical therapy regimen based on risk factors for stiffness. Arthroscopy: J Arthroscopic Relat Surg 27:155–160. https://doi.org/10.1016/j.arthro.2010.07.007
19. Stojanov T, Modler L, Müller AM et al (2022) Prognostic factors for the occurrence of post-operative shoulder stiffness after arthroscopic rotator cuff repair: a systematic review.

BMC Musculoskelet Disord 23:99. https://doi.org/10.1186/s12891-022-05030-4
20. Denard PJ, Lädermann A, Burkhart SS (2011) Prevention and Management of Stiffness after arthroscopic rotator cuff repair: systematic review and implications for Rotator Cuff Healing. Arthroscopy: J Arthroscopic Relat Surg 27:842–848. https://doi.org/10.1016/j.arthro.2011.01.013
21. Parsons BO, Gruson KI, Chen DD et al (2010) Does slower rehabilitation after arthroscopic rotator cuff repair lead to long-term stiffness? J Shoulder Elb Surg 19:1034–1039. https://doi.org/10.1016/j.jse.2010.04.006
22. Guo AA, Hackett L, Murrell GAC (2023) Stiffness and arthroscopic rotator cuff repair: a literature review. Ann Jt 8:7–7. https://doi.org/10.21037/aoj-22-26
23. Severud EL, Ruotolo C, Abbott DD, Nottage WM (2003) All-arthroscopic versus mini-open rotator cuff repair: a long-term retrospective outcome comparison. Arthroscopy: J Arthroscopic Relat Surg 19:234–238. https://doi.org/10.1053/jars.2003.50036