Published Online February 14, 2012

Shoulder stiffness and rotator cuff repair

Rocco Papalia[†], Francesco Franceschi[†], Sebastiano Vasta[†], Andrea Gallo[†], Nicola Maffulli[‡*], and Vincenzo Denaro[†]

[†]Department of Orthopaedic and Trauma Surgery, Campus Biomedico University of Rome, Via Alvaro del Portillo 200, Rome, Italy, and [‡]Centre for Sports and Exercise Medicine, Barts and The London School of Medicine and Dentistry, Mile End Hospital, 275 Bancroft Road, London E1 4DG, UK

Downloaded from https://academic.oup.com/bmb/article/104/1/163/326626 by guest on 16 August 2022

Introduction: Shoulder stiffness is a frequent complication of surgical repair of rotator cuff tears. Post-operative stiffness negatively affects surgical outcomes leading to a substantial comorbidity and to the failure of surgical treatment. Also, a stiff shoulder could commonly be concomitant with an rotator cuff tear (RCT).

Sources of data: We performed a comprehensive search of CINAHL, Embase, Medline and the Cochrane Central Registry of Controlled Trials, from inception of the database to 31 July 2011. Sixteen articles published in peer-reviewed journals were included in this comprehensive review.

Areas of controversy: The management of shoulder stiffness is still controversial. The role of rehabilitation programs (standard versus early passive mobilization) after RCT repair on the development of stiffness is not clear, while the role of arthroscopic capsular release for post-operative stiffness is better defined, although a threshold of decreased the range of movement for which capsular release is advised has not been identified.

Areas of agreement: Several factors have been identified to predispose the development of shoulder stiffness. There is also evidence in favor of surgical management of RCTs even when accompanied by shoulder stiffness, and there are strong evidences that arthroscopic capsular release is reliable and effective in managing shoulder stiffness.

Growing points: The post-operative rehabilitation protocol remains controversial. We are still far from definitive guidelines for the management of pre- and post-operative stiffness, and prospective double-blinded randomized clinical trials are needed to obtain evidence allowing to establish a reliable and effective management plan for shoulder stiffness.

**Correspondence address. Centre for Sports and Exercise Medicine, Barts and The London School of Medicine and Dentistry, Mile End Hospital, 275 Bancroft Road, London E1 4DG, UK. E-mail: n.maffulli@qmul.ac.uk*

Keywords: rotator cuff tears/shoulder/complications/outcome/systematic review/range of motion/stiffness/stiff shoulder

Accepted: January 4, 2012

© The Author 2012. Published by Oxford University Press.
All rights reserved. For permissions, please e-mail: journals.permissions@oup.com

Introduction

Shoulder stiffness is one of the most frequent complication of surgical repair of the rotator cuff (RC).[1,2] Although its incidence in not established, available studies report a rate ranging from 4.9[1] to 32.7%.[3] Post-operative stiffness negatively affects surgical outcomes, and, if untreated, leads to substantial morbidity, causing failure of surgical management. Post-operative stiffness may be related to immobility after surgery, or to rehabilitation programs which have been too conservative,[4–6] or to independent risk factors such as diabetes.[7] Also, a stiff shoulder could commonly accompany an RC tear. The exact etiology is still not established, but different factors have been suggested as possible causes: bursal inflammation, contracture and atrophy of the muscles as well as pain and weakness related to the injured RC tendons.[3] The definition of stiff shoulder is one other controversial point, and authors have used different definitions (Table 1). Few studies have reported on the management of pre- and post-operative shoulder stiffness and, as a consequence, little is known on how to best manage it. The uncertainty on the etiology of pre-operative shoulder stiffness accompanying an RC tear does not allow to establish whether a patient will recover from pain and disability after an RC tear repair; the role of rehabilitation after an RC tear repair on the development of stiffness is not clear, while the role of arthroscopic capsular release appears more certain in managing post-operative stiffness, although a threshold of decreased range of movement for which capsular release is advised has not been identified. The uncertainty on the management of

Table 1 Definition of stiff shoulder from different authors

Study	Definition of shoulder stiffness
Seo *et al*.[3]	Restriction of active and passive motions of 100° of elevation or less, <50% of external rotation when compared with the motion of the contralateral shoulder and internal rotation only to the sacrum
Parsons *et al*.[19]	Passive forward elevation was <100° and passive external rotation was <30° in the operated-on shoulder
Brislin *et al*.[2]	Total passive external rotation with the arm at the side of <10°, total passive external rotation with the arm in 90° abduction of <30° or total passive forward flexion of <100°. The diagnosis of stiffness was made only when these motion deficits persisted for 90 days postoperatively
Tauro[20]	Total passive ROM deficit (abduction, forward flexion, external rotation and internal rotation added together): 0–20° = mild stiffness; 25–70° = moderate stiffness and >70° = severe stiffness
Hsu *et al*.[14]	Active and passive limitation of motion of equal to or more than half the normal range for at least 3 months. The ranges of motion were flexion = 90°, abduction = 90°, external rotation = 25° and internal rotation = sacral level

Downloaded from https://academic.oup.com/bmb/article/104/1/163/326626 by guest on 16 August 2022

pre- and post-operative shoulder stiffness led us to review in a systematic fashion the available literature on this issue to determine:

(i) predisposing factors and management of shoulder stiffness concomitant with an RC tear;

(ii) predisposing factors and management of shoulder stiffness developed after RC surgical repair;

(iii) the best post-operative management after an RC repair to prevent stiffness development.

Downloaded from https://academic.oup.com/bmb/article/104/1/163/326626 by guest on 16 August 2022

Search study and study selection

A literature search was performed using the isolated or combined keywords 'RC repair and shoulder stiffness', 'rotator cuff tear and shoulder stiffness' and 'post-surgical shoulder stiffness and rotator cuff tear', with no limit regarding the year of publication.

Pub Med (http://www.ncbi.nlm.nih.gov/sites/entrez/), Google Scholar (http://scholar.google.it/), CINAHL (http://www.ebscohost.com/cinahl/), Cochrane Central (http://www.thecochranelibrary.com/view/0/index.html) and Embase Biomedical (http://www.embase.com/) databases were accessed on 31 July 2011 to search English, Spanish, French, Portuguese and Italian publications.

At the first electronic search, 574 articles were identified. Two authors (RP and AG) independently reviewed the text of each abstract. Full-text versions were obtained to include or exclude the study. The reference lists of the selected articles were reviewed by hand to identify articles not identified at the electronic search. All journals were considered and all

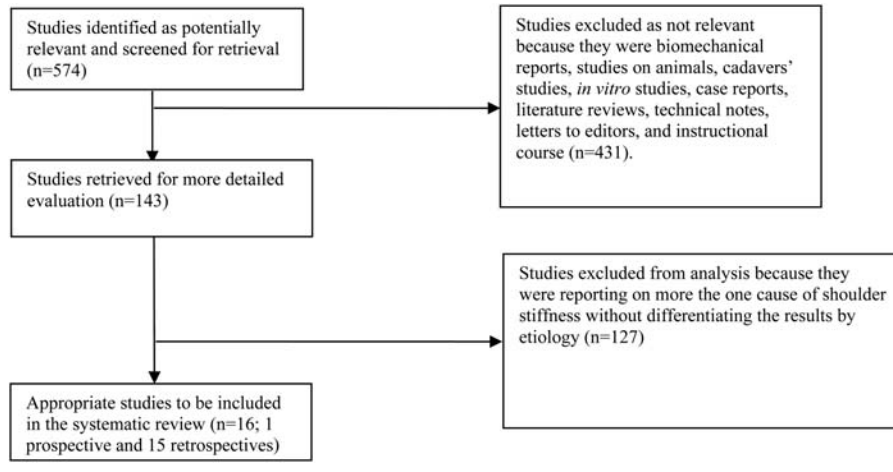

Fig. 1 A flow chart illustrating articles selection process.

relevant articles were retrieved. Studies focusing on the clinical status of patients who had pre- or post-operative shoulder stiffness relative to RC disorders were selected. Biomechanical reports, studies on animals, cadavers, *in vitro*, case reports, literature reviews, technical notes, letters to editors and instructional course were also excluded. One hundred and forty-three articles investigating shoulder stiffness concomitant with an RC repair or arising post-operatively, or concerning post-operative rehabilitation program to prevent shoulder stiffness after RC repair, and, finally, on the predisposing factors for shoulder stiffness were found. To avoid bias, all these articles were reviewed and discussed by all the authors: 127 articles were excluded because they did not report clinical data or they were reporting on more the one cause of shoulder stiffness without differentiating the results by etiology. Eventually, 16 publications relevant to the topic at hand were included (Fig. 1).

Quality assessment

Two investigators (RP and AG) separately evaluated each article using the Coleman methodology score (CMS), a 10 criteria validated scoring system[8] assessing the methodological quality of each study, with a final score ranging from 0 to 100. An investigation scoring 100 would represent a perfect study design with no influence of chance, various biase, and confounding factors. The two investigators discussed scores where more than a two-point difference was evident, until consensus was reached. Additionally, data on gender, age, type of surgery, comorbidities and complications, and scores were assessed.

Results

We evaluated 16 studies (1 prospective[9] and 15 retrospective[1–3,7,10–20] studies).

Pre-operative features

The mean age of patients was 58 ± 6.5 years, ranging from 18[1] to 86 years.[19]

Study size and follow-up

A total of 1940 patients who suffering from shoulder stiffness were involved. From the available data of 14 studies, the mean follow-up of

Downloaded from https://academic.oup.com/bmb/article/104/1/163/326626 by guest on 16 August 2022

those patients was 21.3 months (range from 3[2] to 48[14]). The average modified CMS was 59.5 (range: 37[19]–73[20]).

Year of publication

There was no evidence of a statistically significant association between the year of publication and CMS data (*R*: 0.04), and more recently published investigations did not score better than older studies.

Subject selection

A sufficiently detailed description of the patient's selection criteria was reported in 5 of the 16 (31.2%)[2,3,10,11,18] studies.

Surgical description and post-operative rehabilitation

The description of the surgical technique was adequately given in all studies but 2 studies[19,20] and 12 of 16 studies reported exhaustively (10/10 at the Coleman Score) on post-operative rehabilitation[1–3,9,11–14,16–18,20]. In the other four studies, the description of the rehabilitation program was incomplete or not reported[3,7,10,19].

Outcome measures

The scores used to collect the outcome measures are reported in Table 2. The most frequently used tests are the Constant and Murley score, the

Table 2 Scores used to assess outcomes

Study	Score
Beaufils *et al*.[10]	Constant and ROM
Nicholson[17]	VAS, ASES, simple shoulder test and ROM
Gerber *et al*.[12]	constant, ROM and subjective shoulder value
Elhassan *et al*.[11]	Constant and ROM and subjective shoulder value
Holloway *et al*.[13]	ASES and ROM
Huberty *et al*.[1]	UCLA, VAS and ROM
Oh *et al*.[18]	ROM, VAS, ASES, Constant, SST and SF-36
Mormino *et al*.[16]	ROM and UCLA
Namdari and Green[7]	ROM, DASH, SST and VAS
Parsons *et al*.[19]	ASES, ROM and Constant
Seo *et al*.[3]	ROM
Hsu *et al*.[14]	Constant and ROM
Tauro[20]	ROM and UCLA
Trenerry[9]	ROM and shoulder service questionnaire

VAS, visual analogue scale; SST, simple shoulder test; SF-36, short form (36) health survey.

Downloaded from https://academic.oup.com/bmb/article/104/1/163/326626 by guest on 16 August 2022

University of California, Los Angeles (UCLA) and the American shoulder and elbow surgeons (ASES). Six studies[10–12,14,18,19] used the Constant and Murley score; the UCLA was used by three studies[1,16,20]; the ASES score was administered by four studies[13,17–19]; range of motion values were recorded by all the studies.

Outcome data

Of the 16 articles concerning shoulder stiffness related to RC tears, four[3,14,18,20] focused on shoulder stiffness concomitant with an RC tear; five[1,2,7,9,10] on the stiffness arising after RC repair; five[10–13,17] reporting on the influence that the etiology of stiffness has on the outcomes of arthroscopic capsular release and two[15,19] on the post-operative management of RC repair to prevent stiffness.

Predisposing factors and management of shoulder stiffness concomitant with RC tear

The intrinsic features of an RC tear, such as type (full thickness, partial thickness bursal sided) and direction of the tear (postero-superior) and the presence of trauma are significantly associated with a higher risk of stiffness development concomitant with an RC tear,[3] with a possible role for diabetes and bursal inflammation.[20] There appears to be no evidence of an association between stiffness development and gender, age, size and retraction of the tear and associated pathologies.[18] Oh *et al*.[18] proposed to address moderate pre-operative stiffness accompanying RC tears with arthroscopic capsular release and manipulation added to RC repair. Comparing the outcomes of these patients with the ones from non-stiff patients undergoing an RC repair alone, range of motion values did not reach statistical significance until 6 months after the operation. Hsu *et al*.[14] performed manipulation, lysis of adhesions, acromioplasty and repair of RC in patients with shoulder stiffness concomitant with an RC tear. Statistically significant improvements were recorded between pre- and post-operative Constant and Murley score values, but this study lacks for the control group. In the only study stratifying stiff patients according to the total range of motion deficit,[20] patients underwent RC repair alone. Three of the six patients with more severe total range of motion deficit ($>70^\circ$) did not gain in terms of pain reliefs and range of motion improvement, subsequently needing arthroscopic capsular release. These three patients showed arthroscopic evidence of adhesive capsulitis. The author concluded that, while a mild-to-moderate stiffness (the total range of motion deficit $<70^\circ$) associated with an RC tear generally recovers

Downloaded from https://academic.oup.com/bmb/article/104/1/163/326626 by guest on 16 August 2022

when the RC is repaired, patients with severe stiffness (i.e. the total range of motion deficit $>70^{\circ}$) should be assumed to have developed adhesive capsulitis, and therefore have low possibility to recover after RC repair alone, and conservative management until the inflammatory phase has concluded should be implemented.

Predisposing factors and management of shoulder stiffness developed after RC surgical repair

Many factors predisposing to post-surgical stiffness development have been identified (Table 3). In patients with shoulder stiffness secondary to surgical RC tendon tear repair, arthroscopic capsular release should be considered. Shoulder pain and range of movement improved in all but one study[10] after arthroscopic release of capsular adhesions[1,11–13,17]. Comparing different etiologies of shoulder stiffness, lower improvements are achieved in patients with post-operative than in those with post-traumatic or idiopathic stiffness[10,11,13] (Table 4). However,[2] 23 of 24 stiff patients resumed through conservative measure (physical therapy in 21 patients, and physical therapy associated with steroid injection in 3 patients).[2]

Post-operative management after RC repair

Post-operative rehabilitation after RC repair is still controversial. Given the currently available studies,[15,19] both standard conservative

Table 3 Factors associated with a higher risk of stiffness development

Author	Factors
Namdari and Green[7]	Limited pre-operative active forward elevation, active external rotation and passive internal rotation
	Diabetes
	Open repair
	Size of tear
	Duration of symptoms
	Subscapularis tear
	Biceps tear
	Workman's compensation
	Dominant extremity
Trenerry[9]	Preoperative hand behind back motion restriction
Huberty *et al*.[1]	Calcific tendinitis
	Adhesive capsulitis
	Single-tendon cuff repair
	PASTA repair
	Being <50 years of age
	Workers' compensation insurance

PASTA, partial thickness articular-surface tendon avulsion.

Downloaded from https://academic.oup.com/bmb/article/104/1/163/326626 by guest on 16 August 2022

Table 4 Outcome of arthroscopic capsular release in patient suffering from postoperative shoulder stiffness

Author	Outcome of arthroscopic capsular release
Beaufils *et al*.[10]	Average Constant's score: 66.4 (range, 39–95) in the postinjury/postsurgery group. Pain: from 7.6 pre-operatively to 8.9 post-operatively. Range of motion improvement: from 15.8 pre-operatively to 30.6 post-operatively
Elhassan *et al*.[11]	Pain: from 7.4 (4–10) pre-operatively to 1.5 (0–7) post-operatively. The subjective shoulder value: from 32 (20–70) pre-operatively to 69 (25–90) post-operatively. Constant's score: from 36 (17–54) pre-operatively to 81 (34–100) post-operatively. Forward flexion: from 94 (30–110) to 128 (80–160) post-operatively. External rotation: from 11 (20–25) to 39 (0–70) post-operatively. Internal rotation: from Sacrum pre-operatively to L1 post-operatively
Holloway *et al*.[13]	Average preoperatively modified American shoulder and elbow surgeons: 39 $\pm$ 17. Average postoperatively modified American shoulder and elbow surgeons: 57 $\pm$ 20 Change in forward flexion (°): 26 $\pm$ 21 Change in external rotation (°): 29 $\pm$ 19 Change in external rotation (°): 31 $\pm$ 25 Change in internal rotation (°): 23 $\pm$ 20
Huberty *et al*.[1]	Visual analog pain values range from 0 to 3 (median, 1). UCLA scores range from 28 to 35 (median, 33) and all patients were satisfied with the result of their procedures
Gerber *et al*.[12]	The subjective shoulder value approximately doubled from 33 to 68% and the relative Constant–Murley score increased from 48 to 76%.
Mormino *et al*.[10]	Pre-release and post-release UCLA scores averaged 14.8 and 30.1, respectively. Pre- and post-release UCLA pain scores averaged 2.6 and 7.7, respectively. Pre- and post-release range of motion: flexion, 141/158; abduction, 123/141; internal rotation, 47/69 and external rotation, 53/74.

rehabilitation program with sling immobilization and early passive motion exercises do not lead to stiffness development. Although shoulder stiffness may arise after using sling immobilization for 6 weeks, this is transient, and patients recover motion fully without any special treatment.[19] A rehabilitation program with early closed chain overhead stretches (table slides) potentially does not increase the risk for RC re-tear, and may be effective in patients with one or more predisposing factors to stiffness development.[15]

Discussion

Rotator cuff disorders are a common cause of shoulder pain and dysfunction, with a frequency of RC tear ranging from 5 to 39% depending on the study.[21–25] While operative management of RC tears is well defined, a lower interest has been given to the complications of surgical repair. One of the most frequent post-surgical complication is shoulder stiffness.[2] Stiffness may be related to post-operative immobilization, low compliance of the patient with physical therapy[26] or associated shoulder osteoarthritis.[27] Based on a different etiopathogenesis, shoulder stiffness may be concomitant with RC tears. Because of the

Downloaded from https://academic.oup.com/bmb/article/104/1/163/326626 by guest on 16 August 2022

persistent uncertainties in the management of pre- and post-operative shoulder stiffness, we systematically reviewed 16 articles on this issue, and assessed their quality using the CMS.[8] The average CMS was 59.5, showing a general low methodological quality of the studies examined. Although each study used reliable and validated shoulder rating systems, the large heterogeneity of the clinical scores employed and the small number of prospective studies do not allow a meaningful statistical analysis.

We identified three aims in our systematic analysis of the literature. The first was to assess the predisposing factors and the current management of shoulder stiffness concomitant with an RC tear. Predisposing factors are still controversial, especially the role of systemic diseases such as diabetes have not been established unanimously. No study reported contraindications to surgical repair of RC tears when pre-operative shoulder stiffness is concomitant. The management varies from isolated repair to repair associated with manipulation under anesthesia, capsular release and acromioplasty. Two studies[14,18] addressed pre-operative shoulder stiffness, although they did not define the degree of stiffness, with manipulation under anesthesia and arthroscopic capsular release associated with arthroscopic RC repair. The authors stated that this management regimen is effective in restoring shoulder mobility. One study outlined that repair of an RC tear associated with mild-to-moderate stiffness is likely to improve shoulder function, while more severe pre-operative stiffness should be managed with RC repair associated with capsular release.[20]

The second aim was to assess the predisposing factors and the current management of stiffness secondary to RC repair. Namdari and Green[7] outlined that many factors could influence the development of shoulder stiffness, however at 1 year after surgery only 3 of the 47 patients considered 'stiff' necessitated arthroscopic capsular release, while the others recovered spontaneously. Trenerry[9] sustained the predictive role for restriction of the range of motion for the pre-operative hand behind the back, and showed that the highest range of motion limitation occurs at 6 weeks after the index procedure, while shoulder stiffness generally recovers during the 76 weeks. Huberty *et al.*[1] reported that factors intrinsic to the RC tendons and external factors such as age, worker's compensation and single-tendon cuff repair increase the risk for stiffness development. Twenty-four of 489 patients who were considered 'stiff' underwent arthroscopic capsular release resulting in normal motion in all cases. Although conservative management is possible through manipulation under anesthesia,[28,29] some authors consider it unhelpful for post-operative stiffness probably because of extra-articular in addition to the capsular adhesions.[30–32]

Downloaded from https://academic.oup.com/bmb/article/104/1/163/326626 by guest on 16 August 2022

Each one of the studies by Beaufils *et al*.[10], Elhassan *et al*.[11] and Holloway *et al*.[10,11,13] reported the outcomes after arthroscopic capsular release for different etiologies of shoulder stiffness: idiopathic, post-traumatic and post-surgical. Comparing the outcomes in the three different groups, each study reported poorer results for post-surgical etiology. Gerber *et al*.[12] found the poorest results in patients with post-traumatic stiffness, although the differences were not statistically significant. Huberty *et al*.[1] focused both on identifying possible predisposing factors and on reporting the outcomes of arthroscopic capsular release. Of 24 patients, 22 were available for the follow-up and all were satisfied. Mormino *et al*.[16] proposed an etiological explanation in post-surgical limitation, especially in true abduction. The authors suggested that the development of subdeltoid adhesions lead to an alteration in the gleno-humeral biomechanics, preventing the normal rolling movement and the concomitant deltoid tenodesis limits the effectiveness of this muscle. However, after adequate release of these adhesions, the normal shoulder function was restored.

The last aim of the present investigation was to describe the evidence around the rehabilitation programs implemented after RC arthroscopic repair. Unfortunately, the current available studies are few, and no definitive evidences can be established. Parsons *et al*.[19] found that the standard conservative protocol with sling immobilization for the first 6 weeks post-operatively does not lead to increased long-term stiffness. The authors suggest that the strength of this rehabilitation program is to improve the rate of tendon healing. Koo *et al*.[15] proposed a modified rehabilitation protocol that added early overhead closed-chain passive motion exercises to the standard protocol for patients with at least one predisposing factor, based on the risk factors identified from Huberty *et al*.[1] for development of shoulder stiffness. Of the 79 patients positive for at least one risk factor, none developed shoulder stiffness. In this way, the authors lowered the rate of stiffness development from 7.8% of the control group (patients from the study by Huberty *et al*.) to 0%. Despite the risk of impaired tendon healing from early mobilization, no patients reported re-tear after undertaking rehabilitation. For this reason, the authors suggest to adopt it only for patients who suffer at list from one risk factor.

Likely, the main issue in the studies examined is the lack of a unanimous definition of shoulder stiffness. The limitation in shoulder movement should be used to define shoulder stiffness and a threshold of the deficit in the range of movement should be established as a total range of movement deficit and as a deficit in the range of motion of each plane. No strong evidences emerged from our systematic review of the literature, as a consequence we are still far from definitive guidelines for the management of pre- and post-operative stiffness, and more

Downloaded from https://academic.oup.com/bmb/article/104/1/163/326626 by guest on 16 August 2022

prospective double-blinded randomized clinical trials are needed to obtain more evidences allowing to establish a reliable and effective program for the management of shoulder stiffness.

Funding

The authors disclose any conflicts and any founding source.

References

1 Huberty DP, Schoolfield JD, Brady PC *et al*. Incidence and treatment of postoperative stiffness following arthroscopic rotator cuff repair. *Arthroscopy* 2009;**25**:880–90.
2 Brislin KJ, Field LD, Savoie FH III. Complications after arthroscopic rotator cuff repair. *Arthroscopy* 2007;**23**:124–8.
3 Seo SS, Choi JS, An KC *et al*. The factors affecting stiffness occurring with rotator cuff tear. *J Shoulder Elbow Surg* 2011.
4 Debeyre J, Patie D, Elmelik E. Repair of ruptures of the rotator cuff of the shoulder. *J Bone Joint Surg Br* 1965;**47**:36–42.
5 McLaughlin HL. Lesions of the musculotendinous cuff of the shoulder. The exposure and treatment of tears with retraction. *Clin Orthop Relat Res* 1994;3–9.
6 Nixon JE, DiStefano V. Ruptures of the rotator cuff. *Orthop Clin North Am* 1975;**6**:423–47.
7 Namdari S, Green A. Range of motion limitation after rotator cuff repair. *J Shoulder Elbow Surg* 2010;**19**:290–6.
8 Coleman BD, Khan KM, Maffulli N *et al*. Studies of surgical outcome after patellar tendinopathy: clinical significance of methodological deficiencies and guidelines for future studies. Victorian Institute of Sport Tendon Study Group. *Scand J Med Sci Sports* 2000;**10**:2–11.
9 Trenerry K. Prevention of shoulder stiffness after rotator cuff repair. *Clin Orthop Relat Res* 2005;**430**:94–9.
10 Beaufils P, Prevot N, Boyer T *et al*. Arthroscopic release of the glenohumeral joint in shoulder stiffness: a review of 26 cases. French Society for Arthroscopy. *Arthroscopy* 1999;**15**:49–55.
11 Elhassan B, Ozbaydar M, Massimini D *et al*. Arthroscopic capsular release for refractory shoulder stiffness: a critical analysis of effectiveness in specific etiologies. *J Shoulder Elbow Surg* 2010;**19**:580–7.
12 Gerber C, Espinosa N, Perren TG. Arthroscopic treatment of shoulder stiffness. *Clin Orthop Relat Res* 2001;**390**:119–28.
13 Holloway GB, Schenk T, Williams GR *et al*. Arthroscopic capsular release for the treatment of refractory postoperative or post-fracture shoulder stiffness. *J Bone Joint Surg Am* 2001;**83-A**:1682–7.
14 Hsu SL, Ko JY, Chen SH *et al*. Surgical results in rotator cuff tears with shoulder stiffness. *J Formos Med Assoc* 2007;**106**:452–61.
15 Koo SS, Parsley BK, Burkhart SS *et al*. Reduction of postoperative stiffness after arthroscopic rotator cuff repair: results of a customized physical therapy regimen based on risk factors for stiffness. *Arthroscopy* 2011;**27**:155–60.
16 Mormino MA, Gross RM, McCarthy JA. Captured shoulder: a complication of rotator cuff surgery. *Arthroscopy* 1996;**12**:457–61.
17 Nicholson GP. Arthroscopic capsular release for stiff shoulders: effect of etiology on outcomes. *Arthroscopy* 2003;**19**:40–9.
18 Oh JH, Kim SH, Lee HK *et al*. Moderate preoperative shoulder stiffness does not alter the clinical outcome of rotator cuff repair with arthroscopic release and manipulation. *Arthroscopy* 2008;**24**:983–91.

Downloaded from https://academic.oup.com/bmb/article/104/1/163/326626 by guest on 16 August 2022

19 Parsons BO, Gruson KI, Chen DD *et al*. Does slower rehabilitation after arthroscopic rotator cuff repair lead to long-term stiffness? *J Shoulder Elbow Surg* 2010;**19**:1034–9.
20 Tauro JC. Stiffness and rotator cuff tears: incidence, arthroscopic findings, and treatment results. *Arthroscopy* 2006;**22**:581–6.
21 Cotton RE, Rideout DF. Tears of the humeral rotator cuff; a radiological and pathological necropsy survey. *J Bone Joint Surg Br* 1964;**46**:314–28.
22 Keyes EL. Observations on rupture of the supraspinatus tendon: based upon a study of seventy-three cadavers. *Ann Surg* 1933;**97**:849–56.
23 Neer CS II. Impingement lesions. *Clin Orthop Relat Res* 1983;**173**:70–7.
24 Ozaki J, Fujimoto S, Nakagawa Y *et al*. Tears of the rotator cuff of the shoulder associated with pathological changes in the acromion. A study in cadavera. *J Bone Joint Surg Am* 1988;**70**:1224–30.
25 Petersson CJ, Gentz CF. Ruptures of the supraspinatus tendon. The significance of distally pointing acromioclavicular osteophytes. *Clin Orthop Relat Res* 1983;**174**:143–8.
26 Vezeridis PS, Goel DP, Shah AA *et al*. Postarthroscopic arthrofibrosis of the shoulder. *Sports Med Arthrosc* 2010;**18**:198–206.
27 Warner JJ, Greis PE. The treatment of stiffness of the shoulder after repair of the rotator cuff. *Instr Course Lect* 1998;**47**:67–75.
28 Andersen NH, Sojbjerg JO, Johannsen HV *et al*. Frozen shoulder: arthroscopy and manipulation under general anesthesia and early passive motion. *J Shoulder Elbow Surg* 1998;**7**:218–22.
29 Neviaser RJ, Neviaser TJ. The frozen shoulder. Diagnosis and management. *Clin Orthop Relat Res* 1987;**223**:59–64.
30 Warner JJ. Frozen shoulder: diagnosis and management. *J Am Acad Orthop Surg* 1997;**5**:130–40.
31 Warner JJ, Allen A. Management of the stiff shoulder. *Op Tech Orthop* 1995;**5**:238–47.
32 Neer CS II, Satterlee CC, Dalsey RM *et al*. The anatomy and potential effects of contracture of the coracohumeral ligament. *Clin Orthop Relat Res* 1992;**280**:182–5.

Downloaded from https://academic.oup.com/bmb/article/104/1/163/326626 by guest on 16 August 2022