Systematic Review

Management of Concomitant Preoperative Rotator Cuff Pathology and Adhesive Capsulitis: A Systematic Review of Indications, Treatment Approaches, and Outcomes

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Purpose: Concomitant preoperative adhesive capsulitis (AC) and rotator cuff (RC) pathology pose therapeutic challenges in light of contrasting interventional and rehabilitative goals. The purposes of this systematic review were to assess the literature regarding the management and rehabilitation of patients with concomitant RC tears and preoperative AC and to compare overall clinical outcomes between strategies for this common scenario. **Methods:** In accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, 3 databases (MEDLINE, Embase, and PubMed) were searched and screened in duplicate using predetermined criteria for studies on the aforementioned patient population. Descriptive statistics are presented. **Results:** Of 952 studies, 17 involving 662 shoulders, with a mean age of 59.6 $\pm$ 3.5 years, 57.9% female patients, and a mean follow-up period of 18.6 months, were included. Capsular release (CR) (86.1%) and manipulation under anesthesia (MUA) (33.1%) were the most common co-interventions with RC repair. Across studies, mean preoperative American Shoulder and Elbow Surgeons scores ranged from 29.0 to 61.3, visual analog scale scores (pain) ranged from 5.3 to 8.0, and Constant scores ranged from 18.0 to 48.0. Mean postoperative American Shoulder and Elbow Surgeons scores ranged from 76.9 to 92.0, visual analog scale scores (pain) ranged from 0.3 to 2.5, and Constant scores ranged from 72.6 to 93.2. Postoperative rehabilitation comprised abduction braces and passive range of motion immediately postoperatively for mean durations of 5.0 weeks and 5.3 weeks, respectively, followed by active range of motion at a mean of 5.3 weeks and strengthening at 10.9 weeks. Postoperative complications included stiffness, RC retear, instability, glenoid fracture, and superficial infection. **Conclusions:** The results of this systematic review support treatment of patients with degenerative RC tears and concomitant AC with a combination of RC repair and MUA, CR, or both MUA and CR. Regardless of the treatment modality, accelerated postoperative rehabilitative protocols are beneficial in preventing postoperative persistence of AC and can be safely used in this scenario without a substantial increase in complication rates compared with patients undergoing RC repair alone with conservative rehabilitation. **Level of Evidence:** Level V, systematic review of Level II, III, IV, and V studies.

Rotator cuff (RC) tears are a common cause of shoulder dysfunction and can lead to numerous functional deficits including limited range of motion (ROM), pain, and weakness.[1] Concomitant shoulder stiffness in the setting of RC tears is common and can manifest in a variety of forms ranging from mild ROM deficits to adhesive capsulitis (AC), and it is important to distinguish mere shoulder stiffness as a result of RC tears from concomitant AC.[2] As a result of AC, these patients experience reductions in passive ROM that cannot be fully accounted for by the RC tear and/or muscular guarding.[3,4] The prevalence of RC tears concomitant with shoulder stiffness ranges from 12.3% to 41.7% among all RC tears, with rates varying based on demographic factors.[1,5,6] Several factors influence the development of AC in the setting of RC tears, including formation of adhesions and concomitant injury to structures such as pericapsular ligaments.[3,7,8] Several challenges exist in the management of this commonly encountered clinical scenario because RC repair requires a protected postoperative protocol to

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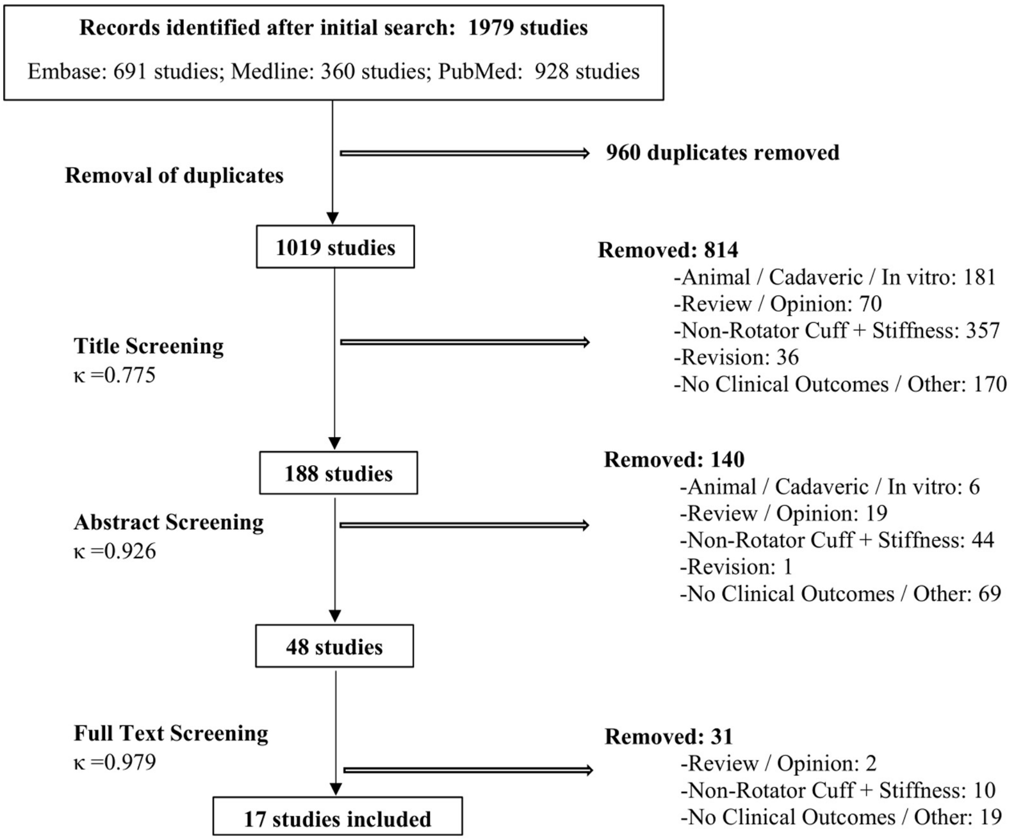

Fig 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart.

optimize tendon-to-bone healing, whereas management of shoulder stiffness typically involves procedures for release of soft-tissue structures with rehabilitation focused on accelerated progressive ROM.[3,9-11]

Existing reviews investigating RC tears with concomitant AC provide limited insight into the range of treatment options and their efficacy relative to one another.[2,12] A greater understanding of available treatment modalities, technical considerations, and risk profiles would assist clinicians in developing relevant treatment algorithms for this scenario. Given this apparent gap in knowledge, the purposes of this systematic review were to assess the literature regarding the management and rehabilitation of patients with concomitant RC tears and preoperative AC and to compare overall clinical outcomes between strategies for this complex scenario. It was hypothesized that a more comprehensive treatment approach, with adjunct operative modalities to RC repair alone and an accelerated rehabilitative protocol, would be beneficial for clinical and patient-reported outcomes in the postoperative course.

Methods

Search Strategy

Three online databases (Embase, MEDLINE, and PubMed) were searched from inception to April 10, 2018, using the following Medical Subject Headings (MeSH) terms: ("shoulder stiffness" OR "frozen shoulder" OR "adhesive capsulitis") AND "rotator cuff." The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines were followed in the development of the study, and Figure 1 shows the search strategy. The inclusion criteria were (1) all levels of evidence, (2) skeletally mature patients, (3) human studies, (4) studies published in English, (5) studies reporting clinical outcomes, and (6) studies including patients with both RC tears and preoperative stiffness. The exclusion criteria were (1) cadaveric studies, (2) review articles or book chapters, and (3) absence of reported clinical outcome data.

Study Screening

Two reviewers (K.Z. and A.K.) independently screened titles, abstracts, and full texts of retrieved studies. Discrepancies at the title and abstract screening stages were included at subsequent stages, and discrepancies at the full-text stage were discussed to arrive at a consensus between reviewers. References of included studies were screened to identify any studies that were not identified in the initial search. Inter-reviewer agreement for each stage of study screening was calculated with the κ statistic. The κ values were categorized a priori as follows: 0.81 to 0.99 was considered excellent agreement; 0.61 to 0.80, substantial agreement; 0.41 to 0.60, moderate agreement; 0.21 to 0.40, fair agreement; and 0.20 or less, slight agreement. The initial search produced 1,979 studies, of which 960 duplicates, 187 animal, cadaveric, or in vitro studies, 91 reviews, 411 studies of non-RC pathology with concomitant stiffness, 37 studies of revision cuff repair, and 258 studies lacking clinical outcomes were excluded in the screening process.

Quality Assessment

Quality assessment of included nonrandomized studies was completed independently by 2 reviewers (K.Z. and A.K.) using the Methodological Index for Non-Randomized Studies (MINORS) criteria, with maximum scores of 16 for noncomparative studies and 24 for comparative studies.[13] Inter-rater reliability for MINORS scoring was calculated with the interclass correlation coefficient (ICC) with the following parameters classified a priori: ICC of 0.9 to 1.0, excellent reliability; 0.75 to 0.89, substantial reliability; 0.5 to 0.74, moderate reliability; and less than 0.5, poor reliability. The levels of evidence of included studies were assessed with the American Academy of Orthopaedic Surgeons classification system.[14] Revised Assessment of Multiple Systematic Reviews (R-AMSTAR) guidelines for high-quality systematic reviews were followed in this study.[15]

Data Abstraction

Relevant data including study characteristics, demographic characteristics, outcomes, and complications from included articles were abstracted and recorded in a Microsoft Excel spreadsheet (Microsoft, Redmond, WA). For the purposes of this review, internal rotation (IR) relative to vertebral levels (IR-S) was converted into numerical values, with the level of S5 equivalent to 0 and each spinal level above S5 assigned an increment of 1.

Statistical Analysis

All statistics were calculated by use of Minitab statistical software (version 17; Minitab, State College, PA). Because of heterogeneous and limited reporting, data could not be combined in a meta-analysis, and all data were summarized descriptively according to previous recommendations.[16]

Results

Quality Assessment

Of 952 studies identified in the initial search, 17 were included in the final analysis. The κ values were substantial or nearly perfect at all stages of study screening and are detailed in Figure 1. The ICC for MINORS scores was substantial, at 0.856. The median MINORS score was 9 of a possible 16 for noncomparative studies (range, 4-12) and 18 of a possible 24 (range, 13-23) for comparative studies. Included studies were noted to have clearly stated aims, appropriate endpoints, and appropriate follow-up periods. Furthermore, among comparative studies, gold-standard control groups and adequate statistical analyses were used consistently. Methodologic weaknesses among included studies were most frequently related to lack of prospective collection of data, prospective sample size calculation, or unbiased endpoint evaluations.

Definitions and Patient Demographic Characteristics

Study characteristics and patient demographic factors are outlined in Table 1. A total of 662 shoulders were included across all studies. Among studies that reported sex and age, there were 147 male patients (42.1%) and 202 female patients (57.9%) with a mean age of 59.6 ± 3.5 years and a mean postoperative follow-up period of 21.7 ± 1.2 months.

Of 17 studies, 10 defined parameters for preoperative AC. Seven studies included limitations in flexion and external rotation (ER). Allowable flexion ranged from 90° to 135°, and allowable ER ranged from 20° to 60°. Five studies also included IR as defined by the highest spinal level reached, and 2 studies included abduction as part of their criteria. Upper limits of IR ranged from T12 to S1, whereas any abduction below 90° was allowed. Two studies (132 shoulders) used ROM in combined planes as part of their criteria for AC. One study defined AC as a deficit of greater than 70° in the sum of glenohumeral flexion, abduction, ER at 90° of abduction (ER-90), and IR at 90° of abduction (IR-90). Another study defined AC as less than 120° of combined ER-90 and IR-90.

RC tear size was reported in 8 studies (179 shoulders) based on the classification of DeOrio and Cofield.[19] There were 66 partial, 39 small, 54 medium, and 20 massive tears. The cause of RC tears was specified in 5 studies (240 shoulders). Four studies excluded all traumatic RC tears, whereas 1 study included 3 traumatic RC tears that were treated identically to degenerative tears.

Interventions

Specific operative modalities and techniques used are detailed in Table 2. Fifteen studies (637 shoulders) used RC repair and 1 study (25 shoulders) used subacromial decompression (SAD) as the primary treatment for RC tears. All procedures were performed with patients under general anesthesia, which was supplemented with a preoperative interscalene nerve block in 5 studies (104 shoulders) and an axillary nerve block in 2 studies (72 shoulders). Patient positioning was specified in 14 studies (514 shoulders), with 9 studies (342 shoulders) using lateral decubitus and 5 studies (172

Table 1. Study Characteristics, AC Definitions, and Postoperative Rehabilitative Protocol

Authors (Year)	Title	LOE	Mean MINORS Score	No. of Shoulders	Criteria for Stiffness	Rehabilitation Protocol
Manaka et al. (2011)	Functional recovery period after arthroscopic rotator cuff repair: Is it predictable before surgery?	IV	7.5	126	Sum of ER-90 and IR-90 < 120°	Abduction bracing immediately postoperatively Pendulum and passive ROM exercises at 2 d postoperatively Bracing discontinued and active ROM exercises at 6 wk postoperatively Strengthening exercises at 8 wk postoperatively Rehabilitation discontinued at 6 mo postoperatively
Koh et al. (2013)	Iatrogenic glenoid fracture after brisement manipulation for the stiffness of shoulder in patients with rotator cuff tear	V	8.5	1	NR	Abduction bracing immediately postoperatively Bracing discontinued; passive ROM, active ROM, and strengthening exercises at 4 wk postoperatively
Huberty et al. (2009)	Incidence and treatment of post-operative stiffness following arthroscopic rotator cuff repair	IV	9	30	NR	Abduction bracing, active hand-wrist-elbow ROM, passive ROM exercises immediately postoperatively Bracing discontinued, rope and pulley passive ROM exercises at 7 wk postoperatively Active ROM, strengthening exercises at 3 mo postoperatively Return to activity 6-12 mo postoperatively
Oh et al. (2008)	Moderate pre-operative shoulder stiffness does not alter the clinical outcome of rotator cuff repair with arthroscopic release and manipulation	III	20	30	Flexion < 120°, with ER-0 < 30° or IR < L3	Abduction bracing, passive ROM immediately postoperatively Bracing discontinued, active ROM at 4-6 wk postoperatively Strengthening exercises at 9 wk postoperatively Return to activity at 6 mo postoperatively
Ho et al. (2013)	One-stage arthroscopic repair of rotator cuff tears with shoulder stiffness	III	20.5	41	Flexion < 135°, ER-90 < 60°	Abduction bracing, passive ROM, active-assisted exercises immediately postoperatively Bracing discontinued, active ROM, strengthening exercises at 6 wk postoperatively Return to activity at 3-6 mo postoperatively
Shishido et al. (2012)	Post-operative outcomes of arthroscopic subacromial decompression for rotator cuff tear with shoulder stiffness	II	16	25	Flexion < 120°, ER-0 < 30°	Passive ROM, pendulum, active-assisted exercises immediately postoperatively Active ROM, strengthening exercises at 4 wk postoperatively
Tauro (2006)	Stiffness and rotator cuff tears: Incidence, arthroscopic findings, and treatment results	IV	15	6	Total ROM deficit (sum of glenohumeral flexion, abduction, ER-90, and IR-90) > 70°	Abduction bracing, cold therapy cuff immediately postoperatively Active hand-wrist-elbow ROM, passive ROM at 2 d postoperatively Active ROM at 6 wk postoperatively Strengthening exercises at 10 wk postoperatively
Hsu et al. (2007)	Surgical results in rotator cuff tears with shoulder stiffness	IV	9	47	Flexion < 90°, abduction < 90°, ER-0 < 25°, IR-S < S1	Passive ROM, pendulum exercises at 2 d postoperatively Active-assisted exercises at 4 d postoperatively Active ROM at 1 wk postoperatively
Cho et al. (2012)	Anterolateral approach for mini-open rotator cuff repair	IV	10.5	110	NR	Abduction bracing immediately postoperatively Passive ROM, pendulum exercises at 1 d postoperatively Bracing discontinued, active ROM at 6 wk postoperatively Strengthening exercises at 3 mo postoperatively Return to activity at 6 mo postoperatively

(continued)

Table 1. Continued

Authors (Year)	Title	LOE	Mean MINORS Score	No. of Shoulders	Criteria for Stiffness	Rehabilitation Protocol
Kim et al.[17] (2015)	Are delayed operations effective for patients with rotator cuff tears and concomitant stiffness? An analysis of immediate versus delayed surgery on outcomes	II	22.5	63	Flexion < 100°, ER-0 < 45°, IR-S < L1	Abduction bracing, passive ROM immediately postoperatively Bracing discontinued, active-assisted exercises at 4 wk postoperatively Strengthening exercises at 2 mo postoperatively Return to activity at 6 mo postoperatively
Ji et al. (2017)	Arthroscopic fixation of iatrogenic glenoid rim fracture caused by brisement manipulation: Two case reports	V	8	1	NR	Abduction bracing immediately postoperatively Pendulum exercises, passive ROM at 2 d postoperatively Bracing discontinued, active ROM exercises at 4 wk postoperatively Strengthening exercises at 12 wk postoperatively Return to activity at 3 mo postoperatively
Giuseffi et al.[18] (2016)	Arthroscopic rotator cuff repair with concomitant capsular release	V	5.5	36	Flexion < 120°, ER-0 < 30°	NR
Chuang et al. (2012)	Arthroscopic treatment of rotator cuff tears with shoulder stiffness: A comparison of functional outcomes with and without capsular release	III	18.5	31	NR	Abduction bracing, passive ROM, active-assisted exercises immediately postoperatively Bracing discontinued, active ROM, strengthening exercises at 6 wk postoperatively Return to activity at 3-6 mo postoperatively
Cho et al. (2015)	Clinical outcomes of rotator cuff repair with arthroscopic capsular release and manipulation for rotator cuff tear with stiffness: A matched-pair comparative study between patients with and without stiffness	III	18	26	NR	Abduction bracing, passive ROM exercises immediately postoperatively Bracing discontinued, active ROM exercises at 6 wk postoperatively Strengthening exercises at 3 mo postoperatively Return to activity at 6 mo postoperatively
Park et al. (2014)	Effect of capsular release in the treatment of shoulder stiffness concomitant with rotator cuff repair: Diabetes as a predisposing factor associated with treatment outcome	IV	19	49	NR	Abduction bracing, passive ROM exercises immediately postoperatively Bracing discontinued, active ROM exercises at 6 wk postoperatively Strengthening exercises at 8 wk postoperatively Return to activity at 6 mo postoperatively
McGrath et al.[20] (2016)	The effect of concomitant glenohumeral joint capsule release during rotator cuff repair—A comparative study	IV	16.5	25	Flexion < 90°, abduction < 90°, ER-0 < 20°, IR-S < T12	Passive ROM, active hand-wrist-elbow ROM, pendulum exercises immediately postoperatively Active ROM at 6 wk postoperatively Strengthening exercises at 3 mo postoperatively
Cho and Rhee (2008)	Functional outcome of arthroscopic repair with concomitant manipulation in rotator cuff tears with stiff shoulder	III	15.5	15	Flexion < 120°, ER-0 < 40°	Passive ROM, pendulum exercises immediately postoperatively Active ROM, strengthening exercises at 6 wk postoperatively Return to activity at 6 mo postoperatively

NOTE. Rehabilitative protocols and criteria for patients with AC are translated from those listed in the included studies. All measurements for the diagnosis of AC were confirmed with patients under anesthesia in the included studies. Unless otherwise specified, exercises that were initiated in the immediate postoperative period were discontinued on initiation of active ROM or strengthening exercises. The interclass correlation coefficient for inter-rater reliability in MINORS scoring was substantial, at 0.856.

AC, adhesive capsulitis; CR, capsular release; ER-90, external rotation at 90° of abduction; ER-0, external rotation at 0° of abduction; IR, internal rotation; IR-90, internal rotation at 90° of abduction; IR-S, internal rotation relative to vertebral level; LOE, level of evidence; MINORS, Methodological Index for Non-Randomized Studies; MUA, manipulation under anesthesia; NR, particular field not reported in study; RC, rotator cuff; ROM, range of motion.

Table 2. Operative Interventions and Technique Used in Studies

Authors (Year)	Patient Positioning	Anesthetic Technique	RC Repair Technique	CR Technique	MUA Technique	Postprocedure Analgesia	Other Procedures
Manaka et al. (2011)	Lateral decubitus	General anesthetic	Arthroscopic, single or double row with suture anchors	NR	None	None	SAD
Koh et al. (2013)	NR	General anesthetic, interscalene block	Arthroscopic, double row with suture anchors	None	NR	None	None
Huberty et al. (2009)	NR	General anesthetic	Arthroscopic, double row with suture anchors	NR	None	None	None
Oh et al. (2008)	Lateral decubitus	General anesthetic	Arthroscopic	Rotator interval, anterior capsule, inferior capsule, MGHL	Forward flexion, extension, adduction, ER-0, ER-90, IR-90	None	Acromioplasty; SLAP repair with suture anchors for 5 type II and IV SLAP lesions
Ho et al. (2013)	Lateral decubitus	General anesthetic, interscalene block, axillary block	Arthroscopic	Anterior capsule, inferior capsule, posterior capsule	Forward flexion, abduction, ER-90, IR-90	None	Acromioplasty
Shishido et al. (2012)	Lateral decubitus	General anesthetic	None	Rotator interval, anterior capsule, posterior capsule, MGHL, IGHL	None	None	SAD
Tauro (2006)	Lateral decubitus	General anesthetic	Arthroscopic, suture anchors	NR	None	Subacromial and intra-articular bupivacaine, intra-articular corticosteroid	NR
Hsu et al. (2007)	Beach chair	General anesthetic	Open repair, tendon-to-bone suturing technique Massive irreparable tears sutured to partial-thickness deltoid flap	Rotator interval, CHL, periarticular adhesiolysis	None	None	Open acromioplasty
Cho et al. (2012)	Lateral decubitus	General anesthetic	Mini-open repair, double row with suture anchors	NR	None	None	Biceps tenodesis for concomitant biceps tendon pathology
Kim et al.[17] (2015)	Lateral decubitus	General anesthetic	Arthroscopic, single or double row with suture anchors	Rotator interval, anterior capsule, MGHL, IGHL	None	None	Acromioplasty
Ji et al. (2017)	NR	General anesthetic, interscalene block	Arthroscopic, single row with suture anchors	Anterior capsule, posterior capsule, MGHL, SGHL, CHL	Forward flexion, ER-0, ER-90, IR-90	None	Arthroscopic fixation of iatrogenic glenoid fracture with suture anchors

(continued)

Table 2. Continued

Authors (Year)	Patient Positioning	Anesthetic Technique	RC Repair Technique	CR Technique	MUA Technique	Postprocedure Analgesia	Other Procedures
Giuseffi et al.[18] (2016)	Beach chair	General anesthetic, interscalene block	Arthroscopic	Anterior capsule, inferior capsule, posterior capsule	Forward flexion, abduction, ER-0, ER-90, IR-90, adduction	None	None
Chuang et al. (2012)	Lateral decubitus	General anesthetic, axillary block	Arthroscopic, single or double row with suture anchors	Rotator interval, anterior capsule, posterior capsule, MGHL	Forward flexion, ER-90, IR-90, abduction	Intra-articular and subacromial bupivacaine, corticosteroid	SAD
Cho et al. (2015)	Lateral decubitus	General anesthetic	Arthroscopic	Rotator interval, anterior capsule, inferior capsule, posterior capsule	None	None	SAD
Park et al. (2014)	Beach chair	General anesthetic	Arthroscopic, single or double row with suture anchors	Rotator interval, anterior capsule, inferior capsule, CHL	ER-0, ER-90, IR-90, abduction	None	SAD; biceps tenodesis or tenotomy for concomitant biceps tendon pathology
McGrath et al.[20] (2016)	Beach chair	General anesthetic, interscalene block	Arthroscopic, single row with suture anchors	Anterior capsule, inferior capsule, posterior capsule	Forward flexion, ER-90, IR-90, abduction	None	None
Cho and Rhee (2008)	NR	General anesthetic	Arthroscopic, single or double row with suture anchors	None	Forward flexion, ER-0, ER-90, IR-90, adduction	None	SAD

NOTE. Reported data on primary and adjunct operative interventions, along with anesthetic and analgesic considerations, are summarized. Postprocedure analgesia includes interventions after all operative procedures but before patients awakened from anesthesia. "None" indicates that particular intervention was not used in the study.

CHL, coracohumeral ligament; CR, capsular release; ER-90, external rotation at 90° of abduction; ER-0, external rotation at 0° of abduction; IGHL, inferior glenohumeral ligament; IR-90, internal rotation at 90° of abduction; MGHL, middle glenohumeral ligament; MUA, manipulation under anesthesia; NR, technical details not provided for intervention in study; RC, rotator cuff; SAD, subacromial decompression; SGHL, superior glenohumeral ligament.

shoulders) using beach-chair positioning. Operations were arthroscopic in 15 studies (505 shoulders), used a mini-open approach in 1 study (110 shoulders), and used an open approach in 1 study (47 shoulders). Concomitant interventions with the primary operative procedure included capsular release (CR) in 15 studies (646 shoulders), manipulation under anesthesia (MUA) in 10 studies (229 shoulders), SAD in 5 studies (247 shoulders), and acromioplasty in 3 studies (140 shoulders).

The technique for RC repair was described in 12 studies (504 shoulders). Single-row repairs alone were performed in 2 studies (26 shoulders); double-row repairs alone, in 3 studies (141 shoulders); and either single- or double-row repair based on tear size, in 5 studies (284 shoulders). Tendon fixation was accomplished with suture anchors in 11 studies (457 shoulders) and with tendon-to-bone suturing in 1 study (47 shoulders). For massive irreparable tears, 1 study (47 shoulders) created a partial-thickness flap of the anterior deltoid for suture fixation of the torn tendon edge. In 4 studies (138 shoulders), 66 partial RC tears were first converted to complete tears, followed by RC repair. The technique for CR was described in 11 studies (374 shoulders), with 10 studies (327 shoulders) performing release of the anterior capsule; 7 studies (271 shoulders), the rotator interval; 7 studies (185 shoulders), the posterior capsule; 6 studies (207 shoulders), the inferior capsule; 4 studies (125 shoulders), the middle glenohumeral ligament; 2 studies (50 shoulders), the coracohumeral ligament; and 1 study (63 shoulders), the inferior glenohumeral ligament.

The technique for MUA was described in 9 studies, with 9 studies (228 shoulders) including mobilization in ER-90 and IR-90; 8 studies (179 shoulders), forward flexion; 5 studies (181 shoulders), abduction; 5 studies (131 shoulders), ER at 0° of abduction (ER-0); 3 studies (81 shoulders), adduction; and 1 study (30 shoulders), extension. In all cases, MUA was performed gradually until a distinct popping sound was heard with loss of resistance and with scapular stabilization to isolate glenohumeral motion.

Shoulder ROM and Patient-Reported Outcomes

Preoperative and postoperative clinical outcomes are listed in Tables 3 and 4. Mean preoperative flexion in 13 studies (396 shoulders) ranged from 78.3° to 161.4°; ER-0 in 13 studies (396 shoulders), from 7.3° to 68.1°; abduction in 8 studies (192 shoulders), from 67.7° to 154.6°; IR-S in 6 studies (160 shoulders), from 0 to 10; IR-90 in 3 studies (78 shoulders), from 6.0° to 61.0°; and ER-90 in 2 studies (78 shoulders), from 38.5° to 74.2°. Mean postoperative flexion ranged from 143.0° to 177.0°; ER-0, from 30.0° to 83.0°; abduction, from 120.0° to 173.8°; IR-S, from 10 to 14; IR-90, from 30° to 82°; and ER-90, from 82.0° to 95.3°.

Comparisons between preoperative and postoperative Constant scores, University of California—Los Angeles (UCLA) scores, American Shoulder and Elbow Surgeons (ASES) scores, and pain visual analog scale (pVAS) scores were made in 9 studies. The mean preoperative ASES scores in 9 studies (352 shoulders) ranged from 29.0 to 61.3; pVAS in 9 studies (282 shoulders), from 5.3 to 8.0; Constant scores in 8 studies (215 shoulders), from 18.0 to 48.0; and UCLA scores in 5 studies (149 shoulders), from 12.3 to 16.8. The mean postoperative ASES scores ranged from 76.9 to 92.0; pVAS scores, from 0.3 to 2.5; Constant scores, from 72.6 to 93.2; and UCLA scores, from 32.2 to 35.0.

Rehabilitative Course

Abduction braces were used in 12 studies (534 shoulders, 80.6%) immediately postoperatively for a mean of 5 ± 0.4 weeks (range, 3-7 weeks). Passive ROM exercises were used in all studies immediately postoperatively for a mean of 5.3 ± 0.3 weeks (range, 1-7 weeks). Adjunct therapies during this stage included pendulum exercises (182 shoulders); pulley exercises (60 shoulders); active hand, wrist, and elbow ROM (36 shoulders); regional nerve blocks (36 shoulders); parascapular exercises (6 shoulders); and cryotherapy (6 shoulders). Active ROM exercises were initiated in 15 studies (591 shoulders, 89.3%) at an average of 5.3 ± 0.4 weeks (range 1.5-6 weeks), and strengthening exercises were initiated in 15 studies (580 shoulders, 87.6%) at an average of 10.9 ± 0.6 weeks (range, 6-12 weeks). Return to activity took place at an average of 21.6 ± 1.9 weeks (range, 12-24 weeks) in 10 studies (386 shoulders).

Postoperative Complications

Complication rates stratified by operative procedure are detailed in Table 5. Postoperative complications were reported in 15 studies (622 shoulders). Among 418 shoulders undergoing RC repair plus CR, persistent stiffness was reported in 40; RC retear, in 23; and multidirectional instability, in 1. Among 171 shoulders undergoing RC repair plus MUA and CR, recurrent RC tears were reported in 7; multidirectional instability, in 3; and superficial infection, in 3. Among 33 shoulders undergoing RC repair plus MUA, iatrogenic glenoid fracture was reported in 2; multidirectional instability, in 1; and superficial infection, in 1. Three RC retears required revision RC repair, 27 persistently stiff shoulders required further operative intervention with CR and/or MUA, and 2 glenoid fractures required fixation with suture anchors.

Comparative Studies

One study comparing concomitant RC repair with SAD and MUA (16 shoulders) against RC repair with SAD, MUA, and CR (15 shoulders) showed significantly greater flexion, ER-0, and ER-90 in the latter group at

Table 3. Preoperative Clinical Outcomes by Study

Authors (Year)	ASES Score	Constant Score	VAS Pain Score	UCLA Score	Flexion, °	Abduction, °	ER-0, °	IR-S, Level	ER-90, °	IR-90, °
Manaka et al. (2011)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Koh et al. (2013)	18.0	29.0	8.0	NR	130.0	70.0	10.0	0.0	NR	NR
Huberty et al. (2009)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Oh et al. (2008)	37.3	44.4	6.3	NR	128.0	NR	37.0	10.0	NR	NR
Ho et al. (2013)	39.0	45.0	8.0	14.0	124.0	120.0	30.0	NR	41.0	6.0
Shishido et al. (2012)	NR	NR	6.2	NR	99.0	88.2	18.2	7.0	NR	NR
Tauro (2006)	NR	NR	NR	16.8	172.0	148.0	60.0	NR	NR	61.0
Hsu et al. (2007)	NR	45.1	NR	NR	78.3	67.7	7.3	NR	NR	NR
Cho et al. (2012)	38.3	NR	NR	NR	NR	NR	NR	NR	NR	NR
Kim et al.[17] (2015)—concomitant group	44.8	57.4	5.3	NR	124.2	NR	68.1	9.0	73.5	NR
Kim et al. (2015)—delayed group	44.8	61.3	5.4	NR	121.2	NR	67.7	9.0	74.2	NR
Ji et al. (2017)	18.0	29.0	8.0	NR	100.0	70.0	20.0	5.0	NR	NR
Giuseffi et al.[18] (2016)	NR	NR	NR	14.8	106.0	NR	4.0	NR	NR	NR
Chuang et al. (2012)—RC repair + MUA	40.7	45.6	7.2	13.4	118.2	115.0	27.5	NR	38.5	5.1
Chuang et al. (2012)—RC repair + MUA + CR	40.8	44.9	6.9	12.6	117.1	112.5	28.8	NR	40.5	5.3
Cho et al. (2015)	34.6	NR	6.6	12.3	100.6	NR	24.2	5.8	NR	NR
Park et al. (2014)—RC repair + MUA + CR	33.4	37.5	7.1	NR	88.1	NR	25.3	NR	NR	NR
Park et al. (2014)—RC repair + MUA	40.4	40.5	6.2	NR	93.6	NR	26.1	NR	NR	NR
McGrath et al.[20] (2016)	NR	NR	NR	NR	104.0	81.0	29.0	4.0	NR	NR
Cho and Rhee (2008)	NR	44.6	6.5	14.6	118.3	112.5	34.6	7.0	NR	NR

NOTE. Mean values provided in each study are listed to 1 decimal place. For studies with multiple groups of patients with RC tears with concomitant adhesive capsulitis, the results are stratified by specific intervention.

ASES, American Shoulder and Elbow Surgeons; CR, capsular release; ER-90, external rotation at 90° of abduction; ER-0, external rotation at 0° of abduction; IR-90, internal rotation at 90° of abduction; IR-S, internal rotation relative to vertebral level; MUA, manipulation under anesthesia; NR, particular field not reported in study; RC, rotator cuff; UCLA, University of California–Los Angeles; VAS, visual analog scale.

Table 4. Postoperative Clinical Outcomes by Study

Authors (Year)	ASES Score	Constant Score	VAS Pain Score	UCLA Score	Flexion, °	Abduction, °	ER-0, °	IR-S, Level	ER-90, °	IR-90, °
Manaka et al. (2011)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Koh et al. (2013)	92.0	88.0	NR	NR	150.0	120.0	30.0	14.0	NR	NR
Huberty et al. (2009)	NR	NR	1.0	NR	NR	NR	NR	NR	NR	NR
Oh et al. (2008)	86.6	79.1	NR	NR	166.0	NR	64.0	14.0	NR	NR
Ho et al. (2013)	90.0	92.0	1.7	33.0	175.0	170.0	60.0	NR	93.2	31.3
Shishido et al. (2012)	NR	NR	1.0	NR	159.1	156.1	53.8	14.0	NR	NR
Tauro (2006)	NR	NR	0.3	36.1	177.0	162.0	78.0	NR	NR	82.0
Hsu et al. (2007)	NR	89.4	NR	NR	165.9	158.2	34.3	NR	NR	NR
Cho et al. (2012)	88.3	NR	NR	NR	NR	NR	NR	NR	NR	NR
Kim et al.[17] (2015)—concomitant group	78.5	85.0	2.1	NR	143.0	NR	81.0	13.0	82.0	NR
Kim et al. (2015)—delayed group	79.0	85.0	2.2	NR	144.0	160.0	83.0	13.0	87.0	NR
Ji et al. (2017)	91.0	93.0	NR	NR	160.0	NR	60.0	10.0	NR	NR
Giuseffi et al.[18] (2016)	NR	NR	2.0	32.2	159.0	NR	65.0	NR	NR	NR
Chuang et al. (2012)—RC repair + MUA	90.3	93.2	0.9	34.3	173.5	172.3	58.5	NR	95.3	31.0
Chuang et al. (2012)—RC repair + MUA + CR	87.7	90.9	1.1	33.0	160.7	170.7	46.5	NR	85.1	30.4
Cho et al. (2015)	87.8	NR	1.4	33.0	168.5	NR	66.2	14.1	NR	NR
Park et al. (2014)—RC repair + MUA + CR	76.9	72.6	1.4	NR	156.6	NR	49.1	NR	NR	NR
Park et al. (2014)—RC repair + MUA	85.3	77.3	2.5	NR	161.4	NR	55.2	NR	NR	NR
McGrath et al.[20] (2016)	NR	NR	NR	NR	161.0	148.0	59.0	11.0	NR	NR
Cho and Rhee (2008)	NR	94.3	0.1	33.2	166.7	173.8	48.8	14.0	NR	NR

NOTE. Mean values provided in each study are listed to 1 decimal place. For studies with multiple groups of patients with RC tears with concomitant adhesive capsulitis, the results are stratified by specific intervention.

ASES, American Shoulder and Elbow Surgeons; CR, capsular release; ER-90, external rotation at 90° of abduction; ER-0, external rotation at 0° of abduction; IR-90, internal rotation at 90° of abduction; IR-S, internal rotation relative to vertebral level; MUA, manipulation under anesthesia; NR, particular field not reported in study; RC, rotator cuff; UCLA, University of California–Los Angeles; VAS, visual analog scale.

Table 5. Postoperative Complications With Stratification by Treatment Modality

	No. of Complications (% of Total Shoulders Treated With Modality)				
	Persistent Stiffness	Cuff Retear	Multidirectional Instability	Glenoid Fracture	Superficial Infection
SAD + CR	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
RCR + MUA	0 (0)	3 (9.1)	0 (0)	2 (6.1)	0 (0)
RCR + CR	40 (9.6)	23 (5.5)	1 (0.2)	0 (0)	0 (0)
RCR + MUA + CR	0 (0)	7 (4.1)	3 (1.8)	0 (0)	3 (1.8)

NOTE. Percentage rates in parentheses after counts in each row are listed based on the proportion of total shoulders treated with a particular combination of operative modalities.

CR, capsular release; MUA, manipulation under anesthesia; RCR, rotator cuff repair; SAD, subacromial decompression.

24 months postoperatively. Moreover, the former group showed slower rates of recovery in flexion and ER-90 up to 6 months postoperatively. A separate study comparing RC repair with both MUA and CR (9 shoulders) against RC repair with MUA (6 shoulders) conducted a subgroup analysis in diabetic patients, finding significantly greater ER-0 and ASES scores in diabetic patients in the former group at 24 months postoperatively. Significantly lower flexion was seen in diabetic patients in the latter group at 3 and 12 months postoperatively but not at final follow-up, in addition to lower ER-0 from 3 months postoperatively onward. Similar stratification of data was not conducted across studies reporting comorbid thyroid dysfunction for included patients.

Staged intervention was investigated in 1 study comparing preoperative physical therapy for 6 months followed by concomitant RC repair and CR (30 shoulders) against immediate concomitant RC repair and CR (33 shoulders). In the former group, significant improvements were seen in shoulder flexion, IR-S, pVAS scores, and ASES scores after preoperative rehabilitation. However, no significant differences were observed at 3, 6, 12, and 24 months postoperatively in shoulder flexion, ER-0, abduction, pVAS scores, ASES scores, Simple Shoulder Test scores, or Constant scores between groups. Although IR-S was significantly greater in the former group at 3 and 6 months postoperatively, no significant differences were present at final follow-up.

Discussion

The primary finding of this study is that degenerative RC tears with preoperative AC can be successfully managed with single-stage RC repair with concomitant MUA and/or CR on the basis of the substantial improvements in shoulder ROM and patient-reported outcomes. Rates of common complications such as RC retear and postoperative stiffness in this patient population are comparable to those with RC repair alone, supporting the safety of this single-stage approach. Furthermore, relative to patients receiving MUA alone, those undergoing both CR and MUA as an adjunct may see greater long-term benefits in shoulder ROM and functional outcomes. These findings lend guidance to clinicians in treating patients with RC tears and concomitant AC, a patient population that is uniquely challenging given that RC tears and AC have contrasting goals of management. Future studies may look to focus on staged operative intervention and investigation of patients undergoing RC repair plus MUA or RC repair plus MUA and CR, given their relative underrepresentation in this review.

MUA is a closed procedure that does not introduce significant technical complexity or increased operative time, yet it appears to offer additional benefit when combined with CR in the management of AC.[10,21] Furthermore, MUA has been postulated to allow for more extensive release of a contracted capsule than CR alone, especially in areas such as the inferior capsule that are adjacent to important neurovascular structures.[22,23] Notably, MUA is a low-morbidity procedure with only a few serious potential complications, such as humeral fracture and brachial plexus injury, that are

Table 6. Sample Accelerated Postoperative Rehabilitative Protocol

Accelerated Postoperative Rehabilitation for RC Repair + MUA and/or CR
0-6 wk
Abduction bracing
Passive shoulder ROM
Active hand and elbow ROM
Potential adjuncts: closed-chain overhead exercises, pendulum exercises, parascapular exercises, regional nerve blocks, cryotherapy, active-assisted shoulder ROM
6-12 wk
Discontinue abduction bracing
Active shoulder ROM
12-24 wk
Strengthening exercises
20-24 wk and later
Unrestricted return to play and activity
Consider longer rehabilitation periods for patients at high risk of RC retear (extensive fatty infiltration, massive RC tear)

NOTE. The sample timeline and exercise recommendations are based on a qualitative synthesis of rehabilitative protocols used across the included studies. Specific parameters regarding ROM limitations, duration of modalities used, and specific exercises incorporated should be determined on a case-by-case basis with the surgeon, patient, and physical therapist involved.

CR, capsular release; MUA, manipulation under anesthesia; RC, rotator cuff; ROM, range of motion.

seldom described in the literature.[9,24-27] Given the apparent benefits of combined MUA and CR compared with either procedure alone for the treatment of persistent AC, a similar combination should be considered to address preoperative AC in the setting of RC tears. In particular, this review supports the use of MUA and CR with RC repair in patients with comorbid diabetes, owing to its strength as a risk factor for the development of both idiopathic and postoperative or post-traumatic AC.[11,28,29]

This review does not suggest the need for substantial technical modifications to be made in performing concomitant RC repair with MUA and/or CR compared with techniques for these interventions previously described in the literature.[18,30-36] Arthroscopic RC repair with suture anchors is well explored in this scenario and can be performed with the patient under general anesthesia in the lateral decubitus or beach-chair position.[30,31] If available, preoperative interscalene or axillary nerve blockade, in addition to postprocedure injection of a local anesthetic, can be beneficial for postoperative analgesia and recovery.[37,38] CR in this context should involve the anterior capsule and rotator interval (including the coracohumeral ligament) whereas MUA should include forward flexion, abduction, ER-0, and IR at 0° of abduction given the association of abnormalities in these structures and planes of motion in AC.[32-36] Release of additional structures and inclusion of other planes of motion in these adjunct interventions can also be considered based on clinical features and intraoperative findings in a given patient.

The use of preoperative physical therapy has been suggested to be beneficial for RC tears with AC to restore shoulder ROM preoperatively and use a less aggressive postoperative rehabilitative protocol.[2,17,39] However, the potential issue of noncompliance with preoperative rehabilitation owing to pain can significantly affect its efficacy.[2,40] Furthermore, progression of the RC tear, fibrosis of the remnant tendon, and fatty infiltration of involved RC muscles can occur as a result of the rehabilitation itself and the operative delay, making the eventual repair more technically challenging.[17,40-43] One study included in this review does support the efficacy of preoperative physical therapy in terms of several clinical outcomes, but it did not incorporate several commonly used nonoperative interventions in AC.[25] Conservative modalities such as corticosteroid injection into the glenohumeral joint and the rotator interval have a strong base of evidence for treatment of AC while lacking certain shortcomings of physical therapy including a long treatment course.[25,28,44-46] Combinations of these interventions should be considered for future investigations of delayed versus immediate operative treatment in this patient population. Nonetheless, this review suggests that although the use of physical therapy can be beneficial in this scenario for poor surgical candidates or patients pursuing nonoperative management, it may compromise the overall prognosis if delaying planned surgical intervention.

The most common postoperative complication identified in this review was persistent stiffness. It is interesting to note that although preoperative AC has been identified as a risk factor for post-arthroscopy shoulder stiffness, the overall prevalence of the latter in this review is comparable to rates described in the literature.[4,47,48] In contrast, the proportion of patients in this review with postoperative stiffness refractory to conservative management appears to be greater than literature rates for patients undergoing arthroscopic RC repair alone.[49] Several factors are likely contributors to these inconsistencies observed in our review. Rates of post—RC repair shoulder stiffness in the literature vary widely, with an incidence ranging between 1.5% and 11.1%.[47] Because risk factors for the development of postoperative stiffness are infrequently addressed thoroughly in such studies, individuals with RC tears and preoperative AC are unlikely to be representative of the RC repair population as a whole.[4,47] In addition, postoperative rehabilitation for RC repair alone is often more conservative than the protocol described throughout the current review.[50,51] Comparisons of early shoulder ROM against immobilization after RC repair have shown a significantly lower incidence of postoperative stiffness in the former group.[52,53] It can thus be speculated that individuals with milder forms of postoperative stiffness may have benefitted from the more aggressive protocol, giving the appearance of a lower complication rate. Notably, all reports of persistent postoperative stiffness in this review arose from the group undergoing RC repair plus CR. This may be the result of a relative over-representation of this treatment group in our review, thus misrepresenting the actual prevalence in different treatment groups. Furthermore, given the complete absence of postoperative stiffness reported in the group undergoing RC repair plus MUA and CR, it is unlikely that CR alone is the primary risk factor for its development in this population.

RC retear is a feared complication in patients with RC tears with preoperative AC, given the nature of the operative interventions and accelerated rehabilitation used to address the latter. Histologic studies have suggested that RC healing after repair occurs in several phases and is most vulnerable in the initial 6 weeks postoperatively.[54,55] Given the risks and complexity inherent to a revision cuff repair, a protected rehabilitation protocol with up to 6 weeks of immobilization has been suggested to ensure integrity of the repair construct.[51,52] Although RC retear was one of the most common complications identified in this review, its rates were lower than those described for patients undergoing RC repair alone.[20,56] This finding can be attributed to several factors including decreased tension placed on the cuff repair itself owing to use of MUA and/or CR and predisposition to faster tissue formation at repair sites in individuals with preoperative AC.[20,57] Several studies comparing conservative against accelerated rehabilitation protocols after RC repair alone were unable to show significant differences in cuff retear rates between groups.[50,58] Furthermore, strong evidence exists for less patient-reported pain and greater functional outcomes in both short- and long-term postoperative periods using accelerated compared with conservative rehabilitation.[50] Regardless, individuals with multiple risk factors for cuff retear might fare better with a more conservative postoperative protocol.[59,60] In the absence of these factors, our review supports use of an accelerated postoperative rehabilitation protocol for treatment of RC tears and preoperative AC. A sample outline for such a protocol is shown in Table 6.[8]

The main strength of this study is that it reports on a topic that has not yet been comprehensively addressed in any prior systematic reviews. Furthermore, although the patient populations among included studies were heterogeneous owing to the variation in inclusion criteria, several clinical and functional outcome measures were used by a substantial proportion of included studies, providing a way to compare data across studies in the form of forest plots and pooled figures. A thorough effort was made to avoid pooling to present relevant data in a holistic manner without misconstruing the included results.

Limitations

The main limitation of this review is the quality of available evidence, with included studies being primarily Level IV evidence. This is not uncommon for systematic reviews in orthopaedic surgery in general and is largely unavoidable until higher-level studies of the current topic and other topics are conducted and published. Another significant limitation comes from the lack of stratification of treatment or clinical outcomes by RC tear cause, despite prioritization of surgical intervention often differing in degenerative compared with traumatic RC tears.[1] Future studies in this setting should aim to differentiate these populations to determine whether the timing of operative treatment affects outcomes in this scenario based on the cause of RC tears as well. Finally, a number of conservative interventions used routinely in the management of AC alone were not identified in any studies of this review. Further investigation is required regarding the viability and effectiveness of these interventions in the context of RC tears with AC.

Conclusions

The results of this systematic review support treatment of patients with degenerative RC tears and concomitant AC with a combination of RC repair and MUA, CR, or both MUA and CR. Regardless of the treatment modality, accelerated postoperative rehabilitative protocols are beneficial in preventing postoperative persistence of AC and can be safely used in this scenario without a substantial increase in complication rates compared with patients undergoing RC repair alone with conservative rehabilitation.

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