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Outcomes for subscapularis management techniques in shoulder arthroplasty: a systematic review

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Background: This systematic review aims to synthesize published data for the most common subscapularis takedown and repair to compare outcomes in the setting of shoulder arthroplasty.
Methods: Searches of MEDLINE and Cochrane Library databases identified studies that reported clinical or radiologic outcomes for subscapularis management in the setting of shoulder arthroplasty. Comparisons included musculotendinous integrity, subscapularis testing and strength, shoulder range of motion, and functional outcome scores.
Results: The 14 included studies reported considerable variability in techniques, outcomes, and musculotendinous integrity. Lesser tuberosity osteotomy (LTO) demonstrated better healing rates (93.1%) than subscapularis peel (SP; 84.1%) and midsubstance tenotomy (ST; 75.7%), although not significantly different. A statistically significant increase in fatty infiltration was found after surgery across techniques, and range of motion and strength were similar. Mean rates of normal results for belly-press and lift-off tests were uniformly better for LTO (79.1% and 80.7%) over ST (66.7% and 65.6%), although multiple studies showed poor correlation between subscapularis functional testing and musculotendinous integrity. Mean total Constant and Western Ontario Osteoarthritis of the Shoulder Index outcome scores were slightly better for LTO (77.6, 84.2) than for SP (71.8 and 82.7). Mean American Shoulder and Elbow Surgeons scores favored the ST group (80.8) over the SP (79.1) and LTO (73) groups.
Conclusions: The data suggest no significant differences exist for postoperative musculotendinous integrity or clinical outcomes among the subscapularis management techniques in shoulder arthroplasty. Subscapularis healing and integrity appear to favor the lesser tuberosity takedown method. Additional randomized controlled comparisons with long-term follow-up are needed to more effectively compare these surgical approaches.
Level of evidence: Level IV; Systematic Review

Keywords: Subscapularis tenotomy; subscapularis peel; lesser tuberosity osteotomy; shoulder arthroplasty; outcomes; systematic review

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Shoulder arthroplasty for the treatment of arthritis has been shown to produce effective and reliable outcomes.[7] Dissection through the deltopectoral interval with subscapularis takedown has long been the standard approach in performing this procedure. The primary methods for subscapularis mobilization include midsubstance tenotomy (ST), insertional peel (SP), and lesser tuberosity osteotomy (LTO). Associated repair techniques are variable in method and configuration, often with overlap. These generally include soft tissue side-to-side suturing, transosseous sutures for tendon-to-bone or bone-to-bone reapproximation, suture incorporation through or around the stem, and augmentation with a metal plate or button. Several advantages and disadvantages have been described for each technique.

Subscapularis deficiency after shoulder arthroplasty is not uncommon[21,22,29,30,42] and is associated with instability, weakness, and poor functional outcomes.[15,29,31] Several studies have described long-term dysfunction after repair of subscapularis tenotomy.[6,22,29,30] LTO was subsequently introduced as a preferred alternative with the theoretical advantage of bone-to-bone healing, leading to, perhaps, greater repair strength at time 0, fewer nonunions or tendon retears, improved subscapularis function, and better clinical outcomes.[15,23,24,34,37] More recent studies, though, have called into question the clinical[25] and biomechanical[16,44] superiority of the LTO, citing improved repair strength and healing rates with primary transosseous and augmented soft tissue repair techniques for tenotomy. Moreover, published data have documented a number of notable difficulties associated with the LTO technique, including increased operative complexity, inability to medialize the tendon to adjust subscapularis tension, potential compromise of press-fit short-stem fixation, and risk of humeral fracture during the operation.[5]

There is no consensus regarding subscapularis management in the setting of shoulder arthroplasty. A recently published meta-analysis examined the available biomechanical data comparing these techniques and determined that load-to-failure for the initial repair is stronger for LTO; otherwise, there is no statistical difference in cyclic displacement.[39] This review examines the clinical and radiologic data for subscapularis takedown techniques to determine whether one is superior to the others in postoperative musculotendinous integrity and clinical outcomes.

Materials and methods

A systematic review was performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist.[27] Two reviewers (W.S.C. and A.K.) searched the MEDLINE database, through PubMed, and the Cochrane Central Register of Controlled Trials databases between September and December 2016 using the following terms: "shoulder arthroplasty" (title/abstract) *or* "shoulder replacement" (title/abstract) *and* "subscapularis" *or* "lesser tuberosity" (title/abstract). English language studies on human subjects were selected, and Levels I to IV evidence were considered for review.[35] Titles and abstracts were reviewed for relatedness to the study question, and 46 records were selected for formal screening. This analysis did not consider outcomes studies for subscapularis management in reverse shoulder arthroplasty. Review articles, scientific meeting abstracts or proceedings, and perception-based studies were identified and excluded.

Of the remaining 29 publications, full texts were reviewed and assessed for eligibility. No restrictions were placed on publication date, study design, or length of follow-up. Only studies reporting clinical or radiologic outcome data, or both, for specifically reported subscapularis management techniques in shoulder arthroplasty were included. Publications were excluded for not specifying the method of subscapularis takedown with repair and for reporting results on subscapularis-sparing techniques, as were all studies not reporting clinical or radiologic data, including biomechanical analyses. Among studies reporting data for heterogeneous subscapularis management techniques, only those that separately reported outcomes for each intervention were included. All underlying causes of glenohumeral arthritis were included; however, arthroplasty performed for primary diagnosis of fracture or cuff tear arthropathy was excluded. One study reported outcomes on a duplicate patient cohort and was excluded. Full text references were also reviewed to assess for any previously unidentified studies related to the review topic. A flow diagram summarizing this selection algorithm can be seen in Fig. 1.

Demographic and surgical technique details were recorded. Clinical outcomes of interest included subscapularis objective and subjective functional tests, subscapularis strength, range of motion, and patient-reported outcome scores. Radiologic outcomes of interest included subscapularis tendon or lesser tuberosity osteotomy integrity, subscapularis fatty infiltration grading, and signs of prosthetic instability. When able and relevant, weighted averages were calculated for like outcome variables.

Results

Fourteen studies met the inclusion criteria and were further analyzed (Table S1).[2,4,6,9,15,22-25,28,30,34,37,40] Most retrospective case or cohort series examined the results of total shoulder arthroplasty (TSA) for the primary diagnosis of osteoarthritis. A Level I, double-blinded randomized controlled trial comparing results for subscapularis peel and LTO techniques was included.[25] The second most common diagnosis indicating arthroplasty was inflammatory or rheumatoid arthritis. Anatomic TSA was the primary surgical treatment measure, although 3 studies included results for hemiarthroplasty (HA) with an incidence of 7% to 39% of cases performed.[6,25,28] None of the 3 studies reported outcome data separately for HA and TSA. Four studies directly compared outcomes between ST or SP and LTO in a consecutive series of patients.[4,23,25,37] Mean final follow-up times were 13 to 43 months.

Surgical technique

Subscapularis tenotomy

Five studies reported outcomes for the subscapularis tenotomy technique (Table S2).[2,6,22,23,29] In these studies, the tendon was incised 1 to 2 cm medial to its insertion on the lesser tuberosity. The typical, primary repair technique

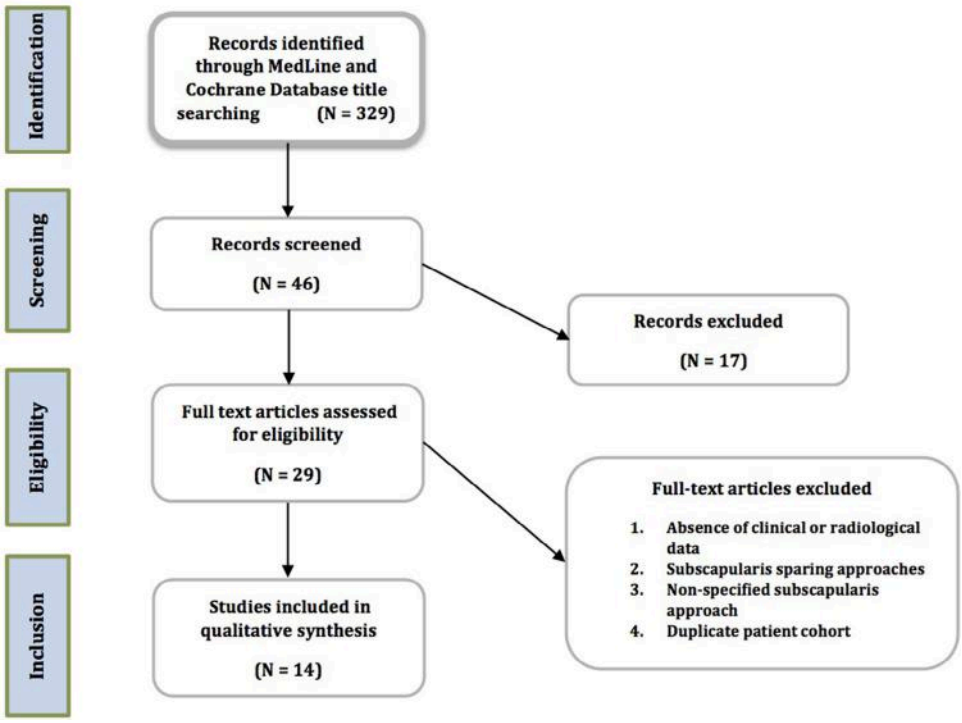

Figure 1 Flowchart describes the process for the systematic review.

included soft tissue side-to-side suturing with 3 to 10 heavy, nonabsorbable knots in figure-of-eight or modified Mason-Allen configuration.[6,22] In 1 instance, the repair was augmented with transosseous suture placement for double-row locked fixation.[23] Alternatively, primary transosseous repair of the tendon to the humeral head osteotomy or subscapularis insertional sites was performed,[2,30] resulting in medialization[30] or lateralization[2] of the subscapularis footprint. In the case of repair to the anatomic neck, only the normal tendinocapsular confluence of the subscapularis was reconstituted.

Subscapularis peel

Four studies reported outcomes for the insertional SP technique (Table S2).[4,25,28,37] In each of these studies, the subscapularis tendinous insertion was peeled from the bicipital groove margin and subsequently repaired back in transosseous fashion. Notably, 2 studies included a medialized repair of the tendon to the humeral head osteotomy site with heavy, nonabsorbable sutures tied over a bone bridge in a mattress or modified Mason-Allen configuration.[28,37] The Buckley et al[4] and Lapner et al[25] groups more broadly and anatomically reattached tendon to the original footprint site, via bicipital groove drill holes, with similar quality sutures wrapped around the prosthesis[4] or tied over a small, lateral reinforcement plate.[25]

Lesser tuberosity osteotomy

Outcomes for the LTO technique were reported in 9 studies (Table S2).[4,9,15,23-25,34,37,40] Four studies included head-to-head outcome comparisons to the LTO or SP methods.[4,23,25,28] Gerber and colleagues' technique for LTO, or subtle variations thereof, was performed in 5 of 9 studies.[4,9,15,23,25] This method used an osteotome or saw to elevate a flat shelf of bone (measuring 0.5-1 cm in thickness by 3-4 cm in length) from the medial bicipital groove margin along with the subscapularis insertion.[15] Alternative techniques focused on the creation of a smaller, thinner "fleck" or wafer robust enough for suture reattachment.[24,34,40] De Wilde et al[9] reported their "C-block" technical variation of the Gerber method, which included preservation of the anterior humeral circumflex vessels and minimal mobilization of the inferior part of the subscapularis.

By nature, all LTO repair techniques were transosseous and anatomic. Like the tenotomy studies, however, there remained significant variability in suture repair configuration, with all performed in single-row (SR) or double-row (DR) fashion. The SR configuration used a single column of drill holes just lateral to the osteotomy site, and sutures were passed out of the top of the humeral cut beneath the head of the prosthesis. The DR configuration included 2 columns of drill holes with suture passing from within the humeral canal through the medial and lateral row for fixation. Qureshi et al[34] did not disclose their LTO repair technique. Lapner et al[25] performed an identical DR repair configuration with the same heavy, nonabsorbable suture and metal plate augmentation for both ST and LTO groups in randomized treatment.

Subscapularis integrity

Twelve studies included advanced imaging, with ultrasound (US) or computed tomography (CT), or plain radiographs (LTO

cases) to assess postoperative subscapularis repair healing and integrity (Table S3).[2,4,9,15,22,23,26,28,34,36,40] Study times ranged from a minimum of 3 months[23] to a mean of 39 months.[15] With no established reference standard, there was inconsistency in imaging methodology and technique between the studies. Those including CT analysis used noncontrasted imaging.[9,15,26,40] Gerber et al[15] defined LTO healing as cortical continuity between the osteotomy fragment and the proximal humerus on axillary radiographs and CT imaging; whereas, De Wilde et al[9] defined healing as visual absence of the osteotomy line. One study used both criteria.[40] Eight studies reported an "intact" subscapularis tendon in 87% to 100% of LTO cases. Of these, 4 studies made this determination using plain radiographs only.[23,24,34,40] Small et al,[44] in the largest radiologic outcome series, cited a 17% incidence of inadequate visualization of the osteotomy site on plain film necessitating further CT analysis.

Methodology and technique for US analysis was equally inconsistent. In most cases, tissue attenuation or partial tearing was constituted by any of the following findings: qualitative thinning ≥50% compared with the contralateral side, thickness ≤6 mm, distinct hypoechoic signal, or visible defect. Rupture or complete tear was defined by full-thickness defect of a portion or the entirety of the subscapularis with or without tissue retraction. Five studies (2 ST, 3 SP) reported an "intact" subscapularis tendon in 53% to 88% of cases, with 2 studies, both for LTO, reporting a complete tear or rerupture rate of 13% and 47%.[2,22] US was used in conjunction with plain radiographs to determine LTO healing in 2 studies,[4,37] and US confirmed the healing rate as both lower[37] and higher[4] than that assessed by orthogonal plain films. Weighted mean healing rates, irrespective of imaging modality, were ST, 75.7%; SP, 84.1%; and LTO, 93.1% (Table S4).

Closer examination of the available data demonstrated the importance of repair by way of restoration of the anatomic footprint with transosseous suture fixation and consideration for implant augmentation. Armstrong et al[2] used a primary transosseous repair method that yielded an 87% healing rate as confirmed by US. Similarly, 2 studies using an anatomic, broad-based tissue reattachment technique for the SP takedown method reported healing rates of 88% and 100%.[4,26] Interestingly, of the 5 studies reporting subscapularis complete rupture or osteotomy nonunion,[2,4,26,37] only 3 reported the presence or absence of radiographic signs of instability[2,22,37]; 2 of which noted no incidence of instability.[22,37]

Finally, 3 studies reported preoperative and postoperative subscapularis fatty infiltration grading, as described by Goutallier et al,[17] and noted a statistically significant increase in fatty infiltration after surgery (mean preoperative grade, 0.56; mean postoperative grade, 0.95; change +0.38). No significant difference was noted between the SP and LTO techniques when the weighted mean preoperative (0.58) and postoperative (0.96) grades for LTO were compared, and the single study reported grades for SP of 0.54 and 0.95.[26] No study reported muscular degenerative changes for ST.

Subscapularis function

Data for subscapularis function before and after surgery for each technique were reported in 13 studies (Table S5).[2,4,6,9,15,22-25,28,30,34,37] Results of the belly-press,[13] lift-off,[14] or shirt-tuck difficulty[13] test were reported as a normal or abnormal finding in 9 studies. Alternatively, in an effort to limit observer error or possible bias, Jandhyala et al[23] evaluated belly-press test performance according to elbow movement and assigned grades 2 and 3 as abnormal. Weighted mean calculations demonstrated that poorer subscapularis functional results are seen with the ST technique than with LTO (Table S4). For ST, the mean incidence of postoperative normal or negative results for belly-press and lift-off testing was 66.7% and 65.6%, respectively. The rate of shirt-tuck difficulty was 42.5%. Comparatively, for LTO, the weighted mean incidence of postoperative normal or negative results for belly-press and lift-off testing was 79.1% and 80.7%, respectively. The rate of shirt-tuck difficulty was 15.3%. Only 1 study reported subscapularis function testing results for SP, which was comparable to the mean LTO results.[28]

Jackson et al[22] used US results (47% complete tears, 0% partial tears) as a reference standard to correlate postoperative subscapularis testing with tendon integrity. The lift-off/belly-press test yielded 4 false negatives (negative predictive value, 56%) and 3 false positives (positive predictive value, 50%) , with no correlation between test results and tendon integrity ($P = 1$). In fact, the lone patient unable to perform a shirt tuck was noted to have an intact tendon on magnetic resonance imaging. Armstrong et al[2] similarly reported that the belly-press test was not reliable for determining tendon integrity (positive predictive value, 13%).

Subscapularis strength measurements using a hand dynamometer in isometric, isokinetic, belly-press, lift-off, shirt-tuck, and bear hug testing were recorded postoperatively in 5 studies with significant variability (Table S5). As such, weighted mean values were not calculated for this review. Jackson et al[22] demonstrated that isokinetic internal rotation ($P < .01$), isometric internal rotation ($P = .01$), and bear hug ($P < .01$) strength measurements correlated well with tendon integrity. Buckley et al[4] showed that abnormal US results correlated with decreased belly-press resistance. Furthermore, the authors asserted that their assessment of the qualitative physical examination findings, including the belly-press, lift-off, and bear hug tests, did not correspond with US findings and were unreliable predictors of subscapularis tendon integrity.[4] The deviation ranges reported in all studies for these measurements were substantial.

Range of motion

Ten studies reported a mix of preoperative and postoperative range of motion data for the ST, SP, and LTO techniques (Table S6).[2,4,6,15,22,23,28,30,34,37] Methodology was quite variable. Significant motion improvement was noted for all ranges, from preoperative to postoperative, in nearly all reporting studies. Weighted mean postoperative active range of motion measurements are summarized in Table S4.

Outcome scores

A variety of outcome scores were reported with considerable inconsistency among 9 studies (Table S6).[2,4,6,9,22,25,28,34,37] The postoperative American Shoulder and Elbow Surgeons (ASES) function score was most commonly used and was reported in 5 studies,[2,6,25,28,34] including 2 ST, 2 SP, and 2 LTO cohorts. The mean preoperative ASES score for ST was 38.4. Only 1 study reported preoperative ASES scores for LTO (40).[34] No studies reported preoperative ASES scores for SP. Weighted mean postoperative ASES scores for the ST, SP, and LTO groups were 80.8, 79.1, and 73, respectively (Table IV).

The Constant score was the next most common outcome measure in this review and was reported in 4 studies,[4,9,28,34] including 3 LTO and 2 SP cohorts. Preoperative scores were infrequently reported. Mean postoperative total Constant scores for the SP and LTO groups were 71.8 and 77.6, respectively (Table S4).

After controlling for a follow-up imbalance between groups, Buckley et al[4] reported statistically significant improvements in WOOS total ($P = .05$), WOOS sports/recreation/work ($P = .05$), and WOOS emotions ($P = .03$) scores in favor of the LTO group over SP, at a mean follow-up of 22.1 and 31.7 months, respectively. Although this difference was clinically insignificant, a higher incidence of subscapularis tendon abnormality was noted in the SP group, which yielded clinically significant inferior WOOS (88 ± 15 vs. 65 ± 18) and Disabilities of the Arm, Shoulder and Hand (11.5 ± 11.4 vs. 25.9 ± 11.2) scores.[4]

Discussion

Subscapularis dysfunction after all types of open shoulder surgery has been attributed to failure of the repaired tendon to heal or subsequent muscle degeneration, or both, and is often associated with poorer clinical outcomes.[19,21,29,31,33,38,42] Surgical technique that optimizes repair strength, tendon healing, and tissue preservation is important. The published literature, to date, has been unclear regarding the superiority of one subscapularis management technique over another in the setting of shoulder arthroplasty. To our knowledge, this systematic review is the first in the literature to evaluate the clinical and radiologic outcomes associated with the most common competing subscapularis management techniques in the setting of shoulder arthroplasty.

In 2003, the Miller et al[30] study reporting a two-thirds incidence of postoperative subscapularis dysfunction after ST and side-to-side repair for shoulder arthroplasty sparked renewed interest in a previously "seldom recognized problem" and led to the development of LTO techniques for an alternative anterior approach to the shoulder. Gerber et al[15] subsequently published the initial outcome results for LTO and noted a 100% osteotomy healing rate with higher rates of normal belly-press and lift-off test results. Generating further enthusiasm for this technique, multiple subsequent retrospective series, directly comparing outcomes for ST and LTO cohorts, reported higher rates of tendon integrity with postoperative healing (90%-100%) and better clinical outcomes for the LTO technique.[4,23,34,39] By contrast, additional studies examining both traditional tenotomy and SP methods reported a 3% to 47% retear rate over mean follow-up of 19 to 43 months.[2,4,22,28,37] From this perspective, the debate appears to be settled in favor of LTO. When data from all studies are compared, the weighted mean "intact" tendon rate after surgery for LTO (93.1%) is significantly better than that of the ST (75.7%) and SP (84.1%) techniques. Yet, although some authors have shown this higher rate of tendon integrity to predict better subscapularis function and overall clinical outcomes,[4,23,37] others have noted a poor correlation.[2,22,28] Moreover, in the only Level I randomized controlled study comparing outcomes for 2 of the approaches using a uniform repair technique, no differences were noted in postoperative musculotendinous integrity, subscapularis strength, or clinical outcomes. These inconsistent findings are likely a function of multiple additional considerations, which should be discussed.

Firstly, clinical measures to evaluate subscapularis integrity and functional outcomes after surgery can be unreliable and inconsistent. Results have been quite variable (0%-67% retear rate), particularly in the absence of advanced imaging for reference.[2,6,29,30] The belly-press test was previously validated as a means to assess subscapularis integrity. Resch et al[35] reported a 100% sensitivity for detection of complete tears. However, the use of US imaging to confirm integrity has shown the belly-press test has poor positive predictive value for detection of subscapularis pathology after shoulder arthroplasty.[30] The lift-off and shirt-tuck tests have also been shown to have poor predictive value.[22] Some authors have demonstrated better correlation between tendon integrity and postoperative strength testing,[4,22] but others have not.[28] Similar variability in methods and results are seen for patient-reported outcome measures as well. The 9 studies that reported functional outcome scoring in this review used 7 different outcome scores. Only 4 studies provided direct outcome comparisons between the takedown groups.[4,23,25,37] Although the weighted mean outcome scores in this review are similar between the techniques, more consistency of valid patient-reported outcome measures is needed in future studies for more accurate comparisons.

Secondly, the true incidence of postoperative subscapularis retear or rupture is unclear. Prior studies have examined rupture in the context of postoperative component instability and need for revision after arthroplasty,[2,29,31] but in short-term to midterm follow-up studies using advanced imaging, the incidence of subscapularis compromise in the absence of clinical or radiographic signs of instability may be relatively high (10% to 47%).[22,37] There has been little consistency in methodology for establishing a reference standard. US was previously established as an appropriate method to assess rotator cuff function after TSA.[20,37,41,43] This modality can be used to dynamically assess musculotendinous integrity after any of the takedown techniques. Unfortunately, this method

is operator dependent, accuracy for detection of smaller tears is a concern, and fatty infiltration of muscle is not easily assessed.

Computed tomography (CT) is an alternative that offers improved ability to evaluate bone-to-bone healing and muscular degeneration; however, accuracy in assessment of soft tissue integrity remains an issue. Streaking artifact can obscure visualization of the uppermost portion of the tendon insertion and muscle. Moreover, interobserver reliability of CT scanning for determination of fatty infiltration status can be modest.[32]

Plain radiographs were the only modality used to assess healing after LTO in 4 studies.[23,24,34,40] Although well executed orthogonal views allow clear visualization of the bony osteotomy site in many cases, evaluation of the adjacent tendon and muscle integrity is impossible. Small et al[40] reported a 17% incidence of nonvisualization of the osteotomy site on plain films. In addition, a healed osteotomy does not preclude adjacent musculotendinous abnormality. Scalise et al[37] reported 100% healing in 20 shoulders, but also noted tendon "attenuation" or partial tearing on US imaging in 2 shoulders. With such variability, subscapularis integrity after takedown and repair is quite difficult to assess and compare between studies and takedown techniques. A more reliable and accurate method is needed to establish a reference standard.

Thirdly, as summarized in Table S2, there is considerable technical variability between studies that obscures direct outcome comparisons between the ST, SP, and LTO takedown methods. Repair configuration, for example, yields significant biomechanical influence. Although no standard repair technique exists within groups, review of the synthesized data demonstrates that clinical and radiologic outcomes appear to favor anatomic bony or broad soft tissue reattachment to the bony footprint with transosseous suture fixation and consideration for further repair reinforcement via prosthesis or metal plate/button incorporation. SP, rather than the more traditional ST technique, offers the advantage of increasing the tissue-to-bone surface area for healing.

Studies reporting tendon reattachment to the anatomic neck or humeral head osteotomy site, for example, have shown significantly higher rates of postoperative tissue compromise as confirmed by US.[28,37] Biomechanical data confirm less mechanical strength and smaller healing contact area for this technique compared with the broader and more anatomic method of tendon-to-tendon fixation enhanced with bone tunnels.[1] Similar findings have also been shown for simple side-to-side soft tissue repair after traditional tenotomy.[22] Lapner et al[26] performed the only head-to-head comparison between SP and LTO by using an identical anatomic and transosseous repair configuration for both groups. In doing so, they reported no significant differences in postoperative musculotendinous tearing or fatty infiltration.[26] Alternative subscapularis-sparing anterior approaches to the shoulder have been described, with excellent tissue healing and clinical outcome results reported.[18,36] These methods are not considered common in use and, thus, were excluded for the purposes of this review.

Adjunctive closure of the rotator interval has been shown to have important biomechanical implications in the setting of shoulder arthroplasty.[8] Although partial or complete rotator interval closure is frequently performed, many studies included in this review failed to disclose their management of the rotator interval,[23-25,30,34,40] and 1 study specifically reported not closing the interval.[22] Other important technical aspects that likely affect outcomes and are poorly controlled between studies include repair tension on the subscapularis (anatomic, medialized, or lateralized), humeral component type, sizing, version, and offset, and the postoperative rehabilitation protocol.

Fourthly, multiple factors contribute to subscapularis function and clinical outcomes after surgery that further confound comparative analysis between takedown techniques. Independent of tendon integrity, fatty muscular degeneration also influences subscapularis strength, mobility, and functional outcome scores.[10,15] Even in cases of universal tendon reattachment with healing, degeneration of the subscapularis muscle after open surgical release remains a concern.[15,22,30,38] Gerber et al[15] reported progression of subscapularis fatty infiltration by at least 1 stage in 45% of shoulders postoperatively, despite no CT evidence of tendon tearing or attenuation. Similarly, Lapner et al[26] demonstrated 95% to 100% healing rate for ST and LTO repairs, yet fatty infiltration increased in all shoulders. At 24 months of follow-up, only 22% of patients reached normal strength, and strength on the operative side remained significantly lower than that on the normal contralateral side.[26] Multiple authors have hypothesized that more aggressive intraoperative subscapularis release and lengthening likely play a contributory role for both muscular degeneration and risk for repair failure.[1,28,30,38,47] Other factors that may influence postoperative musculotendinous integrity and function include intrinsic, irreversible tissue degeneration in the setting of advanced shoulder arthritis and biomechanical changes secondary to arthroplasty.

With these considerations in mind, no clear evidence exists to support the superiority of one subscapularis management approach over another in shoulder arthroplasty for postoperative tendon integrity, subscapularis function, or clinical outcomes. Weighted mean calculations are summarized in Table S4. Shoulder range of motion means are similar. Although subscapularis functional testing results favor LTO over ST, the clinical significance of this finding is unclear. For the ASES and Constant mean scores, differences between techniques are less than the minimum clinically important difference threshold previously established for each measure after shoulder arthroplasty (ASES, 9; Constant, 10.4).[45,46] A minimum clinically important difference has not been determined for the WOOS. Multiple studies have demonstrated the association between intact subscapularis tendon and better clinical outcomes after surgery.[4,22,28,37] From that standpoint, the SP method may be superior to that of ST because it allows broad, anatomic footprint restoration to bone with secure transosseous fixation, which appears optimal for healing. No study has directly compared clinical or imaging results for ST and SP.

Our findings should be viewed in the context of certain study limitations. Unfortunately, to this point, the evidence evaluating subscapularis takedown and repair techniques in the setting of shoulder arthroplasty is predominately derived from small, uncontrolled retrospective case series. The potential for selection bias is present. Moreover, inclusion criteria are noticeably inconsistent between the studies. Five studies included patients with a primary diagnosis of rheumatoid/inflammatory-mediated arthropathy (2%-25%)[4,15,25] or post-traumatic arthritis (12%-15%).[6,30] One study included patients with history of rotator cuff surgery (9%).[30] The risk for preoperatively compromised or diseased subscapularis tendon is theoretically greater for these patients.

Another possible confounding factor was the inclusion of outcomes for both HA and TSA in 3 studies.[6,25,28] Multiple prior studies have shown better pain relief for TSA over HA.[3,11,12] With less pain after surgery, one might expect better subscapularis strength and function. Although 1 study reported an incidence of HA of nearly 40% in its study group,[28] the remaining 2 reported a much smaller percentage. For the purposes of this review, excluding studies with heterogeneous arthroplasty methods would, by necessity, eliminate the only Level I study available from analysis, and from that standpoint, was deemed disadvantageous.

Finally, as previously discussed, methodological heterogeneity between studies remains a significant limiting factor in this analysis. Future studies should include randomized controlled comparisons between the different subscapularis release and repair techniques and, in doing so, use reproducible, valid, and accurate methods for assessing subscapularis integrity, subscapularis function, and patient-reported clinical outcomes.

Conclusion

The best available evidence suggests no clear differences exist for subscapularis strength, shoulder range of motion, or functional outcome scores between subscapularis mobilization techniques in the setting of shoulder arthroplasty. Musculotendinous integrity appears to favor anatomic or broad-based tissue reattachment to bone with transosseous suture fixation and consideration for further repair reinforcement via prosthesis or metal plate/button incorporation. SP, rather than ST release, may be the optimal tenotomy method. Additional randomized controlled comparisons are needed to more effectively compare these techniques.

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Supplementary data

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