The subscapularis-sparing approach in humeral head replacement

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Background: This report represents a prospective case series evaluating an open deltopectoral approach, both radiologically and clinically, without tenotomy or complete takedown of the subscapularis tendon insertion. We hypothesized that this novel technical approach would allow preservation of the upper tendon border, thus decreasing subscapularis repair failures and fatty infiltration while simultaneously allowing accelerated rehabilitation.

Methods: Fifty patients underwent humeral head replacement surgery through a subscapularis-sparing approach. In this approach, we take down only the inferior 30% to 50% of the subscapularis tendon, leaving the critical superior aspect of the tendon attached to the lesser tuberosity. Forty-three patients were included in the postoperative results (7 were lost to follow-up). Nineteen patients had a postoperative magnetic resonance imaging study, and 24 patients had ultrasound evaluation. Physical examination included belly-press and lift-off tests; follow-up included visual analog scale, American Shoulder and Elbow Surgeons, Constant, modified UCLA, Rowe, and Short Form 12 scores.

Results: All patients had a minimum 2-year follow-up. All patients had subscapularis strength equal to the opposite side as measured by lift-off, belly-press, and bear hug tests. Average postoperative scores all showed statistically significant improvement except for general health. All had an intact subscapularis tendon attachment as evaluated by either magnetic resonance imaging or ultrasound imaging. None had atrophy in the muscle belly.

Conclusions: The subscapularis-sparing, minimally invasive approach to the glenohumeral joint provides adequate exposure to allow humeral head replacement. When the upper border of the subscapularis insertion is left intact, there is a decreased risk of postoperative failure (rupture or atrophy) of the subscapularis tendon.

Level of evidence: Level IV, Case Series, Treatment Study.

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remain a concern after both tenotomy \cite{9,17,18} and lesser tuberosity osteotomy \cite{2,10,21} despite multiple variations in subscapularis takedown and reattachment techniques, with incidence reported as high as 40% in some studies. \cite{31,32} In addition to failure of the reattachment of the tendon, neurologic atrophy and fatty infiltration of the muscle belly may also be a cause of pain and functional impairment. \cite{8,25,26} Montgomery and Jobe described the subscapularis split and repair with suture anchors as a way to avoid taking down the subscapularis during capsulolabral repair in athletes. \cite{20} We have been concerned about the propensity for subscapularis detachment for many years and have been seeking an alternative, mini-open approach that would allow shoulder replacement without taking down the entire tendon. After multiple cadaver dissections, we developed a new technique for taking down only the inferior 30% to 50% of the subscapularis tendon and preserving the more critical upper part, thus preventing well-known complications and allowing earlier rehabilitation.

This report represents a prospective case series evaluating this approach, both radiologically and clinically. We hypothesized that this novel technical approach would allow preservation of the upper tendon border, thus decreasing subscapularis repair failures and fatty infiltration while simultaneously allowing accelerated rehabilitation.

**Materials and methods**

**Preoperative data**

Fifty consecutive patients underwent humeral head replacement (Copeland Humeral Head Resurfacing [Biomet, Warsaw, IN, USA], GLOBAL CAP [Conservative Anatomic Prosthesis] [DePuy, Raynham, MA, USA], or GLOBAL ADVANTAGE humeral stem [DePuy]) surgery for arthritis of the shoulder through a subscapularis-sparing approach between May 2007 and March 2010. The present study was limited to humeral hemiarthroplasty patients. All of the patients considered for the study were being treated for glenohumeral arthritis; conservative treatment had failed, and each patient decided to schedule glenohumeral joint replacement surgery. Inclusion criteria for this study consisted of grade III degenerative changes \cite{10,22} of the shoulder and a willingness to undergo this subscapularis-sparing procedure. Exclusion criteria were glenoid asymmetry (Walch B2 or C) \cite{31,32}, unwillingness to undergo the procedure, and unwillingness to complete the postoperative questionnaire or to participate in the examination.

The study included 29 men and 21 women, and there were 27 right shoulders and 23 left shoulders. The mean age of the patients was 63.2 years (range, 32-87 years). Of the 50 patients, 7 were withdrawn for reasons of severe physical illness unrelated to the shoulder (1), the patient’s decision (4), and other reasons (2). All 7 patients had intact subscapularis function postoperatively at last clinical follow-up but were not included in the follow-up study data for reasons stated. Outcome measures included age, active and passive shoulder range of motion, visual analog scale (VAS) pain level, and the following rating scales: American Shoulder and Elbow Surgeons (ASES), Rowe, Constant, modified University of California–Los Angeles (UCLA), and Short Form 12 (SF-12). All outcomes measures were collected by independent evaluators blinded to the procedure and not by the operative surgeons. The preoperative physical examination included the lift-off test, \cite{29} belly-press test, \cite{29} and bear hug test. \cite{4}

**Operative technique**

All patients were positioned in the beach chair position and placed under general anesthesia in combination with an interscalene block. Prophylactic antibiotics were administered before incision. A 5- to 7-cm vertical incision was made with a standard deltopectoral approach. The long head of the biceps was located at the top of the pectoralis major tendon, followed up through the rotator interval, and released off the superior labrum if a tenodesis is to be performed. The biceps was tagged and later tenodesed with suture as part of the final closure. The subscapularis tendon was identified, and a split was made in the lower muscle tendon raphe approximately one half to two thirds inferior to the superior border of the tendon (Fig. 1). An electrocautery was then used to follow a line straight down the humerus on the medial ridge of the bicipital groove down to the pectoralis major insertion. This left the tissue along the lateral groove as an anchor for future soft tissue repair. The inferior third to half of the subscapularis was elevated off the humerus from the raphe inferiorly in a subperiosteal manner (Fig. 2).

It is important to continue the release medially under and around any inferior humeral spurs. As the soft tissues are released, the arm is continually and slowly externally rotated and abducted to allow exposure of the inferior humeral head. Once the dissection reaches the posterior aspect of the humerus, a Cobb retractor is used to “flip” the upper subscapularis muscle over the superior aspect of the humeral head as the arm continues to be abducted and externally rotated. A Chandler retractor is placed medially and a Hohmann retractor superiorly to protect the soft tissues and completely expose the humeral head (Fig. 3). All inferior osteophytes are removed to allow adequate sizing of the implant. The humeral head may be either reamed for surface-type replacement or cut for humeral head replacement. In this approach, it is relatively easy to re-create the patient’s normal version because of the exposure of the humeral head. The replacement is then performed in standard fashion, with symmetrical reaming for surface replacement arthroplasty (48 patients) or humeral cut in anatomic version, humeral shaft reaming, and implantation of a stemmed implant (2 patients). After replacement of the humeral head, the arm is adducted and internally rotated to allow the head to relocate into the glenoid. The preserved upper subscapularis tendon is easily visualized (Fig. 4). The lower subscapularis tendon is then repaired with either bungler #2 orthocord or by a double-loaded suture anchor and a double-row repair technique (Fig. 5) as well as interrupted polydioxanone sutures (PDS II; Ethicon Endo-Surgery, Johnson & Johnson Company, New Brunswick, NJ, USA) to reinforce the repair, both in the split raphe and at the distal tendon insertion. All patients were placed into a sling with an abduction pillow in the operating room before awakening from anesthesia.

**Postoperative**

Radiographs taken in the recovery room and all postoperative visits confirmed proper implant positioning, with no malposition due to
limiting the exposure by preserving the subscapularis muscle. Postoperatively, passive range of motion and active external rotation exercises were started at 1 week, and active internal range of motion exercises were started at 3 weeks. Physical therapy was allowed to be progressed as tolerated beginning at 4 weeks, with most patients resuming gym workouts before 8 weeks.

Results

Preoperative data

Initial radiographs showed grade III or grade IV arthritic changes, with bone contacting bone, on the axillary view in all cases. The degree of degenerative change was also measured on preoperative magnetic resonance imaging (MRI) or computed tomography, or both, as grade III or grade IV in all cases.29

The preoperative evaluations showed a mean ASES score of 16.7 and UCLA score of 10.1, Rowe score of 44.4, and Constant score of 24.2. The mean preoperative scores on the SF-12 were as follows: physical functioning, 32.6; role—physical, 37.5; bodily pain, 27.3; general health, 53.5; vitality, 33.7; social functioning, 49.4; role—emotional, 39.8; and mental health, 42.2. The mean preoperative score on the VAS pain scale was 7.8 on a scale ranging from 0 to 10 (Table I).

Postoperative data

Despite the limited immobilization and early, aggressive rehabilitation, all patients had a negative belly push-off and lift-off test result at 4 weeks postoperatively. All patients had a physical examination and completed questionnaires at 2-year follow-up or more postoperatively to ascertain the condition of the subscapularis tendon. The mean length of follow-up was 48 months (range, 24 to 60 months). Of the 43 patients who were willing to be included in the study and to return for repeated imaging, 19 received MRI scan formatted to evaluate the tendon and muscle of the subscapularis while minimizing scatter. The remaining 24 patients received an ultrasound examination by a trained ultrasonographer to evaluate the attachment of the...
subscapularis, the inferior repair, and the amount of atrophy, if any, present in the muscle of their operative shoulder. The same measures and rating scales (including the SF-12) collected preoperatively were collected postoperatively for all 43 patients who returned.

**Statistical methods**

All data were independently tested for clinical significance by the use of Wilcoxon signed rank test of variance to analyze the hypothesis that there was an improvement from baseline to follow-up and to quantify the effectiveness of the approach.

**Final follow-up examination and imaging**

The ability to perform the lift-off test, the bear hug test, and a normal belly-press test was present in all 50 (the 43 included in the study and the 7 who declined to return for reasons previously listed) patients at 1 month postoperatively. All 3 test results have remained normal throughout follow-up in all patients, and all 3 test results were still negative in the 43 who returned for final evaluation.

All patients improved after the subscapularis-sparing deltopectoral procedure with humeral head replacement. Most patients noticed an initial improvement, and all have
Table I

<table>
<thead>
<tr>
<th>Mean ratings at final follow-up</th>
<th>Preoperative scores</th>
<th>Postoperative scores</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASES</td>
<td>16.7</td>
<td>74.40</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>UCLA</td>
<td>10.1</td>
<td>27.00</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Bankart</td>
<td>44.4</td>
<td>81.70</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Constant</td>
<td>24.2</td>
<td>78.30</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>SF-12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical functioning</td>
<td>32.6</td>
<td>64.50</td>
<td>.0001</td>
</tr>
<tr>
<td>Role—physical</td>
<td>37.5</td>
<td>66.00</td>
<td>.009</td>
</tr>
<tr>
<td>Bodily pain</td>
<td>27.3</td>
<td>73.30</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>General health</td>
<td>53.5</td>
<td>61.90</td>
<td>.1615</td>
</tr>
<tr>
<td>Vitality</td>
<td>33.7</td>
<td>53.50</td>
<td>.002</td>
</tr>
<tr>
<td>Social functioning</td>
<td>49.4</td>
<td>79.70</td>
<td>.0005</td>
</tr>
<tr>
<td>Role—emotional</td>
<td>39.8</td>
<td>78.20</td>
<td>.0002</td>
</tr>
<tr>
<td>Mental health</td>
<td>42.2</td>
<td>72.70</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>VAS</td>
<td>7.8</td>
<td>2.20</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

ASES, American Shoulder and Elbow Surgeons; UCLA, modified University of California–Los Angeles; SF-12, Short Form 12; VAS, visual analog scale pain level.

Discussion

In this patient cohort in which humeral replacement was performed through a partial subscapularis takedown, the physical examination and imaging showed that postoperatively, the muscle tendon and strength were normal. The study provides a novel variation to a common surgical approach for shoulder arthroplasty. The short-term clinical results and outcomes have been excellent compared with earlier results in studies in which the entire subscapularis tendon is taken down.

Subscapularis takedown does provide an excellent exposure to the shoulder joint during open shoulder procedures. The actual incidence of subscapular rupture after open surgical takedown is unknown but remains an underreported problem. Jackson et al evaluated 15 asymptomatic total shoulder arthroplasty patients by ultrasound and found that 7 of the 15 had significant failure of the repaired subscapularis tendon.12 Concerns about maintaining the functional integrity of the subscapularis in athletes are what led Montgomery and Jobe to develop the subscapularis split technique for open capsule-labral work.20 Other authors have shared these concerns about subscapularis failure after open surgery, but the focus during arthroplasty has always been that complete takedown is necessary for exposure; therefore, numerous techniques have been postulated to prevent postoperative detachment or failure of the repaired subscapularis tendon. These techniques have included lesser tuberosity osteotomy, varying suture patterns, and soft tissue reinforcement techniques.1,5,6,11,13,15,23,30 Surgeons have recently been trying to address this problem by avoiding takedown of the subscapularis. Lafosse et al described total shoulder arthroplasty through the rotator interval without detachment of any of the subscapularis,14 but it was limited by an inability to remove inferior humeral spurs by this approach. Simovitch et al recently discussed total shoulder arthroplasty by a subscapularis preservation technique in which they combined the Lafosse technique with the one used in the present study with satisfactory results in 3 cases. However, no postoperative imaging of the subscapularis was performed.27 Gerber et al reported that postoperative subscapularis insufficiency appears to be lessened with lesser tuberosity osteotomy10,24; however, increases in fatty infiltration were seen in 49% of patients and failure and weakness to belly press in 11% of patients.21 Lapner et al compared lesser tuberosity osteotomy with subscapularis continued to improve during the lifetime of the replacement. There were no cases of instability postoperatively; however, there was 1 postoperative surgical wound dehiscence. This patient underwent a formal incision and drainage and closure; intraoperative cultures remained negative. No other patients have required reoperations after their initial shoulder replacement. These data led to an overall success rate of 100% in regard to subscapularis repair after humeral head replacement by a minimally invasive subscapularis-sparing approach. The mean ratings of the entire group at final follow-up were as follows: ASES score, 74.4 (preoperatively, 16.7; P < .0001); UCLA score, 27.0 (preoperatively, 10.1; P < .0001); Rowe score, 81.7 (preoperatively, 44.4; P < .0001); and Constant score, 78.3 (preoperatively, 24.2; P < .0001). The postoperative SF-12 scores were as follows: physical functioning, 64.5 (preoperatively, 32.6; P = .0001); role—physical, 66.0 (preoperatively, 37.5; P = .009); bodily pain, 73.3 (preoperatively, 27.3; P < .0001); general health, 61.9 (preoperatively, 39.8; P = .0002); social functioning, 79.7 (preoperatively, 49.4; P = .0005); role—emotional, 78.2 (preoperatively, 33.7; P = .002); and mental health, 72.7 (preoperatively, 42.2; P < .0001). The mean VAS pain score was 2.2 (preoperatively, 7.8; P < .0001) (Table I). Thus, all parameters showed statistically significant (P < .05) improvement except for the general health category in the SF-12.

Postoperative imaging

MRI with special sequencing to show the subscapularis muscle and tendon while minimizing implant scatter was performed in 19 of the 43 shoulders at 2 to 5 years postoperatively and showed an intact subscapularis tendon and absence of neuromuscular atrophy or fatty infiltration in all 19 patients.9,10,15,16 Similarly, the ultrasound evaluation of the remaining 24 patients revealed an intact subscapularis tendon without muscle atrophy. These were specific areas of interest because of the lower tendon’s being very thin and the previous documentation of muscle atrophy or tearing as noted in multiple previous studies of the subscapular tendon after tenotomy.10,12,16,18,25,26

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peel in a series of patients and found no significant differences, although the primary outcome measure was the belly-press test with a hand-held dynamometer; no postoperative imaging of the subscapularis was attempted.\textsuperscript{15,16} Despite these advances, subscapularis failure remains a difficult problem to prevent and to treat and can lead to instability, weakness, pain, and early failure in shoulder arthroplasty.\textsuperscript{12,17,18,26,28} Postoperative fatty infiltration of the subscapularis may also cause dysfunction and is seen after both subscapularis tenotomy and lesser tuberosity osteotomy.\textsuperscript{16} It is unknown if fatty infiltration occurs because of the tenotomy or osteotomy, or if retraction or lengthening of the muscle and tendon results in nerve damage that leads to the fatty infiltration.

The present approach represents an attempt to avoid these problems. Our initial dissections centered on approaching the shoulder from the axilla, but we thought that the retraction of the axillary nerve during this approach represented too much of a risk. Our next approach was to use one of the muscle tendon raphes present in the subscapularis as an entry point. This would allow preservation of the upper half of the subscapularis, which accounts for 70\% or more of the strength and function of the subcapsular muscle-tendon unit, while allowing complete access to the humeral head. Approaching the humerus through an inferior subscapularis interval allows removal of the inferior humeral head spurs, capsular release, and access to the glenoid through both the inferior subscapularis interval and the rotator interval while preserving the majority of the subscapularis.

Key technical points in the approach include the following: (1) open the rotator interval by following the biceps tendon superiorly; (2) the initiating point for the inferior takedown is along the medial ridge of the bicipital groove; and (3) the entire flap is elevated as a unit subperiosteally around the humerus to the posterior aspect of the humeral shaft inferior to the humeral spurs to maintain soft tissue protection of the axillary nerve. The lower half could then be repaired with an anchor or with suture. We believe that preserving the superior half of the subscapularis allows a much more rapid postoperative rehabilitation to regain motion and strength while minimizing the risk of atrophy or detachment, as seen in the present study, in which our accelerated rehabilitation program did not result in detachment of the repair.

Weaknesses of the study include a relatively small sample size and a lack of comparative control group with a complete tenotomy of the subscapularis tendon. The lack of full exposure of the glenoid should be considered a weakness of this approach to humeral hemiarthroplasty.\textsuperscript{27}

**Conclusion**

Humeral head arthroplasty performed with this subscapularis-sparing approach provides adequate exposure to allow hemural head replacement. When the upper border of the subscapularis insertion is left intact, there is a decreased risk of postoperative failure or rupture of the subscapularis tendon, even with the more rapid rehabilitation employed for these patients.


