



# Quantification of the exposure of the glenohumeral joint from the minimally invasive to more invasive subscapularis approach to the anterior shoulder: a cadaveric study

Jaime L. Bellamy, DO, MS<sup>a,\*</sup>, Anthony E. Johnson, MD<sup>a</sup>, Michael J. Beltran, MD<sup>a</sup>, Joseph R. Hsu, MD<sup>b</sup>, Skeletal Trauma Research Consortium (STReC)<sup>b</sup>

<sup>a</sup>Department of Orthopaedics & Rehabilitation, San Antonio Military Medical Center, Fort Sam Houston, TX, USA

<sup>b</sup>Orthopaedic Trauma Service, United States Army Institute of Surgical Research, Fort Sam Houston, TX, USA

**Background:** There are multiple techniques to approach the glenohumeral joint. Our purpose was to quantify the average area of the glenohumeral joint exposed with 3 subscapularis approaches and determine the least invasive approach for placement of shoulder resurfacing and total shoulder arthroplasty instruments.

**Methods:** Ten forequarter cadaveric specimens were used. Subscapularis approaches were performed sequentially from split, partial tenotomy, and full tenotomy through the deltopectoral approach. Glenohumeral joint digital photographs were analyzed in Image J software (National Institutes of Health, Bethesda, MD, USA). Shoulder resurfacing and total shoulder arthroplasty instruments were placed on the humeral head, and anatomic landmarks were identified.

**Results:** The average area of humeral head visible, from the least to the most invasive approach, was 3.2, 8.1, and 11.0 cm<sup>2</sup>, respectively. The average area of humeral head visible differed significantly according to the approach. Humeral head area increased 157% when the subscapularis split approach was compared with the partial tenotomy approach and 35% when the partial approach was compared with the full tenotomy approach. The average area of glenoid exposed from least to most invasive approach was 2.0, 2.3, and 2.5 cm<sup>2</sup>, respectively. No significant difference was found between the average area of the glenoid and the type of approach. Posterior structures were difficult to visualize for the subscapularis split approach. Partial tenotomy of the subscapularis allowed placement of resurfacing in 70% of the specimens and total arthroplasty instruments in 90%.

**Conclusions:** The subscapularis splitting approach allows adequate exposure for glenoid based procedures, and the subscapularis approaches presented expose the glenohumeral joint in a step wise manner.

**Level of evidence:** Anatomy Study, Cadaver Dissection.

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**Keywords:** Glenohumeral joint; cadaver; subscapularis split; partial tenotomy; full tenotomy; shoulder resurfacing; total shoulder arthroplasty

The Brooke Army Medical Center Institutional Review Board approved this study (#C.2011.161n).

\*Reprint requests: Jaime L. Bellamy, DO, MS, Department of Orthopaedics & Rehabilitation, San Antonio Military Medical Center, 3851 Roger Brooke Dr, Fort Sam Houston, TX 78234, USA.

E mail address: [jaime.l.bellamy.mil@mail.mil](mailto:jaime.l.bellamy.mil@mail.mil) (J.L. Bellamy).

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The frequency of total shoulder arthroplasty has increased significantly within the last decade.<sup>15</sup> The deltopectoral approach to the shoulder through the subscapularis has proven over time to provide adequate access to the shoulder joint for treatment of fractures to the glenoid or proximal humerus, shoulder resurfacing, total shoulder arthroplasty, and soft tissue repair around the shoulder, including the labrum, rotator cuff, and cartilaginous surfaces of the glenohumeral joint.<sup>13,21</sup> A surgical approach should have the parallel goals of providing adequate exposure for safe performance of the desired procedure, allow for minimal disruption of soft tissue attachments to the region of interest, and avoid putting adjacent neurovascular structures of interest at risk of injury.

The partial and full tenotomies of the subscapularis have both been under scrutiny. Loss of function of the subscapularis has been reported due to failure of the tendon repair or muscular changes, or both, leading to muscle insufficiency,<sup>10,11,30,31</sup> which has the potential to negatively affect clinical outcome.<sup>10,20,23,24,27,29</sup> Multiple alternative approaches have been developed, including the subscapularis split,<sup>14</sup> through the rotator interval,<sup>16</sup> lesser tuberosity osteotomy,<sup>9</sup> subscapularis peel,<sup>12</sup> dual-window subscapularis-sparing approach combined with the subscapularis splitting approach,<sup>3</sup> and the anterior-superior approach.<sup>25</sup>

Some reports have shown primary tendon-to-tendon repairs have inadequate results; however, others have shown it is more efficient and avoids nonunion with osteotomy.<sup>6</sup> A more recent study in which the lesser tuberosity osteotomy was compared with the subscapularis peel found no significant difference in fatty infiltration, strength, and shoulder outcome scores at 2 years of follow-up.<sup>17,18</sup> Despite the alternatives, the subscapularis tenotomy has been the most widely used approach to the glenohumeral joint.

The subscapularis splitting approach has less theoretical risk, but whether it allows adequate exposure of the glenohumeral joint compared with the partial and full tenotomies is unknown. The purpose of the study was to quantify the average area of the humeral head and glenoid exposed with each type of approach, identify 6 anatomic landmarks, and determine the least invasive approach that can be used for placement of the instruments used for shoulder resurfacing and total shoulder arthroplasty. To our knowledge, quantification of the average area of the humeral head and glenoid through the subscapularis approaches presented in this study has not been previously reported.

## Materials and methods

The study used 10 fresh frozen cadaveric limb specimens (each composed of 1 forequarter shoulder). All procedures were performed by the 2 senior authors (A.E.J. and J.R.H.). A standard deltopectoral approach to the shoulder was performed as described below.

## Dissection

With the specimens supine, a 10 cm line was drawn on the skin of the anterior shoulder using a metric ruler to develop the deltopectoral interval. This line was made 3 cm distal to the coracoid process, along the lateral border of the biceps, and parallel to the anterior aspect of the deltoid. An incision was made along this line to expose the cephalic vein. The clavipectoral fascia was exposed and divided just lateral to the coracoid and conjoint tendon. The incision was extended vertically to the coracoacromial ligament and distally to the level of the anterior circumflex artery to expose the subscapularis tendon.

The subscapularis approaches were performed sequentially to further expose the glenohumeral joint. The subscapularis muscle was split in the mid portion, parallel to the plane of pull and in line with the tendon fibers of the muscle. For the partial tenotomy portion of the approach, a vertical incision (perpendicular to the plane of pull of the muscle) was made through the tendinous portion of the muscle 1 cm medial to its insertion on the lesser tuberosity and taken down to where the muscle was split for the subscapularis split. The partial tenotomy was completed for the full tenotomy. A capsulotomy was performed after the subscapularis splitting approach to expose the glenohumeral joint. The shoulder was externally rotated to relax the nerve and enhance capsule exposure.

## Identification of landmarks

Shoulder resurfacing and total shoulder arthroplasty instruments were placed on the humeral head with each approach (Fig. 1). Six anatomic landmarks (Table I) were identified by direct visualization or palpation, or both. Maximum reach along the anterior and posterior glenoid was identified for each specimen.

## Photographic analysis

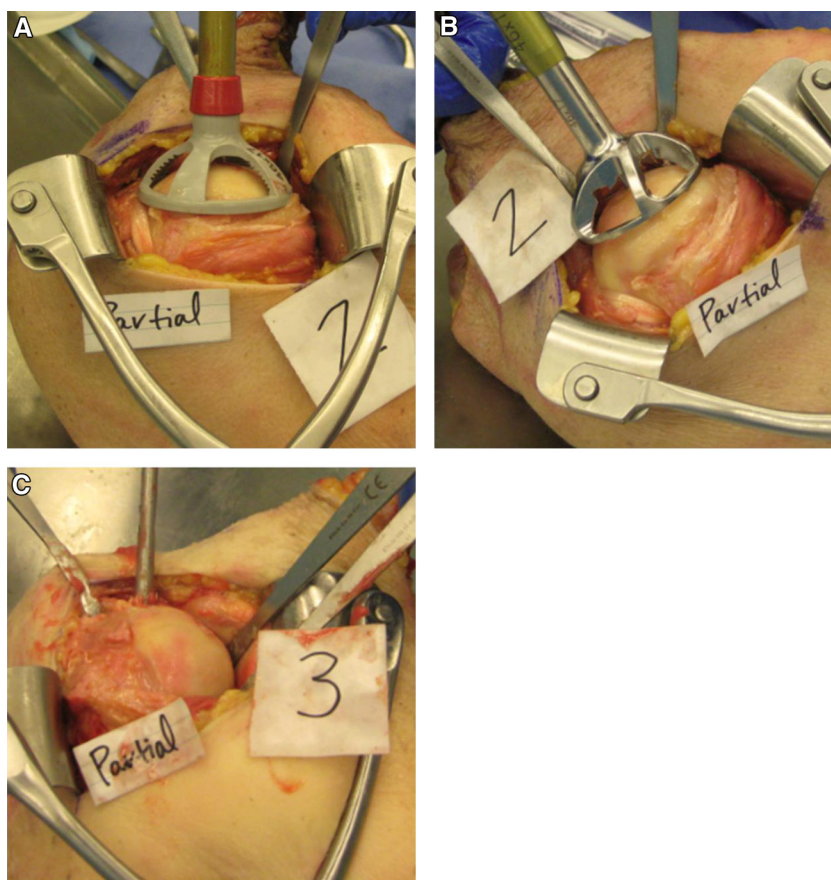
After each surgical exposure, the best view, in the opinion of the operating surgeon, was obtained and maintained for photographs using standard surgical retractors to expose the glenohumeral joint. Digital photographs of the exposed glenohumeral joint were taken perpendicular to the dissection from the surgeon's perspective and analyzed using Image J software (National Institutes of Health, Bethesda, MD, USA), as previously described.<sup>2,4,7</sup> This program compared a known distance (ie, a metric ruler in each image) with the actual number of pixels in each image to calculate the square area of the glenoid and humeral head in each exposure.

## Statistical analysis

Statistical analysis consisted of 2 way, repeated measures analysis of variance with Tukey adjustment for pair wise comparisons. A *P* value of <.05 was considered significant.

## Results

Demographic data for all specimens are included in Table II. One specimen had rheumatoid arthritis of the hands and feet, 1 specimen had rheumatoid arthritis of the



**Figure 1** Shoulder resurfacing and total shoulder instruments were placed on the humeral head: (A) humeral head pin positioning guide for shoulder resurfacing, (B) corresponding reamer for shoulder resurfacing, and (C) humeral intramedullary canal reamer for total shoulder arthroplasty.

**Table 1** Anatomic landmarks that were visualized and palpated

| Anatomic landmarks           |
|------------------------------|
| Coracoid                     |
| Biceps anchor                |
| Biceps groove                |
| Axillary pouch               |
| Posterior capsule            |
| Anterior humeral start point |

hands, 1 had arthritis not specified, 1 had osteoarthritis of the left hip, and 1 had no arthritis reported. Specimens 1, 3, 5, 6, 7, and 8 had obvious osteoarthritis of the humeral head. The soft tissues were not inspected for rotator cuff, labral tears, or biceps tendinopathy.

The average area of humeral head exposed from the least to the most invasive approach was 3.2, 8.1, and 11.0 cm<sup>2</sup>, respectively (Table III). A significant difference found in the average area of the humeral head exposed among the subscapularis split, partial tenotomy, and full tenotomy approaches ( $P < .0001$ ). A significant difference was found in average area of the humeral head exposed between the

partial and full tenotomy approaches ( $P = .012$ ; Fig. 2). The humeral head area exposed increased 157% when the subscapularis split was compared with the partial tenotomy approach and increased 35% when the partial tenotomy was compared with the full tenotomy approach (Fig. 2).

The average area of glenoid exposed, from the least to the most invasive approach was 2.0, 2.3, and 2.5 cm<sup>2</sup>, respectively (Table III). No significant difference found between the average area of the glenoid and type of subscapularis approach (Fig. 2). The glenoid area exposed increased 18.6% when the subscapularis split was compared with the partial tenotomy approach and increased 7.2% when the partial tenotomy was compared with the full tenotomy approach (Fig. 2).

For the subscapularis split approach, the coracoid, biceps anchor and groove, axillary pouch, and posterior capsule were palpated in all specimens. Visualization of the coracoid, axillary pouch, and posterior capsule was 90%, 70%, and 50%, respectively, through the subscapularis split approach. The biceps anchor and groove were visible in all specimens. The humeral start point was visualized in 10% and palpated in 20% of specimens through the subscapularis split approach. All 6 anatomic landmarks were identified by direct visualization and palpation in 100% of

**Table II** Specimen demographics

| Variable                           | Average (range) or No. (n = 10) |
|------------------------------------|---------------------------------|
| Age, y                             | 66.6 (45-77)                    |
| Height, cm                         | 166.9 (149.9-175.3)             |
| Weight, kg                         | 63.6 (57.7-80.9)                |
| Body mass index, kg/m <sup>2</sup> | 22.8 (20-27)                    |
| Sex                                |                                 |
| Male                               | 2                               |
| Female                             | 3                               |
| Caucasian race                     | 10                              |
| Laterality                         |                                 |
| Right                              | 5                               |
| Left                               | 5                               |

the specimens through the partial and full tenotomy approaches. Neither the resurfacing nor total arthroplasty instruments could be placed on the humeral head through the subscapularis split approach. Partial tenotomy of the subscapularis allowed placement of resurfacing instruments in 70% of the specimens and total shoulder arthroplasty instruments in 90%. Resurfacing and total shoulder arthroplasty instruments were easily placed with full tenotomy of the subscapularis.

The subscapularis split approach allowed maximum reach to the 6 o'clock position on the anterior and posterior aspect of the glenoid in 50% and 60% of the specimens, respectively (Table IV). Partial and full tenotomies allowed maximum reach in 80% to 100% of the specimens (Table IV).

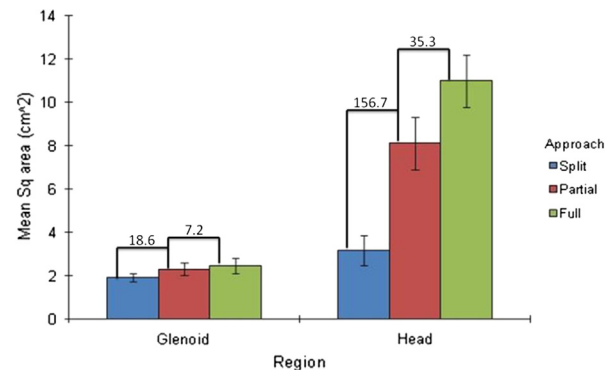
## Discussion

The anterior approach to the shoulder through the deltopectoral interval through the subscapularis muscle is a standard approach with many utilities. The 3 approaches to the subscapularis in this study were the subscapularis split, partial tenotomy, and full tenotomy. The tenotomies provide the most exposure, but there are risks to surrounding neurologic structures and reported negative effects on rehabilitation after repair.

The least invasive exposure in this study was the subscapularis split approach. The subscapularis split approach involves splitting the muscle along its fibers to expose the capsule rather than tenotomy at the lesser tuberosity, providing a protective barrier to the axillary nerve inferiorly.<sup>14</sup> A study of 128 anterior stabilization surgeries using the subscapularis split approach, without exposing the axillary nerve in any case, reported only 1 patient who developed paresthesia in the axillary nerve distribution, with complete resolution by 6 weeks.<sup>22</sup> Maynou et al<sup>20</sup> compared the partial tenotomy and subscapularis split approaches and found higher functional scores and less fatty degeneration with the subscapularis split approach, with a mean follow-up of 7.5 years. However, preoperative

**Table III** Average area of the glenoid and humeral head exposed for the subscapularis split, partial tenotomy, and full tenotomy approaches

| Structure    | Approach | Average area (cm <sup>2</sup> ) | Standard deviation |
|--------------|----------|---------------------------------|--------------------|
| Glenoid      | Split    | 2.0                             | 0.59               |
|              | Partial  | 2.3                             | 0.91               |
|              | Full     | 2.5                             | 1.12               |
| Humeral head | Split    | 3.2                             | 2.16               |
|              | Partial  | 8.1                             | 3.84               |
|              | Full     | 11.0                            | 3.79               |



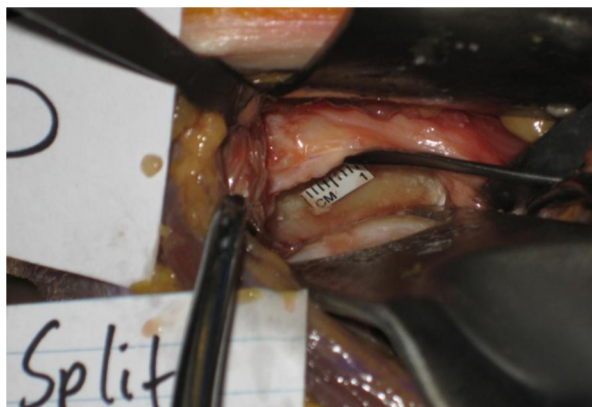
**Figure 2** Average area (cm<sup>2</sup>) of the glenoid and humeral head exposed for the subscapularis split, partial tenotomy, and full tenotomy approaches, with an incremental increase in exposure among the approaches.

imaging was done with computed tomography.<sup>20</sup> The subscapularis split approach is an attractive choice because it may expedite postoperative motion and rehabilitation and maintain an anatomic guard against iatrogenic axillary nerve injury, but there is less exposure.

In this study, the subscapularis split had the least amount of exposure by surface area, identification of landmarks, and placement of arthroplasty instruments. The average area of the humeral head exposed was significantly smaller compared with the partial and full tenotomies. The humeral head area exposed increased 157% when the subscapularis split was compared with the partial tenotomy and increased another 35% when partial tenotomy was compared with the full tenotomy. If more visualization is required, a tenotomy may be sequentially performed. The glenoid area exposed for each approach was not significantly different (Fig. 3). For the subscapularis split approach, posterior landmarks were difficult to visualize, not all were palpated, and resurfacing and total shoulder arthroplasty instruments could not be placed in any specimen. Anterior soft tissue based procedures of the glenohumeral joint, such as anterior capsular plication of the capsulolabral ligamentous complex (eg, Bankart procedure), may be performed with the subscapularis split with the same amount of exposure as a tenotomy, with the added benefit of protecting the

**Table IV** Number of specimens in which maximum reach on the glenoid was obtained to the 6 o'clock position by approach

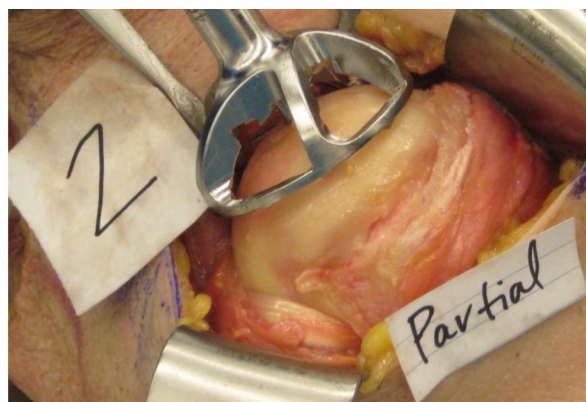
| Approach            | Specimens, No. (%) (n = 10) |
|---------------------|-----------------------------|
| Subscapularis split |                             |
| Anterior            | 5 (50)                      |
| Posterior           | 6 (60)                      |
| Partial tenotomy    |                             |
| Anterior            | 8 (80)                      |
| Posterior           | 9 (90)                      |
| Full tenotomy       |                             |
| Anterior            | 10 (100)                    |
| Posterior           | 9 (90)                      |

**Figure 3** Subscapularis split approach shows almost complete exposure of the glenoid.

subscapularis from axillary nerve injury while avoiding the complications of fatty infiltration and weakness.<sup>20,22,26,28</sup>

The partial tenotomy of the subscapularis involves detachment of a portion of the tendon. Multiple studies have reported that subscapularis tenotomy leads to degenerative changes; however, this is not consistent across all studies and may already be present preoperatively.<sup>8</sup> The average area of the humeral head exposed by partial tenotomy was 8.1 cm<sup>2</sup>. There was a large incremental increase, 157%, in exposure of the humeral head from the subscapularis split to the partial tenotomy. The partial tenotomy approach allowed visualization and palpation of all 6 landmarks and was the least invasive adequate approach that allowed placement of resurfacing and total shoulder arthroplasty instruments (Fig. 4). Because the theoretical risks of tenotomy have not been consistent, a tenotomy should be used to approach the humeral head because it will give the most cost-effective exposure compared with the subscapularis split approach.

Traditionally, the subscapularis approach involves full tenotomy with complete detachment of the subscapularis tendon. The axillary nerve courses along the inferolateral border of the subscapularis 3 to 5 mm medial to its musculotendinous junction and contacts the inferior capsule as it passes through the quadrilateral space.<sup>1,19</sup> With full

**Figure 4** Subscapularis partial tenotomy approach represents a difficult placement of the shoulder resurfacing instrument on the humeral head.**Figure 5** Subscapularis full tenotomy approach allows almost an entire view of the humeral head.

tenotomy and elevation of the subscapularis, an anatomic barrier to injury of the axillary nerve is removed. A review of neurologic complications from shoulder surgery found that the nerve injury rate was 1% to 2% in rotator cuff repairs, 1% to 8% in anterior stabilization procedures, and 1% to 4% in shoulder arthroplasty.<sup>5</sup> Some authors recommend visualizing the nerve before tenotomy of the subscapularis tendon due to the high risk of injury during exposure.<sup>19</sup> Postoperatively, the subscapularis repair must be allowed to heal sufficiently, limiting motion and rehabilitation.

The largest average surface area exposed of the humeral head in our study, 11.0 cm<sup>2</sup>, was through the full tenotomy. If more exposure is needed beyond a partial tenotomy, this can be completed to a full tenotomy and will give an additional 35% more exposure of the humeral head. All 6 landmarks were visualized and palpated, and resurfacing and total shoulder arthroplasty instruments were easily placed in all specimens with the full tenotomy approach (Fig. 5).

This study has numerous limitations. Specimens 1, 3, 5, 6, 7, and 8 had obvious osteoarthritis of the humeral head, and the soft tissues were not inspected for rotator cuff, labral tears, or biceps tendinopathy. The osteoarthritis and presence of soft tissue pathology could have affected the amount of exposure of the glenohumeral joint. In addition, there was no variability in the race or ethnicity of our specimens, and a small number of cadavers were used.

The typical dissection of the subscapularis for the partial tenotomy uses a 2/3 and 1/3 split of the tendon from proximal to distal. To ease sequential dissection in this study, the partial tenotomy cut the subscapularis tendon in half, which may have underestimated the amount of exposure. No method was used to control for a specific point on the landmarks visualized. During the dissection, no method was used to control for the amount of arm rotation or the amount of torque used by retractors that were placed, and both could have increased or decreased amount of exposure.

This study used digital imaging software, which used a 2-dimensional photograph attempting to represent a 3-dimensional surface. However, this photograph was quantified and has been deemed appropriate, as previously described.<sup>2,4,7</sup> The photograph taken in the surgeon's view may have underestimated the average area exposed: surgery in real time is a dynamic process because retractors and arm placement can change.

This is the first study to quantify the amount of exposure of the humeral head and glenoid by the anterior approach to the shoulder through the subscapularis split, partial tenotomy, and full tenotomy. Six landmarks were identified in all 3 exposures of the subscapularis. In addition, this is the first study to compare placement of shoulder resurfacing and total shoulder arthroplasty instruments through each exposure of the subscapularis.

## Conclusions

The type of subscapularis approach does not matter for procedures focused on the glenoid. However, the type of subscapularis approach does matter for procedures focused on the humeral head. The partial tenotomy was the least invasive adequate approach for resurfacing and total shoulder arthroplasty instruments. The subscapularis split approach allows adequate exposure for glenoid-based procedures, and the subscapularis approaches presented expose the glenohumeral joint in a step-wise manner.

## Disclaimer

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