The Deltoid Lift: A Comparison Study of Exposure Area in Proximal Humeral Approaches

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Abstract

Background: Adequate exposure of the proximal humerus is necessary to address atypical or complex proximal humerus fractures and orthopedic tumors. Surgical management may be difficult through existing approaches due to their limited nature and the delicate neurovascular anatomy of the shoulder. The deltoid lift, a previously described extensile approach, can be incorporated into the surgeon's armamentarium as an alternative exposure to the proximal humerus. The objective of this study was to quantify and compare the humeral exposure achieved through the deltoid lift with the standard direct lateral deltoid-splitting, anterolateral acromial, and deltopectoral approaches in terms of surface area and exposure of key anatomic landmarks. **Methods:** Each approach was performed a minimum of 8 times on 18 cadaveric specimens. After identifying landmarks, exposure area of exposed humerus was quantified using digital images and ImageJ software. **Results:** The deltoid lift yielded an average exposure area of 46 cm². Comparison of the exposure area for the deltoid lift against each of the other approaches yielded statistical significance ($P < .01$). The exposure provided was 2-folds greater than that of the next most extensive approach. All anatomic landmarks were directly visible through the deltoid lift as compared with the remaining approaches, through which only 1 landmark was directly visualized and only 2 of the 3 remaining were palpable through the approach. **Conclusions:** The deltoid lift extensile surgical exposure to the proximal humerus provides the largest humeral exposure with the greatest visibility of landmarks relative to the 3 most widely utilized standard approaches.

Keywords: surgical approaches, proximal humeral fractures, orthopedic tumors, proximal humerus, deltoid lift

Introduction

Selection of the appropriate surgical approach to the proximal humerus requires the surgeon to balance soft tissue preservation with adequacy of exposure for the given procedure. However, achieving sufficient exposure through existing standard approaches to the proximal humerus may prove difficult and ultimately be insufficient in the setting of tumors or more atypical or highly comminuted proximal humerus fractures (Figure 1).^{5,15} In these cases, a more extensile surgical approach to the proximal humerus is requisite. The deltoid lift has been previously shown to offer judicious exposure to the proximal humerus while preserving the axillary nerve and other important neurovascular pedicles.¹⁴ In this investigation, we sought to quantify and compare the humeral exposure of the deltoid lift with that of the standard deltopectoral, anterolateral acromial, and lateral deltoid-splitting approaches. We hypothesized that the deltoid lift would provide significantly greater humeral exposure area with improved access to the important anatomic landmarks

including the greater tuberosity, lesser tuberosity, posterior-most aspect of humeral head, and superior-most aspect of humeral head.

Methods

Eighteen formalin-preserved cadaveric specimens were used. Four approaches were performed: standard deltopectoral, anterolateral acromial, lateral deltoid splitting, and deltoid lift. The authors performed the approaches in series on the cadaveric shoulders. Care was taken to perform each approach in sequential fashion, so as not to significantly affect subsequent approaches. If the soft tissue of the specimen was deemed to

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Figure 1. Example of a highly comminuted proximal humerus fracture.

be of poor quality or significantly disrupted following the previous exposures, then only those exposures that could be performed accurately were done. The lateral deltoid-splitting approach was performed first. Given that this approach was far enough lateral to the anterolateral acromial and deltopectoral approaches, it could be performed safely without disrupting the anterior tissues and therefore typically did not have an effect on the subsequent exposure. The anterolateral acromial approach was then performed, followed by the deltopectoral approach. Given the extensive nature of the dissection involved with the deltoid lift, this exposure was performed independent of the others on 10 shoulders. The incision markings for the lateral deltoid-splitting, anterolateral acromial, and deltopectoral approaches can be seen in Figure 2.

Lateral Deltoid-Splitting Approach

The lateral deltoid-splitting approach was performed as described by Hoppenfeld et al.⁹ An incision was made through the skin and subcutaneous tissues, beginning at the lateral edge of the acromion and longitudinally down the lateral aspect of the arm. Once the deltoid fascia was encountered, it was incised sharply in line with the skin incision, exposing the deltoid muscle which was then split in line with its fibers. The split was carried distally until the axillary nerve was encountered. Soft tissue retractors were placed within the wound to aid in exposure.

Figure 2. Markings for the skin incisions of the anterior deltopectoral, anterolateral, and lateral approaches.

Note. The coracoid process is indicated with an "x," and the corner of the acromion is marked.

Anterolateral Acromial Approach

The standard anterolateral acromial approach was performed as described per Gardner and colleagues.⁷ An incision was made beginning at the anterolateral tip of the acromion and extended 5 cm distally again along the longitudinal axis of the arm. The deltoid fascia was encountered and incised sharply, exposing the deltoid muscle and permitting a split along the avascular raphe separating the anterior and middle heads. Starting at the raphe's attachment to the acromion, the deltoid was split sharply for 2 cm. Once the axillary nerve was identified via digital palpation, the incision was carefully extended distally to the deltoid insertion. The axillary nerve and posterior humeral circumflex vessels were isolated and protected. Soft tissue retractors were placed for final exposure.

Deltopectoral Approach

The deltopectoral approach was subsequently performed as described by Hoppenfeld et al.⁹ Beginning over the tip of the coracoid process, an incision was made traveling

Figure 3. Lateral incision of the proximal humerus for the deltoid lift extensile approach.

laterally and distally following the deltopectoral groove. The cephalic vein was identified, and the deltopectoral fascia was incised in line with the deltopectoral interval, bluntly separating the deltoid and pectoralis major muscles. Dissection and exposure of the humeral shaft was achieved through lateral retraction of the deltoid and medial retraction of the pectoralis major with soft tissue retractors. At this point, the subscapularis and joint capsule were peeled from the humeral head as one layer, providing for maximal exposure. Further release of the pectoralis major, latissimus dorsi, or teres major was not performed so as to allow comparison of the results of this study with those of other investigations quantifying proximal humerus exposures.²

Deltoid Lift Approach

Finally, the deltoid lift approach was performed as originally described by Ting and colleagues.¹⁴ In this exposure, the incision was begun directly over the clavicle, 3 cm medial to the acromioclavicular joint and often in line with the deltopectoral interval. The skin incision was then carried directly lateral until the fullness of the shoulder is encountered at which point it was curved distally along the lateral border of the arm up unto 2 cm past the location of the deltoid insertion (Figure 3). An anterior skin flap was developed by following the deltotrapezial fascia to the anterior border of the deltoid and then continued distally and laterally until the deltoid insertion is exposed (Figure 4). The insertion was then released sharply with care taken to protect the axillary nerve and posterior circumflex artery. The deltoid was then lifted cleanly from the proximal humerus in a retrograde fashion with an elevator (Figure 5). This dissection was continued proximally from the insertion until the rotator cuff insertions were encountered. At this point, the anterior deltoid flap was flipped and taken posteriorly, exposing the entire proximal extent of the humerus.

Figure 4. Anterior and posterior flap development. Anterior and posterior flaps were formed along the deltotrapezial fascia to allow complete visualization of the deltoid.

Figure 5. Retrograde elevation of the deltoid.

Measuring Areas of Exposure

Once each of the approaches was complete, the humerus was exposed with the aid of optimally placed soft tissue retractors. Visibility of the greater tuberosity, lesser tuberosity, posterior-most aspect of humeral head, and superior-most aspect of humeral head was noted with the shoulder at neutral. Photographs from the surgeon's perspective were taken with a reference ruler in frame. Each photograph was taken with the same digital camera (Canon EOS 40D) using a standard focal length of 60 mm. ImageJ (National Institutes of Health, Bethesda, Maryland) computer software was subsequently utilized to analyze each photograph and to determine the respective exposure areas. This was performed by tracing the exposed humerus in each image, after which the software would calculate the surface area. For each photograph, 3 measurements were performed and an average was taken. All photographs, measurements, and calculations were performed by the same primary investigator (M.T.). Figures 6 through 9 demonstrate how the authors utilized this technique for each approach.

Figure 6. Humeral exposure of the anterior deltopectoral approach with ruler and area measurement outline.

Figure 7. Humeral exposure of the anterolateral acromial approach with deltoid splitting with ruler and area measurement outline.

Figure 8. Humeral exposure of the lateral nonextensile approach with ruler and area measurement outline.

Identification of Osseous Landmarks

For each approach, direct visibility, as well as indirect palpation, of the following 4 key osseous landmarks was

Figure 9. Humeral exposure of the extensile approach with deltoid lift with ruler and area measurement outline.

evaluated: (1) greater tuberosity, (2) lesser tuberosity, (3) posterior-most aspect of humeral head, and (4) superior-most aspect of humeral head. In vivo, manual rotation of the humerus following each exposure would potentially increase visibility of each of these landmarks. However, this was not performed due to the varying degrees of rigidity of formalin-fixed specimens, as this would introduce variability among our measurements.

Statistical Analysis

We first established our sample size as that which would achieve greater than 90% power. The calculation was performed using area measurements from a similar study and a 2-sample *t* test. The particular grouping scheme used in our study was also taken into consideration. A previous study of proximal humeral exposure areas reported a mean exposure area of 11.0 cm² (SD, 3.79 cm²) through the anterior deltopectoral approach.² We anticipated areas of similar magnitude for the deltopectoral, direct lateral deltoid-splitting, and anterolateral approaches. For the deltoid lift, we expected at least twice this exposure area (22 cm²) with a similar standard deviation based on our original investigation.¹⁴ With these assumptions and a 2-sample *t* test with a level of significance set most conservatively at 1%, a sample size of 6 per group (*n* = 18) was found to have a greater than 90% power for detecting differences among the means of exposure area. Thus, the sample sizes of 10 cadaveric shoulders for the deltoid lift group and 8 for the deltopectoral, lateral, and anterolateral groups were deemed sufficient.

Quantitative data were described using means and standard deviations, whereas gender distribution was described using frequencies and percentages. A 2-sample *t* test was used to compare deltoid lift exposure areas with the areas of the other approaches, and significance was conservatively determined with *P* < .01 (Bonferroni correction). Furthermore, the comparisons of exposure area among the deltopectoral, direct lateral, and anterolateral acromial approaches were performed using linear regression analysis after adjusting for clustering effect using a robust variance approach followed by post hoc comparisons with Bonferroni correction. Age and humeral length were

Table 1. Comparison of Cadavers' Characteristics Across 3 Groups.

Variables	Deltoid lift group (n = 10)		Anterolateral and lateral group (n = 8)		Deltopectoral group (n = 8)		P value
	Mean	SD	Mean	SD	Mean	SD	
Age, y	76.1	12.4	77.9	9.0	76.9	10.9	.9121 ^a
Humeral length (cm)	31.3	1.4	33.0	2.4	32.1	1.1	.1899 ^a
Gender, male, n (%)	5 (50)		3 (37.5)		2 (25)		.4456 ^b

Note. The deltopectoral group includes 2 specimens from the deltoid lift group and 6 specimens from the anterolateral/lateral group.

^aP value was obtained using linear regression after accounting for clustering effect.

^bP value was obtained using logistic regression after accounting for clustering effect.

Table 2. Comparison of Exposure Area in 4 Proximal Humeral Approaches.

	Deltoid lift approach (n = 10)		Anterolateral approach (n = 8)		Lateral approach (n = 8)		Deltopectoral approach (n = 8)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Exposure area (cm ²)	46.25	5.17	21.47	3.81	6.62	3.59	3.19	0.75
P value ^a			<.001		<.001		<.001	
P value ^b			<.001		<.001		<.001	
P value ^c							.073	

^aP value was obtained using unpaired t test of each approach as compared with the deltoid lift.

^bP value was obtained using linear regression after accounting for the clustering effect in reference to the anterolateral approach.

^cP value was obtained using linear regression after accounting for the clustering effect in reference to the lateral approach.

compared across the three groups using linear regression, after adjusting for clustering effect using robust variance. For gender distribution, logical regression was used with a similar consideration for clustering effect. The Pearson correlation coefficient was tested between humeral length and exposure area. Statistical analysis was performed using STATA software version 12.1 (StataCorp LP, College Station, Texas).

Results

The mean age of the cadavers was 77 years (range, 61-95). There were no demographic differences between each group (Table 1).

The extensile approach with deltoid lift was observed to have an average humeral exposure area of 46 cm² (SD, 5.2 cm², range, 38-53 cm²) with the greater tuberosity, lesser tuberosity, posterior-most aspect of humeral head, and superior-most aspect of humeral head directly visible. The anterolateral acromial approach demonstrated the next greatest average exposure area of 21.5 cm² (SD, 3.8 cm², range, 16-27 cm²), and the greater tuberosity was observable through visual inspection, whereas the superior-most aspect of humeral head and lesser tuberosity could be reached through digital inspection. The lateral nonextensile approach was observed to have an average exposure area of 6.6 cm² (SD, 3.6 cm², range, 3.1-13 cm²), and the greater tuberosity was observable through visual inspection.

The superior-most and posterior-most aspects of humeral head were consistently palpable through the incision. The deltopectoral approach was observed to have an average exposure area of 3.2 cm² (SD, 0.7 cm², range, 2.1-4.3 cm²), and the lesser tuberosity was observable through direct visual inspection. The superior-most aspect of humeral head and greater tuberosity were palpable through the incision.

The exposure area for the deltoid lift approach was significantly greater than that of anterolateral, lateral, and deltopectoral groups ($P < .001$). The exposure area for the anterolateral approach was also found to be significantly improved over the lateral and deltopectoral approaches as well ($P < .001$). The exposure through the lateral deltoid-splitting approach was, however, not significantly different in area from the deltopectoral approach ($P = .073$). There was no significant correlation ($P = .466$) between humeral length and area (Table 2).

Discussion

In this investigation, we correctly hypothesized that the deltoid lift would offer significantly increased exposure of the proximal humerus as compared with the existing standard approaches, both in regard to absolute area and to key anatomic landmarks. We also quantified the degree to which the exposure afforded by the deltoid lift exceeded the others. Specifically, the deltoid lift provided more than twice

the exposure than the anterolateral acromial approach, the approach with the next largest exposure. Anatomic landmarks key to anatomic reduction or identification of the extent of tumor were also consistently more accessible with the deltoid lift, directly exposing the greater and lesser tuberosities and the superior-most and posterior-most aspects of humeral head without requiring manual rotation of the humerus to augment visibility. In comparison, the alternative approaches only reliably exposed various landmarks. Adequate exposure of the proximal humerus can aid in obtaining anatomic reduction and stable fixation, especially in the setting of atypical or highly comminuted proximal humerus fractures in young active patients,^{5,7} resulting in improved patient outcomes.^{5,8,12} Furthermore, complete exposure is necessary to enable careful and thorough tumor resection such as with sarcoma of the proximal humerus. This is often not possible through standard trauma approaches.

In addition to the large area of humeral exposure, the deltoid lift functions to preserve the important local neurovascular pedicles. Given the anatomic course of the axillary nerve, posterior retraction of the deltoid and underlying axillary nerve minimizes the possibility of traction neurapraxia. Although the nature of this study precludes comparison of relative degrees of traction or risk of injury with the nerve based on the varying approaches, there is a reasonable risk of injury with other approaches. Care must be taken with access to proximal humerus through the deltopectoral approach, as the axillary nerve is often only palpable but not directly visualized and is at an increased risk of tractional injury within the axillary recess with undue manipulation of the shoulder or fracture fragments.² With both the lateral and anterolateral acromial approaches to open reduction and internal fixation, the axillary nerve must be carefully identified and protected beneath the deltoid. Despite efforts to identify and protect it, the axillary nerve is at risk for transection, as well as tractional neurapraxia, during the splitting of the deltoid and placement of hardware.⁶ By design, the deltoid lift preserves the axillary nerve by reflecting the muscle toward the origin.

Despite the advantages, the shortcoming of the deltoid lift is the subsequent need for repair of the deltoid insertion and altered rehabilitation and recovery postoperatively. Clinical outcomes following repair of the deltoid to its insertion remain largely unexplored.¹⁰ However, a number of investigations involving deltoid release with subsequent repair similar to that performed in the deltoid lift report favorable outcomes. Martini¹¹ first described a subdeltoid approach with a V-shaped incision and elevation of the deltoid insertion. Tamai et al¹³ later described a similar technique for sarcomatous excision from the subdeltoid region in 2 patients. At final follow-up, both patients had

subjectively good functional outcomes in regard to deltoid function. Al Absi and colleagues¹ reported a similar approach to the deltoid lift in the treatment 6 patients with tumors of the proximal humerus, but instead of a release at the distal insertion, they released the deltoid at the proximal origin and reflected the muscle body distally. The authors noted that following stout repair none of the patients experienced cosmetic or functional deficits postoperatively. In a series of 25 patients with deltoid contractures who underwent titrated release of the deltoid insertion, Chen and associates³ found that all 25 patients went on to obtain full range of motion and strength by the 4-year final follow-up. Finally, in a series of 3 chronic deltoid insertion avulsions, Donnelly et al⁴ reported that despite nonoperative management, none experienced significant functional deficits at 2-year follow-up. Given the robust nature of the deltoid insertion, deltoid avulsions are rare injuries. Therefore, most experience arises from iatrogenic deltoid release during tumor surgery. Series are, however, limited, and there is no clear consensus on either method of repair or postoperative rehabilitation, both of which are beyond the scope of this investigation. However, in the experience of Dr. Pirela-Cruz, repair of the tendon can be performed through suture anchors or bone tunnels, as is standard with most tendinous disruptions. During this process, restoration of the normal myofascial tension and broad footprint are essential so as to avoid deltoid insufficiency. For this reason, the authors recommend anatomic repair to the insertion site utilizing a Krackow-based technique to capture the deltoid tendon and typically 2 to 3 suture anchors to secure it down to its insertion. Postoperatively, an abduction pillow should be used to minimize tension on the repair and may be discontinued at 6 weeks. Starting at 3 weeks postoperatively, Codman-type exercises are initiated with the abduction pillow in place with a goal of return to full range of motion by 6 to 8 weeks. At this point, strengthening may be initiated with a goal of return to full function by 4 to 6 months postoperatively.

As a cadaveric analysis, our study is limited by its clinical application. Due to limitations on obtaining a larger sample size, the lateral deltoid-splitting, anterolateral acromial, and deltopectoral approaches were often performed concurrently on the same specimen. A possible effect of this is an overestimation of exposure area for these approaches due to increased tissue mobility with multiple approaches done in the same area. However, the sample size was adequate to obtain statistical significance. Furthermore, the authors mitigated this shortcoming by carefully performing each approach in sequential fashion so as not to significantly affect subsequent approaches, and if the soft tissue was determined to be of poor quality or too disrupted following a previous exposure, subsequent exposures were not performed on the specimen. Comparison of our study with that of Bellamy and colleagues² additionally illustrates the

limitation of formalin-fixed cadavers. The average humeral exposure area was significantly less in our study. However, as an internal control, all approaches were performed on the same set of formalin-fixed cadavers. Therefore, the results of our study may serve as a relative but not absolute comparison of areas of exposure for each approach. Finally, each of the standard exposures may certainly be extended or augmented with various releases. Given the degree of variability that this would introduce among these exposures and for the sake of external validity, the authors chose to utilize only the standard approaches. Despite these limitations, we successfully compared the novel deltoid lift exposure with the existing standard exposures, demonstrating the significant degree of proximal humeral exposure the deltoid lift provides over the standard deltopectoral, anterolateral acromial, and lateral deltoid-splitting approaches. In the proper context, such an approach could allow improved exposure for open reduction and internal fixation of atypical or complex proximal humerus fractures as well as for adequate tumor excision over current techniques. Future investigations are warranted to validate this exposure in fresh cadaveric specimens as well as the outcomes in vivo.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

Informed consent was not necessary for the work presented in this article. No patient identifying information was presented in this article.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Dr Miguel A. Pirela-Cruz is a paid consultant with Trimed.

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