Research Article

Surgical Approaches to the Proximal Humerus: A Quantitative Comparison of the Deltopectoral Approach and the Anterolateral Acromial Approach

Luke S. Harmer, MD, MPH
Colin V. Crickard, MD
Kevin D. Phelps, MD
R. Randall McKnight, MD
Katherine M. Sample, MD
Erica B. Andrews, MD
Nady Hamid, MD
Joseph R. Hsu, MD

From the Quincy Medical Group, Quincy, IL (Dr. Harmer); the Medical Corps, United States Navy, Naval Medical Center, Portsmouth, VA (Dr. Crickard); the Department of Orthopaedic Surgery, University of Texas, Houston, TX (Dr. Phelps); the Department of Orthopaedic Surgery, Carolinas Medical Center, Charlotte, NC (Dr. McKnight and Dr. Hsu); the University of North Carolina Chapel Hill School of Medicine, Chapel Hill, NC (Drs. Sample and Andrews); the Shoulder and Elbow Center, OrthoCarolina, Charlotte, NC (Dr. Hamid); and Atrium Health Musculoskeletal Institute, Charlotte, NC (Drs. Hsu, McKnight, Hamid).

Correspondence to Dr. McKnight: Richard.
mcknight@carolinashealthcare.org

JAAOS Glob Res Rev 2018;2:e017

DOI: 10.5435/
JAAOSGlobal-D-18-00017

Abstract

Background: Debate exists over the optimal approach for addressing fractures of the proximal humerus. The purpose of this study was to objectively quantify the surface area of the humerus exposed using the deltopectoral (DP) and anterolateral acromial (ALA) approaches and to compare visualized and palpable anatomic landmarks.

Methods: Ten arms on five fresh-frozen torsos underwent the DP and ALA approaches. The arms were positioned to simulate a supine patient and held in a fixed position. Visual and/or palpable access to relevant surgical landmarks and the myotendinous junctions were recorded. The myotendinous junctions were used as a rough approximation of consistent proximal exposure of a clinically retracted tuberosity. Landmarks were grouped into quadrants based on the location. Calibrated digital photographs of each approach were analyzed to calculate the surface area and the length of the exposed bone.

Results: The DP and ALA approaches exposed 22.9 ± 6.3 cm^2 and 16.3 ± 6.4 cm^2, respectively ($P = 0.03$). The DP and ALA approaches provided equivalent visual and palpable access to all landmarks in the superior and inferior quadrants. The ALA allowed improved visual (80% versus 70%) and palpable (100% versus 70%) access to the myotendinous junction of the infraspinatus in the posterior quadrant. The DP approach allowed better access to anterior quadrant structures, including improved ability to visualize the myotendinous junction of the subscapularis (100% versus zero), the subscapularis insertion (100% versus 80%), and the medial anatomic neck (100% versus 20%). Palpable access to the myotendinous junction of the subscapularis (100% versus 70%) and medial anatomic neck (100% versus 60%) was also improved with the DP.

Conclusions: In a cadaver model with fixed arm position, the DP provides increased exposure to the proximal humerus and more reliable access to anterior surgical landmarks, whereas the ALA allows improved access to the most posterior aspect of the shoulder.

Fractures of the proximal humerus are common orthopaedic injuries, accounting for between 7% and 9% of all fractures.[1,2] The described approaches for treating these injuries are designed to minimize trauma to the surrounding musculature and limit tendinous detachment while providing adequate exposure for fixation. Historically, the proximal humerus has been approached through the deltopectoral (DP) interval.[3,4] More recently, an alternative approach that splits the anterior and middle heads of the deltoid has been advocated.[5-10]

An ongoing debate exists regarding the relative merits of both approaches. Although the DP approach is most commonly used, it is often criticized because of difficulty visualizing and accessing the posterolateral aspect of the shoulder.[8,10,11] Its advocates, however, stress its safety because it avoids the axillary nerve and stays in a true internervous plane.[3,11] Advocates of the deltoid-splitting approach argue that it offers more direct access to the greater tuberosity for reduction and fixation while also minimizing soft-tissue stripping and trauma to the deltoid muscle by retractors.[5,9,10,12,13]

Although both approaches have gained favor among orthopaedic trauma and shoulder surgeons, neither has been previously quantified. The purpose of this study was to (1) objectively quantify the surface area of the humerus exposed using the DP and anterolateral acromial (ALA) approaches and to (2) compare the qualitative ability of a surgeon to visualize or palpate important anatomic landmarks in each exposure.

Methods

Five cadavers with 10 upper extremities were used for the study. These cadavers were obtained from a distributer (Research for Life) and stored according to the institutional policy at the Carolinas Medical Center Vivarium. This protocol was exempt from institutional review board review. Funding was obtained internally though a competitive review process. The demographic information of each specimen was collected (Table 1).

The cadavers were positioned supine, with the arms abducted and internally rotated in a fixed position. All procedures were performed by one of the authors under the direct supervision of a fellowship-trained shoulder and elbow or orthopaedic trauma surgeon to simulate approaches performed in teaching hospitals. The specimens were randomly assigned using a coin flip to have the DP approach performed first on either the right or left arm. The contralateral arm had the ALA approach performed first. The comparison approach was then performed in sequence.

The DP approach consisted of a 15-cm skin incision being made from the coracoid process toward the deltoid insertion.[3] The cephalic vein was identified and the DP interval developed. The subacromial bursa was resected to allow placement of a Hohmann retractor under the deltoid just lateral to the acromion. A second Hohmann was placed under the deltoid along the humeral shaft, and a third was placed medially just distal to the subscapularis tendon but proximal to the pectoralis major insertion. The arm was abducted and internally rotated. A calibrated photograph was taken from the surgeon's best view (Figure 1).

The ALA approach consisted of a 15-cm skin incision made from the anterolateral corner of the acromion and extending longitudinally down the arm.[5] The raphe between the anterior and lateral deltoid heads was identified and split proximally for 4 cm below the acromion. The deltoid origin was released for 1 cm posterior from the acromion transversely. A 4-cm bridge of deltoid was left intact, and the split between the heads was continued to the distal extent of the incision. The axillary nerve was palpated on the underside of the deltoid muscle, and the muscle bridge was narrowed to leave only a 1-cm cuff of deltoid surrounding the nerve. Two Hohmann retractors were placed below the axillary nerve on the lateral and medial sides of the humerus and retracted until the cuff of muscle containing the nerve was tight but not stretched. Two right-angle retractors were placed superiorly above the nerve (Figure 2).

After each approach, the ability to visualize and palpate important surgical landmarks was recorded. They were grouped based on the location into anterior, posterior, superior, or inferior. In clinical situations, fractures of the greater and lesser tuberosities tend to be retracted. The myotendinous junctions of the infraspinatus and supraspinatus muscles were used as a rough estimation of consistent level of proximal exposure needed to identify a retracted tuberosity because of limitations with a cadaver model. The posterior landmarks included the myotendinous

Dr. Hamid or an immediate family member serves as a paid consultant to Biomet. Dr. Hsu or an immediate family member serves as a member of a speakers' bureau or has made paid presentations on behalf of Smith & Nephew; serves as a paid consultant to Acumed; and serves as a board member, owner, officer, or committee member of the Limb Lengthening Research Society. None of the following authors or any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Dr. Harmer, Dr. Crickard, Dr. Phelps, Dr. McKnight, Dr. Sample, and Dr. Andrews.

Table 1

Demographic Information of Five Torso Specimens

Specimen	Age (yr)	Sex	Height (in)	Weight (lb)	BMI
1	84	Female	62	170	31.1
2	65	Female	63	140	24.8
3	92	Female	62	140	25.6
4	70	Female	65	148	24.6
5	74	Female	67	120	18.8

BMI = body mass index

junction of the infraspinatus and the insertion of the infraspinatus onto the greater tuberosity. The superior landmarks included the myotendinous junction of supraspinatus and the insertion of supraspinatus onto greater tuberosity. The anterior landmarks include the myotendinous junction of subscapularis, the insertion of subscapularis onto lesser tuberosity, and the medial surgical neck of the humerus. The inferior landmark was the lateral insertion of the deltoid.

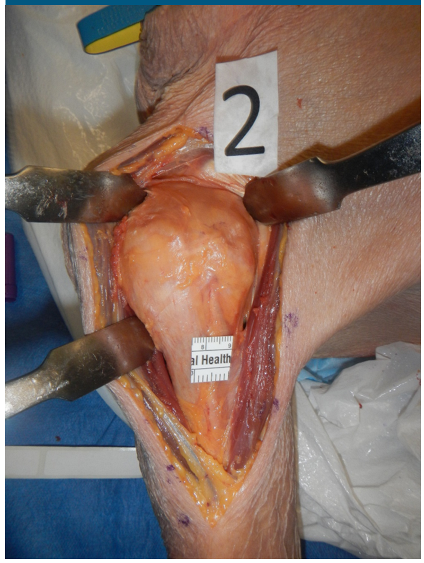
Each photograph was analyzed using ImageJ software (NIH). This software allows measurement of a calibrated digital photograph, calculates the two-dimensional surface area of bony exposure, and is useful in quantifying surgical exposure.[14-16]

Data were tabulated, and the exposure obtained with the various approaches was compared. The continuous variables were compared using a paired Student *t*-test, whereas the binary variables were compared using the chi-squared test. Alpha was set at 0.05.

Results

The DP and ALA approaches exposed 22.9 (±6.3) cm^2 and 16.3 (±6.4) cm^2, respectively ($P = 0.03$) (Figure 3). The ALA approach exposed 5.7 (±2.7) cm^2 of the humerus below the axillary nerve and 10.6 (±4.9) cm^2 above the axillary nerve (Figure 3). The deltoid bundle containing the axillary nerve was 5.5 (±0.7) cm below the tip of the greater tuberosity. The DP and ALA approaches provided equivalent visual and palpable access to all landmarks in the superior and inferior quadrants. The ALA allowed improved visual (80% versus 70%) and palpable (100% versus 70%) access to the myotendinous junction of the infraspinatus in the posterior quadrant compared with the DP approach. The DP did, however, provide consistent visual access to the insertion of the infraspinatus on the greater tuberosity (100%). The DP approach allowed improved access to anterior quadrant structures compared with the ALA approach including visual access to the myotendinous junction of the subscapularis (100% versus zero), the subscapularis insertion on the lesser tuberosity (100% versus 80%), and the medial anatomic neck (100% versus 20%). Palpable access to the myotendinous junction of the subscapularis (100% versus 70%) and medial anatomic neck (100% versus 60%) was also improved with the DP approach versus the ALA approach (Figures 4 and 5). Body mass index of the cadavers varied between 18 and 31. Linear regression was performed to between body mass index and DP area, which showed no correlation.

Figure 1



Photograph showing deltopectoral approach retractor placement with ruler in place.

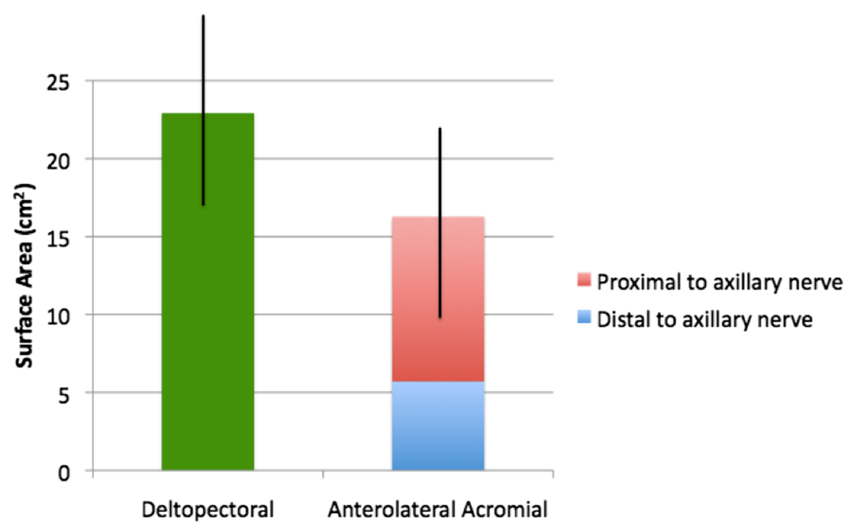
Figure 2

Photograph showing anterolateral acromial approach retractor placement with ruler in place.

Discussion and Summary

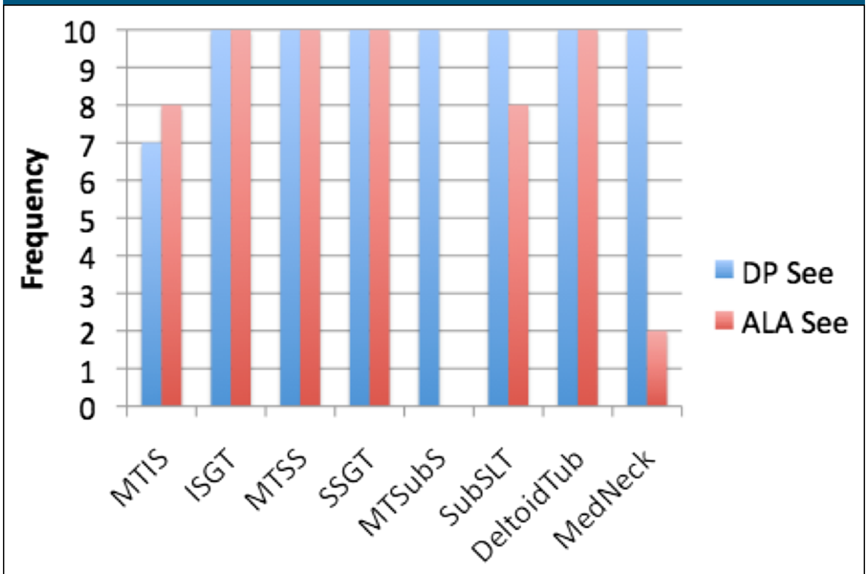
Our study confirms that more surface area of the proximal humerus is visible with the DP approach compared with the ALA approach. This finding is consistent with other authors' claims that the DP approach allows improved visualization and is potentially more utilitarian.[7] In addition, although extensile approaches have been described for

Figure 3



Graph showing the surface area exposed in the deltopectoral and anterolateral acromial approaches.

Figure 4



Graph showing the ability of surgeons to see surgical landmarks through two different surgical approaches (deltopectoral [DP], anterolateral acromial [ALA]): the myotendinous junction of infraspinatus [MTIS], infraspinatus insertion onto the greater tuberosity [ISGT], myotendinous junction of the supraspinatus [MTSS], supraspinatus insertion onto the greater tuberosity [SSGT], myotendinous junction of the subscapularis [MTSubS], subscapularis insertion onto the lesser tuberosity [SubSLT], deltoid insertion at the deltoid tubercle [DeltoidTub], and medial anatomic neck of the humerus [MedNeck]).

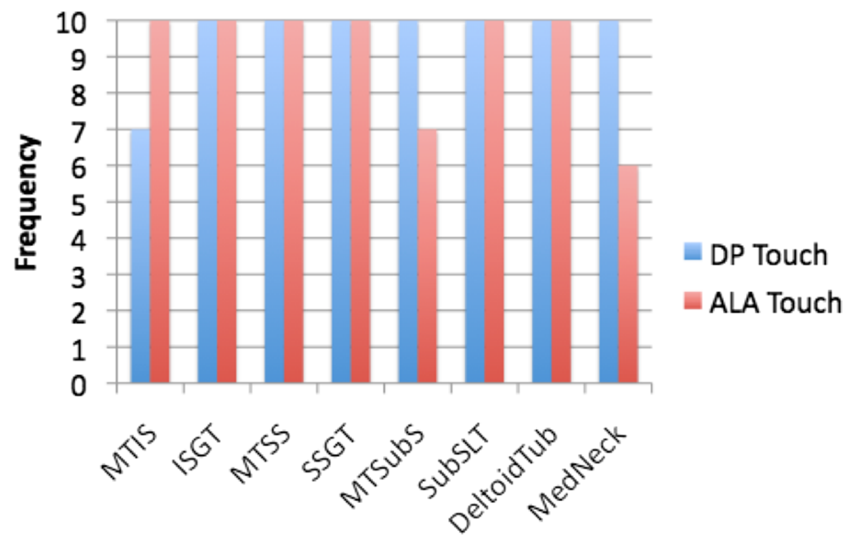
both,[15] the method to extend the DP approach is more familiar to most surgeons.

At least two separate groups have described deltoid-splitting approaches in the past decade. Robinson and colleagues[8,9] have described the "extended deltoid-splitting" approach, which uses a shoulder strap incision parallel to the skin tension lines to raise a full-thickness distally based flap to provide visualization of the deltoid. The deltoid is then split longitudinally between the anterior and middle portions.[8] The axillary nerve is protected in this description by palpating it on the undersurface of the deltoid and leaving a surrounding cuff of muscle intact.[8] This approach can be extended anteriorly, and the DP interval developed simultaneously, or it may be extended distally into a direct lateral approach to the humeral shaft.[9] Gardner and colleagues[5-7] have also described the ALA approach, which uses a longitudinal incision beginning at the anterolateral corner of the acromion. The same raphe between the anterior and middle portions of the deltoid is split with direct visualization and protection of the axillary nerve.[5-7]

The DP approach exposed 1.4 times the surface area of the ALA approach and markedly improved access to the anterior quadrant landmarks. The ALA, however, provided improved access to the landmarks in the posterior quadrant. Given these findings, the DP approach should be adequate for addressing most proximal humerus fractures other than a markedly displaced and retracted greater tuberosity, which may be easier to address through an ALA approach. In light of this, improved access to the posterolateral shoulder is likely possible with release of up to 20% of the deltoid insertion, a technique that we did not evaluate in this study.[17-19]

Our study has several limitations. We performed the dissections on intact specimens, which represent ideal surgical conditions in a bloodless field. Although modification of either approach and manipulation of the arm can allow additional structures to be seen and accessed, our study evaluated only a standard

Figure 5



Graph showing the ability of surgeons to touch surgical landmarks through two different surgical approaches (deltopectoral [DP], anterolateral acromial [ALA]): the myotendinous junction of the infraspinatus [MTIS], infraspinatus insertion onto the greater tuberosity [ISGT], myotendinous junction of the supraspinatus [MTSS], supraspinatus insertion onto the greater tuberosity [SSGT], myotendinous junction of the subscapularis [MTSubS], subscapularis insertion onto the lesser tuberosity [SubSLT], deltoid insertion at the deltoid tubercle [DeltoidTub], and medial anatomic neck of the humerus [MedNeck]).

incision length for all specimens regardless of the size. This fact did not limit our exposure of landmarks; however, we recognize that the total surface area would correlate with the incision length. In addition, as a cadaver study, no definitive conclusions regarding clinical efficacy or safety can be made. However, human cadaver dissections are well established as a reliable method for defining anatomic relationships and comparisons.[20-23]

Although this study used advanced digital imaging software, it relied on two-dimensional images to approximate the surface area of three-dimensional structures. In addition, all photographs were taken from the surgeon's best view, with the arm in a standard position when, in an actual surgical setting, exposure is a dynamic process that can change based on retractor locations or adjustment in the surgeon's line of sight. These factors combined inherently led to the underestimation of the actual surface area, although this underestimation was consistent across all specimens and comparisons.

In conclusion, with standardized retractors and arm placement, the DP approach provides increased exposure to the proximal humerus and more reliable access to surgical landmarks other than the most posterior aspect of the shoulder. Each approach may provide advantages for specific reduction or fixation strategies that are not addressed by this study.

References

1. Aaron D, Shatsky J, Paredes JCS, Jiang C, Parsons BO, Flatow EL: Proximal humeral fractures: Internal fixation. *Instr Course Lect* 2013;62:143-154.

2. Carroll EA, Schweppe M, Langfitt M, Miller AN, Halvorson JJ: Management of humeral shaft fractures. *J Am Acad Orthop Surg* 2012;20:423-433.

3. Hoppenfeld S, deBoer P, Buckley R: *Surgical Exposures in Orthopaedics: The Anatomic Approach*, ed 4. Philadelphia, Lippincott Williams & Wilkins, 2009.

4. Zlotolow DA, Catalano LW III, Barron OA, Glickel SZ: Surgical exposures of the humerus. *J Am Acad Orthop Surg* 2006;14:754-765.

5. Gardner MJ, Boraiah S, Helfet DL, Lorich DG: The anterolateral acromial approach for fractures of the proximal humerus. *J Orthop Trauma* 2008;22:132-137.

6. Gardner MJ, Griffith MH, Dines JS, Briggs SM, Weiland AJ, Lorich DG: The extended anterolateral acromial approach allows minimally invasive access to the proximal humerus. *Clin Orthop Relat Res* 2005;123-129.

7. Gardner MJ, Griffith MH, Dines JS, Lorich DG: A minimally invasive approach for plate fixation of the proximal humerus. *Bull Hosp Jt Dis* 2004;62:18-23.

8. Robinson CM, Khan L, Akhtar A, Whittaker R: The extended deltoid-splitting approach to the proximal humerus. *J Orthop Trauma* 2007;21:657-662.

9. Robinson CM, Murray IR: The extended deltoid-splitting approach to the proximal humerus: Variations and extensions. *J Bone Joint Surg Br* 2011;93:387-392.

10. Flatow EL, Cuomo F, Maday MG, Miller SR, McIlveen SJ, Bigliani LU: Open reduction and internal fixation of two-part displaced fractures of the greater tuberosity of the proximal part of the humerus. *J Bone Joint Surg Am* 1991;73:1213-1218.

11. Abbott LC, Saunders J: Surgical approaches to the shoulder joint. *J Bone Joint Surg Am* 1949;31A:235-255.

12. Gardner MJ, Voos JE, Wanich T, Helfet DL, Lorich DG: Vascular implications of minimally invasive plating of proximal humerus fractures. *J Orthop Trauma* 2006;20:602-607.

13. Hettrich CM, Boraiah S, Dyke JP, Neviaser A, Helfet DL, Lorich DG: Quantitative assessment of the vascularity of the proximal part of the humerus. *J Bone Joint Surg Am* 2010;92:943-948.

14. Beltran MJ, Blair JA, Huh J, Kirby JM, Hsu JR; Skeletal Trauma Research Consortium (STReC): Articular exposure with the swashbuckler versus a "Mini-swashbuckler" approach. *Injury* 2013;44:189-193.

15. Beltran MJ, Collinge CA, Patzkowski JC, et al: The safe zone for external fixator pins in the femur. *J Orthop Trauma* 2012;26:643-647.

16. Huh J, Krueger CA, Medvecky MJ, Hsu JR: Medial elbow exposure for coronoid fractures: FCU-split versus over-the-top. *J Orthop Trauma* 2013;27:730-734.

17. Klepps S, Auerbach J, Calhon O, Lin J, Cleeman E, Flatow E: A cadaveric study on the anatomy of the deltoid insertion and its

relationship to the deltopectoral approach to the proximal humerus. *J Shoulder Elbow Surg* 2004;13:322-327.

18. Morgan SJ, Furry K, Parekh AA, Agudelo JF, Smith WR: The deltoid muscle: An anatomic description of the deltoid insertion to the proximal humerus. *J Orthop Trauma* 2006;20:19-21.

19. Rispoli DM, Athwal GS, Sperling JW, Cofield RH: The anatomy of the deltoid insertion. *J Shoulder Elbow Surg* 2009;18:386-390.

20. Taser F, Shafiq Q, Ebraheim NA: Anatomy of lateral ankle ligaments and their relationship to bony landmarks. *Surg Radiol Anat* 2006;28:391-397.

21. Grothaus MC, Holt M, Mekhail AO, Ebraheim NA, Yeasting RA: Lateral femoral cutaneous nerve: An anatomic study. *Clin Orthop Relat Res* 2005:164-168.

22. Bible JE, Choxi AA, Kadakia RJ, Evans JM, Mir HR: Quantification of bony pelvic exposure through the modified Stoppa approach. *J Orthop Trauma* 2014;28:320-323.

23. Salassa TE, Hill BW, Cole PA: Quantitative comparison of exposure for the posterior Judet approach to the scapula with and without deltoid takedown. *J Shoulder Elbow Surg* 2014;23:1747-1752.