Coracoacromial Arch Anatomy: Anatomic Cadaver Study for Purpose of Identifying Alternative Solutions for End-Stage Rotator Cuff Arthropathy

Drew Warnick, MD ; Jeremy Goodsitt, ; Mark Sartori, BS ; Josh Snyder, MD ;Robert M. Havey BS ; Pietro Tonino, MD; Avinash G. Patwardhan, PhD; Steven Chudik, MD

OTRF, Musculoskeletal Biomechanics Laboratory, Hines Va, Loyola University Medical Center, Hinsdale Orthopaedics

Introduction

Rotator cuff arthropathy and chronic irreparable rotator cuff tears are difficult problems to manage with unique challenges and limited treatment options available for both patient and orthopaedic surgeon. Reverse total shoulder arthroplasty has emerged as a solution for patients with these types of rotator cuff syndromes[9]. There are now a number of different reverse total shoulder arthroplasty systems and many variations on the technique of the first reverse total shoulder arthroplasty introduced, in which a convex articular surface is fixed to the proximal part of the glenoid and a concave surface to the humerus, "reversing" the polarity of the joint[3]. With this approach, deltoid function could be increased by moving the center of rotation medially and distally in comparison to the native glenohumeral articulation and the center of glenohumeral rotation could be maintained in the absence of a functioning rotator cuff[3]. However, because the reverse total shoulder arthroplasty is a new, nonanatomic approach to the treatment of a variety of difficult shoulder conditions, it is not surprising that it is associated with frequent and substantial complications, including hematoma formation, infection, scapular notching, instability, acromial insufficiency, and glenoid component failure and high revision rates[6].

Though variables in the current prostheses have been developed to address concerns that have arisen with reverse total shoulder arthroplasty, persistent problems and high complication rates have been described extensively in the current literature[3]. In addition, previous studies show a decline in the functional rate, particularly active internal and external rotation, as well as general stability in subsequent postoperative years, despite its significant improvement in reduction of pain[3]. Finally, performing a reverse total shoulder arthroplasty is technically demanding and can be complicated by humeral cortical perforations, shaft or tuberosity fractures during surgery, and intraoperative glenoid fracture, involving the rim, major portions of the glenoid surface, or glenoid neck[9]. With this knowledge, there is a need to find better alternatives to reverse total shoulder arthroplasty. By examining the coracoacromial arch and its anatomy as it relates to the stabilizing function of the rotator cuff, there is potential to better understand the shoulder anatomy biomechanics and perhaps develop better treatment alternatives to reverse total shoulder arthroplasty for patients with rotator cuff deficient shoulders.

Objectives

The aim of the present study was to quantify and characterize the relative morphology of the acromion, glenoid, and coracoid as they relate to constraining the humeral head in the glenocoracoacromial space in order to reveal relative anatomic relationships and potential for developing other stabilizing solutions for the glenohumeral joint in the absence of a functioning rotator cuff.

Methods

Specimens:
This was a prospective study of 156 scapulae (65 right and 91 left) harvested from deceased donors at the Cleveland Museum of Natural History Hamann-Todd Collections and Database department in June 2017 (Fig. 2). The scapulae were obtained from 136 men and 20 women with an average age of 53 years (range, 25-96). The 156 scapulas were scanned using the 3-dimensional (3D) MicroScribe digitizer, and measurements were taken using Rhino software at a resolution of 1000 µm. Scapulae that showed evidence of fracture, previous surgery, or other bony damage were excluded from the study.

Coracoid, Glenoid, and Acromion Anatomy:
To best characterize the glenocoracoacromial space and anatomy, measurements were taken by directly touching specific bony points on the coracoid, glenoid, and acromion using the 3D digitizer, with the data points being directly entered into the Rhino: coracoid area, acromion area, glenoid area, coracoacromial distance, distance between center of glenoid to center of anterior and posterior acromion, and glenoid cavity parameters, such as superior-inferior glenoid diameter and anterior-posterior glenoid diameter at multiple different levels, The data collected from Rhino software was analyzed via SPSS 16.0 software. The mean, standard deviation, and level of significance will be determined for the male and female specimens with the level of significance set at $P < 0.05$.

Results

The complied data from the study can be seen below in Table 1, Table 2, and Table 3. The mean coracoid area was 206 ± 54 mm^2 and the mean coracoacromial distance was 40 ± 6 mm. The mean glenoid area was 730 ± 119 mm^2, the mean superior-inferior glenoid diameter was 39 ± 3 mm, and the anterior-posterior glenoid diameters were 18 ± 3, 26 ± 3, and 26 ± 3 mm for each of the three levels. The mean acromion area was 940 ± 204 mm^2, the mean distance from the center of the anterior acromion to the center of the glenoid was 44 ± 3 mm, and the mean distance from the center of the posterior acromion to center of glenoid was 42 ± 4.

A statistically significant difference was found for all of the above measurements in males compared to females ($p < 0.001$). The data is in agreement with other anatomical studies that used similar measurement methods[1] and alternative measurement methods[2,6,10].

Table 1. *Coracoid Measurements*

Measurement	All (n = 156)	Male (n = 136)	Female (n = 20)
Coracoid area (mm²)	206.4 ± 53.9	217.3 ± 48.3	131.8 ± 20.3
Coracoacromial distance (mm)	39.8 ± 5.5	40.7 ± 5.0	34.0 ± 5.6

Table 2. *Glenoid Measurements*

Measurement	All (n = 156)	Male (n = 136)	Female (n = 20)
Glenoid area (mm²)	730.2 ± 118.8	761.0 ± 92.2	520.6 ± 40.3
Superior-Inferior glenoid diameter (mm)	39.1 ± 3.1	39.9 ± 2.4	33.9 ± 2.1
Anterior-posterior glenoid diameter 1 (mm)	18.2 ± 2.7	18.8 ± 2.4	14.7 ± 1.5
Anterior-posterior glenoid diameter 2 (mm)	26.1 ± 3.1	26.9 ± 2.5	21.2 ± 1.9
Anterior-posterior glenoid diameter 3 (mm)	25.5 ± 2.8	26.1 ± 2.4	21.4 ± 1.4

Table 3. *Acromion Measurements*

Measurement	All (n = 156)	Male (n = 136)	Female (n = 20)
Acromion area (mm²)	939.9 ± 204.1	981.5 ± 178.5	657.0 ± 130.3
Center of anterior acromion to center of glenoid (mm)	43.9 ± 3.3	44.6 ± 2.5	38.6 ± 3.0
Center of posterior acromion to center of glenoid (mm)	42.2 ± 3.6	43.1 ± 3.0	36.5 ± 1.9

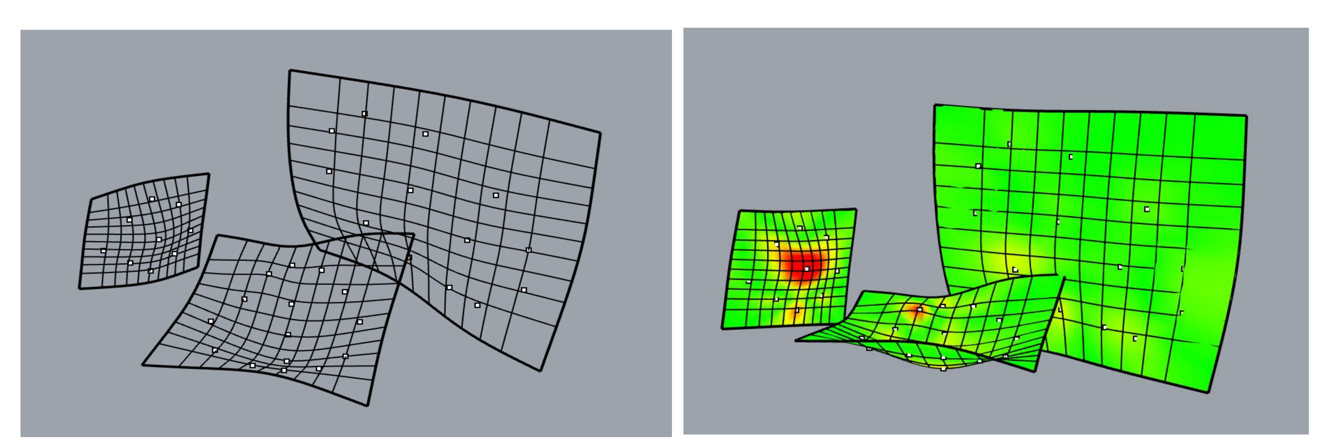

Figure 1. A. View of the reconstructed articular surface of acromion, glenoid fossa, and coracoid process of cadaveric specimen. B. Curvature analysis of acromion, glenoid fossa, and coracoid process of specimen.

Conclusion

Discussion: This study reveals that scapular measurements, namely coracoid, glenoid, and acromion parameters, vary between men and women. The data that were collected via the 3D MicroScribe digitizer and Rhino software correspond well with previous studies in which similar measurements were made both with similar and different modalities of methodology. Although principles of some of the measurement methods for some of the parameters have been reported in previous studies, some new parameters have been identified to provide additional data of the body anatomy of the shoulder.

Comparison with previous studies: No previous studies appear to have direct measurement of the coracoid, glenoid, or acromion articular surface area. Instead, El-Din categorized the acromion and glenoid cavity by morphology, flat/curved/hooked or oval-shaped/pear-shaped/inverted comma-shaped, respectively. In the present study, coracoid, glenoid, and acromion surface areas were quantified. It was determined that all three articular surface areas were significantly greater in male shoulders than in female shoulders.

Piuawinijwong et. al. and Paraskevas et. al. both measured the distance between the coracoid and acromion (coracoacromial distance) with a mean distance of 31 mm and 28 mm, respectively. This difference could be related to the methodology used in their studies, which were cadaveric samples and computer tomography (CT), respectively. The mean distance observed in the present study was longer, being similar to that of Alobaidy, whose values ranged from 37 – 39 mm. The similarity in measurements with Alobaidy could be attributable to the use of the 3D MicroScribe digitizer in Alobaidy and the current study's methodology.

Implications: Using three-dimensional modeling, the areas and lengths of several different parameters of the acromion, glenoid, and coracoid were able to be characterized and quantified. Understanding the scapular anatomy and recognizing variations in the size and shape of the acromion, glenoid, and coracoid processes will be of great help for orthopaedic surgeons to better understand shoulder pathology as it relates to the role of reverse total shoulder in the treatment of end-stage rotator cuff arthropathy. The data provides potentially important information on the biomechanics of the shoulder that can be applied the design and development of an alternative, more anatomically palpable prostheses that decreases the complications, limitations, and failure rate associated with the current procedure.

Figure 2. A. 3-dimensional (3D) MicroScribe digitizer. B. Cadaveric scapula used to quantify specific parameters of the coracoid, glenoid, and acromion processes. C. Cleveland Museum of Natural History Hamann-Todd Collections of cadaveric specimens used for study.

References

1. Alobaidy M, Soames R (2016) Evaluation of the coracoid and coracoacromial arch geometry on Thiel-embalmed cadavers using the 3D MicroScribe digitizer. J Shoulder Elbow Surg 25:136–141.
2. El-Din WAN, Ali MHM. A Morphometric Study of the Patterns and Variations of the Acromion and Glenoid Cavity of the Scapulae in Egyptian Population. Journal of Clinical and Diagnostic Research : JCDR. 2015;9(8):AC08-AC11.
3. Flatow EL, Harrison AK. A History of Reverse Total Shoulder Arthroplasty. Clinical Orthopaedics and Related Research. 2011;469(9):2432-2439.
4. Gallino, M, et al. "Anthropometry of the Scapula: Clinical and Surgical Considerations." National Center for Biotechnology Information, U.S. National Library of Medicine, May 1998
5. Gumina, S., Postacchini, F., Orsina, L., & Cinotti, G. (1999). The morphometry of the coracoid process – its aetiologic role in subcoracoid impingement syndrome. International Orthopaedics, 23(4), 198–201.
6. Mathews S, Burkhard M, Serrano N, et al. Glenoid morphology in light of anatomical and reverse total shoulder arthroplasty: a dissection- and 3D-CT-based study in male and female body donors. BMC Musculoskeletal Disorders. 2017;18:9.
7. Owaydhah, Wejdan H., et al. "Three-Dimensional Analysis of the Proximal Humeral and Glenoid Geometry Using MicroScribe 3D Digitizer." SpringerLink, Springer Paris, 17 Nov. 2016
8. Tham, Allen, et. al. "The Relation of the Coracoid Process to the Glenoid: An Anatomic Study." Arthroscopy: The Journal of Arthroscopic & Related Surgery, W.B. Saunders, 5 Aug. 2009.
9. Virk MS, Nicholson GP, Romeo AA. Irreparable Rotator Cuff Tears Without Arthritis Treated With Reverse Total Shoulder Arthroplasty. The Open Orthopaedics Journal. 2016;10:296-308
10. Zuckerman, Joseph D., et al. "The Influence of Coracoacromial Arch Anatomy on Rotator Cuff Tears." Journal of Shoulder and Elbow Surgery, Mosby, 2 Feb. 2009.

Orthopaedic Surgery & Sports Medicine Teaching & Research Foundation

LOYOLA UNIVERSITY CHICAGO STRITCH SCHOOL of MEDICINE

Hinsdale Orthopaedics

STEVEN CHUDIK MD
SHOULDER & KNEE INJURY CLINIC