A reliable method for classifying acromial shape

Jens Stehle\textsuperscript{a,b,c}, Susan M. Moore\textsuperscript{a}, Dimosthenis A. Alaseirlis\textsuperscript{b}, Richard E. Debski\textsuperscript{a} and Patrick J. McMahon\textsuperscript{a,b,}\* 

\textsuperscript{a}Musculoskeletal Research Center, Department of Bioengineering, University of Pittsburgh, Pittsburgh, PA, USA; \textsuperscript{b}Musculoskeletal Research Center, Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, PA, USA; \textsuperscript{c}Sportklinik Ravensburg, Ravensburg, Germany

(Received 28 June 2014; accepted 29 January 2015)

The method commonly in use today to categorize the shape of the acromion is qualitative and not reliable, but often used to make clinical judgments. Other classifications are quantitative but have not been compared with each other. The objective of this study was to compare the intra- and inter-observer reliability of three methods for classifying acromial shape. Three clinicians evaluated standardized lateral-view radiographs of twenty-four human scapulas three times with intervals of at least two weeks for the intra-observer reliability. Thirteen clinicians evaluated 11 of these radiographs once for inter-observer reliability. We evaluated the classification described by Bigliani as well as two other classifications (acromial angle and modified Epstein classifications) that assign acromions to a type according to specific geometric measurements obtained from three anatomic landmarks. Reliability was assessed with Kappa statistics. The three classifications showed moderate to good intra-observer reliability (Kappa values between 0.50 and 0.72) without significant differences ($p > 0.05$), respectively. The classification described by Bigliani showed slight inter-observer reliability (Kappa value 0.25), the acromial angle classification revealed moderate inter-observer reliability (Kappa value 0.44), and the modified Epstein classification showed good inter-observer reliability with the highest inter-observer Kappa value of 0.62. These differences between the classifications were significant ($p < 0.05$), respectively. This study compared the intra- and inter-observer reliability of three classifications of acromial shape. The modified Epstein classification was the most reliable and should be used for classifying acromial shape to make clinical judgments and in future research studies.

Keywords: acromion; shoulder; rotator cuff

Introduction

Rotator cuff pathology has been long associated with anatomic variants of the acromion. Neer (1972) stated that most rotator cuff pathology is caused by a mechanical conflict between the undersurface of the acromion and the rotator cuff insertion. Therefore, surgeons have traditionally performed an acromioplasty at the time of rotator cuff repair. In 1986, Bigliani et al. (1986) described a classification of acromial shape that qualitatively distinguished ‘flat’ (Type 1), ‘curved’ (Type 2), and ‘hooked’ (Type 3) acromion shapes. A rare ‘reversed curved’ (Type 4) acromion was subsequently added (Farley et al. 1994; Vanarthos & Monu 1995; Yazici et al. 1995) (Figure 1). This is today’s commonly used classification and a strong correlation was found between hooked acromions and rotator cuff disease (Morrison & Bigliani 1987; Bigliani et al. 1991). Outcomes after acromioplasty in the treatment of rotator cuff disease were good when surgeons converted a ‘curved’ or ‘hooked’ acromion into a ‘flat’ shape (Morrison 1988; Bigliani et al. 1991). Interestingly, later studies found this classification unreliable (Haygood et al. 1994; Jacobson et al. 1995; Peh et al. 1995; Bright et al. 1997; Zuckerman et al. 1997; Hamid et al. 2012).

In attempts to improve the reliability of classifying acromial shape in lateral-view radiographs, quantitative measures have been introduced (slope of the acromion, acromion-scapula angle, spina-scapula angle, spina-acromion angle) using angles to describe scapular and acromial morphology (Toivonen et al. 1995; Prato et al. 1998; Stehle et al. 2005). They showed fair to good intra- and inter-observer repeatabilities (Stehle et al. 2005), but were in different degrees affected by suboptimal radiographs (Stehle et al. 2007).

The acromial angle classification categorizes acromial shape as one of three types (Figure 2) (Toivonen et al. 1995) determined by two lines connecting the highest point both with the most anterior and the most posterior point of the acromial undersurface. This classification assigns the acromion to Type 1, if the acromial angle is $<12^\circ$, to Type 2 from $13^\circ$ to $27^\circ$, and to Type 3 over $27^\circ$.

*Corresponding author. Email: mcmahonp@upmc.edu

© 2015 The Author(s). Published by Taylor & Francis. This is an Open Access article distributed under the terms of the Creative Commons Attribution-Non-Commercial License http://creativecommons.org/licenses/by-nc/4.0/, which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.
A classification introduced by Epstein and co-workers that was initially described for magnetic resonance imaging uses the same three anatomic landmarks, but utilizes a different geometric method to distinguish quantitatively between Type 2 and Type 3 acromions. If the highest point of the acromial undersurface is above the middle third of the acromial length, a Type 2 is assigned. If the highest point is above the anterior third of the acromial length, a Type 3 is assigned (Figure 3) (Epstein et al. 1993).

Reliable classifications of acromial shape are necessary to make dependable clinical and surgical judgments (Jacobson et al. 1995). Furthermore, in future research studies, a reliable classification of acromial shape is needed to compare other factors affecting rotator cuff disease (Gartsman & O’Connor 2004; McCallister et al. 2005; MacDonald et al. 2011; Papadonikolakis et al. 2011), to define indications for acromioplasty, and to compare different impingement tests in biomechanical studies. Therefore, the objective of this study was to compare the inter- and intra-observer reliability of three classifications of acromial shape. We hypothesized that the two quantitative classifications would have better intra- and inter-observer reliability than the qualitative classification described by Bigliani et al (1986).

**Materials and methods**

Twenty-four human scapulas (male: 12; right: 13) were dissected free of all soft tissue. The study was approved by the institutional review board of the University of Pittsburgh as a study using cadaveric specimens and was exempt from individual patient consent requirements. Patient identifiers were removed from all images. In an attempt to include scapulas representative of the general population that is mostly Type 2 (>50%) and only very rare Type 4 (<5%) acromions (Bigliani et al. 1986; Morrison & Bigliani 1987; Bigliani et al. 1991; Epstein et al. 1993; Vanarthos & Monu 1995; Yazici et al. 1995;
Hamid et al. 2012), 12 of these scapulas had full thickness rotator cuff tears (during dissection eight shoulders had medium- and four had large-sized rotator cuff tears according to the classification of Bateman (Cofield 1985)) and 12 had no pathology of the shoulder. The mean age of the specimens was 68.6 ± 14.9 years (range 44 to 94 years).

Standardized lateral-view radiographs of all scapulas were made in a custom device similar to the one of Prato et al. (1998). Briefly, a 15 cm rod was placed in the floor of the supraspinatus fossa and the X-rays were aligned parallel to it, for a true lateral view. Such a radiograph is shown in Figure 4, where the rod in the supraspinatus fossa appears as a perfect circle, indicating that the X-rays were parallel to the rod and also to the supraspinatus fossa. A method of standardizing the radiographic views is needed as variation in the views affects classification (Stehle et al. 2007). Pilot study in our laboratory with these views that standardized the floor of the supraspinatus fossa consistently yielded lateral-views of the acromion, comparable to ideal radiographs which are the goal of the clinician in the clinic (Stehle et al. 2007). In preliminary studies, we tested different radiographic films, but we were not able to make copies because they had lower resolution and less contrast than the originals. Also, radiographs could not be marked without damage to the film. Therefore, the radiographs were scanned into a PACS system and printed with high resolution onto a special paper, described henceforth as printouts. All printouts were assessed by a skeletal radiologist and equaled the quality of the actual radiographs and it was in all cases possible to detect the necessary anatomical landmarks. This method allowed us to have a complete set of identical printouts for each observer and each evaluation.

Three clinicians (Collective 1) evaluated all 24 printouts three times with intervals of at least two weeks for intra-observer reliability. The decision to use three clinicians was based on prior reliability studies that also used two (Jacobson et al. 1995) or three (Zuckerman et al. 1997) clinicians to assess the intra-observer reliability. To further minimize dependence, the clinicians were blinded to the previous results, and the order of printouts was randomized. These three clinicians included two experienced orthopedic surgeons with more than 15 years of clinical practice, specialized in shoulder surgery, members of the American Shoulder and Elbow Surgeons Society, and one musculoskeletal radiologist with more than 20 years of clinical practice.

All attendees of the closed meeting of the American Shoulder and Elbow Surgeons Society were asked to participate in the intra-observer part of this study. Thirteen orthopedic surgeons from different hospitals, all specialized in shoulder surgery, and members of the above-mentioned society were willing to participate (Collective 2). They independently evaluated 11 (taken from the 24 printouts used in the intra-observer part of this study, age 51–94 years, five males, eight right, nine with rotator cuff tears) of the printouts once for inter-observer reliability. These printouts were used because the clinicians were able to evaluate them in reasonable time (30 min) during such a meeting, which was determined in a preliminary study.

Each evaluation consisted of assessing the acromial shape with the classification described by Bigliani et al. (1986; Farley et al. 1994; Vanarthos & Monu 1995; Yazici et al. 1995). All participants from Collectives 1 and 2 were familiar with this classification and also received instructions with pictures shown in Figure 1. For the quantitative classifications, the instructions were to mark the most anterior, most posterior, and highest point of the undersurface of the acromion. All participants were familiar with the purpose of the study and received instructions based on three example pictures as shown in Figure 4.

The marked anatomical landmarks were digitized using a spatial linkage system (MicroScribe-3DX®; Immersion Co., San Jose, CA) that has an accuracy of ±0.23 mm (Immersion Corporation 2002). The necessary geometric measurements to categorize acromial shape according to the acromial angle classification and the Epstein classification that was modified as described below were calculated. The repeatability of the geometric measurement was determined in a pilot study to be within ±0.49° for the acromial angle, ±0.52 mm for the acromial length, and ±0.23 mm for the acromial height.

The classification described by Epstein et al. (1993) quantitatively distinguished between Types 2 and 3 acromions (Figure 3), whereas type 1 and 4 acromions were assigned based on the classification described by Bigliani et al. (1986). In order to achieve a comprehensively quantitative classification, we developed criteria for Types 1 and 4 using the same three acromial landmarks and a similar geometric method to that used to distinguish between Types 2 and 3. The criteria for Type 4 are intuitive and the criteria for Type 1 identify a flat acromial shape. With this modified Epstein classification, we were able to quantitatively assign each acromion, on each printout to a type based on the following criteria (Figure 5):

Type 1: Height is less than or equal to 2% of the acromial length.

Type 2: Height is greater than 2% of the acromial length and the highest point is above middle third of the acromial length.

Type 3: Height is greater than 2% of the acromial length and the highest point is above anterior third of the acromial length.
Type 4: Lowest point of the undersurface was under the acromial length.

Statistics were performed using SAS® (Version 8.02). Kappa statistics for categorical variables were used to compare the reliabilities of different classifications to categorize the acromial shape (Landis & Koch 1977; Shrout & Fleiss 1979). The MAGREE macro has the advantage of reporting the Kappa value of multiple observers as a whole group, whereas other methods use the average Kappa value between multiple paired observers. The 95% confidence interval for each Kappa value was calculated. The Kappa value is reported unweighted, since the categories are nominal (i.e. non ranked), and not adjusted to prevalences. A Kappa value ≤0 was defined as poor, >0 and ≤0.20 as slight, >0.20 and ≤0.40 as fair, >0.40 and ≤0.60 as moderate, >0.60 and ≤0.80 as good, and a value >0.80 was defined as excellent repeatability (Landis & Koch 1977; Shrout & Fleiss 1979). A Kappa value above 0.40 was defined as a minimum acceptable level of repeatability (Landis & Koch 1977; Shrout & Fleiss 1979) and has been used in similar studies (Jacobson et al. 1995; Zuckerman et al. 1997).

A one-way ANOVA was used to detect significant differences in assigning the acromial types between the three classifications in Collective 2. A Tamhane post hoc analysis for multiple comparisons was performed when significant differences were detected. The significance level was set to \( p < 0.05 \).

### Results

#### Anatomic landmarks

Our assessment of radiographs revealed optimal lateral-view radiographs of the scapula to have no overlap of the acromion and the structures of the supraspinatus fossa. The floor of the supraspinatus fossa as well as the sides of the scapular spine had single margins and the body of the scapula was thin and the anterior boarder had a single margin.

#### Intra-observer repeatability (Collective 1)

There were no significant differences between the three observers in intra-observer reliability \((p > 0.05)\), respectively (Table 1). All three clinicians had intra-observer reliability that exceeded an acceptable Kappa value of 0.40 for all classifications.

Between the three classifications, the classification described by Bigliani et al. (1986) had moderate intra-observer reliability, with an average Kappa value of 0.50. The acromial angle and modified Epstein classifications had good average intra-observer reliability with average Kappa values of 0.72 and 0.67, respectively. The differences between the classifications were not significant \((p > 0.05)\), respectively. All three of the classifications revealed an acceptable level of intra-observer reliability, being above 0.40 for the average Kappa value.

#### Inter-observer repeatability (Collective 2)

The Bigliani classification showed slight inter-observer reliability with a Kappa value of 0.25 (Table 2). The acromial angle classification had moderate inter-observer reliability with a Kappa value of 0.44. Lastly, the modified Epstein classification had good inter-observer reliability with the highest inter-observer Kappa value of 0.62. The differences between the classifications were significant \((p < 0.05)\).

The inter-observer reliability, broken down into the different acromial types are listed in Table 3. Types 1, 2, and 4 acromions had significantly higher Kappa values in the modified Epstein classification compared with the other two classifications \((p < 0.05)\). Type 3 acromions

| Classification          | Observer 1      | Observer 2      | Observer 3      | Average      |
|-------------------------|-----------------|-----------------|-----------------|--------------|
| Bigliani                | 0.41 (0.18–0.64)| 0.52 (0.37–0.67)| 0.58 (0.41–0.75)| 0.50 (0.32–0.69)|
| Acromial angle          | 0.68 (0.47–0.89)| 0.89 (0.68–1.10)| 0.60 (0.37–0.83)| 0.72 (0.51–0.94)|
| Modified Epstein        | 0.79 (0.61–0.97)| 0.53 (0.36–0.70)| 0.68 (0.50–0.86)| 0.67 (0.49–0.84)|

Note: Data taken from Collective 1.
had similar Kappa values in the acromial angle classification and modified Epstein classification.

**Discrepancies between classifications**

All three classifications showed equal rankings of the assignments to the acromial types. In all eligible classifications, the Type 4 acromion had the least assignments, followed by Type 1 in all classifications. Additionally, in all classifications, the Type 2 acromion had the most assignments followed by Type 3 (Table 4).

However, when analyzing the absolute numbers and using the statistics, the three classifications revealed different distributions or prevalence of the acromial types. The differences were statistically significant for Collective 2 in assigning Type 2 and 3 acromions. The post hoc tests revealed that the acromial angle classification had more assignments to Type 3 acromions and less to Type 2 acromions compared with the modified Epstein classification \(p < 0.005\). The modified Epstein classifications had significantly more assignments to Type 2 acromions compared with the classification described by Bigliani et al. \(1986\). \(p < 0.005\).

Differences were not significant between the classification described by Bigliani et al. \(1986\) and the acromial angle classification.

In summary, no significant difference was found between the classification described by Bigliani et al. \(1986\) and the acromial angle classification, whereas the Epstein classification revealed different assignments compared with the other two.

### Table 2. Kappa values (with 95% confidence intervals) of the inter-observer reliability of the classifications.

| Classification       | Inter-observer reliability (Collective 2) |
|----------------------|------------------------------------------|
| Bigliani             | 0.25 (0.22–0.28)                         |
| Acromial angle       | 0.44 (0.39–0.49)                         |
| Modified Epstein     | 0.62 (0.58–0.66)                         |

Note: All differences between the classifications were significant \(p < 0.05\), respectively.

Data taken from Collective 2.

### Table 4. Assignments (percent) to the acromial types.

| Classification | Collective 2 |
|----------------|--------------|
|                | Type 1 | Type 2 | Type 3 | Type 4 |
| Bigliani       | 17.5   | 51.0** | 24.5   | 7.0    |
| Acromial angle | 19.4   | 46.0*  | 34.5*  | NA     |
| Modified Epstein | 7.7    | 73.4*** | 14.7*  | 4.2    |

Note: Data taken from Collective 2.

*Significant differences between acromial angle classification and modified Epstein classification \(p < 0.05\).

**Significant differences between Bigliani classification and modified Epstein classification \(p < 0.05\).

### Discussion

Our hypothesis that each of the two quantitative classifications would have better inter-observer reliability than the classification described by Bigliani et al. \(1986\) was partially proved. Neither the acromial angle nor the modified Epstein classification had better intra-observer reliability than the classification described by Bigliani et al. \(1986\). All three clinicians had intra-observer reliability that exceeded an acceptable Kappa value of 0.40 for all classifications. The Kappa value for the classification described by Bigliani et al. \(1986\) was moderate, being within the range found in a prior study that reported Kappa values from 0.26 to 0.80 (Bright et al. 1997).

This is the first study to resolve the prior problem of poor inter-observer reliability in classifying acromial shape with an easy-to-use classification. The Epstein classification after being modified for quantitative inclusion in each of the four acromial types proved to have better inter-observer reliability than either of the other two. Similar to previous studies that showed it to have poor to moderate inter-observer reliability (Haygood et al. 1994; Jacobson et al. 1995; Peh et al. 1995; Bright et al. 1997; Zuckerman et al. 1997; Hamid et al. 2012), we found the classification described by Bigliani et al. \(1986\) to have only slight inter-observer agreement, failing to reach the minimum acceptable level of inter-observer agreement of a Kappa value above 0.40 (Landis & Koch 1977; Shrout & Fleiss 1979). This likely results, in part, from its qualitative distinction of each type (Haygood...
et al. 1994; Jacobson et al. 1995; Bright et al. 1997; Zuckerman et al. 1997). Among the two quantitative classifications, the acromial angle classification had moderate inter-observer reliability. The modified Epstein classification was better, having good inter-observer reliability. It was also the only one to have an acceptable level of inter-observer reliability (Kappa value > 0.40) for each type. The advantage of our modified Epstein classification compared with the original description (Epstein et al. 1993) is the quantitative assignment of Type 1 and 4 acromions and was confirmed by our results of all acromial types being reliably detected.

All three classifications showed equal rankings of the assignments to the acromial types. Type 2 acromion had the most assignments, followed by Type 3 (Table 4). Type 4 acromions had the least assignments, followed by Type 1. However, the modified Epstein classification revealed a different distribution of acromial types compared with the acromial angle and the Bigliani classifications, and no significant difference being found between the latter two when analyzing the absolute numbers. These different distributions might partly be due to the fact that there exists no Type 4 acromion in the acromial angle classification. Most results are consistent with a previous study that found the Bigliani and acromial angle classifications which had similar distributions of acromial types (Toivonen et al. 1995). These findings indicate that future research studies of acromial classification should report the type of classification used.

Different radiographic techniques and views affect acromial classification (Stehle et al. 2007). For example, imperfect views result in the landmarks being altered in appearance and sometimes difficult to identify. Highly standardized radiographs should be the goal in clinical practice and we detailed the features of anatomic landmarks to aid clinicians in assessing their radiographs in their clinics. We used printouts of the radiographs similar in prior studies (Prato et al. 1998; Stehle et al. 2007) to diminish the problem of suboptimal views. We used scapula from shoulders that were similar in age, rotator cuff pathology, and the prevalence of acromial shape as the general population. Lastly, our observers were highly skilled in evaluating shoulder radiographs, so that their classification of acromial morphology is legitimate since the prior study found differences among clinicians of different specialties in classifying acromial types (Toivonen et al. 1995). A limitation is the relatively low number of 11 radiographs used to assess the intra-observer reliability.

In conclusion, the modified Epstein classification of the acromial shape had intra- and inter-observer reliability that demonstrates it to be reliable in classifying acromial shape. It should be used in making clinical judgments and in future research studies that compare factors affecting rotator cuff pathology and in defining indications for acromioplasty, and to compare impingement tests.

Conflict of interest disclosure statement

No potential conflict of interest was reported by the author(s).

IRB-approval

The protocol was approved by the University of Pittsburgh – Institutional Review Board [#950895].

Funding

This work was supported by Deutsche Forschungsgemeinschaft [grant number DFG STE 1073 2-1]; National Institute of Health (NIH).

References

Bigliani LU. 1991. Impingement syndrome, aetiology and overview. In: Watson MS, editor. Surgical disorders of the shoulder. New York (NY): Churchill Livingstone.

Bigliani LU, Morrison DS, April EW. 1986. The morphology of the acromion and its relationship to rotator cuff tears [abstract]. Orthop Trans. 10:228.

Bigliani LU, Ticker JB, Flatow EL, Soslowsky LJ, Mow VC. 1991. The relationship of acromial architecture to rotator cuff disease. Clin Sports Med. 10:823–838.

Bright AS, Torpey B, Magid D, Codd T, McFarland EG. 1997. Reliability of radiographic evaluation for acromial morphology. Skeletal Radiol. 26:718–721.

Cofield RH. 1985. Rotator cuff disease of the shoulder. J Bone Joint Surg Am. 67:974–979.

Epstein RE, Schweitzer ME, Frieman BG, Fenlin JM Jr, Mitchell DG. 1993. Hooked acromion: prevalence on MR images of painful shoulders. Radiology. 187:479–481.

Farley TE, Neumann CH, Steinbach LS, Petersen SA. 1994. The coracoacromial arch: MR evaluation and correlation with rotator cuff pathology. Skeletal Radiol. 23:641–645.

Gartsman GM, O’Connor DP. 2004. Arthroscopic rotator cuff repair with and without arthroscopic subacromial decompression: a prospective, randomized study of one-year outcomes. J Shoulder Elbow Surg. 13:424–426.

Hamid N, Omid R, Yamaguchi K, Steger-May K, Stobbs G, Keener JD. 2012. Relationship of radiographic acromial characteristics and rotator cuff disease: a prospective investigation of clinical, radiographic, and sonographic findings. J Shoulder Elbow Surg. 21:1289–1298.

Haygood TM, Langlotz CP, Kneeland JB, Iannotti JP, Williams GR Jr, Dalinka MK. 1994. Categorization of acromial shape: interobserver variability with MR imaging and conventional radiography. AJR Am J Roentgenol. 162:1377–1382.

Immersion Corporation. 2002. MicroScribe-3DX, specs and features. Oella (MD): Immersion Corporation.

Jacobson SR, Speer KP, Moor JT, Janda DH, Saddemi SR, MacDonald PB, Mallon WJ. 1995. Reliability of radiographic assessment of acromial morphology. J Shoulder Elbow Surg. 4:449–453.

Landis JR, Koch GG. 1977. The measurement of observer agreement for categorical data. Biometrics. 33:159–174.

MacDonald P, McRae S, Leiter J, Mascarenhas R, Lapner P. 2011. Arthroscopic rotator cuff repair with and without acromioplasty in the treatment of full-thickness rotator cuff tears: a multicenter, randomized controlled trial. J Bone Joint Surg Am. 93:1953–1960.
McCallister WV, Parsons IM, Titelman RM, Matsen FA 3rd. 2005. Open rotator cuff repair without acromioplasty. J Bone Joint Surg Am. 87:1278–1283.
Morrison DS. 1988. The use of magnetic resonance imaging in the diagnosis of rotator cuff tears. Atlanta, GA: ASES.
Morrison DS, Bigliani LU. 1987. The clinical significance of variations in acromial morphology [abstract]. Orthop Trans. 11:234.
Neer CS 2nd. 1972. Anterior acromioplasty for the chronic impingement syndrome in the shoulder: a preliminary report. J Bone Joint Surg Am. 54:41–50.
Papadonikolakis A, McKenna M, Warme W, Martin BI, Matsen FA 3rd. 2011. Published evidence relevant to the diagnosis of impingement syndrome of the shoulder. J Bone Joint Surg Am. 93:1827–1832.
Peh WC, Farmer TH, Totty WG. 1995. Acromial arch shape: assessment with MR imaging. Radiology. 195:501–505.
Prato N, Peloso D, Franconeri A, et al. 1998. The anterior tilt of the acromion: radiographic evaluation and correlation with shoulder diseases. Eur Radiol. 8:1639–1646.
Shrout PE, Fleiss JL. 1979. Intraclass correlations: uses in assessing rater reliability. Psychol Bull. 86:420–428.
Stehle J, Moore SM, Alaseirlis DA, Debski RE, McMahon PJ. 2007. Acromial morphology: effects of suboptimal radiographs. J Shoulder Elbow Surg. 16:135–142.
Stehle J, Moore SM, Alaseirlis DA, Debski RE, McMahon PJ. 2005. Acromial geometry can be quantified reliably to identify risk factors for rotator cuff pathology. Transactions Vol. 30, Pres. 0067, ORS 2/05, Washington, DC.
Toivonen DA, Tuite MJ, Orwin JF. 1995. Acromial structure and tears of the rotator cuff. J Shoulder Elbow Surg. 4:376–383.
Vanarthos WJ, Monu JU. 1995. Type 4 acromion: a new classification. Contemp Orthop. 30:227–229.
Yazici M, Kopuz C, Gülman B. 1995. Morphologic variants of acromion in neonatal cadavers. J Pediatr Orthop. 15:644–647.
Zuckerman JD, Kummer FJ, Cuomo F, Greller M. 1997. Interobserver reliability of acromial morphology classification: an anatomic study. J Shoulder Elbow Surg. 6:286–287.