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The Coracoacromial Arch and Rotator Cuff Tendinopathy

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The coracoacromial arch is the superior lateral extension of the scapula and is comprised of the acromion, coracoacromial ligament, and coracoid (Fig. 1). The arch superiorly and the proximal humerus inferiorly serve as rigid boundaries for the soft tissue contents of the subacromial space, which includes the subacromial bursa, tendons of the rotator cuff, and tendon of the long head of the biceps. Each of the structures of the coracoacromial arch, as well as inferior osteophytes of the acromioclavicular joint, has been implicated in the pathology of inflammation of the subacromial bursa and tendinopathy of the rotator cuff. Their role in the etiology of subacromial pathology, i.e., tears of the tendons of the rotator cuff, as primary factors initiating mechanical wear on the underlying subacromial bursa and rotator cuff tendons has been well outlined in the literature (2,5,6,14,15,22,26,35,42,49,51–53,57,59–61,71,73). This has been described as the impingement syndrome by Neer, who isolated the anterior one third of the acromion, including anterior acromial spurs, as the principal offending structure of the coracoacromial arch (59,61) (Fig. 2). The end result of repetitive friction and mechanical wear by rigid structures on soft tissues is failure of these soft tissues, which in this case is rupture of the tendons of the rotator cuff and long head of the biceps (51,53,59,61). Additional factors in the etiology of rotator cuff pathology, including degeneration of the tendons from overuse, aging (8,11,12,66, 67,84,87), vascular abnormalities (9,47,56,74,77, 80), and trauma (11,48,61), have been supported by reports in the literature.

The development and function of the acromion is unique in humans (34). Studies of human embryos have demonstrated that the acromion is identifiable by 5 or 6 weeks of gestation (3,45), and is composed of cartilage at birth (23,83). The centers of ossification in the acromion, most often two, are the last to present in the scapula, appearing during puberty or adolescence (24), and usually fuse between 18 and 25 years of age (83). One variation that has been well outlined is failure of these ossification centers to fuse to each other, or to the spine of the scapula; this is referred to as an unfused acromial epiphysis or os acromiale. There are four different types of unfused acromial epiphyses: pre, meso, meta, and basi, progressing from anterior to posterior and reflecting greater involvement of the acromion. This anomaly may be present in up to 8% of cases (29,46), and is often bilateral (46). An unfused acromial epiphysis has been reported in the literature to be related to rotator cuff pathology (6,57).

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ACROMIAL MORPHOLOGY

Hamilton, in 1875, noted that the acromial epiphysis tended to unite with a "slight downward displacement," and that this would limit motion only if it was of such magnitude to "interfere with the upward movements of the arm" (32). Differences in the shape and slope of the acromion was described as early as 1909 by Goldthwait (28). Neer reported that variation in the shape and slope of the acromion were important factors in the development of subacromial pathology (60). Bigliani and colleagues investigated the shape of the acromion and described a pattern of morphologic variation with a relation to full-thickness rotator cuff tears (5).

In this report (5), 140 shoulders from 71 elderly human cadavers were evaluated. Based on lateral radiographs of the acromion, three types of acromial morphology were determined (Fig. 3). This included the Type I, or flat, acromion found in 17% of shoulders; the Type II, or curved, in 43%; and the Type III, or hooked, in 39%. The same acromial type was noted in both shoulders in 55% of cadavers. The anterior acromial slope, or angle of inclination, was found to be 13.1° for the Type I, 26.9°

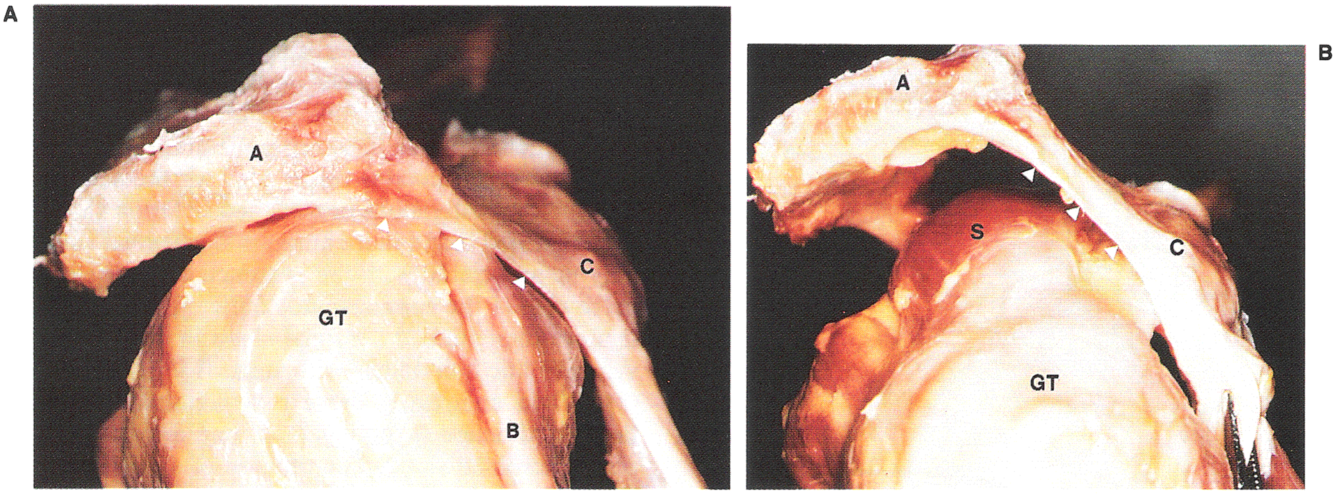


FIG. 1. **A:** Human cadaver specimen showing the relation between the coracoacromial arch and tendons of the rotator cuff and long head of the biceps. **B:** With the humerus displaced inferiorly, the position of the supraspinatus tendon directly below the coracoacromial arch can be appreciated. (A, acromion; B, long head of biceps tendon; C, coracoid; GT, greater tuberosity; S, supraspinatus tendon and muscle.) **White arrowheads** define the leading edge of the coracoacromial ligament. (Reprinted, by permission, from Ticker JB, Bigliani LU. Impingement pathology of the rotator cuff. In: Wilk KE, Andrews JR, eds. *The athlete's shoulder*. New York: Churchill-Livingstone, 1993:121–8.)

for the Type II, and 26.7° for the Type III acromions. A full-thickness rotator cuff tear was noted in 24% of shoulders; however, the Type III acromion was present in 70% of these shoulders with full-thickness rotator cuff tears, but the Type I was present in only 3%. Furthermore, the angle of inclination was significantly higher in the shoulders with full-thickness rotator cuff tears (28.7°), compared with the shoulders with intact rotator cuffs (22.7°). In addition to the Type III acromion, anterior acromial spurs were associated with full-thickness rotator cuff tears. It is important, however, to distinguish between spurs, which are probably acquired, and variations in the native architecture of the acromion.

To examine the differences in acromial morphol-

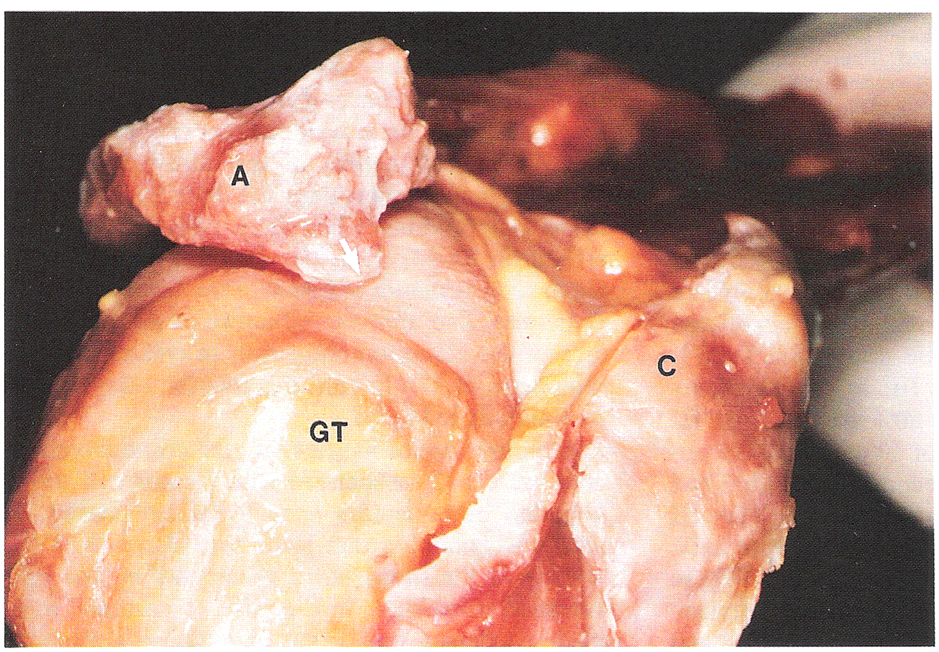


FIG. 2. Anterior acromial spur (**white arrow**) exposed after the acromial attachment of the coracoacromial ligament has been removed (A, acromion; C, coracoid; GT, greater tuberosity.)

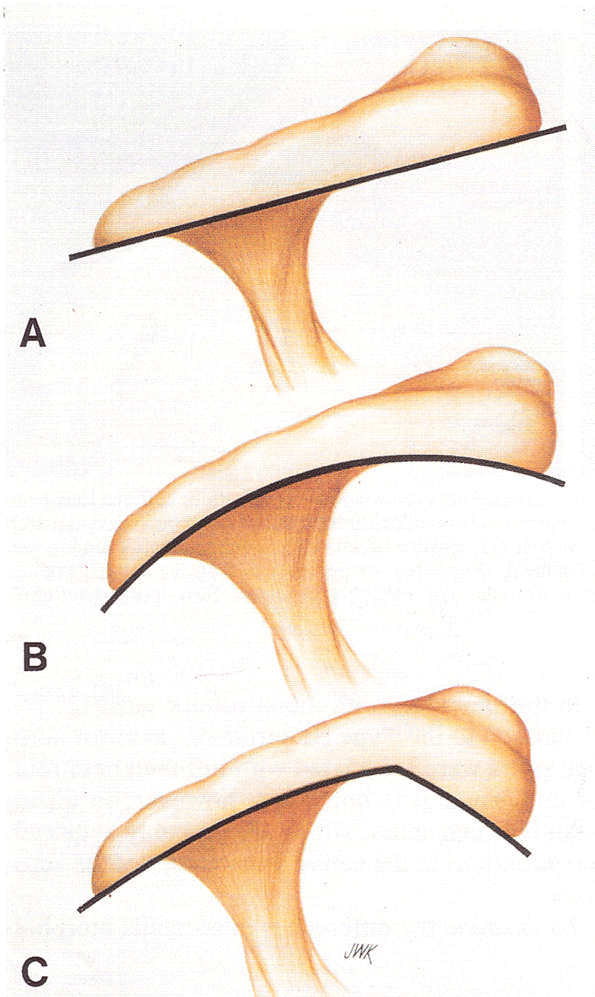


FIG. 3. Classification of acromial morphology. A: Type I, flat. B: Type II, curved. C: Type III, hooked. (Reprinted, by permission, from Bigliani LU. Impingement syndrome: aetiology and overview. In: Watson MS, ed. *Surgical disorders of the shoulder*. Edinburgh: Churchill-Livingstone, 1991:247–58.)

ogy in a clinical population, Morrison and Bigliani evaluated the supraspinatus outlet view in 200 consecutive patients with various shoulder problems (54). The incidence of acromial types correlated quite closely with the anatomic study: 18% Type I, 41% Type II, and 41% Type III. In those patients with a positive arthrogram, 80% had a Type III acromion. In another group of 50 patients who underwent open subacromial decompression, 6% had a Type I, 28% had a Type II, and 66% had a Type III acromion. Seventy percent of this symptomatic group had a full-thickness rotator cuff tear. These findings further established a correlation between the Type III acromion and rotator cuff tears, and confirmed the importance of the supraspinatus outlet radiographic view for evaluating the acromion.

Other investigators have evaluated the slope of the acromion (1,17,88). Aoki and co-workers developed a technique for measuring the acromial slope using the supraspinatus outlet view of the scapula (1). Their investigations of bleached skeleton shoulders revealed that a more horizontal acromial slope may be associated with the presence of a spur and narrowing of the supraspinatus outlet. These investigators then studied acromial slope in normal and symptomatic individuals with stage II impingement (2). When comparing these two populations, patients with stage II impingement had a more horizontal acromial slope. The relation of a more horizontal acromion with anterior acromial spurs and rotator cuff pathology has been reported, subsequently, by other authors (17,88).

In addition to acromial morphology and acromial slope, other factors have been associated with impingement of the rotator cuff. Several series, including those involving overhead athletes, have suggested that the coracoacromial ligament is a primary source of pathology in certain cases (10,35,39, 41,48,52,69,70). Coracoacromial ligament resection, without anterior acromioplasty, has consistently provided pain relief, often with return to the previous level of function (35,70). Impingement by the coracoid on the subscapularis has also been described (15,26,28,68). Although this may lead to bursal and rotator cuff lesions, coracoid impingement should be distinguished from the much more common form of impingement that typically begins in the supraspinatus tendon. Many authors have described the occurrence of inferiorly protruding osteophytes from the anterior aspect of the acromion and the inferior aspect of the acromioclavicular joint that may compromise the integrity of the rotator cuff tendons when they pass below these structures (5,42,59,61,71). Developmental problems, such as failure of fusion of the acromial epiphyses, may also alter the structure of the undersurface of the acromion and result in rotator cuff pathology (6,46,57). In fact, this relation was outlined by Smith in 1834 (79).

Although abnormalities of the coracoacromial arch are clearly associated with rotator cuff tendinopathy, other factors need to be considered. In fact, any condition that leads to a decrease in the volume of the subacromial space may initiate subacromial pathology. In the case of acromial morphology, Nasca found that high-angled acromions indeed decrease the subacromial space (58). Likewise, swelling of the tendons or the bursa in the subacromial space, i.e., bursitis, can infringe upon the volume of the subacromial space to such a point that the soft tissues no longer pass freely under the coracoacromial arch. In sports that require performance of overhead motions, chronic overuse, altered mechanics, or subtle instabilities can subject the soft tissues to wear under the coracoacromial arch (21,33,35,37–40,64,65,70,76,81,82,85). In addition, weakness of the dynamic stabilizers of the humeral head may allow it to translate superiorly during arm motion, thereby decreasing the subacromial space, which could result in subacromial pathology.

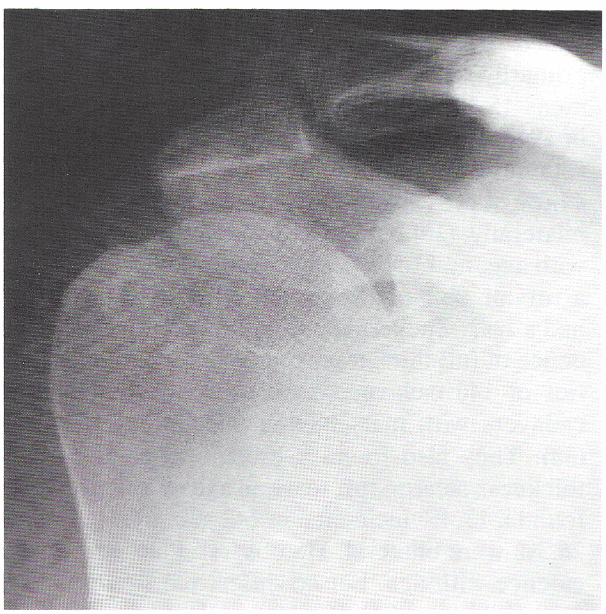
SUBACROMIAL SPACE AND ARCHITECTURE OF THE CORACOACROMIAL ARCH

The subacromial space has been evaluated by assessing the interval between the acromion and humeral head on anteroposterior radiographs and its relation to rotator cuff tears (13,18,27,72,86) (Fig. 4A). Golding found the normal distance between the acromion and the humerus on anteroposterior radiographs in 150 cases to be between 7 and 13 mm (27), whereas Cotton and Rideout noted this distance to range from 6 to 14 mm in 144 normal shoulders (13). Both investigators concluded from their evaluation of abnormal radiographs that a decrease in the acromiohumeral interval was associated with rotator cuff tears. These findings have been confirmed by other investigators (18,72,86). In addition, rupture of the long head of the biceps tendon has been associated with subacromial impingement (62) and a decrease in the acromiohumeral interval (31).

Recent reports have demonstrated that in normal shoulders the subacromial space decreases substantially with arm elevation (7,20). It has also been shown that contact does occur between the anterior acromion and the rotator cuff tendons during arm elevation in the cadaver model. In fact, this contact has been shown to be greatest when the Type III acromion is present; similar findings are suggested by other investigators (7,16,20,36).

Neer and Poppen referred to the subacromial space viewed from the lateral aspect of the scapula as the supraspinatus outlet, through which the supraspinatus passes during arm motion (63). They described the supraspinatus outlet radiograph, a lateral radiograph in the plane of the scapula to create the Y-scapular view, and confirmed the value of this view when evaluating the space below the coracoacromial arch (Fig. 4B). In addition, the supraspinatus outlet view has been used to assess the acromial shape for preoperative planning, and to

A



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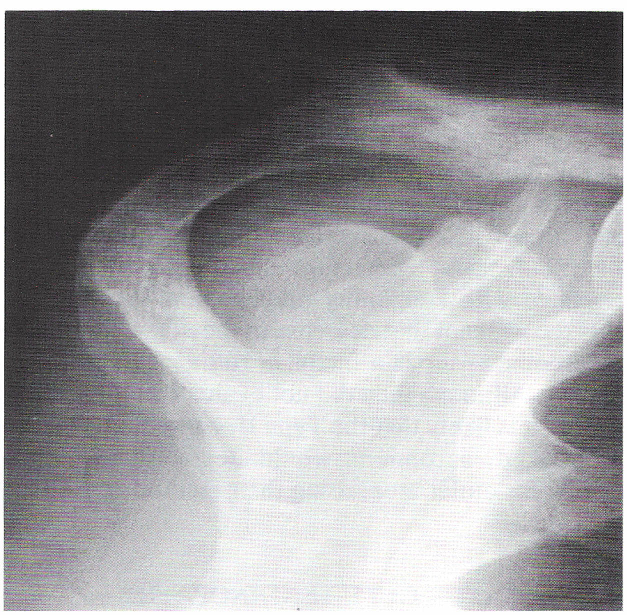

FIG. 4. A: Anteroposterior radiograph of the scapula from a 29-year-old male patient demonstrating the bone-to-bone interval between the acromion and humerus. B: Supraspinatus outlet radiograph of the same individual, with the Type II acromion, again demonstrating the interval between the acromion and humerus.

verify the adequacy of anterior acromioplasty in the postoperative setting by comparing the acromial morphology obtained from surgery with the preoperative morphology (19,25,55,69).

In addition to studies specifically evaluating the shape and slope of the acromion, recent investigations evaluating the structure of the entire coracoacromial arch have been performed (17,50,75,86). Mallon et al. performed measurements from radiographs of 28 scapulas from patients 52 years of age or older (50). In addition to other parameters identified, they found that the anterior tip of the acromion is always posterior to the center of the glenoid with the scapula tilt at neutral, and is on average 5.2 ± 5.1 mm posterior to the center of the glenoid. They also noted that height from the top of the glenoid to the most anterior margin of the acromion measured 18.5 ± 6.8 mm with the scapula in neutral, which provides a guide for the height of the supraspinatus outlet. Edelson and Taitz reported from their observations of 200 scapulas that a higher coracoacromial arch was associated with less degenerative changes on the undersurface of the acromion (17).

Zuckerman and co-workers used 140 shoulders in 70 elderly human cadavers to study the relation of the coracoacromial arch to full-thickness rotator cuff tears (88). They also noted that the anterior acromion was usually posterior to the center of the glenoid. However, in shoulders with full-thickness rotator cuff tears, the acromion projected more anteriorly and the coracoacromial ligament was shorter than these measurements from the intact shoulders. In addition, there was a direct relation between acromions with a more horizontal slope and full-thickness rotator cuff tears. These authors observed a significant decrease in the supraspinatus outlet area of 22.5% in shoulders with full-thickness rotator cuff tears. They emphasized this point as it correlated with their other findings, and this highlights the concept that decrease in the volume of the subacromial space is a factor in rotator cuff tendinopathy. Although they did not evaluate acromions by type, it is likely that the Type II, curved, or Type III, hooked, acromions would decrease the supraspinatus outlet area, using their method of measurement.

ROTATOR CUFF TENDINOPATHY

Rotator cuff tendinopathy occurs as part of the spectrum of pathology observed in the impingement syndrome. The impingement syndrome as outlined by Neer is divided into three stages, although this represents a continuum of progression from normal to pathologic changes and tendon failure (60,61). Initially, in stage I, there is edema and hemorrhage of the subacromial bursa, and it is reversible with conservative treatment. With continued insult to these soft tissues, the changes of stage II develop, including fibrosis and tendinitis.

Without intervention at this point, either rest and nonoperative modalities or operative treatment, progression to stage III may result. This can present as partial-thickness (incomplete) tear or full-thickness (complete) tear of the rotator cuff. Associated pathologic changes in the acromion and the acromioclavicular joint may be present, as well as fraying or rupture of the long head of the biceps tendon. The region of the rotator cuff that is initially affected is in the supraspinatus tendon ~1 cm proximal to its insertion in the greater tuberosity, and this was referred to as the critical area by Codman (11). With continued insult, the infraspinatus, teres minor, and/or subscapularis tendons may rupture. In the general population, most individuals will not progress to stage III earlier than 40 years of age (4). However, in the athletic population, especially those in sports which require overhead motion, an individual may progress through each stage more rapidly. As a result, such patients may present with pathology at an earlier age.

Numerous reports in the literature have determined the incidence of rotator cuff tendinopathy, primarily from elderly autopsy and cadaver specimens (5,12,30,43,44,66,67,71,78,84,87,88). Grant, in 1948, found an 18.9% incidence of full-thickness rotator cuff tears in 190 cadaver shoulders, with 44.0% of the cadavers with tears demonstrating this bilaterally (30). He noted an increased incidence with age, as 13.5% of specimens ≤66 years old had a rotator cuff tear, whereas 41.9% ≥67 years old had a tear. Zuckerman et al. reported a 20.0% incidence of full-thickness rotator cuff tears in their series of 140 cadaver shoulders, with 47.4% of the cadavers with tears having this finding bilaterally (88). They also found a greater incidence of full-thickness rotator cuff tears as age increased. Keyes found a 13.4% incidence in 142 shoulders, of which 26.3% were bilateral. He observed an increased incidence with age, but no difference by sex or race (43). Wilson and Duff noted an incidence of 16.7% in 216 shoulders from a population of cadaver and autopsy specimens >30 years of age, of which

33.3% were bilateral (87). However, they found no difference in the incidence of full-thickness rotator cuff tears with aging. Bigliani and co-workers reported a 23.6% incidence in 140 shoulders, with 37.5% bilateral (5). Other series of cadaver and autopsy shoulder specimens describing the incidence of full-thickness rotator cuff tears include those of Codman and Akerson (39.0% with 35.9% bilateral) (12), Skinner (6.0%) (78), Petersson and Gentz (12.9%) (71), Uhthoff et al. (19.9%) (84), Ozaki et al. (13.5%) (67), Ogata and Uhthoff (25.0%) (66), and Kolts (16.2%) (44). For all these series combined, 332 full-thickness rotator cuff tears occurred in 1,817 left and right shoulders, for an overall incidence of 18.3%. Some of these series also reported the incidence of partial-thickness rotator cuff tears (66,67,71,84,87). When these were combined, the overall incidence for partial-thickness rotator cuff tears was 28.1% in 253 of the 900 left and right shoulders. Thus, a substantial portion of the elderly population appears to have pathology of the rotator cuff.

CONCLUSIONS

Information regarding the anatomy and morphology of the coracoacromial arch, especially the acromion, has contributed to our understanding of rotator cuff tendinopathy. Variations in the architecture of the coracoacromial arch have been shown to alter the volume of the subacromial space. Decrease in this volume by any number of factors can result in the initiation of the impingement syndrome. An important goal of surgical procedures that address rotator cuff pathology is to increase the space beneath the coracoacromial arch to reduce impingement.

REFERENCES

1. Aoki M, Ishii I, Usui M. The slope of the acromion and rotator cuff impingement. *Orthop Trans* 1986;10:228.
2. Aoki M, Ishii I, Usui M. Clinical application for measuring the slope of the acromion. In: Post M, Hawkins RJ, Morrey BF, eds. *Surgery of the shoulder*. St Louis: Mosby-Year Book, 1990:200.
3. Bardeen CR, Lewis WH. The development of limbs, body-wall, and back. *Am J Anat* 1901;1:1.
4. Bigliani LU, D'Alessandro DF, Duralde XA, McIlveen SJ. Anterior acromioplasty for subacromial impingement in patients younger than 40 years of age. *Clin Orthop* 1989;246: 111.
5. Bigliani LU, Morrison DS, April EW. The morphology of the acromion and rotator cuff impingement. *Orthop Trans* 1986;10:228.
6. Bigliani LU, Norris TR, Fischer J, Neer CS. The relationship between the unfused acromial epiphysis and subacromial lesions. *Orthop Trans* 1983;7:138.
7. Bigliani LU, Ticker JB, Flatow EL, Soslowsky LJ, Mow VC. The relationship of acromial architecture to rotator cuff disease. *Clin Sports Med* 1991;10:823–38.
8. Brewer BJ. Aging of the rotator cuff. *Am J Sports Med* 1979;7:102–10.
9. Brooks CH, Revell WJ, Heatlet FW. A quantitative histological study of the vascularity of the rotator cuff tendon. *J Bone Joint Surg* 1992;74B:151–3.
10. Burns WC, Whipple TL. Anatomic relationships in the shoulder impingement syndrome. *Clin Orthop* 1993;294: 96–102.
11. Codman EA. Normal motions of the shoulder joint. In: *The shoulder: rupture of the supraspinatus tendon and other lesions in or about the subacromial bursa*. Boston: Thomas Todd, 1934.
12. Codman EA, Akerson IB. The pathology associated with rupture of the supraspinatus tendon. *Ann Surg* 1931;93: 348–59.
13. Cotton RE, Rideout DF. Tears of the humeral rotator cuff: a radiological and pathological necropsy survey. *J Bone Joint Surg* 1964;46B:314–28.
14. Diamond B. In: *The obstructing acromion: underlying diseases, clinical development, and surgery*. Springfield, IL: Thomas, 1964:72.
15. Dines DM, Warren RE, Inglis AE, Pavlov H. The coracoid impingement syndrome. *J Bone Joint Surg* 1990;72B:314–6.
16. Drillings G, Nuber G, Swartz S. Strain measurements of the undersurface of the acromion [paper 387]. In: Scientific Program of the 58th Annual Meeting of the American Academy of Orthopaedic Surgeons, Anaheim, CA, 1991, p 237.
17. Edelson JG, Taitz C. Anatomy of the coraco-acromial arch: relation to degeneration of the acromion. *J Bone Joint Surg* 1992;74B:589–94.
18. Ellman H, Hanker G, Bayer M. Repair of the rotator cuff: end-result study of factors influencing reconstruction. *J Bone Joint Surg* 1986;68A:1136–44.
19. Ellman H. X-ray measurement of the subacromial angle: correlations following arthroscopic acromioplasty. *Orthop Trans* 1987;11:230.
20. Flatow EL, Soslowsky LJ, Ticker JB, Pawluk RJ, Mow VC, Bigliani LU. Excursion of the rotator cuff under the acromion: patterns of subacromial contact. *J Shoulder Elbow Surg* 1993;2:S22.
21. Fowler P. Swimmer problems. *Am J Sports Med* 1979;7: 141–2.
22. Fu FH, Harner CD, Klein AH. Shoulder impingement syndrome: a critical review. *Clin Orthop* 1991;269:162–73.
23. Gardner E, Gray DJ. Prenatal development of the human shoulder and the acromioclavicular joint. *Am J Anat* 1953; 92:219.
24. Gardner E, Gray DJ, O'Rahilly R. Bones of the upper limb. In: *Anatomy: a regional study of human structure*. Philadelphia: WB Saunders, 1960:107.
25. Gartsman GM. Arthroscopic acromioplasty for lesions of the rotator cuff. *J Bone Joint Surg* 1990;72A:169–80.
26. Gerber C, Terrier F, Ganz R. The role of the coracoid process in the chronic impingement syndrome. *J Bone Joint Surg* 1985;67B:703–8.
27. Golding FC. The shoulder: the forgotten joint. *Br J Radiol* 1962;35:149–58.
28. Goldthwait JE. An anatomical and mechanical study of the shoulder-joint, explaining many of the causes of painful shoulder, many of the recurrent dislocations, and many of the causes of brachial neuralgias or neuritis. *Am J Orthop Surg* 1909;6:579–606.
29. Grant JCB. The upper limb. In: *A method of anatomy, 2nd Ed.* Baltimore: Williams and Wilkins, 1940:72.
30. Grant JCB, Smith CG. Age incidence of rupture of the supraspinatus tendon. *Anat Rec* 1948;100:666.

31. Hamada K, Fukuda H, Mikasa M, Kobayashi Y. Roentgenographic findings in massive rotator cuff tears: a long-term observation. *Clin Orthop* 1990;254:92–6.
32. Hamilton FH. Fractures of the scapula. In: *A practical treatise on fractures and dislocations,* 5th Ed. Philadelphia: Henry C. Lea, 1875:218.
33. Hawkins RJ, Kennedy JC. Impingement syndrome in athletes. *Am J Sports Med* 1980;8:151–8.
34. Inman VT, Saunders M, Abbott LC. Observations on the function of the shoulder joint. *J Bone Joint Surg* 1944;26:31.
35. Jackson DW. Chronic rotator cuff impingement in the throwing athlete. *Am J Sports Med* 1976;4:231–40.
36. Jerosch J, Castro WHM, Sons HU, Moersler M. Zur Ätiologie des subacromialen Impingement-Syndrome: eine biomechanische Untersuchung. *Beitr Orthop Traumatol* 1989; 36:411–8.
37. Jobe FW. Thrower problems. *Am J Sports Med* 1979;7:139.
38. Jobe FW. Impingement problems in the athlete. *ICLS* 1989; 38:205–11.
39. Jobe FW, Jobe CM. Painful athletic injuries of the shoulder. *Clin Orthop* 1983;173:117–24.
40. Jobe FW, Kvitne RS, Giangarra CE. Shoulder pain in the overhand or throwing athlete: the relationship of anterior stability and rotator cuff impingement. *Orthop Rev* 1989;18: 963.
41. Johansson JE, Barrington TW. Coracoacromial ligament division. *Am J Sports Med* 1984;12:138–41.
42. Kessel L, Watson M. The painful arc syndrome: clinical classification as a guide to management. *J Bone Joint Surg* 1977;59B:166–72.
43. Keyes EL. Observations on rupture of the supraspinatus tendon: based upon a study of seventy-three cadavers. *Ann Surg* 1933;97:849–56.
44. Kolts I. A note on the anatomy of the supraspinatus muscle. *Arch Orthop Trauma Surg* 1992;111:247–9.
45. Lewis WH. The development of the arm in man. *Am J Anat* 1902;1:145.
46. Liberson F. Os acromiale: a contested anomaly. *J Bone Joint Surg* 1937;19:683–9.
47. Lohr JF, Uhthoff HK. The microvascular pattern of the supraspinatus tendon. *Clin Orthop* 1990;254:35–8.
48. McLaughlin HL, Asherman EG. Lesions of the musculotendinous cuff of the shoulder. IV. Some observations based upon the results of surgical repair. *J Bone Joint Surg* 1951; 33A:76–86.
49. McMasters PE. Tendon and muscle ruptures: clinical and experimental studies on the causes and location of subcutaneous ruptures. *J Bone Joint Surg* 1933;15:705–22.
50. Mallon WJ, Brown HR, Volger JB, Martinez S. Radiographic and geometric anatomy of the scapula. *Clin Orthop* 1992;277:142–54.
51. Meyer AW. Unrecognized occupational destruction of the tendon of the long head of the biceps brachii. *Arch Surg* 1921;2:130–44.
52. Meyer AW. Further observations upon use-destruction in joints. *J Bone Joint Surg* 1992;4:491–511.
53. Meyer AW. Chronic functional lesions of the shoulder. *Arch Surg* 1937;35:646–74.
54. Morrison DS, Bigliani LU. The clinical significance of variations in acromial morphology. *Orthop Trans* 1987;11:234.
55. Morrison DS, Rosen MA. Acromial morphology and the results of arthroscopic subacromial decompression. In: Post M, Morrey BF, Hawkins RJ, eds. *Surgery of the shoulder.* St Louis: Mosby-Year Book, 1990:196–9.
56. Moseley HF, Goldie I. The arterial pattern of the rotator cuff of the shoulder. *J Bone Joint Surg* 1963;45B:780–9.
57. Mudge MK, Wood VE, Frykman GK. Rotator cuff tears associated with os acromiale. *J Bone Joint Surg* 1984;66A: 427–9.
58. Nasca RJ, Salter EG, Weil CE. Contact areas of the subacromial joint. In: Bateman JE, Welsh RP, eds. *Surgery of the shoulder*. New York: Dekker, 1984:134–9.
59. Neer CS. Anterior acromioplasty for the chronic impingement syndrome in the shoulder: a preliminary report. *J Bone Joint Surg* 1972;54A:41–50.
60. Neer CS. Impingement lesions. *Clin Orthop* 1983;173:70–7.
61. Neer CS. Cuff tears, biceps lesions, and impingement. In: *Shoulder reconstruction*. Philadelphia: WB Saunders, 1990:41–2.
62. Neer CS, Bigliani LU, Hawkins RJ. Rupture of the long head of the biceps related to subacromial impingement. *Orthop Trans* 1977;1:111.
63. Neer CS, Poppen NK. Supraspinatus outlet. *Orthop Trans* 1987;11:234.
64. Neer CS, Welsh RP. The shoulder in sports. *Orthop Clin North Am* 1977;8:583–91.
65. Norwood LA, Del Pizzo W, Jobe FW, Kerlan RK. Anterior shoulder pain in baseball pitchers. *Orthop Trans* 1978;2:20.
66. Ogata S, Uhthoff HK. Acromial enthesopathy and rotator cuff tear: a radiologic and histologic postmortem investigation of the coracoacromial arch. *Clin Orthop* 1990;254: 39–48.
67. Ozaki J, Fujimoto S, Nakagawa Y, Masuhara K, Tamai S. Tears of the rotator cuff of the shoulder associated with pathological changes in the acromion: a study in cadavera. *J Bone Joint Surg* 1988;70A:1224–30.
68. Patte D. The subcoracoid impingement. *Clin Orthop* 1990; 254:55–60.
69. Paulos LE, Franklin JL. Arthroscopic shoulder decompression development and application: a five year experience. *Am J Sports Med* 1990;18:235–44.
70. Penny JN, Welsh RP. Shoulder impingement syndromes in athletes and their surgical management. *Am J Sports Med* 1981;9:11–5.
71. Petersson CJ, Gentz CF. Ruptures of the supraspinatus tendon: the significance of distally pointing acromioclavicular osteophytes. *Clin Orthop* 1983;174:143–8.
72. Petersson CJ, Redlund-Johnell I. The subacromial space in normal shoulder radiographs. *Acta Orthop Scand* 1984;55: 57–8.
73. Pujadas GW. Coraco-acromial ligament syndrome. *J Bone Joint Surg* 1970;52A:1261.
74. Rathbun JB, Macnab I. The microvascular pattern of the rotator cuff. *J Bone Joint Surg* 1970;52B:540–53.
75. Renoux S, Monet J, Pupin P, et al. Preliminary note on the biometric data relating to the human coracoacromial arch. *Surg Radiol Anat* 1986;8:189–95.
76. Richardson AB, Jobe FW, Collins HR. The shoulder in competitive swimming. *Am J Sports Med* 1980;8:159–63.
77. Rothman RH, Parke WW. The vascular anatomy of the rotator cuff. *Clin Orthop* 1965;41:176–86.
78. Skinner HA. Anatomical considerations relative to rupture of the supraspinatus tendon. *J Bone Joint Surg* 1937;19: 137–51.
79. Smith JG. Pathological appearances of seven cases of injury of the shoulder joint; with remarks. *London Med Gaz* 1834; 14:280–5.
80. Swiontkowski MF, Ianotti JP, Boulas HJ, Esterhai JL. Intraoperative assessment of rotator cuff vascularity using laser doppler flowmetry. In: Post M, Morrey BF, Hawkins RJ, eds. *Surgery of the shoulder*. St. Louis: Mosby-Year Book, 1990:208–12.
81. Tibone JE, Jobe FW, Kerlan RK, et al. Shoulder impingement syndrome in athletes treated by an anterior acromioplasty. *Clin Orthop* 1985;198:134–40.
82. Tibone JE, Elrod B, Jobe FW, et al. Surgical treatment of tears of the rotator cuff in athletes. *J Bone Joint Surg* 1986; 68A:887–91.

83. Trotter M, Peterson RR. Osteology. In: Anson BJ, ed. *Morris' human anatomy: a complete systematic treatise,* Ed. 12. New York: McGraw-Hill, 1966:133.
84. Uhthoff HK, Lohr J, Sarkar K. The pathogenesis of rotator cuff tears. In: Takagishi N, ed. *The shoulder*. Tokyo: Professional Postgraduate Service, 1986:211–2.
85. Warner JJP, Micheli LJ, Arslanian LE, Kennedy J, Kennedy R. Patterns of flexibility, laxity, and strength in normal shoulders and shoulders with instability and impingement. *Am J Sports Med* 1990;18:366–75.
86. Weiner DS, MacNab I. Superior migration of the humeral head: a radiological aid in the diagnosis of tears of the rotator cuff. *J Bone Joint Surg* 1970;52B:524–7.
87. Wilson CL, Duff GL. Pathologic study of degeneration and rupture of the supraspinatus tendon. *Arch Surg* 1943;47: 121–35.
88. Zuckerman JD, Kummer FJ, Cuomo F, Simon J, Rosenblum S. The influence of coracoacromial arch anatomy on rotator cuff tears. *J Shoulder Elbow Surg* 1992;1:4–14.