

The Classic

Surgical Anatomy of the Rotator Cuff and the Natural History of Degenerative Periarthritis

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A discussion of the surgical anatomy of the rotator cuff of necessity embodies the following topics: (1) anatomy of the components of the rotator cuff, (2) anatomy of the coraco-acromial arch and the structures in the subacromial region, (3) anatomy of the biceps tendon and its gliding mechanism, and (4) anatomy of the axillary region of the glenohumeral joint.

Anatomy of the Components of the Rotator Cuff

The rotator cuff consists of four muscles. These are the subscapularis, the supraspinatus, the infraspinatus and the teres minor muscles. These muscles end in short, flat, broad tendons which fuse intimately with the fibrous capsule to form the musculotendinous cuff. This fusion occurs approximately $\frac{1}{2}$ to $\frac{3}{4}$ inch from the point of the insertion of the tendons into the humerus.

The *subscapularis muscle* is a large, flat structure arising from the subscapular fossa. Its tendon fibers blend with the fibrous capsule just lateral to the glenoid brim, and then this portion of the musculotendinous cuff inserts into the lesser tuberosity. In addition, some of the fibers of this muscle insert directly into the shaft of the humerus immediately below the tendinous insertion. Roughly, the volume and power of the subscapularis muscle is sufficient

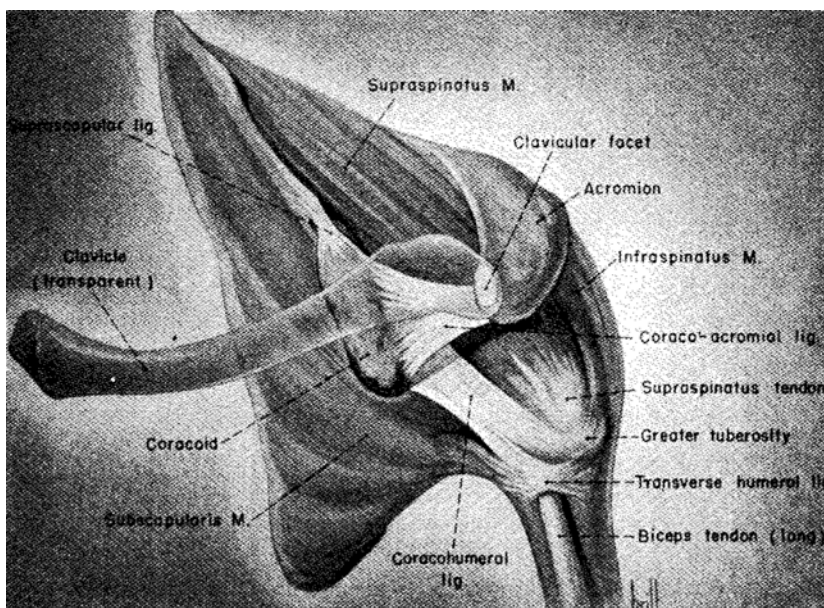
to oppose the volume and power of the infraspinatus and teres minor muscles posteriorly (Fig. 1).

The *infraspinatus muscle* takes origin from the infraspinous fossa on the posterior aspect of the scapula, and its tendon together with the fibrous capsule inserts into the greater tuberosity. It is intimately associated both structurally and functionally with the teres minor muscle. It is innervated by the suprascapular nerve (Fig. 1).

The *teres minor muscle* takes origin from the axillary border of the scapula, and its tendon together with the capsule inserts into the inferior facet of the greater tuberosity. Like those of the subscapularis muscle, some of its fibers insert directly into the humerus distal to its tendinous insertion. This muscle is innervated by a branch of the axillary nerve.

The *supraspinatus muscle* takes origin in the supraspinous fossa, and after its tendon fuses with the capsular fibers, it inserts into the greater tuberosity just posterior to the bicipital groove (Fig. 1). At this point it should be noted that the supraspinatus, infraspinatus and teres minor muscles at their points of insertion cannot be separated into anatomic units. However, between the supraspinatus and subscapularis there is a definite interval which is occupied by the *coracohumeral ligament*. Also, through this interval the biceps tendon together with its synovial covering passes through the joint capsule. The supraspinatus muscle is innervated by the suprascapular nerve.

Fig. 1 Coraco-acromial arch overhanging the head of the humerus. Observe that the acromion is broad, flat and massive; the oval clavicular facet faces obliquely upward; and the triangular coraco-acromial ligament extends from the horizontal portion of the coracoid process to the tip of the acromion lateral to the clavicular facet. (From DePalma, *Surgery of the Shoulder*, J. B. Lippincott Company, 1950 [4].)

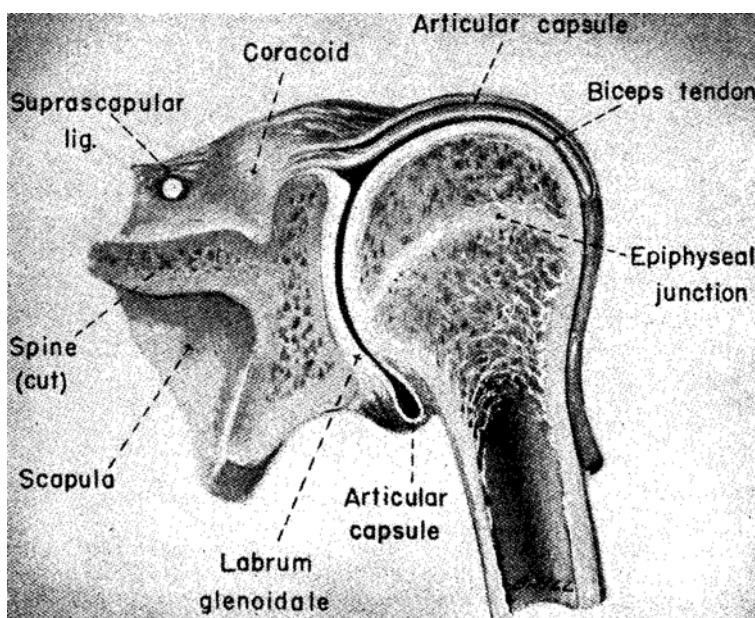


The *fibrous capsule* is a loose, redundant structure twice the surface area of the humeral head. On all sides except the inferior portion the fibrous capsule is strengthened by the broad, flat tendons of the rotator muscles. Where the cuff is absent inferiorly the capsule is very lax, and with the arm at the side it falls into folds which are obliterated when the arm is brought into the elevated position. This weak point of the capsule is significant because it permits the head of the humerus to be displaced downward during normal elevation of the arm (Fig. 2).

Anatomy of the Coraco-Acromial Arch and the Structures in the Subacromial Region

The *coraco-acromial arch* is formed by the coraco-acromial ligament which is a strong triangular structure stretching from the coracoid process to the acromion (Fig. 3). It arises with a wide base from the outer edge of the coracoid and tapers to a narrow band to insert into the inner border of the acromion just in front of the acromio-clavicular joint.

Fig. 2 Frontal section of the right shoulder joint, posterior view. Observe the redundancy of the capsule on the inferior aspect of the neck of the humerus. The fibrous capsule is lined with synovial membrane which is prolonged around the tendon of the long head of the biceps muscle as far as the surgical neck of the humerus, providing a synovial cover for the osseofibrous bicipital tunnel. It then ends as a blind sac and is reflected upon the tendon. (Redrawn from S. W. Spalteholz: *Hand Atlas of Human Anatomy*, Philadelphia, Lippincott, for DePalma, *Surgery of the Shoulder* [4].)



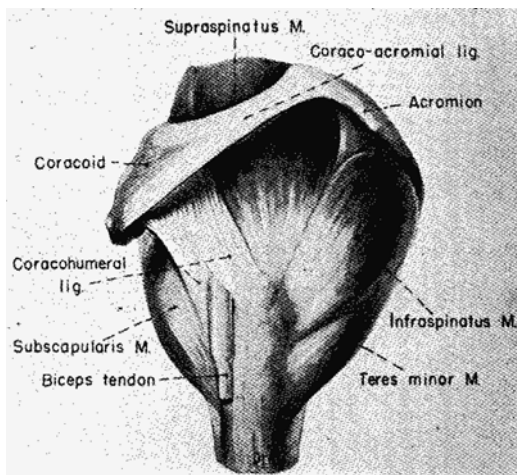


Fig. 3 Subdeltoid region of the left shoulder. Observe the coraco-humeral ligament extending from the outer border of the horizontal limb of the coracoid process to both tuberosities bridging the intertubercular sulcus; also the triangular coraco-acromial ligament and the compactness of the rotator muscles which fuse with the fibrous capsule forming the musculotendinous cuff before they insert into the superior portion of the anatomic neck of the humerus. Note that the lower fibers of the subscapularis muscle anteriorly and the infraspinatus muscle and the teres minor posteriorly insert directly into the shaft of the humerus. (From DePalma, *Surgery of the Shoulder* [4].)

This arch is intimately related to the structures below it. It, together with the head of the humerus and the rotator cuff and the *subacromial bursa*, is frequently referred to as the superior humeral articulation. The subacromial bursa and the areolar tissue in this region provide the gliding mechanism. The rotator cuff, particularly its supraspinatus portion, is in close proximity to the under surface of the coraco-acromial ligament, the acromioclavicular joint and the under surface of the acromion. Between the cuff and the arch lies the subacromial bursa whose floor is adherent to the greater tuberosity and its roof to the acromion and the coraco-acromial ligament.

Variations may be noted in the subacromial bursa. It may be a single structure extending as far as the base of the coracoid or this portion may be a separate bursa often referred to as the subcoracoid bursa. Hence, it becomes apparent that the coraco-acromial arch protects the rotator cuff and tuberosities from external injuries inflicted on the top of the shoulder. On the other hand, an upward thrust such as a fall on the elbow may force the cuff against the arch, resulting in varying degrees of injury. Hypertrophic changes in the bursa or of the tuberosities may cause impingement of the bursal wall against the arch, thereby interfering with the smooth rhythmical elevation and descent of the arm. Degenerative abnormalities such as hypertrophic changes and spur formation on the inferior aspect of the acromioclavicular joint may be formed as the

result of this trauma. In addition, thickening of the inferior capsular tissues of this joint may traumatize the subacromial bursa or cuff during abduction of the arm, producing loss of normal function and pain. As previously noted, two bursae may be found in the subacromial region. The subcoracoid bursa may be an independent bursa; it frequently extends as far as the base of the coracoid process and downward under the short head of the biceps and the coracobrachialis muscle. Failure to appreciate this anatomic feature while exploring the rotator cuff may result in failure to visualize the subscapularis portion of the cuff and any lesion that may be located at this site.

Anatomy of the Biceps Tendon and its Gliding Mechanism

The *tendon of the long head of the biceps* inserts into the supraglenoid tubercle; it leaves the joint through an exit between the superior capsule and the head of the humerus and enters the bicipital groove. The intracapsular portion of the tendon lies immediately below the coracohumeral ligament and between the supraspinatus and subscapularis muscles (Fig. 4). Its proximal insertion is in relation to the superior glenohumeral ligament. The tendon is enveloped in a synovial covering which is an outpouching of the synovial membrane of the joint into the bicipital groove. Certain developmental variations should be noted (Fig. 5). The tendon may appear as a double structure. It may be absent. It may be lying in an extrasynovial position in a tunnel in the fibrous capsule, or it may have a mesentery of varying length. Variations also occur in the region of the bicipital groove. Meyer in 1928 described the supratubercular ridge—a ridge of bone continuous with the medial wall of the bicipital groove (Fig. 6). Hitchcock and Bechtol found this ridge to be well developed in 8 per cent and moderately developed in 59 per cent of the specimens reviewed. It tends to displace the biceps tendon against the transverse humeral ligament. These observers also noted variations in the obliquity of the medial wall of the bicipital groove. Only 10 per cent of the specimens had a medial wall of 90 degrees. In 35 per cent it was 75 degrees; in 34 per cent it was 60 degrees; in 13 per cent it was 45 degrees. In 6 per cent it was 30 degrees, and in 2 per cent it was 15 degrees. Shallow grooves favor displacement of the tendon, forcing it to lie on a fascial sling.

When the arm is used constantly in the position of internal rotation, the tendon performs over the medial wall of the groove. The lesser tubercle now, from a mechanical viewpoint, functions as a trochlea. In this position, the tendon is working at a great mechanical disadvantage which results in attritional changes in the tendon, in the groove and in the adjacent soft tissues. These alterations

Fig. 4 Interior of right shoulder joint, posterior view; the posterior portion of the capsule has been reflected medially. Observe the arrangement of the three glenohumeral ligaments reinforcing the anterior aspect of the fibrous capsule. They are all directed toward the superior aspect of the glenoid fossa; in this instance they all blend with the labrum glenoidale (not the case in all shoulders). Note the direct communication of the subscapularis recess with the inside of the joint cavity. In this joint the subscapularis recess communicates with the joint cavity, both above and below the middle glenohumeral ligament. (From DePalma, Surgery of the Shoulder [4].)

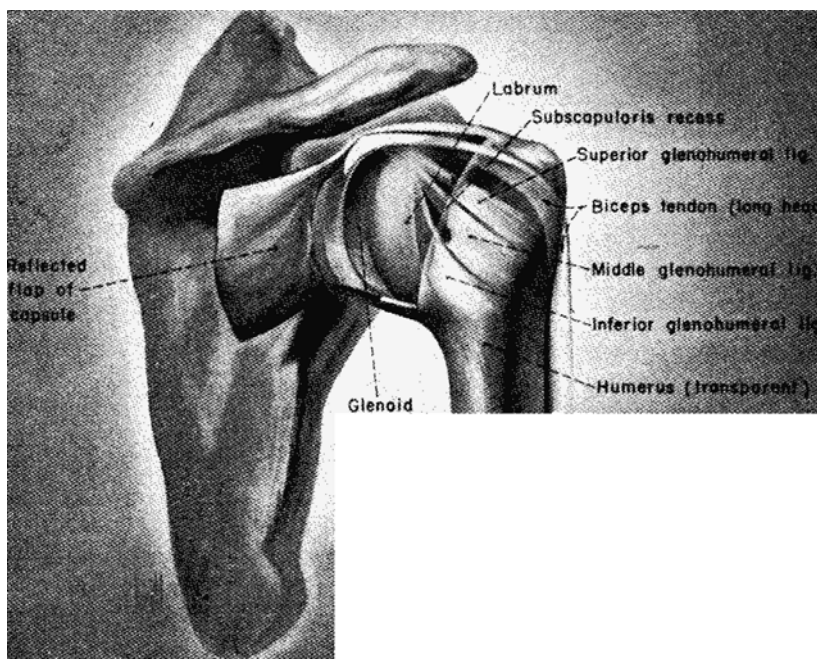
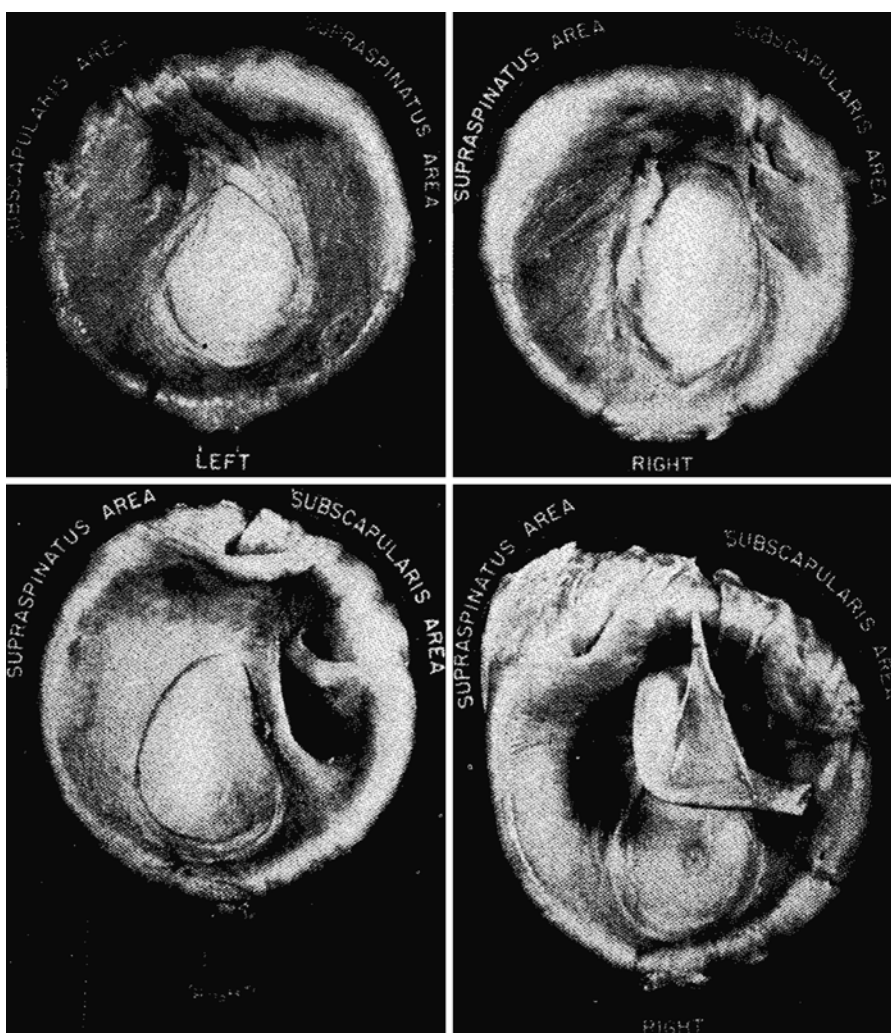


Fig. 5 *Top, left*, A double biceps tendon. *Top, right*, Absence of a biceps tendon and a firmly attached labrum to the glenoid rim. *Bottom, left*, The biceps tendon is extrasynovial, lying within the fibrous capsule. This structure has failed to migrate to an intracapsular position. Note the firm attachment of the labrum to the rim of the glenoid cavity. The inferior glenohumeral ligament in this specimen is well defined and extends from the subscapular area to the triceps area. *Bottom, right*, A well-formed mesentery of the biceps tendon and a large incomplete tear in the musculotendinous cuff in the supraspinatus area, proximal to which there is a distinct hypertrophied falciform ligament. (From DePalma, Surgery of the Shoulder [4].)



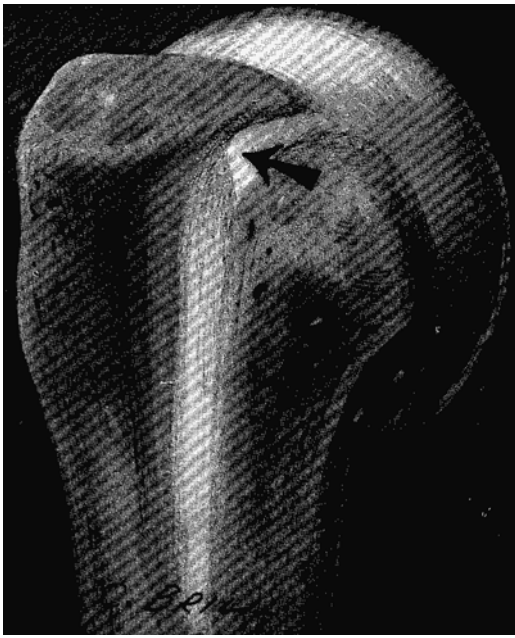
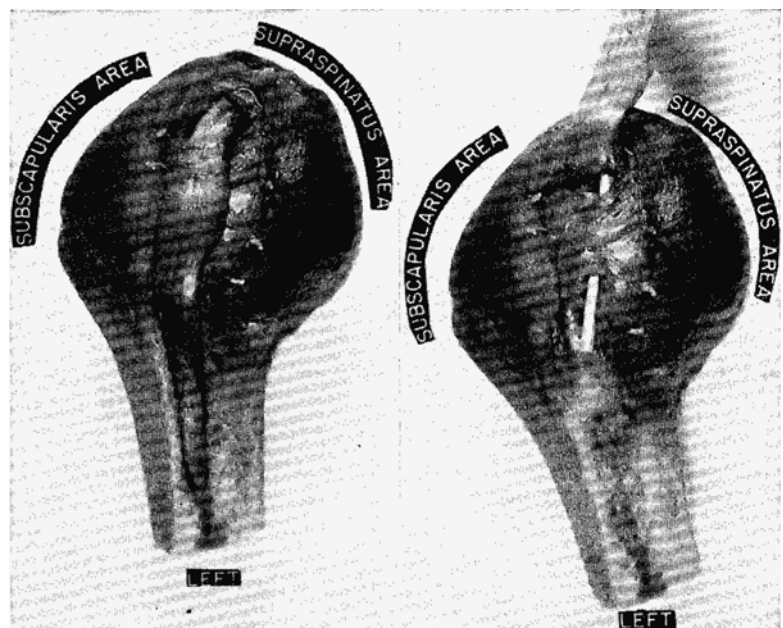


Fig. 6 Schematic drawing showing a supratubercular ridge, which may facilitate displacement of biceps tendon out of the intertubercular sulcus. (From DePalma, *Surgery of the Shoulder* [4].)

are enhanced if the groove is shallow (Fig. 7). In the face of a shallow groove, displacement of the tendon onto a fascial sling may occur. In addition, rupture of the cuff in this area is frequently encountered, as also are excrescences on either side of the bicipital groove, more so on its medial border (Fig. 8).

Fig. 7 *Left*, Biceps tendon lies to inside of the lesser tuberosity. *Right*, Note the reduction in the height of the lesser tuberosity; also a well-formed fascial sling extending from the fibrous capsule to the remainder of the lesser tuberosity. The under surface of the biceps tendon reveals advanced degenerative changes. (From DePalma, *Surgery of the Shoulder* [4].)



Anatomy of the Axillary Structures in Relation to the Inferior Aspect of the Glenohumeral Joints

In this region, note should be made of the course of the neurovascular bundle as it makes its way distally around the coracoid process under the pectoralis minor muscle and onto the subscapularis (Fig. 9). Also of importance is the relationship of the circumflex nerve and the posterior circumflex vessels as they traverse the subscapularis across the inferior aspect of the capsule of the glenohumeral joint and continue posteriorly across the teres minor to reach the posterior border of the muscle (Fig. 10).

Natural History of Degenerative Periarthritis of the Shoulder

The following observations were made in a study of 96 shoulder joints obtained post-mortem from 50 individuals. Only individuals who were unaware of any disability were selected for this investigation. However, most of those over 40 years of age gave a history of having some temporary disability in one or both shoulders at some time in their lives. None had severe traumatic lesions followed by marked dysfunction. There were 36 males and 14 females. The age ranged from 18 to 74 years.

Many workers have described the degenerative alterations that occur in the musculotendinous cuff past middle life. The progressive nature of the process is best observed when the inside of the cuff is visualized in specimens of successive decades. In this investigation, it was noted that

Fig. 8 *Left*, Note defect in frayed biceps tendon and spur in the floor of the bicipital groove. *Right*, When the tendon is in its normal position the defect in its substance fits snugly around the bony spur. (From DePalma, Surgery of the Shoulder [4].)

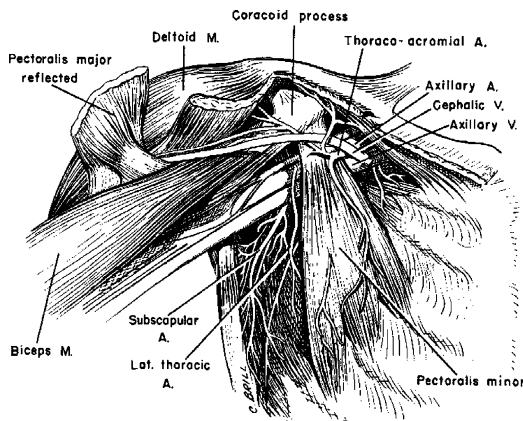
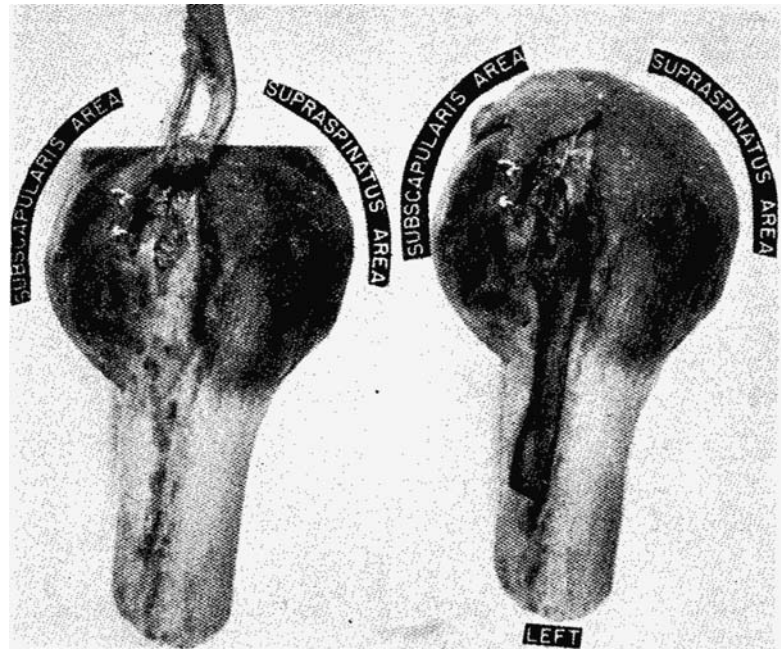


Fig. 9 Vessel under the pectoralis minor muscle. (From DePalma, Surgery of the Shoulder [4].)

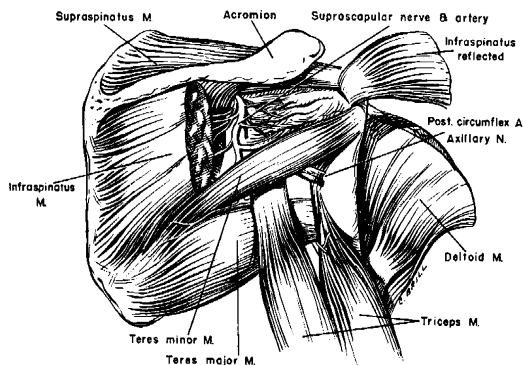


Fig. 10 Course of the suprascapular nerve. (From DePalma, Surgery of the Shoulder [4].)

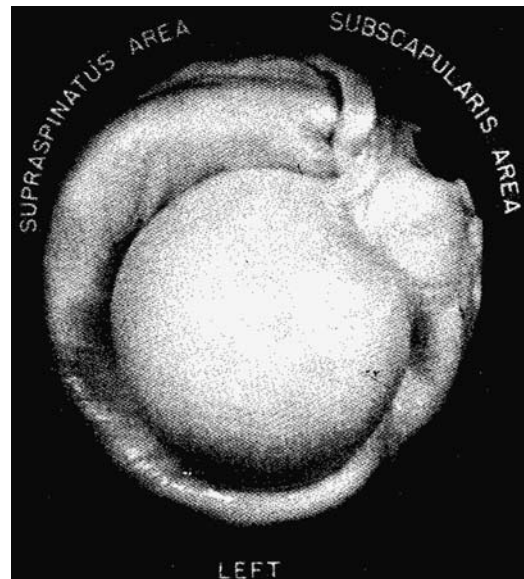


Fig. 11 D.A., male, white, age 23. Left shoulder. This specimen discloses no macroscopic evidence of degenerative changes. Note that the musculotendinous cuff with its synovial lining is in close proximity to the margin of the articular cartilage. Nowhere is there any recession of the cuff fibers. (From DePalma, Surgery of the Shoulder [4].)

in the specimens of the first four decades the cuff and its synovial lining were in close proximity to the articular cartilage of the humeral head. There was no evidence of tearing away of the cuff from its insertion (Fig. 11). However, in the fifth decade several specimens disclosed deltoid gradual pulling away of the cuff at its site of

insertion. In addition, there was evidence of fibrillation, lamination and some thinning of the cuff fibers, particularly in the "critical zone" or the site of insertion of the cuff into the tuberosity. Inasmuch as these lesions did not involve the full thickness of the cuff, they are in essence partial tears. The earliest lesions were noted in the supraspinatus and infraspinatus regions and in the subscapularis regions of the cuff. As a rule, the tears in the supraspinatus area also extend into the infraspinatus region (Fig. 12). With each successive decade after the fifth, the incidence and severity of the lesion increased. In this series there were 20 subscapularis tears or 20.8 per cent and 35 supraspinatus

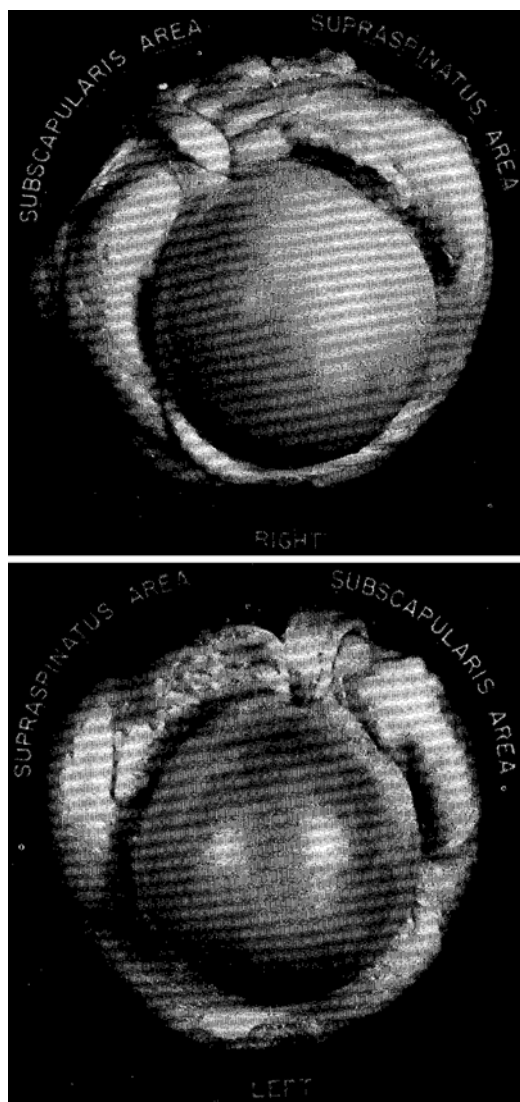


Fig. 12 *Top*, T.C., male, white, age 43. Right shoulder. Large incomplete tear in supraspinatus area of the cuff. Note the recession of the cuff fibers and thickening of the torn fibers. *Bottom*, Left shoulder. Large incomplete tear in supraspinatus and infraspinatus portion of the cuff, with recession of cuff and marked thickening of the torn fibers. (From DePalma, *Surgery of the Shoulder* [4].)

and infraspinatus tears or 37.3 per cent. In the earlier decade, the fibers showed marked thickening and hyperplasia while in the later decade thinning and increased fibrosis were the more common characteristics.

In nine of the specimens of the late decades, complete tears were found. These involved the entire thickness of the cuff and permitted direct communication between the joint cavity and the subacromial bursa (Fig. 13). The tears ranged from small defects, 1 cm. wide in the supra- and infraspinatus region, to large extensive lesions implicating all of the supraspinatus and infraspinatus and even part of the subscapularis region.

In most specimens with extensive implication of the cuff, other secondary changes were noted. Most important is the wearing away or recession of the greater and lesser tuberosities of the humerus. This is undoubtedly due to the abutment of the humeral head against the coraco-acromial arch during elevation of the arm (Fig. 13). This absorptive process also involves the bicipital sulcus and the groove so that the biceps tendon is forcefully compressed against the edge of the arch and, therefore, undergoes attritional changes and even rupture. In those instances in which the



Fig. 13 M.A., female, colored, age 59. Left shoulder. Large complete tear exists, involving all the supraspinatus and infraspinatus portions of the cuff. Only the teres minor tendon remains intact. There is also evidence of advanced degenerative changes in the subscapularis region of the musculotendinous cuff. Both tuberosities have been leveled off. In this specimen, the subacromial bursa has been distended and fixed in order to exhibit marked widening and hypertrophy of its walls. (From DePalma, *Surgery of the Shoulder* [4].)

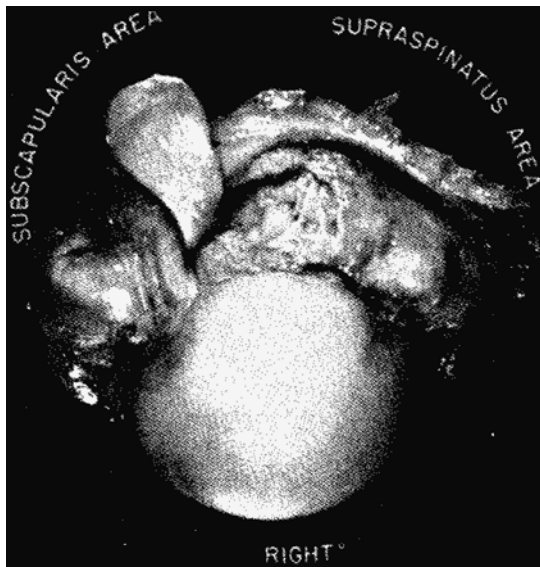


Fig. 14 A.R., male, white, age 62. Right shoulder, synovial side. A massive complete tear exists, involving the whole supraspinatus and a large portion of the infraspinatus tendon. Observe the thickness of the biceps tendon which has been completely displaced from the intertubercular groove and lies on a fascial sling formed by the upper border of the intact subscapularis tendon. There is also evidence of marked degenerative changes in the synovial membrane of the entire cuff. Such an arrangement as is shown by the biceps tendon permits it a free excursion of motion in the new wide tunnel. (From DePalma, *Surgery of the Shoulder* [4].)

tendon does become severed, the intra-articular portion usually is absorbed and the extra-articular end of the tendon becomes anchored to the shaft of the humerus in the region of the bicipital groove. It was interesting to note that implication of the biceps tendon was also usually associated with tears of the cuff on either side of the exit of the tendon from the joint so that the tendon lay in a fascial sling which usually comprised the border of the subscapularis tendon (Fig. 14). Hypertrophic changes also occurred in the bicipital groove and, in some instances, the groove was completely obliterated.

Hand in hand with the changes noted in the musculotendinous cuff are the changes observed in the subacromial bursa, particularly when a complete tear was present. The walls of the bursa in most instances were markedly hyperplastic and thickened and, when a complete rupture existed, there was marked distention of the bursal sac.

Finally, one should mention the fact that in many instances the secondary changes were noted on the inferior aspect of the acromion, particularly in the old and extensive lesions; there was evidence of contact between the tuberosities and the inferior aspect of the acromion. In many specimens, this region of the acromion was sclerotic and eburnated, undoubtedly due to friction with the humeral head.

Based on the above observations, one can reasonably construct the natural history of peri arthritis of the shoulder. It is apparent that aging is an important etiological factor, and with aging certain changes take place in the connective tissue elements of the musculotendinous cuff which cause it to lose its elasticity and undergo regressive changes. These alterations are progressive in nature with each successive decade. However, it also becomes apparent that in slowly developing lesions of this nature compensating adjustments in the mechanics of the joint take place so that severe alterations in the mechanics of the joint do not appear. However, one must admit that such a joint is very vulnerable and, if subjected to minor trauma, the existing degenerative lesion would be extended and aggravated.

When sudden interruption of the mechanics of the joint occurs, nature does not have time to make the necessary adjustment for good function and hence definite impairment of the joint function ensues. Also, one can conclude that the presence of a complete tear in the rotator cuff does not determine whether or not abduction of the arm can take place. The loss of function in the scapulohumeral joint is in direct proportion to the impairment of muscle balance between the rotator muscles which fix and depress the head in the glenoid cavity and the deltoid muscle. In other words, so long as the intact portion of the musculotendinous cuff, regardless of the size of the tear, contains sufficient power to balance the action of the deltoid, abduction of the scapulohumeral joint should ensue. However, this statement must be qualified by saying that, although a defective cuff can stabilize the humeral head sufficiently to produce complete abduction, it may not be capable of maintaining this fulcrum against resistance. Also, that all grades of dysfunction may exist in different shoulders depending upon the degree of impairment of balance between the rotator apparatus and the deltoid muscle.

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