THE ROLE OF THE CORACOID PROCESS IN THE CHRONIC
IMPINGEMENT SYNDROME

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Symptomatic impingement of the rotator cuff between the humeral head and the coracoid process has been studied and three varieties recognised: idiopathic, iatrogenic and traumatic. In all three the clinical findings consisted of pain in front of the shoulder, referred to the upper arm and forearm, and especially felt during forward flexion and medial rotation; the pain could be reproduced by medial rotation with the arm in 90° of abduction, or by adduction with the shoulder flexed to 90°. Patients were relieved of their symptoms by restoring adequate subcoracoid clearance.

Impingement of the tendinous cuff beneath the coracoacromial arch is an established cause of chronic shoulder disability (Meyer 1922; Watson-Jones 1943; Neer 1972, 1983). The antero-inferior edge of the acromion, the coraco-acromial ligament and occasionally the undersurface of the acromioclavicular joint are known sites of impingement (Neer 1972, 1983; Laumann 1982; Petersson and Gentz 1983). With regard to treatment, complete acromionectomy was introduced in 1943 by Watson-Jones and by Smith-Petersen; Aufranc and Larson; this seemed to relieve pain which had formerly been considered incurable (Meyer 1922). However, long-term results were unsatisfactory (McLaughlin 1962; Neer 1972; Neer and Marberry 1981), and alternatives proposed included partial acromionectomy (Neviser 1962), and bevelling the antero-inferior acromion combined with resection of the coraco-acromial ligament (McLaughlin 1962). Neer expanded this latter approach by introducing his anterior acromioplasty, which has become the standard operation for patients whose chronic shoulder impingement resists conservative management (Neer 1972).

The space below the coracoacromial arch is defined by the acromion superiorly, the coraco-acromial ligament supero-medially, and the coracoid process anteriorly (Laumann 1982). Neer has repeatedly pointed out that the functional arc of shoulder movement is forward (1972, 1983), and that forward flexion is often associated with medial rotation at the glenohumeral joint (1972). Nevertheless, impingement of the tendinous cuff against the anterior border of the subacromial space—that is, against the coracoid process itself—has never been considered in the recent literature (Neer 1972, 1983; Hawkins and Kennedy 1980; DePalma 1983; Petersson and Gentz 1983).

This paper describes the clinical syndrome associated with subcoracoid impingement and is partly based on the results of a computer-tomographic study of the coracohumeral space.

PATIENTS AND METHODS

Anatomy. In order to establish the normal anatomical relationship between the humeral head and the coracoid process, we studied CT scans of normal shoulders in two different positions: 40 shoulders (in 27 individuals) with the arm at the side, and 16 shoulders (of 16 individuals) with the arm in forward flexion and medial rotation (the modified impingement test, Hawkins and Kennedy 1980). No individual had a history of previous shoulder pain, dysfunction or injury; clinical and radiographic examinations were normal.

![Fig. 1](image1.jpg)

Figure 1—CT scan of a normal shoulder in the transverse plane of the body at the level of the coracoid tip (C). In these scans the average distance between the humeral head and the tip of the coracoid in normal shoulders was 8.6 mm. Figure 2—CT scan of another shoulder with the arm in forward flexion/medial rotation. The coracoid process lies opposite the biceps tendon. In this position the average distance between the humeral head and coracoid tip was 6.7 mm. C, coracoid tip; black arrow, lesser tuberosity; white arrow, greater tuberosity.
In these normal shoulders the distance between the bony outlines of the humeral head and the coracoid tip varied with position and with the individual anatomy; with the arm at the side (Fig. 1), this distance was least in medial rotation of the humerus and averaged 8.6 mm. Proximity of the coracoid tip to the anterior scapular neck or its large lateral projection and especially the combination of the two, led to particularly small coracohumeral distances. Forward flexion combined with medial rotation (Fig. 2) reduced the coracohumeral distance to an average of 6.7 mm. Any anatomical variation, that is, any iatrogenic or traumatic change in skeletal anatomy which brought the humeral head closer to the coracoid process, decreased the coracohumeral clearance 1.5 times more in forward flexion/medial rotation than with the arm at the side.

The coracohumeral interval must accommodate the articular cartilage of the humeral head (2–3 mm), the joint capsule (1–2 mm), the subscapularis (2–4 mm) and the subacromial bursa—and still leave room for the soft tissue to glide between the coracoid process and the humeral head. Consequently, even minor variations of shape or position of the coracoid tip or the humeral head can jeopardise coracohumeral clearance of the rotator cuff and the biceps tendon. Individual variation can diminish the coracohumeral space and lead to “idiopathic” subcoracoid soft-tissue impingement (Figs 3–7). In addition, traumatic or iatrogenic changes in the orientation of the coracoid process (Figs 8–11), in the position of the glenoid (Figs 12 and 13) or in the shape of the humeral head (Figs 14 and 15), may have the same effect. It must, however, be recognised that soft-tissue clearance is affected much less with the arm at the side than in forward flexion/medial rotation, and that symptoms of subcoracoid impingement are therefore likely to be aggravated in this position.

**Clinical material.** Patients with a clinical diagnosis of subcoracoid impingement have been studied. In 37 shoulders the diagnosis had been confirmed by CT scan and at operation; in 50 others the diagnosis had been
made on clinical grounds alone. In all shoulders the symptoms, signs and operative findings were alike, irrespective of the cause of impingement.

The main symptom in patients with proven subcoracoid impingement was a dull pain in front of the shoulder. In two-thirds of patients, this pain was referred to the front of the upper arm and in one-third it extended to the forearm. Pain was consistently brought about or aggravated by forward flexion and medial rotation. In contrast to the more familiar type of impingement, forward flexion was often most painful between 80° and 130° rather than when it was full. Activities often associated with pain were driving a car (the "driver's position"), drawing on a blackboard, or the follow-through phase of throwing.

Patients with iatrogenic coracohumeral impingement after a Trillat procedure or a posterior glenoid neck osteotomy suffered severe postoperative pain which was referred to the whole of the anterior aspect of the arm and was resistant to conservative treatment. This pain was often associated with paraesthesia which never corresponded with the sensory area of a cervical root or a peripheral nerve. In addition to their persistent pain, these patients also complained of limited movement, especially horizontal flexion and medial rotation (Figs 8–11).

Case 2. Figure 8—An iatrogenic impingement: a bilateral Trillat procedure had been performed on this patient. Medial rotation in abduction (top) and horizontal flexion (centre) were severely restricted in the right shoulder and normal in the left. CT scans documented bony subcoracoid impingement; note that this did not involve the screw head but the coracoid tip. Radiographs showed a marked overlap of the right coracoid tip with sclerotic reaction on the humeral head (Fig. 9), and a correct coracohumeral position in the other shoulder (Fig. 10). Figure 11—The same patient 18 months after revision: mobility in the right shoulder is almost normal. During a Bristow-type repair the coracoid process was brought to the most lateral position possible to compensate for the severe deficit in the subscapularis.
Physical examination revealed an exquisitely tender coracoid tip. Abduction to 90° combined with medial rotation (Fig. 4) was restricted and was consistently painful; sometimes it reproduced the radiation to the upper arm and forearm. During operation we could demonstrate that, in this position, the lesser tuberosity (and, with increasing forward flexion of the abducted arm, the biceps tendon and supraspinatus also) approached closer to the coracoid process. Of all positions tested during operation, abduction/medial rotation was the one with the smallest coracohumeral distance and examining patients in this position was the most sensitive way of detecting subcoracoid impingement. As this is not a functional position of the shoulder, the surgeon may miss subcoracoid impingement if he only examines the painful positions reported by the patient. Horizontal flexion (Fig. 8, centre) was markedly restricted in iatrogenic coracohumeral impingement and often moderately painful.

Forward flexion combined with medial rotation was chosen as the position in which to identify subcoracoid impingement by CT scan because, in our patients, this was usually the most painful position of the shoulder (Fig. 5). Intra-operative studies showed that lesions in the cuff, which ranged from superficial erosions in idiopathic cases to complete cuff destruction in iatrogenic cases, lay between the humeral head and the coracoid process in this position.

Subacromial infiltration of local anaesthetic sometimes relieved pain; this may be because a subacromial bursa possibly communicating with the subcoracoid bursa had been infiltrated. Subcoracoid injections may relieve the pain and paraesthesia of subcoracoid impingement without necessarily relieving an associated subacromial impingement; hence two injections may be necessary to confirm or exclude subcoraco-acromial impingement.

The findings on radiological examination and CT scan depended on the underlying pathology. Our idiopathic cases had large coracoid processes which projected laterally more than usual; the glenoid had the normal amount of retroversion. However, the diagnosis of coracohumeral impingement does not require tomographic studies: it can and should be made clinically. At operation we have been able to prove clinically suspected coracohumeral impingement even when this had not been demonstrable by CT scan. Bony impingement would be shown only if all soft tissue had been destroyed. However, if a CT scan reveals a humeral head close to the coracoid process, this may well indicate soft tissue impingement. The computer tomograms in this study were done for confirmation of a condition previously unknown to us.

We documented idiopathic subcoracoid impingement (Figs 3–7) clinically, computer-tomographically and operatively in four painful shoulders, and we had sufficient clinical evidence of its occurrence in 21 others.

As in most cases of chronic idiopathic impingement, the symptoms could usually be treated conservatively. It is noteworthy, however, that all patients who needed operative treatment had virtually complete relief of both local and referred pain. As anterior acromioplasty is an established and successful procedure for the chronic impingement syndrome, we carried out isolated resection of the anterolateral coracoid tip only once; this was when, at operation, we had unequivocal proof of coraco-humeral impingement whereas there was no impingement against the acromion or the coraco-acromial ligament. This patient had a completely painfree, physically normal shoulder 18 months after operation. In the three other idiopathic cases we not only resected the coracoid tip but also resected the coraco-acromial ligament; two of these cases had a standard anterior acro-
mioplasty (Neer 1972). We cannot yet comment on the frequency of isolated idiopathic coracohumeral impingement. However, because the coracoid process, as well as the antero-inferior acromion and the coraco-acromial ligament, can be involved in impingement, this involvement should always be sought by examination in the positions described.

**DISCUSSION**

Impingement on the coracoid process was described by Goldthwait in 1909; he not only recognised that variations in the shape of the acromion can cause subacromial impingement but also demonstrated that the subcoracoid bursa can be irritated by compression between the humeral head and the coracoid process. He found remarkable differences in the shape and size of individual coracoid processes and felt that such anatomical variations explained the occurrence of subcoracoid impingement. His findings were subsequently confirmed by Meyer (1922, 1937). However, Codman (1984) did not accept the possibility of subcoracoid impingement. His authoritative text, which has served as the basis for subsequent studies on this subject, may have discouraged further investigations on the role of the coracoid process.

In a CT study of the normal anatomy we have confirmed significant individual differences in the anatomical clearance between the bony outlines of the humeral head and the tip of the coracoid process; distances in the different shoulders were related to their individual skeletal anatomy. With the arm at the side, the coracohumeral space was larger in 13 of 16 shoulders studied than in forward flexion/medial rotation. It is possible that a person with a small anatomical clearance may never experience impingement symptoms until engaging in activities which require repeated overhead use of the arm. Our anatomical studies confirm the importance of the anatomical variations described by Goldthwait (1909); this is further substantiated by the invariably large coracoid tips in our idiopathic cases of proven subcoracoid impingement. Operative exploration of these shoulders also confirmed Goldthwait’s pathoanatomical findings.

The associated clinical syndrome had originally been characterised by shoulder pain referred to the upper arm and forearm, mainly reproducible by rotation of the abducted humerus (Goldthwait 1909). Bennett (1941) confirmed the clinical relevance of this syndrome in athletes who throw. Unfortunately, neither he nor Dines, Warren and Inglis (1982), who reported two cases of subcoracoid impingement of the long biceps tendon, described the clinical findings of their patients explicitly. The signs (except for the markedly restricted range of motion in iatrogenic cases) and the symptoms of our patients strikingly resembled those of the patients in Goldthwait’s study.

Subcoracoid impingement after bone block procedures for anterior instability of the shoulder (Figs 8–11) has not previously been described. In Trillat’s procedure for recurrent anterior shoulder instability (Trillat and Leclerc-Chalvet 1973), the coracoid is incompletely osteotomised at its base and moved distally and somewhat laterally to provide an anteromedial bony buttress. Trillat attributed the limited medial rotation in about one-third of his patients to “a capsular problem”; ill-defined shoulder pain, usually promoted by vigorous activities, was often associated with radiolucency around the coracocapular nail and hence attributed to “intolerance of the material”. Removal of the nail had apparently cured these patients, but Trillat did not mention whether the transplanted coracoid process had completely united or whether there was fibrous union. In our experience of 56 Trillat procedures, this type of pain associated with limited medial rotation was typical of bony coracohumeral impingement. Radiolucent lines around the coracocapular screw we used were not related to the implant itself, but to its loosening; this occurred when the humeral head abutted against the transposed coracoid.

Any other bone block procedure (Eden 1918; Hybbinette 1932; Latarjet 1958) is apt to lead to impingement of the humeral head on the transplant, especially if the bone block (or its fixation device) overlaps the glenoid plane. We have observed this complication after Bristow-type procedures, where transplants which have been placed too laterally led to rapid traumatic arthritis and destruction of the humeral head. Although the overlap of an anterior bone block (or its fixation device) over the original glenoid plane has been advocated (Eden 1918; Hybbinette 1932; Palmer and Widén 1948), we regard it as a surgical error which requires early re-intervention. Displaced fractures of the coracoid process, or an imperfectly reduced osteotomy of the coracoid process, are apt to cause the same anatomical and clinical problems as the Trillat procedure.

Subcoracoid impingement after posterior glenoid osteotomy (Kretzler and Blue 1966; Scott 1967) or after a fracture of the neck of the glenoid (Fig. 12) have also not been reported in the literature. However, in Scott’s description of this operation (1967) one patient had a prolonged history of chronic pain and grossly limited adduction, suggesting that he had iatrogenic subcoracoid impingement. We have documented symptomatic coracohumeral impingement in two cases of posterior glenoid osteotomy (Fig. 13) and successfully treated them by inferolateral coracoplasty. Details of the anatomical problems encountered with posterior glenoid osteotomy will be the subject of a separate report. A posterior glenoid osteotomy is only one example of how abnormal orientation of the glenoid can cause coracohumeral impingement; others include displaced fractures of the scapular neck and coracoid erosion, the latter a common finding in rheumatoid shoulders, where the head migrates medially due to glenoid destruction.

Subcoracoid impingement after a fracture of the
The arrows in the radiograph (Fig. 16) and CT scan (Fig. 17) point to a calcific deposit in the supraspinatus tendon which impinges on the coracoid process during forward flexion/medial rotation. This was the most painful position of the patient’s shoulder.

The humeral head and neck (Figs 14 and 15) is an obvious possibility, given the small coracohumeral clearance of the normally shaped humerus. In two of our patients it was documented clinically, tomographically and operatively after an anterior fracture-dislocation and after a three-part fracture of the humeral head. Both cases were treated by shortening the inferolateral coracoid process. Both patients regained a significantly better range of movement and a painfree shoulder. Clinically it seems that mild coracohumeral impingement, not sufficient to warrant operation, is a common sequel of slightly mal-united fractures of the proximal humerus. Deformation of the head can also be caused by an implant, as in one of our patients: after a derotation osteotomy to correct anterior shoulder instability, a correctly applied semi-tubular plate caused painful impingement on the coracoid process.

The presentation of a case of impingement of a calcific deposit on the coracoid process (Figs 16 and 17) shows that any “enlargement” of the greater tuberosity area can cause painful coraco-acromial impingement. In this patient the most painful position of the shoulder was that in which the calcific deposit impinged upon the coracoid process, and decompression of the subcoraco-acromial space without removal of the calcium provided prompt and lasting pain relief. This suggests that if a surgeon elects to treat a case of calcific tendinitis by subcoraco-acromial decompression, he may be wise to consider including an inferolateral coracoplasty in order to relieve impingement effectively.

We have only once observed subcoracoid impingement after acromiectomy. It could not be demonstrated by a CT scan because the patient had severe pain on any attempt to move the shoulder, but it was unequivocally revealed at operation. As the tip of the coracoid process usually lies at a level above the maximum diameter of the humeral head, slight upward migration of the humerus (also observed in rotator cuff disease) may have secondarily narrowed the coracohumeral clearance and caused painful impingement. Removal of the inferolateral coracoid tip resulted in lasting pain relief. The weakness, reported to occur commonly in these shoulders (Neer and Marberry 1981), was not changed by the inferolateral coracoplasty.

We feel it is important to emphasise two points. Firstly, that the coracoid process is another possible site of soft-tissue impingement, which should always be considered with any chronic impingement syndromes; and secondly, that operative procedures around the shoulder must respect the anatomical relationship between the humeral head and the coracoid process in order to avoid painful iatrogenic pathology.

REFERENCES


