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Direct observations on the function of the capsule of the sternoclavicular joint in clavicular support

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Inman, Saunders & Abbott (1944) made a major contribution to the understanding of the role played by muscles during movements of the shoulder joint and answered many important questions concerning this region. However, the problem of the support and stability of the shoulder girdle in the upright posture was not discussed in this paper and was ignored in a later study (Scheving & Pauly, 1959).

Although the responsibility for maintaining clavicular poise is usually assigned to the trapezius muscle (*Gray's Anatomy*, 1962), an electromyographic investigation of the trapezius and other shoulder muscles showed that when the shoulder is lowered to the fully depressed position, activity in the trapezius decreases dramatically and even completely (Bearn, 1961). As a result of this work it was suggested that tension in the ligaments of the sternoclavicular joint might play an important role in maintaining clavicular poise, thereby explaining the decrease or absence of activity in the trapezius in the fully depressed position. To study this aspect of the problem further, a series of experiments have been carried out to determine the role of the various ligaments of the sternoclavicular joint in maintaining clavicular poise.

MATERIAL AND METHODS

(A) Five specimens, each comprising the manubrium sterni and the upper half of the body of the sternum, both first ribs and both clavicles, were obtained at post mortem. The sternum was transected between the fourth and the fifth costal cartilages, the first ribs were divided anterior to their tubercles and the clavicular lateral extremities disarticulated by cutting the conoid and trapezoid components of the coracoclavicular ligament and the capsule of the acromioclavicular joint.

The material was carefully cleaned of all muscles; the fibrous joint capsule of the sternoclavicular joint and the interclavicular and costoclavicular (rhomboid) ligaments were then defined. The specimen was firmly attached to a wood block by screws passing through both the manubrim and the body of the sternum and the block rigidly clamped in a vice so that the body of the sternum was vertical. The sternoclavicular joint and the upper half of the manubrium projected above the block to allow free movement of the clavicle.

The lateral end of each clavicle in the region of the conoid tubercle was loaded through a spring balance with weights of 10, 15 and 20 lb, and the clavicular depression so produced measured with a vertical scale. The effect of cutting specific components of the joint complex on clavicular depression was then determined. Each ligament in turn was divided either singly or in combinations. The inferior attachment

of the intra-articular disc was also divided through an incision made in the weak inferior part of the joint capsule.

In addition the first costal cartilage was divided medial to the attachment of the costoclavicular ligament, between it and the inferior capsule of the joint.

The relative strength of the disc and the capsule of the sternoclavicular joint was estimated by dividing each in turn and then loading the system until rupture of the other occurred.

Passive movements of the acromial end of the clavicle were executed in the horizontal and vertical planes to correspond to the respective movements of protraction–retraction and elevation–depression of the shoulder. The range of movement and the factors limiting clavicular excursions were assessed. Rotation of the clavicle about its long axis was similarly investigated in maximal elevation, maximal depression and in intermediate positions.

(B) The interclavicular ligament was palpated in the suprasternal notch in a series of fifty male subjects with the shoulder fully depressed. The shoulder girdle was then elevated and fully depressed and the tension in the ligament during these movements was assessed.

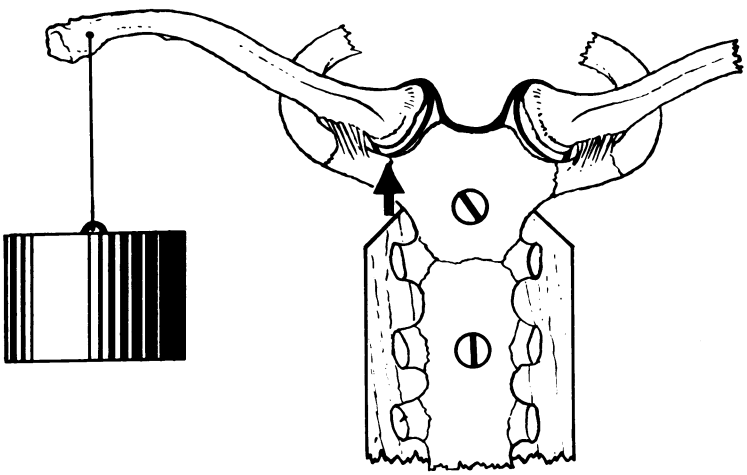

Fig. 1. The poise of the lateral end of the clavicle is maintained during loading by tension in the capsule of the sternoclavicular joint. The arrow indicates the fulcrum.

RESULTS

A. Loading the intact specimen

In the intact and unloaded specimen the poise of the clavicle was seen to be maintained by tension in the capsule of the sternoclavicular joint, the lateral end of the clavicle in all cases being some 2–2·5 in. higher than the medial end. The addition of 10 lb (approximately the weight of the upper limb) to the lateral end of the clavicle resulted in its depression by 1·0–1·5 in. as the superior capsule of the joint lengthened under the increased load (Fig. 1). Thereafter, increasing the loading to 15 and 20lb depressed the clavicular lateral extremity by a further 0·1 in. with each additional weight.

Due to the obliquity of the first rib, loading the acromial end of the clavicle tended to drive it forwards as well as downwards and simultaneous movements of its sternal end occurred in a complementary fashion upwards and backwards, so that the maximum tension was in the posterior–superior part of the capsule.

In two specimens loading was continued until the sternoclavicular joint capsule ruptured. This occurred between 30 and 40 lb loading at which point the posterior–superior part of the capsule was avulsed from the sternum with a flake of bone. The

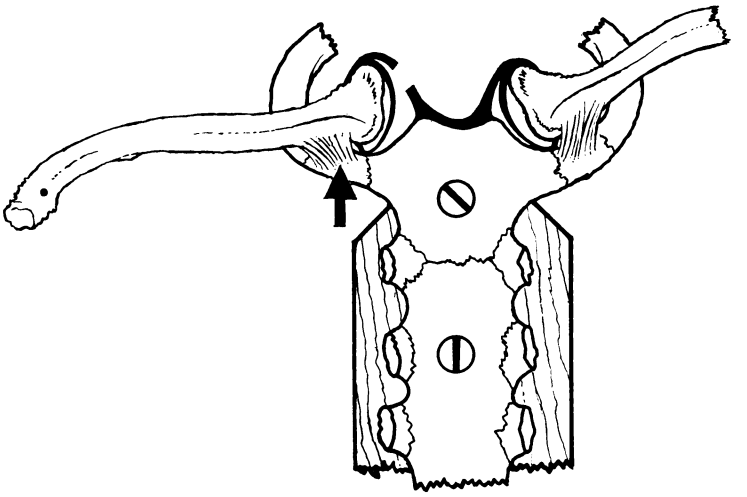

Fig. 2. Division of the capsule of the sternoclavicular joint results in descent of the lateral end to a level lower than the medial end. The clavicle is now supported by the disc.

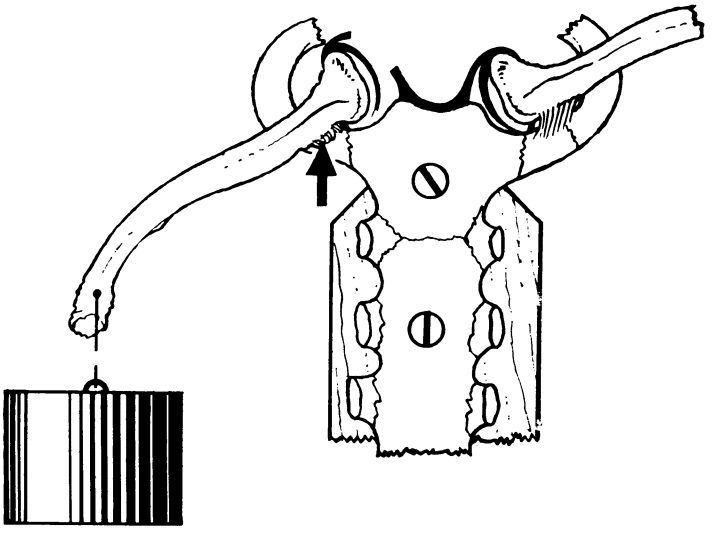

Fig. 3. Division of the capsule of the sternoclavicular joint with 10 lb loading results in full depression of the lateral end about an axis indicated by the arrow, with tearing of the disc from the costal cartilage.

clavicle then hung downwards about an axis at the costoclavicular ligament and remained attached to the first rib by this ligament; the disc was then seen to have torn from its thin lower attachment to the costal cartilage. So long as the integrity of the capsule of the joint was maintained, the acromial end of the clavicle remained at all times higher than the sternal end.

B. Loading following selective division of the ligaments

The capsule. When the capsule was divided completely, leaving only the disc and the costoclavicular ligament intact, the lateral end of the clavicle descended under its own weight without any loading until it was about 1·0 in. lower than the medial end, and was then seen to be supported by the disc (Fig. 2). When 10 lb load was added to the lateral end of the clavicle, the disc at once tore from the first costal cartilage and hung down attached by the costoclavicular ligament (Fig. 3). When the 10 lb load was added gradually through a spring balance, it was found that a weight of less than 5 lb was enough to tear the disc from the costal cartilage.

Examination of the capsule of the sternoclavicular joint showed that in all specimens it was thickest in the posterior and superior portion, and thinnest anteriorly.

The interclavicular ligament. Its thickness was found to be extremely variable in different specimens and was considered to be more an interconnexion between the superior capsule of each sternoclavicular joint rather than a separate ligament. It became tense under a loading of 10 lb at the lateral end of the clavicles. When the ligament was cut through completely in the midline, no alteration in clavicular poise occurred even with loadings of up to 20 lb.

The disc. Selective division of the inferior attachment of the intra-articular disc did not result in any alteration in the poise of the clavicle with loadings of up to 20 lb. The disc was considerably thicker in its superior part. Inferiorly it was found to wrap round the articular area on the inferior aspect of the head of the clavicle and blend with the upper surface of the costal cartilage. At this position, the disc was thin and easily torn from the attachment to the cartilage.

The costoclavicular ligament. When this was cut either with or without division of the disc, no further depression of the clavicle occurred with loadings up to 20 lb (Fig. 4.)

As loading proceeded, the ligament was not found to be under tension, but rather appeared to be under some compression between the clavicle and the first rib. To determine whether or not this compression constituted the establishment of a fulcrum lateral to the inferior capsule of the sternoclavicular joint, the following two investigations were carried out.

First the costoclavicular ligament was cut, and second, the first costal cartilage was divided medial to the attachment of the costoclavicular ligament and removed. In neither situation was there any appreciable increase in the depression of the lateral end of the clavicle with loadings of up to 20 lb, the lateral end of the clavicle remaining higher than the medial end (Fig. 5).

A bursa was found between the anterior and posterior fibres in all cases and in one specimen articular facets were present, giving the appearance of a diarthrodial joint between the clavicle and the first rib.

The fixity of the synchondrosis uniting the first costal cartilage to the manubrium

sterni was confirmed, although a certain degree of flexibility in the cartilage was noted when deformation was attempted by forceful passive movements of the posterior end of the rib.

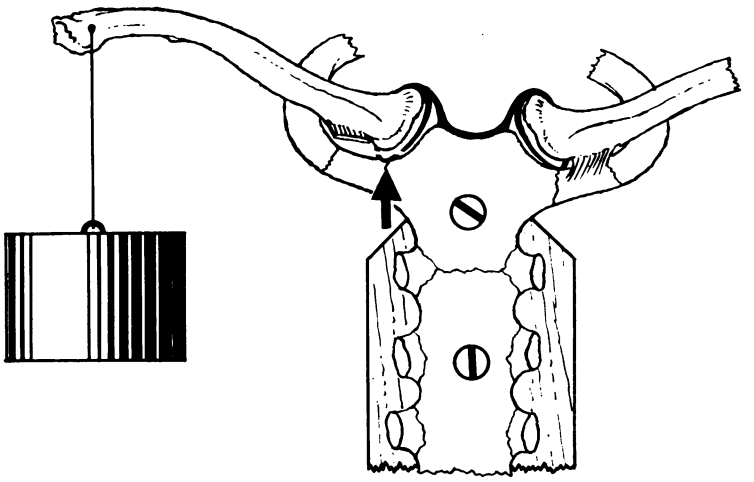

Fig. 4. Division of the costoclavicular ligament and the disc does not alter clavicular poise.

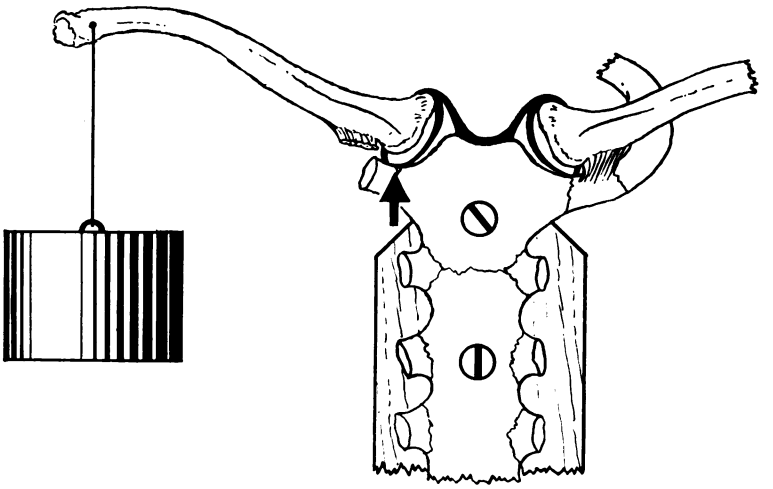

Fig. 5. Division of the first costal cartilage medial to the costoclavicular ligament does not alter clavicular poise.

C. Passive movements

Elevation and depression. The principal limiting factor in elevation of the lateral end of the clavicle was found to be the costoclavicular ligament. Division of this ligament resulted in a small increase in the degree of elevation. The superior fibres of the joint capsule also limited elevation in the intact joint system. It was found that

as elevation proceeded, tension in the costoclavicular ligament established a fulcrum and subsequent terminal elevation was possible only by the gliding of the clavicular head in an inferior direction, which was finally arrested by tension in the superior fibres of the sternoclavicular joint capsule.

Depression of the clavicular lateral extremity by passive movement confirmed the results of loading, in which the principal factor was the posterior–superior capsule of the joint.

Protraction and retraction. When the clavicle was depressed, protraction and retraction did not occur in the horizontal plane owing to the obliquity of the first rib, which demanded a certain degree of elevation as a concomitant of retraction. Conversely, protraction was accompanied by depression, and in the position of maximal depression little further forward movement of the lateral end of the clavicle was possible. The fibres of the anterior lamina of the costoclavicular ligament limited retraction, while protraction produced a limiting tension in the posterior laminar fibres. Division of the costoclavicular ligament permitted a slight increase in the range of protraction and retraction, which then became limited by tension in the posterior and anterior fibres of the sternoclavicular joint capsule respectively.

Rotation. Rotation of the clavicle about its long axis was found to be minimal in terminal elevation and terminal depression of its acromial end, being at all times less than 5°. Maximum rotation was possible in the intermediate position and in the five specimens studied was not less than 15° and not more than 25°. Although the anterior fibres of the costoclavicular ligament appeared tense in upward rotation of the clavicle, and the posterior lamina appeared tense in downward rotation, dividing this ligament did not allow any increase in rotation in any of the positions. The limiting factor was a 'screwing-up' of the fibres of the sternoclavicular joint capsule. These fibres have already been shown to be under limiting tension in both full depression and full elevation, therefore explaining why little or no rotation of the clavicle takes places in these two extreme positions.

D. Palpation of the interclavicular ligament

In a series of fifty male subjects this ligament was palpated and was found to be under tension in 78 % when the shoulder girdle was fully depressed. When the shoulder girdle was elevated, the ligament relaxed. As the shoulder was lowered again, tension in the ligament occurred before the shoulder became fully dependent. About a further 2·0 in. of depression at the lateral end of the clavicle occurred after tension was first felt in the ligament. The ease with which this ligament was felt when the shoulder was depressed fully varied from a thick easily definable band to an ill-defined structure in the suprasternal notch. In 22 % of subjects no ligament could be detected at all.

DISCUSSION

This investigation provides two lines of evidence to indicate that the capsule of the sternoclavicular joint is under tension when the shoulder girdle is in the fully dependent position. It is suggested that this tension plays an important role in maintaining the poise of the lateral end of the clavicle in this posture.

This work now provides an explanation for the relaxation of the trapezius muscle in the fully dependent position of the shoulder girdle. Although it is widely assumed that 'the trapezius is responsible for maintaining the level and poise of the shoulder' (*Gray's Anatomy*, 1962) an electromyographic investigation (Bearn, 1961) demonstrated that in the fully dependent position electromyographic activity in the occipito-clavicular fibres of the trapezius decreases dramatically and even completely, activity occurring immediately any attempt is made to elevate the shoulder. It was suggested that an alternative mechanism must be responsible for maintaining the poise of the clavicle in the dependent position and evidence provided by this present investigation indicates that the mechanism resides in the capsule of the sternoclavicular joint, which provides a 'locking mechanism' preventing further downward displacement of the lateral end of the clavicle.

The results indicate that the capsule of the sternoclavicular joint is far stronger than has been supposed previously. Of the four components of the sternoclavicular joint —the capsule, the disc, the costoclavicular ligament and the interclavicular ligament —the capsule of the joint clearly plays the major role in stabilizing the joint. Division of the other three components of the joint does not alter clavicular poise but division of the capsule alone results in downward depression of the lateral end of the clavicle about an axis at the costoclavicular ligament, the disc tearing at its thin lower attachment to the first costal cartilage with less than 5 lb load once the capsule has been cut.

Further support for this view is provided by the results of palpation of the inter-clavicular ligament in the living subject. This ligament plays no important role in clavicular support but, by virtue of the fact that it is an interconnexion between the superior capsule of each sternoclavicular joint, tension in this ligament is therefore an indicator of tension in the capsule of the joint. The development of tension in the interclavicular ligament never coincides with full depression of the lateral end of the clavicle, but always precedes it by about 2·0 in, suggesting that the capsule is to some extent extensible. In this connexion although ligaments are usually described as being inelastic, Smith (1954) has reported that the anterior cruciate ligament of the rabbit can be extended by as much as 20 % of its original length. In observations on tension in the supraspinous and interspinous ligaments during trunk flexion, Silver (1954) found that tension always preceded the relaxation of the erectores spinae, and accounted for this by the presence of elastic fibres in the ligaments.

This investigation provides a further example of the capacity for ligaments to support loads, with relaxation of the muscles concerned. Similar muscular relaxation has been reported for the erectores spinae in full flexion of the vertebral column (Ackerblom, 1948; Allen, 1948; Floyd & Silver, 1951, 1955) and also for the deltoid when the arm is in the dependent position (Basmajian & Bazant, 1959; Bearn, 1961).

Since excising the costal cartilage with the costoclavicular ligament does not effect clavicular poise, the fulcrum is situated between the undersurface of the medial end of the clavicle and the adjacent first costal cartilage and not at the position of the costoclavicular ligament as suggested by Cave (1961). However, in the one specimen in which articular facets were present on opposing surfaces of the clavicle and first rib, this clearly constituted the site of the fulcrum. When depression of the clavicle is

attempted, the clavicular head moves upward along the arc of a circle whose centre is this fulcrum. The two primary components of this upward motion of the clavicular head are in a superior and lateral direction. If movement in either direction is arrested, then movement in the other is impossible. The disc is admirably situated to arrest the upward component of this movement, whereas the capsule is so alined to arrest the lateral component. The negligible role played by the disc in stabilizing the sternoclavicular joint may be correlated with the two observations made in this study; first, that the disc becomes thin and weak at its lower attachment and little force is required to tear it from the costal cartilage, and second, that by virtue of its intimate contact with the clavicular head, the disc is much closer to the fulcrum than the superior capsule. A similar mechanism has been described for the shoulder joint where the transversely running coracohumeral ligament has a comparable function (Basmajian & Bazant, 1959).

Owing to the obliquity of the first rib, the lateral end of the clavicle moves forward as well as downward during full depression. The clavicular head thus moves backward as well as upward, thereby throwing the major strain on the posterior–superior capsule. In two cases where the lateral end of the clavicle was loaded until the capsule ruptured, it tore from the sternum with a flake of bone avulsed from the posterior–superior part of the sternum, indicating the strength of this part of the capsule. That the anterior capsule is weaker may be correlated with the clinical observation that dislocation is usually anterior and rarely posterior (Watson-Jones, 1952–1955).

Present knowledge does not enable one to determine whether the relaxation of the trapezius is a reflex inhibition due to the tension in the capsule of the joint. Floyd & Silver (1951) have suggested tentatively that the relaxation of the erectores spinae might be explained by a reflex inhibitory mechanism triggered off by tension in the intervertebral ligaments. There is no direct evidence to support this hypothesis, although Boyd & Roberts (1953) have provided some indirect evidence from their work on the stretch receptors in the knee-joint ligaments of the cat.

This investigation is in agreement with the view of Cave (1961) that the costoclavicular ligament is lax when the shoulder girdle is dependent, and its function with its contained bursa is then to act as a cushion between the first rib and the clavicle. As Cave (1961) has observed, when opposed clavicular and costal apophyses exist, the bursa functions as the synovial component of a diarthrodial joint.

Other shoulder-girdle muscles. No evidence has been provided in this study that other muscles acting on the shoulder girdle might take over when the trapezius relaxes. Some support might be obtained by the direct pull of the clavicular head of the sternomastoid muscle. The sternal head lies medial to the fulcrum and can play no part in clavicular support. The clavicular head is attached lateral to the fulcrum, but is at a poor mechanical advantage to assist clavicular elevation and it is concluded that any such action would be negligible. Direct palpation of the sternomastoid muscle when the arms are loaded in the relaxed upright posture confirms that they are inactive.

There is also the possible effect of muscles acting upon the scapula which might operate in such a way as to maintain elevation of the lateral end of the clavicle. No direct studies have been made on the deeper muscles which could support the

scapula in the upright posture, although Scheving & Pauly (1959) found that in a study of certain shoulder muscles the serratus anterior is electromyographically silent when the arm is hanging freely to the side. However, there is clinical evidence to suggest that the scapular muscles do not necessarily play a significant role in clavicular

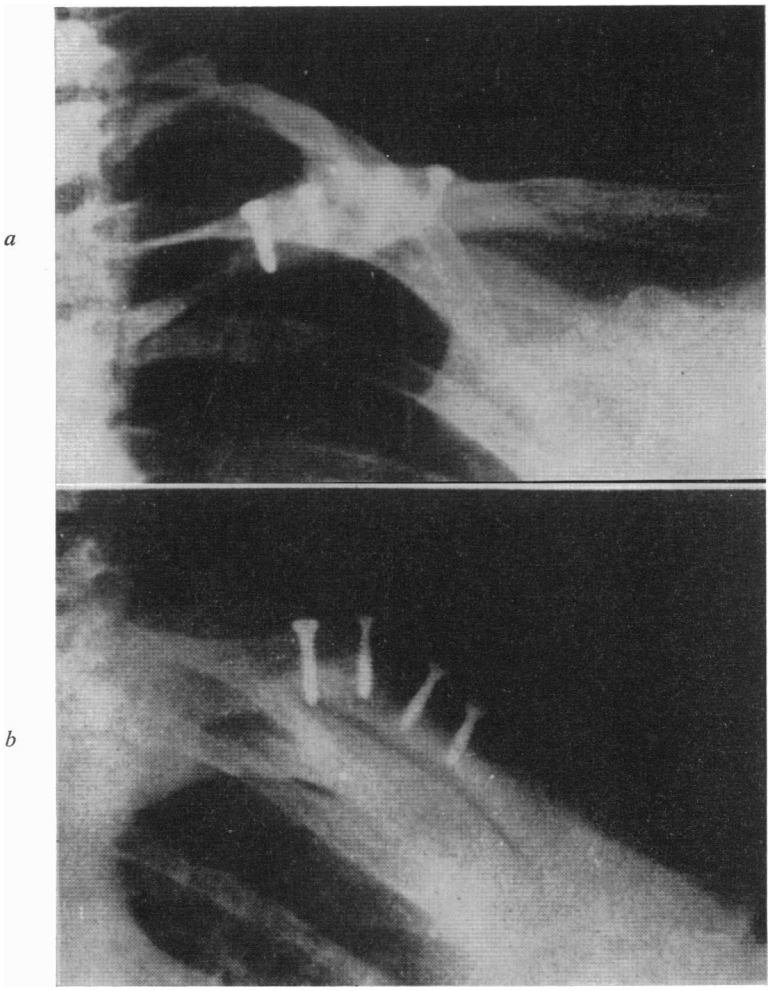

Fig. 6. (*a*) Un-united fracture of the clavicle treated with a bone graft. (*b*) After fracture of the graft, the lateral end of the clavicle angulates downwards. The medial end still points slightly upwards.

support. Mayer (1965) has described a patient who sustained a simple fracture medial to the coracoclavicular ligaments. The fracture failed to unite and was fixed internally with a bone graft from the tibia, thus restoring normal clavicular configuration. However, the graft fractured and a subsequent radiograph showed absorption of the bone graft. Moreover, the lateral half of the clavicle had angulated very markedly

downwards under the weight of the limb. Although the medial stump still pointed slightly upwards supported at the sternoclavicular joint, the lateral end was now several inched lower then the medial end (Fig. 6). If the lateral end of the clavicle were in any way supported upon the scapula such depression would not occur, and further it indicates that the clavicle actively participates in supporting the scapula.

Paralysis of the trapezius. Beevor (1904) reported the scapula to be an inch lower on the affected side, and in a recent case (Bell, 1964) the published photograph (Fig. 7) shows the lateral end of the clavicle to be about 1 in. lower on the paralysed

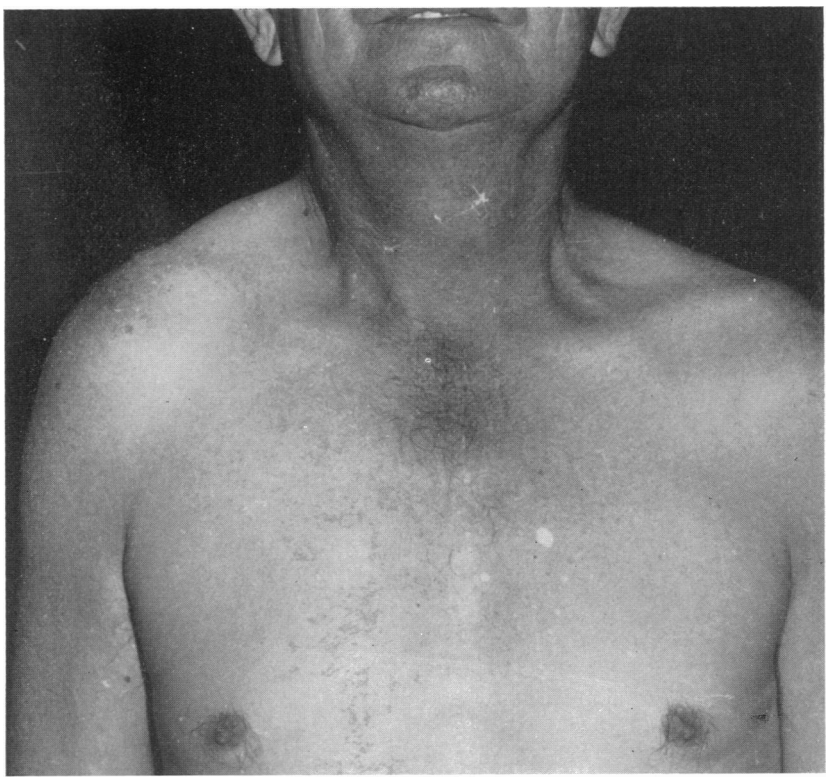

Fig. 7. A patient with complete paralysis of the left trapezius. The lateral end of the left clavicle, although about 1·0 in lower than the right clavicle, is still 2·0 in higher than its medial end.

side. However, the photograph shows clearly that the lateral end of the clavicle is still about 2·0 in higher than its medial end and is now supported by tension in the capsule of the sternoclavicular joint. Clemmensen (1951) has suggested that 'passive elastic tension' is present in a muscle when electromyographically silent. It is likely that such passive tension may play a small accessory role in clavicular support when the trapezius is inactive, and would therefore explain the small degree of depression of the clavicle in complete paralysis of the muscle.

Clavicular rotation. With regard to the question of rotation of the clavicle about its long axis, it was not possible to produce passive rotation of more than 25° in any

of the specimens. This is in marked contrast to results obtained when the range of clavicular rotation during abduction of the arm was measured experimentally by insertion of a pin into the bone of a living subject (Inman *et al.* 1944), and the maximum rotation recorded was 40°. Clavicular rotation could only be produced in positions other than full elevation and depression. In these extreme positions, the capsule of the joint was taut, therefore limiting all rotation.

SUMMARY

1. The responsibility for maintaining clavicular poise is usually assigned to the trapezius muscle. However, when the shoulder is lowered to the fully depressed position electromyographic activity in the trapezius decreases dramatically and even completely. This suggests that tension in the ligaments of the sternoclavicular joint may also be responsible for maintaining clavicular poise in the fully depressed position.

2. A series of five post-mortem specimens consisting of the upper half of the sternum and both clavicles were studied. The ligaments of the joint were defined and each specimen fixed in a vice with the body of the sternum vertical.

3. The lateral end of the clavicle was loaded with 10, 15 and 20 lb. With 10 lb. equivalent to the weight of the upper limb, the capsule and interclavicular ligament became taut, the lateral end of the clavicle descended 1 in. and was then about 1·0 to 2·0 in. higher than the medial end. However, when loading was increased to 15 and 10 lb, the lateral end of the clavicle descended by only 0·1 in. with each additional 5 lb. loading.

4. Cutting the interclavicular ligament, the costoclavicular ligament or the disc, either separately or together, had little effect on clavicular poise.

5. Cutting the capsule and then loading with less than 5 lb resulted in complete downward depression of the lateral end of the clavicle about an axis at the costoclavicular ligament, the disc tearing from its thin lower attachment to the costal cartilage.

6. The first costal cartilage was excised medial to the costoclavicular ligament, leaving the joint capsule and disc intact; this had little effect on clavicular poise.

7. The interclavicular ligament was palpated in fifty male subjects and was found to be under tension in the fully depressed position thus providing direct confirmation that the capsule of the sternoclavicular joint is under tension in this posture.

8. These observations suggest that when the clavicle is fully depressed, its poise can be maintained by tension in the capsule of the joint, and this explains the reduction or absence of activity in the trapezius found in the living subject in this posture.

Grateful acknowledgement to Mr Alasdair Malcolm is tendered for his excellent assistance during this investigation, to Mr Charles Pierce, R.I., for drawing the illustrations, and to Professor E. W. Walls for his interest and encouragement in this research.

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