ZERO POSITION OF THE GLENO-HUMERAL JOINT: ITS RECOGNITION AND CLINICAL IMPORTANCE

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by
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INTRODUCTION

THE TIME HAS come to take stock of the accumulated knowledge on shoulder movements.

The gleno-humeral joint is a ball and socket joint, the head of the humerus having a bigger articular surface with a smaller radius and the glenoid a smaller articular surface with a bigger radius. Participation of the accessory joints in shoulder movements have long been recognised (Morris, 1879; Cathcart, 1884 and Lockhart, 1930). Till recently (*vide infra*) the movements at these and the gleno-humeral joints were believed to be phasic and compartmental.

The occurrence of reverse rotations during flexion and abduction (Martin, 1933; Codman, 1934 and McGregor, 1937) led to the concept of locking with rotation as a mechanism to get past the natural barriers. The plane of the scapula, though a changing plane in a strict sense, replaced the coronal plane as the plane of reference (Johnston, 1937). Later still Milch (1938, 1949) described the cone arrangement of muscles when the arm is lifted overhead. In this position the muscles lose all rotatory power and this suggested the technique of reduction of the shoulder dislocation in the overhead vertical position of the arm. Inman, *et al.* (1944) established the pattern of movements of the accessory joints. They are continuous though they occur at varying rates at different phases of elevation. The function of depressors on the head of the humerus were established. They keep the head in contact with the glenoid during elevation.

ANATOMICAL CONSIDERATIONS

The gleno-humeral joint surfaces are not perfectly spherical. Rotundity is near perfection at the central part of the two articular areas. There are individual variations and variations with age, though their exact relation has not been established (Fig. 1). Spherometry has also established three types of joints—Type A: the glenoid has a bigger radius than that of the humerus; Type B: both have more or less the same radii; and Type C: the glenoid has a smaller radius than that of the humerus (Fig. 2). In Type A, the contact of the adjoining articular surfaces is by a small area, in Type B, by a much bigger surface and in Type C, the contact is mainly by the margin of the glenoid labrum and the adjoining articular surface. Impression studies of the contact surfaces with the help of lamp

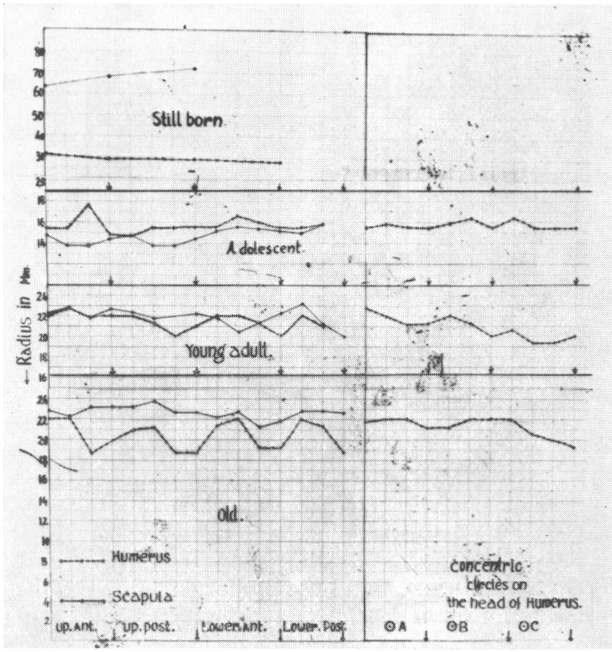
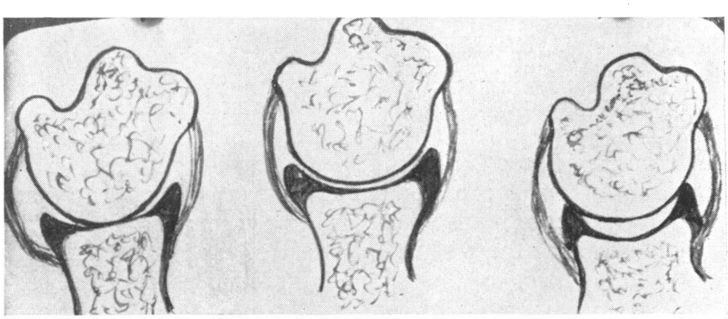


Fig. 1. Graph shows the radii of curvatures of the humeral head and glenoid cavity. Fresh specimens from dead bodies were used. Dotted and continuous lines represent radii of humerus and glenoid respectively. *Left hand* series gives the radii in stillborn mature babies, adolescents, young adults and old, and these were taken in four quadrants. They are seen to be too irregular to be called spherical surfaces. The disparity between the articular surfaces can be seen. Graphs on the *right hand* side represent radii on two concentric bands and a central circle on the heads of the humerii used in the previous determination. The radii are more uniform towards the central part of the articular surface in all than towards the periphery.



Type A. Type B. Type C.

Fig. 2. The three types of joints and their contact surfaces.

black in different positions of elevation have shown three types corresponding with the three types of joints. The contact surfaces do not take uniform impression nor are these identical in different positions of elevation in the same joints. These confirm the irregular nature of the articular surfaces. The contact area migrates in a characteristic way on the humeral articular surface and less so on the glenoid cavity particularly in the Type C joint in the different phases of elevation (Fig. 3). The anatomical axis of the head and neck bears two angles with the axis of the shaft, 16 degs. in the coronal (retrotorsion angle) and about 130 degs. in the sagittal plane (neck-shaft angle). With abduction the contact area is exhausted in the plane of elevation before 90 degs. is reached. How then is the rest of the movement at the gleno-humeral joint carried out ? This is possible by rolling or gliding, analogous to dislocation action within physiological range. This movement would be difficult if the head of the humerus was set on the top of the shaft in a " drum stick " fashion as in quadrupeds. In man with the development of erect posture, the upper limb has come to stay vertical and parallel to the body. So he has developed the neck-shaft and the retrotorsion angulations just mentioned. These structural changes have helped him in another way. The rotation of the shaft gives gliding effect at the articular end till the constantly changing mechanical axis approximates to the anatomical axis in the " zero-position " of the gleno-humeral joint (*vide infra*).

Acromion locking during elevation does not take place in any phase of abduction in a healthy joint. The external rotation of the shoulder is necessary even after acromionectomy during abduction.

Shoulder movements

Movements at the gleno-humeral joint may be analysed as follows :

(i) Movement on a fixed contact point, area or band (hinging). There is no change of mechanical axis.

(ii) Movements that bring about change of contact point, area of band—this has been referred to as gliding, rolling or physiological dislocation action. There is change of mechanical axis with this type of movement.

(iii) Movement of rotation—even if it takes place on a circular band contact, pressure would be distributed equally on all points of the contact surface. Here there is no change in mechanical axis.

One or all of these may be necessary to bring about elevation in any direction.

The nature of the " breast-stroke " movement at the gleno-humeral joint has never been dealt with analytically. " Breast-stroke " movement is a combination of gliding (rolling) and some amount of hinging movements. Its range diminishes with the elevation of the arm.

Rotation of the arm and rotation at the gleno-humeral joints are not identical till the mechanical axis corresponds with the anatomical axis of the shaft of the humerus. It has been seen that rotation of the arm which is

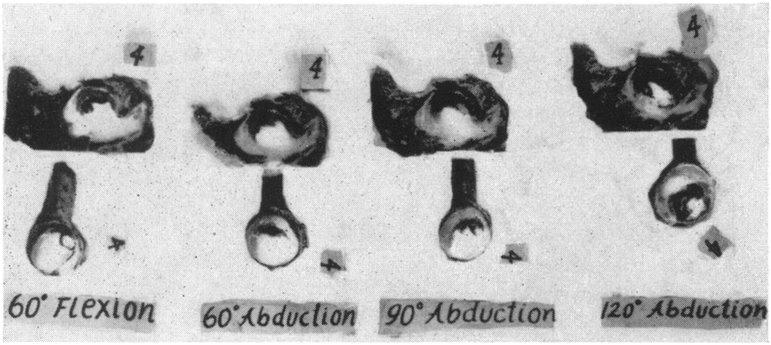


Fig. 3. Lamp black contact impression photographs of the glenoid and humerus at 60 degs. of flexion and abduction, 90 degs. of abduction and 120 degs. of abduction in a typical Type C joint. These irregular circular contact bands hardly migrate in the glenoid with different elevations though they do so on the head of the humerus.

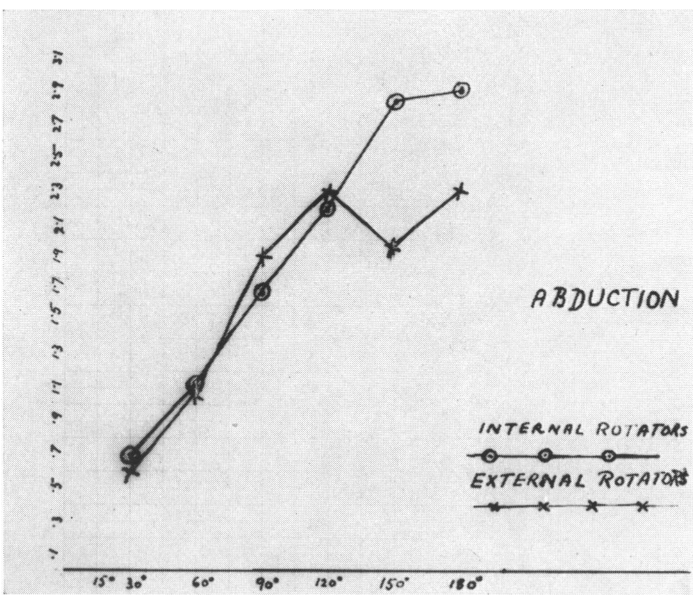


Fig. 4. Sum of action potential of anatomically recognised internal and external rotators are plotted at different phases of abduction. Continuous line with crosses represents summated action potential of external, and continuous line with circles, that of internal rotators.

equivalent to gliding at the gleno-humeral joint steadily diminishes with the raising of the limb. Rotation at the gleno-humeral joint is equivalent to circumduction with vertical position of the extremity. Its range also shows steady diminution with lifting of the limb.

Why the above three movements diminish as the arm is raised is understandable when it is seen that the contact area change-over brings about alteration in the mechanical axis. This, when the movements are " Zero " corresponds most closely to the anatomical axis of the shaft. In this position most of the rotatory power of the muscles is lost.

Muscle power

Action potentials and frequency discharges recorded during abduction and flexion by eight channel electromygraphy have shown that besides the prime movers acting in a particular direction, other muscles also show activity to varying degrees. This accessory power is essential—(*a*) to fix the gleno-humeral joint, (*b*) help gliding and thus bring about change of contact surface, and (*c*) move the accessory joints. For deeper muscles coaxial needle electrodes were used. Unsuspected muscles like the latissimus dorsi and the subclavius are seen to come into play during elevation.

During abduction, the supraspinatus and the deltoid are known to be prime movers. The remaining six muscles, infra-spinatus, teres minor, teres major, subscapularis, pectoralis major (sternal) and latissimus dorsi also show variable amount of contraction starting at about 30 degs. (Fig. 4). The power of the internal rotators balances the power of the external rotators so that the algebraic sum of their power does not alter the rotation state of the humeral head up to about 60 degs. elevation. The power till then is utilized only for fixation of the head against the glenoid. Above 60 degs. the external rotators gain more power which is utilized for gliding purposes. The main internal rotator, the subscapularis, has towards the end of elevation only gliding and fixation action. Above 120 degs. the power of the internal rotators again exceeds that of the external rotators.

In flexion, adjustment of the shoulder girdle takes place at a slightly earlier phase to make elevation at the gleno-humeral joint easy (Fig. 5). From the very onset the internal rotators are more powerful than the external rotators and at the peak (120 degs.) are twice as powerful as the external rotators. The events are explained on the same lines as in abduction. The gleno-humeral articular surfaces change by rotation of the shaft in the initial and end stages of flexion movement.

In movements at the accessory joints we notice that the subclavius plays a major role both in abduction and flexion. The subclavius rotates the clavicle-crankshaft in an anti-clockwise direction (looked at from its outer end) and indirectly adjusts the scapula to bring about the desired elevation. Electromyographic studies show that the movement just mentioned takes place at an earlier phase in flexion (Fig. 6). The rotation

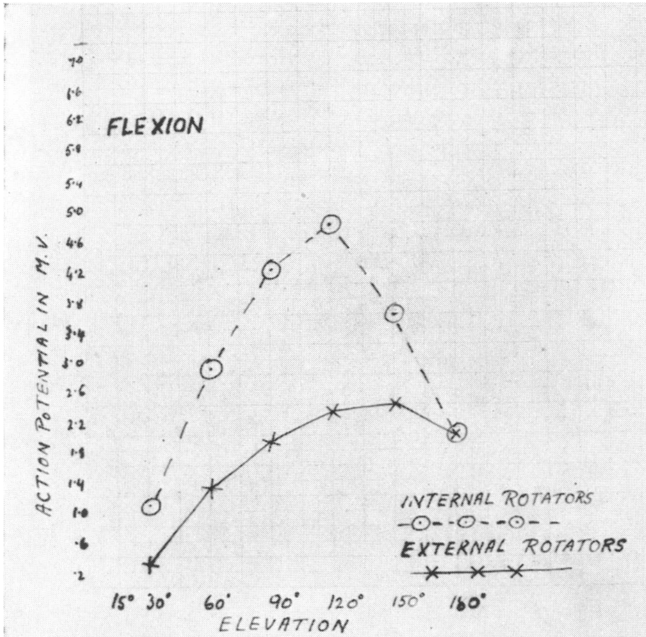


Fig. 5. Sum of action potential of anatomically recognised internal and external rotators are plotted at different phases of flexion. Continuous line with crosses represents summated action potential of external, and dotted line with circles, that of internal rotators.

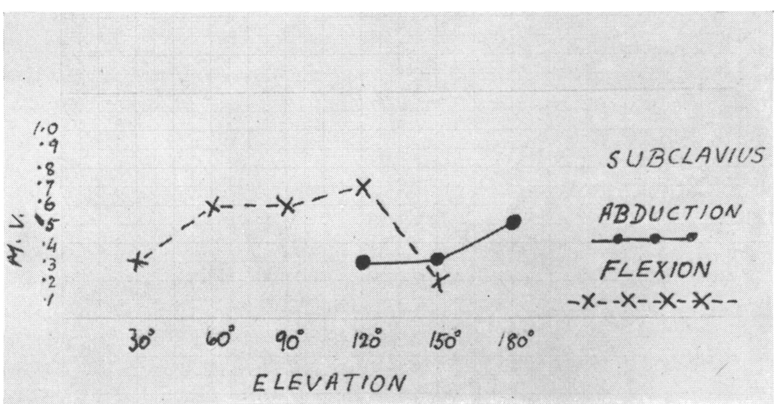


Fig. 6. The diagram represents the action potential in millivolts of subclavius at different phases of abduction and flexion. Dotted line with crosses represents action potential during flexion and continuous line, action potential during abduction.

of the clavicle crankshaft is maximal between 150 degs. and 180 degs. during abduction. During flexion rotation of the clavicle starts at 30 degs. of elevation and is maximal at an earlier phase.

Scapulo-humeral rhythm is an essential component of the sequence of events taking place during elevation of the shoulder. So accurate is the balance and adjustment that even slightest disturbance by way of spasm of any particular muscle, pain from any cause, limitation of movement and disturbance in the mechanism of joint components would upset the scapulo-humeral rhythm.

" Zero-position " of the gleno-humeral joint

The position during elevation in coronal or sagittal plane, in fact in any plane where there is no further rotation, no active gliding of the joint surfaces and circumduction ; where the mechanical axis corresponds to the anatomical axis of the shaft ; where gliding, rotation and " breast-stroke " movements become identical is known as " zero-position." In this position the humerus is neither internally nor externally rotated. The humerus is elevated to about 165 degs. with individual variations and is in the newly acquired scapular plane. The humeral shaft axis roughly is in alignment with the scapular spine in this position. This is the relative position of scapula and humerus which is seen in fast-moving quadrupeds to give stability to the joint. This has brought structural change, the articular surface sits square on the top of the shaft like a "drum-stick."

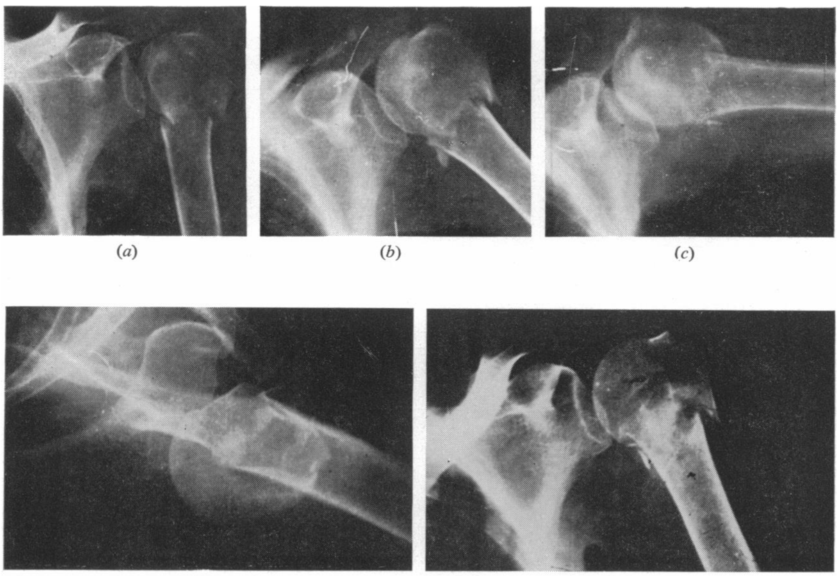
In the unimpacted fracture of the surgical neck it has been shown that, if released from the influences of the lower by elevation in any plane, the upper fragment assumes the " zero-position."

Bearing of the anatomical observations on the aetiology of the recurrent dislocation of the shoulder. Alternative method of treatment on the basis of the concept.

In the Type C joint the humeral articular surface is not in contact with the depth of that of the glenoid cavity. The circular-band-contact in this joint is effected mostly by the glenoid labrum with much less excursion and change of contact band in glenoid cavity than in the other two types. So the physiological dislocation action, bringing about change of contact band on humeral articular surface, will, in these cases, throw maximum pressure on some portion of the glenoid labrum depending on the direction of the motion. If the power of the subscapularis which brings about this in the terminal phases of abduction is insufficient due to various causes including incoordination from sudden contraction of the prime movers and other muscles it may throw extra burden on the anterior and/or inferior part of the labrum thus causing it to be detached from its bony attachment. It is distinct from other types of dislocation where the tear is in the capsule and is capable of healing, but in this type of subluxation, the detached rim cannot heal by itself by reattachment.

To my mind recent views on the pathology of the recurrent dislocation cannot effectively explain (*a*) the groove on the humeral head and (*b*) in some cases splitting and attenuation of the glenoid labrum at the site of detachment analogous to the finding of a medial meniscus tear.

With this untreated and detached glenoid labrum, further unguarded elevation with external rotation may result in forward migration of the head of the humerus when actually there should be a backward rolling.



(*a*) (*b*) (*c*) (*d*) (*e*)

Fig. 7.

(*a*) Antero-posterior skiagram of the shoulder shows unimpacted fracture of the surgical neck. The upper fragment is internally rotated.

(*b*) De-rotation of the proximal fragment with 45 degs. of abduction is seen. Outline of the head is visible as an area medial to the tuberosity.

(*c*) Further elevation has brought in relief the greater part of the head.

(*d*) Elevation to the zero-position has brought the whole of the head outline as would be seen in an ordinary antero-posterior skiagram of the shoulder.

(*e*) Skiagram shows impaction after reduction in the "zero-position." There is some comminution of the fragments during the impaction.

Repeated many times, the subscapularis further elongates and its active rolling action progressively deteriorates, resulting in more frequent recurrences. The feeling of something giving way and locking in that position is due to muscle spasm from riding of the head on the edge of the bony glenoid (subluxation). The characteristic groove on the head, if present, makes slipping easier.

The main principles on which treatment of this condition would be based are thus :

(i) Actual repair of the lesion, i.e., reattachment of the detached labrum to the bony glenoid.

(ii) Shortening and " double breasting " of the subscapularis to increase its power.

(iii) Block or check operations, either by bone, tendon or fascia ; and

(iv) Development of extra power to aid the physiological dislocation action of the subscapularis by muscle transplantation.

On the basis of this last principle a new operative procedure was developed for the cure of the recurrent dislocation of the shoulder. The method consists of transplantation of the insertion of the latissimus dorsi on the posterior aspect of the greater tuberosity so that during abduction the muscle will assist the subscapularis to draw the humeral head backwards and prevent its forward slipping. This muscle was chosen in view of its synergistic action, checked electromyographically during the later stages of abduction of the arm overhead.

The operation was performed by us on a cured epileptic with a bilateral recurrent dislocation where the right side had been treated by the Bankart procedure by one of our colleagues one year before.

The patient last seen about one year from the date of operation has full use of the limb and there has been no recurrence. The operation has been tried only in a single case, so it is too early to pass any definite opinion but the result suggests that it is worth trying in other cases of recurrent dislocation of the shoulder.

Clinical application of " zero-position " in the treatment of dislocation of the shoulder

It is suggested that in treating dislocation of the head of the humerus, the detrimental effect of the rotators, chiefly of the subscapularis, can be effectively eliminated when the limb is brought into the " zero-position." A single force exerted along the axis of the humerus when the limb is in " zero-position " can thus be made to oppose the combined action of all the musculature in spasm.

Method

The patient lies on the table supine, and the surgeon takes his position at the head end and on the side of the dislocation. Usually an anaesthetic is not necessary except in cases of an old dislocation or a neurotic individual. The surgeon gently abducts the arm to bring it in the " zero-position" i.e., 165 degs. overhead and 45 degs. in front of the coronal plane with the medial epicondyle pointing forwards and medially. Slight traction in this direction suffices to reduce the dislocation in recent cases. In older cases an assistant fixes the patient by putting both his hands round the

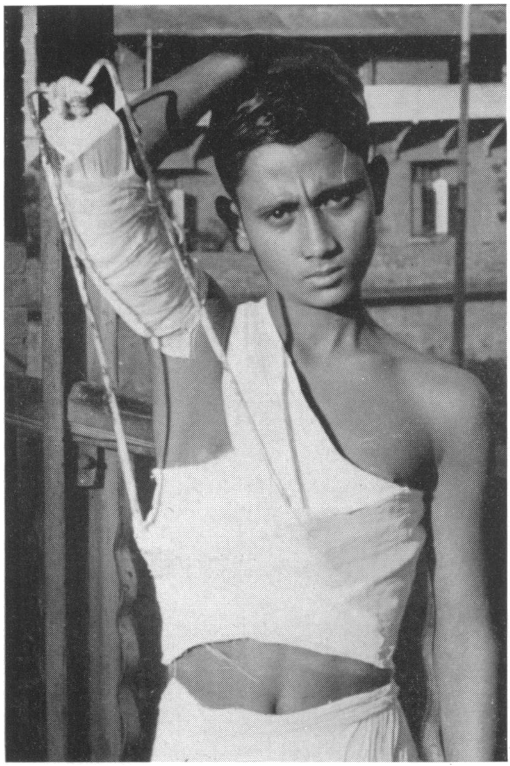
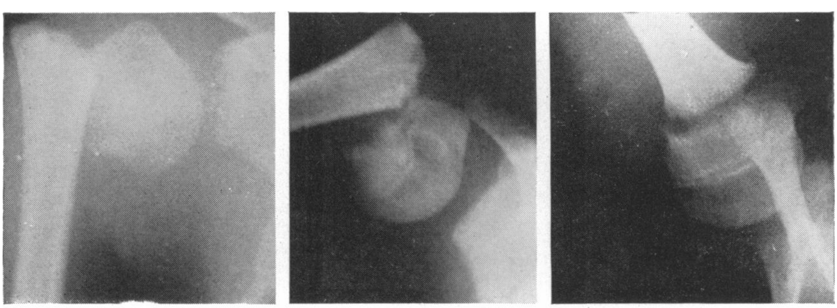


Fig. 8. It shows the method of fixed traction on side bars incorporated in a plastic jacket in the zero-position.



(a) (b) (c)

Fig. 9

(*a*) Epiphyseal separation in an antero-posterior view.
(*b*) Elevation of the distal segment derotates the proximal fragment.
(*c*) The typical cap-appearance of the proximal segment appears in the " zero-position." The fracture is completely reduced with traction.

waist. As the surgeon exerts sustained traction, the head goes back to its original position, pushed by the thumb if necessary. An associated fracture of the greater tuberosity, if present, falls into place during this manoeuvre.

After the dislocation is reduced, early motion is encouraged in all directions except in abduction in an uncomplicated case. To check abduction the patient is provided with a figure of eight bandage round the affected arm and the trunk which acts as a " check " ligament. Every third or fourth day greater degree of abduction is permitted by increasing the length of this " check " ligament. After twenty-one days from the date of reduction the sling is taken off and all movements are allowed.

To give full range of mobility, exercises such as swinging the arm at the shoulder or wall climbing exercises are prescribed and within fifteen days the patient gets back the full use of the injured limb.

Unimpacted fracture of the surgical neck of the humerus: displacement of the proximal fragment

Difference of opinion exists regarding the displacement of the upper fragment. The fragment is abducted, slightly flexed and rotated. The rotational displacement is generally believed to be fully external but according to a few it is moderately externally rotated and others internally rotated. With the hanging position of the upper extremity, the fragment is fully internally rotated if it is free from the influence of the distal fragment. The fully internally rotated position of the proximal fragment is proved by comparing it with the identical antero-posterior radiograph of a 45 degs. abducted and internally rotated normal shoulder. In both, the greater tuberosity hides most of the head of the humerus. Secondly, in a true lateral view of the gleno-humeral joint, the radiograph of the upper fragment is a replica of its antero-posterior view with the greater tuberosity pointing towards the sternum. The curve of the head is directed towards the vertebral column and the greater tuberosity towards the sternum. This is true for epiphyseal separation and upper third fracture.

The displacements of the proximal fragment are dependent on the position of the limb. As the distal segment of the limb is raised the abduction displacement steadily increases till it assumes the " zero-position." This new displacement may appropriately be termed absolute abduction.

It is further seen that while changing to the absolute position, the proximal fragment which in its initial position was fully internally rotated, gradually derotates, i.e., rotates laterally and in the final position it is neither internally nor externally rotated (Fig. 7 *a*, *b*, *c*, *d*).

In the treatment of unimpacted fracture of the neck of the humerus closed reduction is always preferred to the various open methods. Frankau's (1933) method has not proved satisfactory. Perfect anatomical aligment with elimination of rotation deformity is only possible with the help of the " zero-position."

Method of reduction

Under light general anaesthesia the arm is lifted so as to allow the proximal fragment to assume the absolute position, i.e., "zero-position." In this position the fragment is neither rotated internally nor externally. The distal humeral segment is now adjusted to perfect alignment by comparing the direction of the medial epicondyle to that of the sound side when the latter is lifted to the same position. Alignment thus being

Fig. 10

(*a*) Upper fourth fracture of the humeral shaft to show the displacement. The typical appearance of the metaphysis is lost.

(*b*) Gradual elevation brings in view the appearance of the metaphysis with derotation of the proximal fragment.

(*c*) Elevation in the "zero-position" eliminates the rotation and restores alignment which is maintained by traction.

achieved, apposition is obtained by firm traction of the limb till the ends hitch against each other. In the majority of instances, especially elderly persons in whom the fracture is common, this end to end apposition may be maintained by impaction by firm compressive force. The arm is then brought down and tested for the stability of impaction (Fig. 7*e*).

In all our cases possible future disimpaction was prevented by a three-inch overlapping adhesive strapping between the flexed elbow and the top of the shoulder. Cases where there is some comminution are not stable; reduction and fixation is obtained by fixed skin traction over specially constructed iron side bars with a cross loop incorporated in a plaster jacket. A preliminary plaster jacket is applied with a cross bar over the affected shoulder. Specially constructed side bars with a cross loop at the distal ends are incorporated in the plaster. Fixed skin traction is applied with the shoulder in the "zero-position" (Fig. 8). Some of our cases were given mobile skin traction with the help of a Balkan frame and/or Thomas' arm splint. This is especially necessary for very well built individuals. After six to eight weeks of fixation, the movements are allowed till full function is obtained.

Upper humeral epiphyseal separation and fracture of the upper fourth of the shaft of the humerus

In the upper humeral epiphyseal separation, the internal rotation deformity of the upper fragment is not so well demonstrated owing to the poor development of the tuberosity region. The normal upper humeral epiphysis sits like a beret on the proximal diaphyseal end in the antero-posterior view. The presence of rotation deformity masks this appearance. When the rotation deformity is eliminated in the "zero-position" this picture reappears. With alignment of the fragments in this position, slight or moderate traction brings about perfect apposition (Fig. 9 *a*, *b*, and *c*).

Maintenance of reduction has not been possible in our series of cases by impaction. The limb has to be kept under traction for a period of three weeks by one of the methods outlined above till clinical union is obtained. The subsequent management is on the same lines as unimpacted fracture of the surgical neck.

Upper fourth fracture of the humeral shaft

In the upper fourth shaft fracture the displacements are similar. Reduction and fixation are on the same lines. The period of fixation till clinical union is a little longer and varies from four to six weeks (Fig. 10 *a*, *b* and *c*).

CONCLUSION

The present day concept of the mechanism of the shoulder joint has been outlined. Anatomical peculiarities have been shown to explain the aetiology of recurrent dislocations and a new line of treatment has been advocated.

The " zero-position " has been defined and its clinical use in the treatment of dislocations, unimpacted abduction fractures of the surgical neck, epiphyseal separations and upper fourth shaft fractures has been described.

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