COMPRESSION ARTHRODESIS OF THE SHOULDER

JOHN CHARNLEY and JAMES KIRK HOUSTON, WRIGHTINGTON, ENGLAND

From the Centre for Hip Surgery, Wightington Hospital

Predictable and rapid arthrodesis of the shoulder is the aim of any operation. Albert was reported to have attempted it in 1881 and since then many techniques have been evolved, both intra-articular and extra-articular, either alone or with the use of bone grafts and internal fixation. The Research Committee of the American Orthopaedic Association in 1942 drew attention to the fact that none of these methods was entirely satisfactory and their survey of the end-results of stabilisation of the paralytic shoulder revealed an overall incidence of 22 per cent of non-union. Arthrodesis of the tuberculous shoulder was not included.

In 1951 a new approach to this problem was put forward by Charnley who introduced a method of applying compression to obtain arthrodesis of the shoulder. Reporting on four cases he was enthusiastic about the results but cautious about drawing conclusions in view of the small number of cases and the short follow-up. This paper reviews the end-results of compression arthrodesis of the shoulder in this clinic over the past thirteen years.

CLINICAL MATERIAL

The total number of patients for study was twenty-three, which does not include the first four cases reported in 1951. All were cases of unilateral arthrodesis and were performed by the senior author. In the follow-up nineteen patients were interviewed and four who could not be interviewed had clinical records and radiographs which were detailed enough for valid conclusions. Of the nineteen patients interviewed the indications for operation are shown in Table I.

<table>
<thead>
<tr>
<th>Indication for operation</th>
<th>Number of cases</th>
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<tbody>
<tr>
<td>Tuberculous arthritis</td>
<td>13</td>
</tr>
<tr>
<td>Flail joint following anterior poliomyelitis</td>
<td>3</td>
</tr>
<tr>
<td>Flail joint following brachial plexus injury</td>
<td>1</td>
</tr>
<tr>
<td>Osteoarthritis following trauma</td>
<td>1</td>
</tr>
<tr>
<td>Primary osteoarthritis</td>
<td>1</td>
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</table>

The nineteen patients examined comprised fourteen men and five women, aged from six to fifty-eight, with an average age of 33-2 years. The longest follow-up was twelve years and five months and the shortest was eleven months, with an average follow-up of 6-6 years.

The four patients followed up by clinical records and radiographs without clinical examination were all men and with tuberculous shoulders. The average age at operation was 29-2 years. The longest follow-up was five years three months and the shortest two years four months, with an average time of 4-4 years.
COMPRESSION ARTHRODESIS OF THE SHOULDER

TECHNIQUE

The technique of operation initially was as described by Charnley in 1951, but after 1958 a modification was introduced to simplify the operation. The original technique demanded that the shoulder should be transfixed by two Steinmann nails and this restricted adjustment of the final position. The present technique offers considerable latitude for adjusting the final position of the arthrodesis, so that the final position is not entirely dependent on accurate sitting of the nails.

A plaster is first applied to the trunk to facilitate applying a shoulder spica at the end of the operation. The patient is operated upon sitting in a dental chair. The shoulder is exposed by an antero-posterior "sabre-cut" incision centred over the lateral border of the acromion. The upper half of the glenoid is denuded of articular cartilage and the under-surface of the acromion is carefully scraped to bare bone. The articular cartilage of the head of the humerus is removed and the humerus is then reduced into the joint with the shaft held in the desired position for arthrodesis. An osteotome is driven into the greater tuberosity to split off a pedicled graft, judging the direction for inserting the osteotome from the lateral border of the acromion. At this stage the pedicled graft is at a lower level than the acromion and no contact will be possible. It is necessary to cut away bone from the upper surface of the humeral head to allow it to ascend under the acromion, making good contact with it, and at the same time allow the pedicled graft of greater tuberosity to overlap the lateral border of the acromion. In this position the head of the humerus is subluxated upwards and inwards and makes contact with the upper part of the glenoid as well as the under-surface of the acromion (Fig. 1).

The design of compression clamp now used is illustrated in Figure 2, where it will be seen that universal joints permit the nails to be inclined at an angle to each other in any of three planes. Compression is exerted by the screw nearest to the articulation, and the bar which separates the free ends of the nails can be adjusted in length. The nail for the scapula (25 centimetres long and 4 millimetres thick) is inserted first and should be held like an awl in a hand-holder. It enters postero-superiorly into the base of the acromion and through the open wound the tip can be palpated and guided into the main mass of the scapula just deep to the glenoid (Fig. 3). The second nail is inserted postero-laterally in relation to the shaft of the humerus, and perpendicular in relation to the axis of the humerus to transfix the region of the surgical neck. The depth of penetration can be judged in both cases by comparing the length of nail projecting with a nail of identical length. At the end of the operation a shoulder spica is constructed by first applying plaster to the arm and forearm and when this has set by joining it to the previously applied body piece. It is important that the compression apparatus should be free from the plaster and not be anchored in it, or this will cause pain.

After operation the pins and compression clamps, covered by a wrist to pelvis plaster-of-Paris shoulder spica, were left in place for an average of 4-8 weeks. After they had been removed the shoulder was tested clinically for solidity and the patient then had another plaster-of-Paris shoulder spica applied which was left on for an average of 5-3 weeks. The plaster was then discarded and the patient begun on active exercises.

Complications—One non-tuberculous patient developed an infected haematoma which, after incision and drainage, discharged intermittently for two years. Two patients had a small chronic discharge from the upper pin track. One stopped eight weeks after discarding plaster and the other persisted for several months before healing. There was no shock and no morbidity.

RESULTS

Of the nineteen patients interviewed all except one had radiological bony fusion. The sole criterion of bony fusion accepted by the reviewer was the presence in the radiographs of unquestionable retrabeculation across the line of operation. Typical examples are illustrated in Figures 4 and 5. The single case, judged radiologically not to be fused by bone, was clinically
The arrangement of nails and compression clamps. These nails penetrate from the lateral aspect and do not transfix the shoulder, requiring only two skin perforations.
firm from the time the compression clamps and pins were removed and has remained absolutely solid and painless and functionally sound (Fig. 6). Of the four patients followed only from their clinical records all had radiological bony fusion.

![Fig. 3](image)

*Fig. 3*
Showing the position of the nails.

![Fig. 4](image) ![Fig. 5](image)

*Fig. 4*  
Two examples of osseous union.

It is worth noting that twenty-two cases were clinically solid when the compression clamps and pins were removed after an average of 48 weeks. The one case which was not certainly solid was judged clinically solid by one examiner, but another felt that this shoulder possibly had a trace of movement: plaster was discarded eight weeks after operation and it was then solid on examination.
The position of fusion aimed for in all of these cases was with the arm in 45 degrees of abduction, 45 degrees of flexion and 45 degrees of medial rotation. The position in which fusion finally occurred and the available range of movement of the nineteen shoulders examined is shown in Table II. In this table the angles are estimated from clinical examination of the patient, because it proved impossible to find a radiological projection of the humero-scapular angle which had any practical value. In this table the terms “fixed abduction,” “fixed flexion” and “fixed medial rotation” indicate the angle of the humerus in relation to the vertical when the vertebral border of the scapula is parallel with the vertical axis of the body. In other words these are the landmarks used by the surgeon when operating.

All patients interviewed said that the range of movement at the shoulder was adequate for all routine tasks and activities. The only troublesome limitation in all cases was the inability to do things above eye level. The women found restrictions in doing their hair and coping with back fastenings of their garments. All remarked on the reliability and painlessness of their shoulders. The relief of pain had allowed one patient to resume swimming for the first time in eight years. All but three of these patients were gainfully employed on standard jobs or were managing their own households without difficulty. They had returned to normal duties in an average of four and a half months. One of the unemployed patients had retired at the age of sixty because of the residual effects of pulmonary tuberculosis; one was an inmate in a mental hospital and the other patient was voluntarily unemployed. As can be seen in Table II, the final positions of these shoulders in flexion and medial rotation were very close to the desired angle of 45 degrees, but abduction, on the average, was 11 degrees below this figure.

Only three extreme divergences from the proposed angles of 45 degrees were discovered in the series. One case had a fixed abduction of 20 degrees, one a fixed abduction of 60 degrees.

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**TABLE II**

**THE FINAL RANGE OF MOVEMENT IN NINETEEN SHOULDERS**

<table>
<thead>
<tr>
<th>Position and movements</th>
<th>Range (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle of relaxed arm to lateral border of thorax with patient standing erect</td>
<td>8</td>
</tr>
<tr>
<td>Fixed abduction</td>
<td>34</td>
</tr>
<tr>
<td>Fixed flexion</td>
<td>42</td>
</tr>
<tr>
<td>Fixed medial rotation</td>
<td>46</td>
</tr>
<tr>
<td>Flexion-extension range</td>
<td>74</td>
</tr>
<tr>
<td>Abduction-adduction range</td>
<td>72</td>
</tr>
</tbody>
</table>

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The isolated tuberculous case without radiological evidence of union. On examination union was firm.
and the third medial rotation of 20 degrees which was due to a fractured humerus sustained some years after the shoulder fusion. The case of fixed abduction of 60 degrees was in a patient with extensive involvement of the entire upper extremity by anterior poliomyelitis. This combination of factors produced a rather prominent winged scapula. None of these three cases showed any significant difference in the range of limb movements from the others in the series.

**DISCUSSION**

The essential feature of this series has been the demonstration of how extremely reliable compression is in producing sound bony fusion of the shoulder in a variety of pathological conditions.

The time element involved in obtaining these results is also of great interest. The average time from operation until all fixation was discarded was just over ten weeks. The Research Committee of the American Orthopaedic Association, in their review of previous techniques (1942) found that if fixation was discarded at ten weeks or less there was an incidence of 42 per cent of non-union. They recommended at least three months in plaster, and five months if there were any doubts about union. These figures only applied to paralytic shoulders, no figures being quoted for the much more uncertain tuberculous shoulder. Individual surgeons put forward much the same sort of time-table. Gill (1931) recommended three to three and a half months immobilisation. Key (1930) suggested four to four and a half months as did Steindler (1927). Watson-Jones (1933) believed that four and a half months of plaster fixation should be followed by an abduction splint until good power of active abduction had returned.

The consistent and rapid osseous union which results from applying compression to arthrodesis of the shoulder is even more striking than in compression arthrodesis of the knee, as there are some surgeons who consider the knee to be an easy joint to arthrodesy by any technique, but such a claim cannot be made for the shoulder. In the shoulder, like the knee and ankle, the surfaces which are compressed together possess a normal blood supply and on these grounds the shoulder is a good example of a true compression arthrodesis according to the definition attempted by Charnley. But more interesting than the knee and ankle, with regard to the theory of compression arthrodesis, is the fact that it is not possible to obtain such rigid fixation by applying compression to the shoulder because the bone surfaces are so small in area. The two points of contact of the head of the humerus, with the upper part of the glenoid and the under-surface of the acromion, are together probably no more than one-quarter of a square inch. The pedicled graft of the greater tuberosity, which is not under pressure, is an asset in hastening the spread of consolidation over a larger area, but it is unlikely that it plays an important part in the early process of fusion as it is a method used in many unsuccessful techniques not using pressure.

To what extent "rigid" fixation contributes to the success of this technique is difficult to estimate because the shoulder fusion is often precariously balanced and loss of position, and even complete loss of contact between the bones, would occur within a few minutes if the shoulder were not supported in a shoulder spica. These considerations would suggest that the fixation factor is a secondary feature in the shoulder and that the primary feature is the excellent blood supply of the bones in contact, under the intimate coaptation produced by pressure. It is possible that, by reason of the plaster protecting the joint from major external strains, quite effective fixation might occur under the light pressure of the compression clamps holding fixation in the absence of external forces. The shoulder joint is not exposed to great forces inside a shoulder spica as, unlike the pelvis in arthrodesis of the hip, the scapula is not rigidly attached to the vertebral column and movements of the trunk inside the plaster need not necessarily strain the shoulder fixation if movement is slight. However, this argument would apply to all shoulder fusions based on internal fixation plus a plaster, yet none of these yields the consistent results of the compression method; so one must attribute the striking
success of the compression method to the compression force itself rather than to the production of absolute fixation.

It has not been possible to make any estimate of the degree of pressure exerted on the bone in this operation, but the total force applied to the joint is certainly very much less than the 100 pounds which, in this clinic, is used as a routine in the knee joint. By reason of the "order of levers" employed in this technique the force delivered to the raw bone surfaces will be only half that produced by the arrangement of clamps and nails used for the knee and ankle. However, the area of contact between the bones in the shoulder arthrodesis is very small compared with the four square inches of the cross-section of a knee joint, and it is quite possible that the same pressure (twenty-five pounds per square inch) may be achieved by light force in the shoulder. When estimating bone pressure in a compression arthrodesis it has been shown (Charnley 1953) that the determining factor is the strength of the bone and not the applied force from the clamps. When the bones are applied to each other contact at first is at a number of points devoid of area, and the compression force will crush the bone until the area presented, in terms of the softness or hardness of the bone, balances the imposed load. This means that equal loads will produce larger areas of contact in soft bone than in hard bone and that, no matter how high the external force applied, the pressure at the point of contact cannot hold above the figure which determines mechanical collapse. This explains, therefore, how the relatively light pressure applied by the clamp in shoulder compression, acting on a small area of contact between the humerus and the scapula, may produce a pressure, in terms of force per unit area, identical with a much higher pressure exerted in arthrodesis of the knee.

SUMMARY

1. A series of twenty-three compression arthrodeses of the shoulder are reviewed.
2. The review demonstrates compression arthrodesis to be an excellent method of obtaining bony fusion of the shoulder.
3. The consistent success in achieving arthrodesis, in what is to be considered a difficult joint to fuse, is significant in the theory of compression arthrodesis, because the shoulder offers a more perfect example of compression arthrodesis than the knee in that the element of absolute fixation is less obvious.

REFERENCES