Percutaneous Fixation of Three- and Four-Part Fractures of the Proximal Humerus

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Unfixed 3- and 4-part fractures of the proximal humerus have a poor functional outcome. Open operation increases the risk of avascular necrosis and percutaneous reduction and fixation may be preferable.

We report 27 patients, 9 with 3-part and 18 with 4-part fractures, treated by percutaneous reduction and screw fixation. Thirteen of the 4-part fractures were of the valgus type with no significant lateral displacement of the articular segment, and five showed significant shift. Instruments were introduced into the fracture through small incisions so that the fragments could be manoeuvred under the control of an image intensifier, taking advantage of ligamentotaxis as far as possible. A good reduction was achieved in most cases.

The average follow-up was 24 months (18 to 47). All the 3-part fractures showed good to very good functional results, with an average Constant score of 91% (84% to 100%), and no signs of avascular necrosis. Good radiological results were achieved in 4-part fractures when impacted in valgus except for one patient with partial avascular necrosis of the head. In those with lateral displacement of the head, revision to a prosthesis was required in one patient because of avascular necrosis and in another because of secondary redisplacement of the fracture. Avascular necrosis was seen in 11% of 4-part fractures. The average Constant score in patients with 4-part fractures who did not need further operation was 87% (75% to 100%).


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Severe fractures of the proximal humerus have a poor functional prognosis when left untreated because of severe displacement of the fragments. Reduction is essential even though there is a danger that open operation may increase the risk of avascular necrosis, especially in 4-part fractures. According to Hägg et al, open reduction doubles the risk of avascular necrosis compared with closed treatment. The risk is increased still further by the exposure required for plating compared with that for a lesser procedure.

For 3-part fractures Neer recommends minimal osteosynthesis and for 4-part injuries he advocates the use of a prosthetic replacement because of the high risk of avascular necrosis. In young patients, however, there is disagreement as to the wisdom of this procedure due to the limited survival of the implants. Percutaneous reduction and fixation of such fractures would therefore seem to be desirable since this also minimises scarring and facilitates postoperative mobilisation.

We initially employed the percutaneous technique for isolated avulsion fractures of the greater tuberosity, but have progressively increased our use of this approach to include 3- and 4-part fractures.

Patients and Methods

Between 1990 and 1994, 72 patients with displaced fractures of the proximal humerus were treated by this technique at the Innsbruck University Hospital and the Salzburg General Hospital. Of these, nine had 3-part fractures and 18 had 4-part. The other 45 patients had 2-part fractures, mainly avulsions of the greater tuberosity. Thirteen of the 4-part fractures showed valgus impaction without significant lateral displacement of the articular segments, while the remaining five were 4-part fractures with significant (>5 mm) lateral displacement of the head. The average age of the 27 patients presenting with 3- and 4-part fractures was 54 years (25 to 68). There were 16 men and 11 women. The injuries were the result of alpine skiing accidents in 15, cross-country skiing in 4, snowboarding in 1, road traffic accidents in 4, and 3 occurred in falls. All the patients were operated on within the first 10 days of injury and 21 within the first 4 days and all were followed up by clinical and radiographic examination for an average of 24 months (18 to 47). The range of movement was assessed.
and compared with that of the opposite shoulder and the
timing of return to work and sporting activities were noted
together with the length of rehabilitation required and the
patient’s subjective assessment. The Constant Function
Score was determined.

Radiographs assessed the quality
of the reconstruction, union of the fracture and evidence of
avascular necrosis as determined by destruction of the
trabecular architecture, loss of bony substance, the presence
diffuse sclerotic areas in the subarticular region and
deforamation of the articular surface of the humerus.

**Technique of reconstruction.** Reduction was performed
with the help of a pointed hook retractor, an elevator and if
necessary a 4 mm Steinmann pin. Screw fixation was
undertaken with an Arthroscopic and Percutaneous Screw
Fixation System (Oswald Leibinger, Freiburg, Germany).
The set comprises cannulated, self-tapping titanium screws
with a diameter of 2.7 mm and a length of 10 to 40 mm.
The use of a cannula set with a blunt trocar helps to
minimise damage to soft tissues.

Operation was normally performed under regional anaes-
thesia, with the patient supine and the upper body inclined
at an angle of about 30°. The arm was draped to allow full
mobility. An image intensifier was located cranially so that
the C-arm position gave a right angle between the central
beam and the axis of the head of the humerus. During the
operation, the surgeon and his assistant wore special radio-
resistant gloves (Fluoro-shield Radiation Reduction Gloves,
Acufex Microsurgical Inc, Mansfield, USA).

**Three-part fracture** (Fig. 1). In this fracture the head of
the humerus may be displaced in internal rotation with
anterior and sometimes medial angulation due to the pull of
the pectoralis major muscle. The subcapital fracture is
reduced with the arm in adduction and internal rotation and,
with simultaneous traction applied to the arm, the surgeon
uses his thumb to apply counter-pressure posterolaterally in
the area of the fracture. The position is then secured by
means of three 2 mm K-wires drilled from below through
the fragment of the humeral shaft, using threaded pins in
elderly osteoporotic patients. The arm is then returned
carefully to the neutral position and the greater tuberosity
reduced by means of the pointed hook retractor which is
inserted into the subacromial space. The greater tuberosity
is engaged at the insertion of the supraspinatus tendon and
moved anteroinferiorly into the correct position. After tem-
porary fixation with a K-wire the position of the tuberosity
is checked by maximum external and internal rotation of
the arm, and then fixed by two cannulated titanium screws.

When there is pronounced rotational displacement, a Stein-
mann pin is drilled into the humeral head and used to
achieve derotation. When the head is displaced medially
and inferiorly, a blunt elevator is advanced from the anter-
ior aspect, following the bone as far as the anatomical neck,
and the head segment is then raised (Fig. 1b). The sliding
action along the bone without losing contact presents no
threat to the neurovascular structures.

**Valgus-impacted 4-part fractures** (Figs 2, 3 and 4).
Reconstruction requires elevation of the head in order to
restore the anatomy of the tuberosities. The arm is held
adducted in the neutral position and an incision is made at
the level of the junction between the anterior and middle
thirds of the head. Monitored by an image intensifier, an
elevator is then advanced towards the impacted articular
segment. The line of fracture between the two tuberosities,
which usually lies about 5 mm posterolateral to the inter-
tubercular groove, is located by gently sliding the tip of the
elevator over the bone anteriorly and posteriorly and the
elevator inserted between the two tuberosities into the
fracture line beneath the impacted head. This is then
reduced and secured with two or three 2 mm K-wires
drilled from below, through the fragment of the shaft into
The greater tuberosity, which has usually been tilted laterally but without longitudinal displacement, will normally regain correct alignment as the head is reduced. It is held inferiorly by the residual periosteum and superiorly by the rotator cuff (Fig. 2). The cannula of the screw fixation system with the blunt trocar is advanced towards the upper part of the greater tuberosity and a screw inserted into the upper part of the articular segment. Another screw is passed through the inferior part of the greater tuberosity into the shaft so that the greater tuberosity has a supporting function between the shaft and the head (Fig. 3).

Finally, the lesser tuberosity, which is usually displaced medially, is reduced. The arm is held in 70° of abduction, and the image intensifier aligned for an axial view. A small incision is made and the hook retractor advanced towards the lesser tuberosity, which is then pulled laterally until it is restored to its normal position, that is until the articular incongruity disappears. Temporary fixation is provided with a K-wire, and a 40 mm screw is placed anteroposteriorly. Finally, the K-wires which were initially drilled into the head are cut off and left just beneath the skin. Four weeks later they are removed under local anaesthesia. Reduction is more difficult, when there is no contact between the articular segment and the glenoid, either because impaction is so severe that it is facing laterally or because it is not only impacted but also displaced laterally, as in a true 4-part fracture. The head must be raised and reduced with the help of the elevator, which is also used to correct lateral displacement before proceeding as described above (Fig. 4). Grafting with cancellous bone was not required in any case.

The axillary nerve runs deep to the deltoid about 6 cm from the acromion and it may lie in the line of approach required for placing screws to secure the greater tuberosity. It can be avoided by one or all of three methods:

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   1. The nerve gives off its terminal branches at the level of the lateral end of the acromion, and may lie in the line of approach required for placing screws to secure the greater tuberosity. It can be avoided by one or all of three methods.
   - 2. If an approach which avoids the main part of the nerve cannot be avoided, the trocar sheath with the blunt trocar is advanced in a craniomedial direction until bone is met and then slid distally down the bone. The sheath will keep the axillary nerve out of harm’s way (Fig. 5).
3. Washers are not used with screws to avoid possible entrapment of the nerve.

**Postoperative management.** The arm is bandaged lightly against the body for three weeks. Depending on the degree of stability achieved, passive exercises in the plane of the scapula without rotation begin on the first day after operation. Rotation and active movement start in the fourth week.

**Exposure to radiation.** The average time of exposure to radiation during operation was seven minutes for the first five patients and 3.5 minutes for the last ten.

**RESULTS**

**Three-part fractures**

*Radiographic follow-up.* All the fractures united in axial alignment. In two, pronounced porosis in the head led to the migration of a wire which had to be removed early. Evaluation of the postoperative result showed that the greater tuberosity had united in an anatomical position in 6 cases, and in 3 there was residual superior displacement of up to 3 mm. There was no evidence of avascular necrosis of the head of the humerus.

*Clinical follow-up.* Table I shows the average restriction of flexion, abduction and external rotation in comparison with the contralateral arm. Two patients could touch their shoulder blades with the back of their hand, four reached T12, and three could reach the lumbar spine.

Of the seven patients still of working age four had jobs involving no physical activity and three were manual workers. All were able to return to work. Seven enjoyed some form of recreational sport before their accident, mostly skiing, and six were able to resume these activities.
The time required for rehabilitation varied considerably with an average period of 4.7 months (2 to 8). The average Constant score adjusted for age and gender was 91% (84% to 100%). Compared with the uninjured side the average score was 93% (83% to 100%). The subjective assessment of the overall result by the patients showed that six were very satisfied and three satisfied.

Four-part fractures

Radiographic follow-up. Of the 13 patients with impaction of the head of the humerus in valgus, anatomical reconstruction was achieved in eight. In three the head was not elevated sufficiently so that the greater tuberosity was up to 3 mm too high. Residual medial displacement of the lesser tuberosity of up to 5 mm (2 to 5 mm) was seen in the axillary view in three patients and one had displacement of both tuberosities. In one of these patients arthroscopic surgery was carried out to overcome restricted internal rotation due to articular incongruity caused by displacement of the lesser tuberosity. Secondary subsidence of the head was not seen. Partial necrosis in the head was seen in only one patient, who was free of symptoms.

Five patients had a 4-part fracture with lateral displacement of the head. One required revision to a prosthesis one week after operative reduction because of secondary displacement of the fragments. In the other four satisfactory reduction was achieved, with good axial alignment of the head and displacement of the tuberosities of no more than 3 mm. One of these patients showed signs and symptoms of avascular necrosis of the head eight months after operation, which necessitated replacement with a hemiprosthesis. The other three patients showed no signs of avascular necrosis at the time of follow-up.

Clinical follow-up. Table II shows the restriction of flexion, abduction and external rotation in comparison with the contralateral arm. Three patients could reach the region of the scapula with the back of their hand, four T12, five the lumbar spine, and two the sacro-iliac joint.

Of the 16 patients, five had jobs involving physical activity while nine were not required to perform manual work. Two were pensioners. All 14 patients of working age resumed employment and the two pensioners their previous activities. All were involved in some form of recreational sport before injury, mostly skiing, and all but one were able to resume these activities.

There was considerable variation in the length of rehabilitation required. The average period was 5.5 months (3 to 12), which was significantly longer than that for the 3-part fractures (p < 0.05, Mann-Whitney U test). The Constant functional score adjusted for age and gender averaged 87% (75% to 100%). One patient had to be excluded from comparison with the opposite side because of a rupture of

| Table I. The restriction of movement in degrees after 3-part fractures compared with the contralateral side |
|---------------------------------------------------|------------------|------------------|
| Average | Minimum | Maximum |
| Flexion | 10 | 0 | 25 |
| Abduction | 15 | 0 | 30 |
| Ext rotation | 15 | 0 | 25 |

The time required for rehabilitation varied considerably with an average period of 4.7 months (2 to 8). The average Constant score adjusted for age and gender was 91% (84% to 100%). Compared with the uninjured side the average score was 93% (83% to 100%). The subjective assessment of the overall result by the patients showed that six were very satisfied and three satisfied.

| Table II. The restriction of movement in degrees after 4-part fractures compared with the contralateral side |
|---------------------------------------------------|------------------|------------------|
| Average | Minimum | Maximum |
| Flexion | 15 | 0 | 30 |
| Abduction | 18 | 0 | 35 |
| Ext rotation | 12 | 0 | 30 |

| Table III. Comparison of the Constant score between 3- and 4-part fractures |
|---------------------------------------------------|------------------|------------------|------------------|------------------|
| | Pain | Activity | Movement | Strength | Total average points | Adjusted score (av. %) | Comparison with other side(%) |
| Three-part fractures | 14.2 | 17.4 | 38 | 15.6 | 85.4 | 91 | 93 |
| Four-part fractures | 12.7 | 16.6 | 37.2 | 14.8 | 82.5 | 87 | 88 |
the rotator cuff, but for the remaining patients the average score in comparison with the uninjured shoulder was 88% (Table III).

Of the 16 patients, nine were very satisfied and seven were satisfied with the outcome.

DISCUSSION

Percutaneous reduction of a fracture of the proximal humerus requires careful study of the radiographs which must be available in at least two planes. We prefer the views advocated by Neer. An assessment of the residual soft tissue linking the various fragments is necessary and important to allow full benefit from ligamentotaxis.

In 3-part fractures with pronounced displacement and avulsion of the greater tuberosity there is often only a residual periosteal connection on the dorsal side, so that the humeral head is highly mobile. The use of a thick K-wire or Steinmann pin to achieve derotation of the head is helpful, and it is important to achieve reduction and fixation before seeking to reduce the tuberosity.

In 4-part fractures the presence of lateral displacement is of great significance. Where this is minimal the periosteum on the medial side of the anatomical neck can be assumed to be intact regardless of the degree of impaction. This residual soft-tissue bridge probably carries an adequate blood supply since such fractures have a lower rate of avascular necrosis than those with marked lateral displacement. During reduction, this periosteum acts like a hinge.

The greater tuberosity normally remains in periosteal connection with the shaft fragment and will usually return to its anatomical position through the inferior pull from the periosteum and the superior pull from the rotator cuff when the head is reduced. However, a fracture of the lesser tuberosity with medial displacement will not fall back into place and almost always requires manipulation.

The marked lateral displacement of the head in some 4-part fractures may have destroyed the medial periosteum. This jeopardises the blood supply to the head, while the loss of ligamentotaxis makes reduction of the fragments more difficult. Nevertheless, it is normally possible to achieve some improvement in the position of the fragments without necessarily achieving an anatomical reduction, but it is arguable whether the head should be preserved in such patients. We have not used cancellous bone grafts in these closed procedures.

After operation, immobilisation of the arm in adduction creates less pressure on the reduced head than the abduction plaster cast which we earlier considered necessary following open surgery, and we saw no secondary subsidence. We were impressed by the results obtained by the percutaneous technique but the low rate of avascular necrosis of 11% in 4-part fractures is not comparable with other series as most of our patients had valgus impaction of the head without any significant lateral displacement. Such fractures have a lower rate of necrosis than 4-part fractures with lateral displace-

12,19 Comparisons can be drawn, however, between valgus-impacted fractures treated by open operation and those managed by the closed technique. For closed reconstruction the necrosis rate was 8%, which is almost identical with the 9% reported in one of our earlier studies and better than the results quoted by Jakob et al. All the patients who had operations to preserve the humeral head were satisfied with the functional result. Without exception they were able to return to work or continue their normal activities. The good functional results are also due to the relatively young age of the patients. We chose the percutaneous approach largely for patients whose bones did not display significant porotic changes. In elderly patients with advanced porosis, the use of a hemiprosthesis is advised.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES