Internal fixation of complex fractures of the proximal humerus

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We treated 34 consecutive articular fractures of the proximal humerus in 33 patients with good bone quality by open reduction and internal fixation. Anatomical or nearly anatomical reduction was achieved in 30, at a mean follow-up of 63 months (25 to 131), complete or partial avascular necrosis had occurred in 12 cases (35%). Two patients subsequently underwent arthroplasty and six further patients required additional surgery. The 32 patients who did not require arthroplasty obtained a mean Constant score of 78 points or 89% of an age- and gender-matched normal score (66 points or 76% in the presence and 83 points or 96% in the absence of avascular necrosis ($p < 0.0005$)); 22 were painfree, and seven had mild pain and three moderate pain. The mean active anterior elevation was 156°. Internal fixation of complex fractures of the proximal humerus restored good shoulder function if avascular necrosis did not develop.

Approximately 80% of the fractures of the proximal humerus are neither displaced nor markedly unstable and conservative treatment usually gives good or excellent results.^{1,2} In the remaining 20%, the fracture fragments are displaced, unstable and may have disruption of their blood supply. Treatment of these fractures remains controversial.³⁻⁶

Displaced and unstable extra-articular fractures are most commonly treated by operative reduction and fixation using various techniques.^{6,7} Treatment is more controversial for articular fractures which carry a high risk of avascular necrosis and subsequent collapse of the humeral head. In Neer's classification,^{1,2} these are the two-part anatomical neck, the three-part and four-part fractures and those with dislocation of the head of the humerus.

A review of the published results suggests that there is no universally accepted form of treatment. Conservative management may be associated with nonunion, malunion and avascular necrosis resulting in painful dysfunction.^{1,5,8,9} Primary hemiarthroplasty is favoured by many authors^{1,5,10-12} but is associated with a large number of complications and objective functional results which are disappointing.^{3,13} Open reduction and internal fixation with plates and screws may restore the anatomy of the proximal humerus but may also further compromise the vascularity of the head, leading to avascular necrosis and poor outcome.^{4,5,9,14} Studies which report poor

results of internal fixation have often been carried out on elderly patients with poor bone quality and have not assessed the quality of the reduction obtained with operative intervention.^{4,5} Conversely, series with a favourable outcome have frequently consisted of younger patients with good bone quality, who had sustained impacted fractures^{6,15,16} for which anatomical reduction was obtained using a relatively non-invasive approach with minimal internal fixation. Interestingly, favourable results have been reported despite subsequent avascular necrosis.¹⁷

We have reviewed the clinical and radiological outcome of open reduction and internal fixation in a consecutive series of complex fractures of the proximal humerus with good bone quality.

Patients and Methods

We treated 35 consecutive patients with 36 complex fractures of the proximal humerus by open or closed reduction and minimal internal fixation. The bone quality was judged to be good with strong trabeculae in the cephalic segment and a thickness of the cortex of the proximal diaphysis of more than 3.5mm.¹⁸

One patient with multiple sclerosis could not be re-examined because of her poor medical condition; and a second patient had left the country and could not be contacted. This left a total of 34 fractures sustained by 19 men and 14 women (one bilateral) with a mean age of

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Table I. Details of the patients, the type of fracture and the treatment

Case	Gender	Age (yrs)	Type of fracture	Side	Type of treatment
1	F	73	3-part, valgus-impacted	Left	Closed reduction, percutaneous pinning
2	M	37	3-part, dislocated	Left	Open reduction, autogenous bone graft, pinning
3	M	49	4-part, dislocated	Left	Open reduction, pinning
4	M	49	3-part, valgus-impacted	Right	Open reduction, autogenous bone graft, osteosuture
5	M	22	2-part, anatomical neck	Left	Open reduction, screw fixation
6	M	16	2-part, anatomical neck	Left	Open reduction, screw fixation
7	M	37	4-part, valgus-impacted	Right	Open reduction, plate fixation, osteosuture
8	F	27	4-part, dislocated	Right	Open reduction, pinning
9	F	21	3-part, dislocated	Left	Closed reduction, percutaneous pinning
10	F	46	3-part, valgus-impacted	Left	Open reduction, pinning
11*	F	54	3-part, valgus-impacted	Right	Open reduction, autogenous bone graft, osteosuture
12*	F	54	4-part, valgus-impacted	Left	Open reduction, autogenous bone graft, osteosuture
13	F	26	4-part, valgus-impacted	Left	Open reduction, pinning
14	F	56	4-part, valgus-impacted	Right	Open reduction, autogenous bone graft, osteosuture
15	M	33	4-part, dislocated	Right	Open reduction, screw fixation
16	M	39	3-part (4th part isolated)	Right	Open reduction, allogeneous bone graft, osteosuture
17	M	37	3-part (4th part isolated)	Left	Closed reduction, percutaneous pinning
18	M	33	3-part valgus-impacted	Right	Open reduction, autogenous bone graft, osteosuture screw fixation
19	F	49	4-part, valgus-impacted	Right	Open reduction, autogenous bone graft, osteosuture
20	M	50	4-part, valgus-impacted	Right	Open reduction, autogenous bone graft, osteosuture screw fixation
21	F	64	4-part, valgus-impacted	Right	Open reduction, autogenous bone graft, osteosuture
22	F	65	4-part	Right	Open reduction, plate fixation, osteosuture
23	M	52	3-part (4th part isolated)	Left	Open reduction, plate fixation, osteosuture
24	M	38	3-part, (2-part plus head-split)	Left	Open reduction, osteosuture
25	M	42	3-part (4th part isolated)	Right	Open reduction, autogenous bone graft, osteosuture
26	F	60	4-part	Left	Open reduction, allogeneous bone graft, osteosuture
27	M	32	3-part dislocated	Right	Open reduction, plate fixation, osteosuture
28	M	56	4-part dislocated	Right	Open reduction, screw fixation, osteosuture
29	M	55	4-part valgus-impacted	Left	Open reduction, pinning
30	F	32	3-part (4th part isolated)	Right	Open reduction, plate fixation
31	M	47	4-part, head-split	Right	Open reduction, plate fixation
32	M	70	3-part valgus-impacted	Right	Open reduction, plate fixation
33	F	50	3-part valgus-impacted	Left	Open reduction, autogenous bone graft, osteosuture
34	F	55	4-part, dislocated	Left	Open reduction, plate fixation, osteosuture

* same patient

44.9 years (16 to 73) and a mean delay between injury and operation of 3.2 days (0 to 14). Table I gives the clinical details of the patients.

The basis of classification was according to Neer's criteria.¹ To address the problems of reproducibility,^{19,20} the fractures were classified by a consensus of all three authors using a true anteroposterior (AP), an axillary lateral and a scapular lateral view with, if necessary, additional consultation of the operation notes. There were two displaced two-part anatomical neck fractures and 16 three-part fractures. Seven of the latter were valgus-impacted, three were three-part fracture-dislocations, one a three-part fracture with a head-split component, and five three-part fractures with an isolated head fragment (fourth part fractured but not displaced). The remaining 16 four-part fractures consisted of ten classic four-part fractures, five four-part fracture-dislocations, and one four-part fracture with an additional head-split component.

Three valgus-impacted fractures undisplaced at the calcar were treated by closed reduction and percutaneous pinning under fluoroscopic control. A rasp was introduced percutaneously between the greater and the lesser tuberos-

ities to elevate the lateral aspect of the head segment. After elevation of the head, the greater tuberosity reduced spontaneously or with a minimal pressure using the rasp through the same incision. The fracture was then stabilised by two pins into the head and with one or two terminally threaded pins passed through the greater tuberosity into the medial diaphyseal cortex.

We reduced 31 fractures through a deltopectoral approach. The tuberosities were touched as little as possible. A rasp was introduced through the anterior vertical line of the fracture line between the greater tuberosity and shaft. The fragment of the greater tuberosity was inspected from inside and positioned so that its distal triangular tip was reduced in the corresponding defect in the shaft. The rasp was then brought underneath the lateral aspect of the humeral head which was elevated until the cartilage was flush with the insertion of the cuff at the greater tuberosity. This was then approximated towards the shaft and could usually be relocated without difficulty. The humerus was rotated and the fracture was stabilised. If the lateral or anterior cortex was multifragmentary, plate fixation was used. If splinting one of the fragments seemed to be appropriate pins

Table II. The outcome of treatment

Case	Malunion	Avascular necrosis	Constant score	SSV (%)	Secondary arthroplasty	Flexion (°)	Abduction (°)	External rotation (°)	Internal rotation (°)	Pain	Re-operation
1	No	None	95	100	No	160	170	45	85	No	
2	No	None	92	95	No	160	160	30	110	No	
3	No	Partial	95	85	No	170	170	30	90	No	
4	No	Total	71	80	No	100	90	5	90	Mild	
5	No	Partial	95	100	No	170	170	60	110	No	
6	No	None	100	95	No	170	170	70	100	No	
7	No	None	92	80	No	160	155	70	80	No	
8	No	Total	70	45	No	160	160	20	90	Moderate	
9	No	Partial	46	70	No	120	100	45	100	Mild	
10	No	Total	81	70	No	160	150	20	90	Mild	
11*	No	None	100	85	No	170	170	20	100	No	
12*	No	None	100	85	No	170	160	20	100	No	
13	No	None	100	90	No	170	170	30	110	Mild	
14	No	None	100	95	No	170	170	50	100	No	
15	No	None	100	95	No	170	170	50	90	No	
16	No	Total			Yes					Moderate	Total shoulder replacement
17	No	None	82	85	No	170	120	45	110	No	
18	No	None	95	100	No	170	170	60	110	No	
19	No	None	100	100	No	170	170	20	100	No	
20	No	Partial			Yes					Moderate	Arthroscopic capsulotomy, biceps tenotomy, subacromial decompression, total shoulder replacement
21	No	Partial	100	75	No	155	150	40	110	No	
22	No	None	100	100	No	115	135	50	85	No	
23	Yes	None	100	100	No	165	170	40	95	No	
24	No	None	96	95	No	150	165	45	110	No	
25	No	None	72	90	No	160	160	45	80	Mild	Arthroscopic capsulotomy
26	No	Total	61	50	No	85	90	5	40	Mild	
27	No	None	98	95	No	165	160	70	110	No	Implant removal Adhesiolysis
28	No	None	100	120	No	160	170	65	95	No	
29	No	None	100	100	No	160	160	25	70	No	
30	No	None	83	80	No	150	130	20	85	Mild	Implant removal
31	Yes	Partial	61	80	No	100	90	35	45	No	Implant removal
32	Yes	None	100	100	No	165	170	40	95	No	Implant removal Adhesiolysis, evacuation of haematoma
33	No	None	95	85	No	165	160	40	90	No	
34	Yes	Partial		75	No					No	Implant removal Bursectomy

* same patient

or screws were used. If maintaining the position of a major cortical fragment seemed to be necessary we used osteosutures. The methods of fixation for each patient are shown in Table I. Radiographs were obtained at the end of the procedure, with the wounds still open. If corrections were considered to be necessary they were carried out immediately.

Post-operative management was dependent on the stability which had been achieved operatively. Generally, pendulum exercises were started immediately and performed twice daily. A sling was worn for three weeks.

One of the 33 patients could only be interviewed over the telephone and sent new radiographs for inclusion in the study as she had moved abroad. The other 32 were examined at a mean of 63 months (25 to 131) after surgery and scored by two observers (CMLW and PV) who did not include the operating surgeon. Examination included a structured interview, physical examination and photographic documentation of shoulder function as well as scoring according to Constant and Murley²¹ using the

technique described by Gerber, Fuchs and Hodler.²² In addition, the patients were asked to estimate the function of their shoulder in percentage terms as compared with a normal shoulder. This value was called the subjective shoulder value (SSV).²²

Radiological assessment included AP views in neutral and internal rotation, an axillary lateral and a Neer scapular lateral view. The quality of reduction, healing, formation of ectopic bone, development of glenohumeral osteoarthritis or avascular necrosis of the head were assessed.

Statistical analysis. This was performed by a statistical consultant using the Mann-Whitney U test, Fisher's exact test and the Kruskal-Wallis rank and Spearman rank-correlation tests. The level of significance was set to $p \leq 0.05$.

Results

All the fractures healed without delayed or nonunion of any segments.

Fig. 1

Radiographs of a three-part fracture with a fractured but undisplaced fourth part.

Fig. 2

Radiographs showing open reduction and internal fixation using bone graft and suture fixation.

Fig. 3

Radiographs one year after operation with no evidence of avascular necrosis.

The operative goal to reduce the fracture anatomically or near anatomically was met in 30 of the 34 fractures. Displacement of at least 1 cm or of 45° of one fragment was present in four fractures which were considered to be malunioned (Table II).

In all of these cases a plate was used (twice with additional screws, twice with additional osteosutures), without a bone graft and the malunion occurred at surgery. There

were no cases of malunion in the 13 fractures with bone graft compared with four in the 21 without graft. Bone grafting did not significantly reduce the rate of malunion.

Twelve of the 34 cases (35%) showed evidence of avascular necrosis of the cephalic fragment. This involved only parts of the head in seven (20.6%) and was total in five (14.7%). Bone grafting was not significantly associated with the development of avascular necrosis. Both fractures

Fig. 4

Photograph showing that the patient has a pain-free, fully functional shoulder one year after operation.

in which allograft was used, however, had complete avascular necrosis.

Two patients (6%) with total and painful avascular necrosis and a subjectively unsatisfactory result underwent total shoulder replacement 57 and 27 months respectively after the initial operation. One patient was followed at our institution and has a good result with a Constant score of 75% and a SSV of 80% 24 months after total shoulder replacement. The second patient elected to have further treatment elsewhere and did not wish to be reviewed or to respond to a questionnaire because he was dissatisfied with the outcome of treatment and was therefore lost to follow-up when total shoulder replacement became necessary.

Six patients underwent seven additional operations, five implant removals, four of which were associated with release of subacromial adhesions, one evacuation of a haematoma and one arthroscopic capsulotomy for stiffness.

The functional results for the 32 shoulders which did not require total shoulder replacement were assessed at a mean of 63 months (25 to 131) after the initial operation with clinical assessment in 31 and telephone interview in one. The mean final Constant score was 77 points or 88.7% of a normal shoulder (46 to 100). The mean subjective should-

Fig. 5

Radiographs showing a collapsed humeral head due to avascular necrosis at three years.

Fig. 6

Photograph showing that after a long period with subjectively normal shoulder, the patient had increasing pain and decreased function.

Fig. 7

Radiographs after total shoulder replacement.

Fig. 8

Photograph showing that three years after total shoulder arthroplasty pain-free, normal shoulder function was restored.

der value was 87.1% (45 to 100). Twenty-four patients had no pain, seven had mild pain and one had moderate pain. The mean range of active anterior elevation was 154° (85 to 170°), of active abduction 152° (mean 90 to 170°) of active external rotation 39° (5 to 70°) and of active internal rotation 93° (40 to 110°).

In the 22 shoulders without avascular necrosis of the cephalic segment, the mean Constant score was 83 points or 96% (61 to 100%) and the SSV was 93%. In the ten with partial or total avascular necrosis, the mean Constant score was 66 points or 76% (46 to 100%) and the mean SSV 73% (50 to 100%). The Constant scores and SSV were significantly better in patients without avascular necrosis ($p < 0.0005$).

Four patients had a mild to moderate malunion. The cephalic segment was in varus in three and in valgus in one. Malunion was associated with partial avascular necrosis in two patients. The overall functional results were good and not significantly different from those of the 28 patients without malunion with a mean Constant score of 87% and a mean SSV of 88%.

No statistically significant differences in Constant score or SSV were found between the different types of fracture (two- and three-part *versus* four-part fractures). The presence of avascular necrosis and outcome were not influenced by age, gender, type of fracture or the type of reconstruction.

Discussion

There is no consensus on the optimal treatment of complex fractures of the proximal humerus.^{3-5,8,10,11,13,23-26} In some studies the objective functional results of conservative treatment or hemiarthroplasty have been unsatisfactory.^{8,12,13} The fracture can be defined by a variety of classification systems including an assessment of bone quality and metaphyseal comminution, all of which are prone to error. None of these systems gives a clear prognosis and direction for treatment. The difficulty in accurately classifying the fracture also creates problems in reporting outcome. Overall, open reduction and internal fixation, although not in all institutions,⁴ have yielded satisfactory results.^{6,15,16,23-25,27,28} The best results are obtained if the fractures are well reduced and maintained reduced until healing has occurred.^{6,17} It must therefore be the goal to select fractures for open reduction and internal fixation which can be anatomically reduced. This is dependent on various factors such as the type of fracture, the quality of the bone, the technique of reduction and fixation and the experience and skill of the surgeon.

In our series, only fractures with a cortical thickness of the proximal humerus of more than 3.5mm¹⁸ were

Fig. 9

Radiographs showing a valgus-impacted four-part fracture.

Fig. 10

Radiographs showing open reduction and internal fixation with autogenous bone graft.

Fig. 11

Radiographs showing that eight years after operation there is no evidence of avascular necrosis.

included. The cases studied may not be representative of all the four-part fractures which a surgeon may encounter. Other authors have selected on the basis of bone quality and age, and have reported improved results.^{6,28,29}

In our series, 33 of 35 patients were younger than 65 years and with a mean age of 45 years were young for the types of fracture considered. In addition, 20 of the 35 patients were men, who may be expected to have better overall bone quality. Most other series have reported a much greater proportion of female patients. Thus, the fractures successfully treated in our series were probably different from those treated without success in other series despite similar Neer classifications.^{4,14} This suggests that

bone quality is an important factor in determining the outcome of open reduction and stabilisation of such fractures and should be strongly considered when selecting treatment for a fracture of the proximal humerus. However, this is not a controlled study and we do not have evidence that fractures with poorer bone quality would do less well if treated in this way. Future studies addressing specifically fractures with poor bone quality may answer this question.

Primary malreduction occurred when the use of a plate was necessary because of metaphyseal extension of the fracture, but malreduction was not associated with a particular type of fracture or a specific type of internal fixation.

The fracture was anatomically reduced in all the 13 cases in which bone grafts were used to support the head segment (Figs 1 to 4), but four malreductions occurred in 21 cases without bone graft, this difference was not statistically significant.

The rate of avascular necrosis (Figs 5 and 6) for these fractures was high (35%). We could not correlate the development of avascular necrosis with either the Neer type of fracture, the type of reduction, the age of the patient or other factors. Other authors have reported that the closer the medial fracture line is to the calcar, the more likely is the fracture to undergo avascular necrosis.^{30,31} This is believed to be because the capsular vessels are important contributors to vascularisation of the humeral head. The rate of avascular necrosis probably reflects the complexity of the fractures treated. If the head segment is deprived of its blood supply, then avascular necrosis will ensue regardless of technique of management. The rate of avascular necrosis of 35% in our study is perhaps less surprising than the lower rates reported in other studies. These lower rates may suggest that the classification systems were not applied identically. An alternative explanation is that the techniques used in our study predispose to avascular necrosis. Two cases of avascular necrosis were painful enough to warrant total joint replacement (Figs 7 and 8). At the time of review no other patient was under consideration for further surgery. The other ten cases of avascular necrosis suggest that the clinical results of anatomically reduced fractures of the proximal humerus which undergo avascular necrosis are functionally satisfactory and with a mean Constant score of 66 points or 76%, this is comparable to the results of hemiarthroplasty.³²

The aftercare of the patients in our series was less aggressive than that in other reports because the priority was to obtain anatomical healing rather than full early mobility. The absence of displacement of the fracture after surgery supports this approach. However, eight patients required further surgery, mostly for functional limitation. This was usually improved by removal of the implant and subdeltoid excision of adhesions.

Overall, these results confirm that the operative treatment of complex fractures of the proximal humerus gives good results, if anatomical or near anatomical reduction is obtained (Figs 9 to 11). If the bone quality, as judged by the thickness of the cortex of the proximal humeral diaphysis is good, anatomical reduction can be obtained and maintained in approximately 90% of cases. If avascular necrosis ensues, the clinical result may remain satisfactory.

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