■ ASPECTS OF CURRENT MANAGEMENT

Early management of proximal humeral fractures with hemiarthroplasty

A SYSTEMATIC REVIEW

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We performed a comprehensive systematic review of the literature to examine the role of hemiarthroplasty in the early management of fractures of the proximal humerus. In all, 16 studies dealing with 810 hemiarthroplasties in 808 patients with a mean age of 67.7 years (22 to 91) and a mean follow-up of 3.7 years (0.66 to 14) met the inclusion criteria. Most of the fractures were four-part fractures or fracture-dislocations.

Several types of prosthesis were used. Early passive movement on the day after surgery and active movement after union of the tuberosities at about six weeks was described in most cases. The mean active anterior elevation was to 105.7° (10° to 180°) and the mean abduction to 92.4° (15° to 170°). The incidence of superficial and deep infection was 1.55% and 0.64%, respectively. Complications related to the fixation and healing of the tuberosities were observed in 86 of 771 cases (11.15%). The estimated incidence of heterotopic ossification was 8.8% and that of proximal migration of the humeral head 6.8%. The mean Constant score was 56.63 (11 to 98). At the final follow-up, no pain or only mild pain was experienced by most patients, but marked limitation of function persisted.

Most fractures of the proximal humerus are either undisplaced or minimally displaced and respond well to conservative treatment, with operation required in only about 20% of cases.¹ Generally these injuries are caused by high energy in the young and low energy in the elderly. In the latter group stable internal fixation is difficult to achieve because of the presence of osteoporosis and severe comminution of the fracture.²

Older patients with three- or four-part fractures, fracture-dislocations or fractures through the humeral head with displacement are considered for hemiarthroplasty of the shoulder, with the primary aim of achieving a functional and painless joint. In younger patients with similar patterns of fracture, hemiarthroplasty is recommended when a stable and nearly anatomical reduction is not feasible.¹

The Neer prosthesis was the first to be used to replace the head of the humerus after a fracture.³ Subsequently, several other designs have become available. The first prostheses were monobloc implants, but these have been followed by modular designs, which aimed to improve the soft-tissue balance and to provide better function.⁴ The third generation of shoulder prostheses was intended not only to achieve soft-tissue balance but also to restore the bony geometry of the shoulder.^{5,6} These prostheses have successfully reproduced the

anatomy of the proximal humerus in degenerative conditions, but not in fractures.^{7,8} Prostheses intended specifically for the management of fractures have been developed which attempt to accommodate re-position, fixation and healing of the tuberosities.⁹⁻¹³

There has been much discussion in regard to the place of hemiarthroplasty in the treatment of fractures of the head of the humerus. Some authors have advocated the procedure,^{3,14-24} but others have expressed concern over its efficacy.²⁵⁻³⁰

We have therefore undertaken a comprehensive review of the literature to examine the role of hemiarthroplasty in the early management of fractures of the proximal humerus.

Materials and Methods

We carried out an electronic search of the Medline database using the PubMed search engine limited to clinical studies in man, as well as of the EMBASE bibliographical database published until January 2008. The terms hemiarthroplasty and proximal humeral fractures were entered. In addition, the appropriate MeSH terms of arthroplasty, prostheses and implants, joint prosthesis, shoulder fractures, shoulder joint, fracture bone were entered and Boolean operators were used. The query was limited to manuscripts published in English. Two reviewers (GK, CK) evaluated each

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Fig. 1

Bar chart showing the distribution of the types of fracture according to the classification of Neer.³

abstract according to the scientific content and allocated them to three broad categories, namely, relevant, possibly relevant and irrelevant. Full articles from the first two categories were retrieved. The names of the institution, authors and journal were concealed on all manuscripts to minimise the risk of bias during the review. Each eligible study was assigned a quality score by each reviewer based on the quality instrument described below.³¹

Articles were considered to be eligible for review if they met the following inclusion criteria:

- 1) Proximal non-pathological humeral fractures treated by hemiarthroplasty in skeletally-mature patients.
- 2) Not less than 15 patients reported either in the study or in the subgroup of interest in comparative studies.
- 3) A mean follow-up of at least 24 months after surgery.
- 4) At least one of the outcomes of interest namely range of movement, pain, evaluation by a functional scale, patient satisfaction and complications were described.

5) A rating of at least five of a maximum of ten points for the quality of the study using a previously published scoring system.³¹ The scoring system was based on the answer to the following five questions: Were the inclusion/exclusion criteria defined? Was the number of withdrawals or lost patients known? Was the follow-up pre-specified? Were the outcomes of interest clearly described? Did the study include pertinent characteristics, such as the technical details, the type of the prosthesis used, the use of antibiotic prophylaxis and the type of surgical approach which might affect the outcome of interest? If the answer was 'yes' to each question two points were awarded. An answer yes but without all of the required information scored one point and an answer 'no' scored no points. Two independent

readers (GK and CK) assessed the quality of the studies. Any disagreements were resolved by a consensus.

Articles which included patients treated by different surgical techniques or conservatively, and those incorporating a mixture of acute and chronic cases treated by hemiarthroplasty were included only if clearly separated data for the hemiarthroplasty group could be extracted. Articles with inconsistencies in the presentation of their data were excluded.

Statistical analysis. This was performed and recorded using Microsoft Excel 2008 for Mac (Microsoft Corp, Redwood, Washington). Because relevant information was provided differently, it was not always possible to calculate each parameter with data from all eligible studies. The number of pooled studies for each parameter was recorded. Bland-Altman analysis³² was used to assess inter-rater agreement for the quality of the published studies.

Results

The electronic search through PubMed yielded 376 citations and the electronic search through EMBASE 1187 citations by mapping to the preferred terminology, by searching also for synonyms and by exploding on the preferred terminology. From these searches 82 full articles were retrieved, considered for inclusion and subjected to further analysis. However, only 16 satisfied the inclusion criteria and received critical analysis.^{10,14,15,17-21,23,24,26,29,33-36}

There were no randomised, controlled trials or non-randomised comparative studies and the formal meta-analysis was consequently undertaken as a systematic review of the literature. For the evaluation of quality, the Bland-Altman analysis of agreement between two independent assess-

Fig. 2

Bar chart showing the type of the prosthesis used.

Table I. Details of the numbers of fractures of the proximal humerus treated per surgeon per year

Authors	Number of operations included in our review	Number of operations in described in each paper	Duration of follow-up (yrs)	Number of surgeons involved in the series	Cases per surgeon per year
Antuña et al ³³	57	85	20	20	0.21
Krause et al ¹⁰	58	82	10	5	1.64
Grönhagen et al ³⁴	46	82	13	5	1.26
Loebenberg et al ³⁵	23	23	9	1	2.55
Christoforakis et al ¹⁴	26	26	7	1	3.71
Mighell et al ²⁰	72	80	13	1	6.15
Robinson et al ²³	138	163	7	8	2.91
Demirhan et al ¹⁵	32	48	5	1	9.60
Boileau et al ²⁶	66	66	7	8*	1.17
Hawkins and Switlyk ¹⁸	20	20	7	6†	0.47

* by the supervision of one senior shoulder surgeon in eight centres

† one surgeon performed 14 operations, two attending surgeons performed three, and three surgeons performed three cases

sors was good. In ten articles there was no difference in the evaluation process and in the remaining six there was one point of difference. The 95% limits of agreement ranged from -1.1 to +1.2.

Clinical details, type of fracture, type of prosthesis. The 16 articles described 808 patients with a fracture of the proximal humerus in whom 810 humeral prostheses had been implanted. There were 230 men and 578 women with a mean age of 67.7 years (22 to 91). The mean follow-up was for 3.7 years (0.66 to 14). Most of the fractures were four-part or four-part fracture-dislocations (Fig. 1). In total 12 different prostheses were used (Fig. 2). Only one study reported exclusively on the same type of third-generation prosthesis.²⁶ In five studies^{18,21,24,35,36} only one type of first or second generation prosthesis was used, while in the remaining ten^{10,14,15,17,19,20,23,29,33,34} there was more than one type. It was not possible to relate the design of the

prosthesis to the outcome or the potential superiority of newer designs to first-generation implants. Information regarding the use of bone cement was given in 590 of 620 operations.^{10,14,15,17,18,20,21,23,24,26,29,33,34,36}

Involved surgeons. Information regarding the surgeons who implanted the hemiarthroplasties was extracted from ten publications (Table I).^{10,14,15,18,20,23,26,33-35} An estimation of the number of hemiarthroplasties for shoulder fractures performed each year by individual surgeons per year was few, with a mean of 2.96 (0.21 to 9.6) procedures.

Rehabilitation. Information regarding post-operative rehabilitation was described in 15 publications.^{10,14,15,17-21,23,24,26,29,33,34,36} Early passive movement the day after surgery, and active movement after union of the tuberosities at approximately six weeks, was described in many. In one study of 168 patients,¹⁹ treated at 12 different centres, 98.2% of the shoulders were immobilised for a mean of

Table II. Details of ranges of internal rotation after hemiarthroplasty

Authors	Number of patients	Mean internal rotation (range)
Antuña et al ³³	57	L5
Loebenberg et al ³⁵	23	L1 (L5 to T8)
Christoforakis et al ¹⁴	16	L3
Mighell et al ²⁰	71	L2 (greater trochanter to T11)
Boileau et al ²⁶	66	L3 (greater trochanter to T8)
Wretenberg and Ekelund ³⁶	18	Gluteal area (greater trochanter to L4)
Goldman et al ¹⁷	22	L2 (sacrum to T7)
Hawkins and Switlyk ¹⁸	19	11 shoulders above L2, nine shoulders sacrum to L2

Fig. 3a

Fig. 3b

Bar charts showing the degree of pain at the final follow-up after shoulder hemiarthroplasty with no pain and mild pain shown a) separately and b) together.

3.26 weeks (1 to 10), with passive movement being commenced at a mean of nine days (0 to 49) post-operatively and active movement at a mean of 30 days (1 to 180). In another study of 27 patients,²⁹ the shoulder was immobilised for three weeks. In a study of 138 patients,²³ passive movement began on the first day after operation and active movements at two weeks. Finally, Tanner and Cofield,²⁴ in a study of 16 patients, reported that half started passive movement immediately and the rest at two weeks after operation.

Range of movement. The mean active anterior elevation reported in 11 papers involving 383 patients^{14,15,17,18,20,24,26,29,33,35,36} was 105.7° (10° to 180°). The mean abduction was 92.4° (15° to 170°) in 87 patients, in four papers^{14,19,29,36} and external rotation 30.4° (-15° to +90°) in 367 patients in 11 papers.^{12,17,18,20,21,24,26,29,33,35,36} In eight papers^{14,17,20,24,26,33,35,36} involving 292 patients, internal rotation was measured actively as the highest posterior spinous process that the thumb could reach behind the back (Table II).

Pain. At the final follow-up, no pain or only mild pain was noted separately in nine papers^{14,17-19,21,24,29,34,36} in 150 patients (41.3%) and in 153 patients (42.1%), respectively (303 of 369 patients) (Fig. 3a). In five papers^{15,20,23,26,33} no pain and mild pain was seen in 145 (90.6%) of 160 patients (Fig. 3b).

Functional scoring. The Constant score³⁷ is rated as 0 to 100 and has two subjective components, pain (15 points)

and activities of daily living (20 points), and two objective components, range of movement (40 points) and strength (25 points). The mean Constant score was 56.6 (11 to 98) in eight papers featuring 560 patients.^{10,14,15,19,23,26,29,34} Three papers evaluated function, grading the results according to Neer,³ and found excellent and satisfactory outcomes in 62 of 155 patients (40%).^{15,26,33} For an excellent result the patient was required to have only slight or no pain, active anterior elevation of more than 140°, external rotation of more than 50° and to be satisfied or very satisfied with the result. For a satisfactory result the patient had to have no, slight or moderate pain only with vigorous activities, active elevation of more than 90°, external rotation to 50% of the normal side and to be satisfied with the result. Other papers used different scoring systems, such as the American Shoulder and Elbow Surgeons evaluation form,²⁰ the simple shoulder test,²⁰ the University of California Los Angeles score,¹⁸ the Hospital for Special Surgery score,²¹ a simple questionnaire for daily activities³⁶ or by performing several daily tasks.^{17,24}

Patient satisfaction. Subjective evaluation of the papers by the patients was reported in seven papers.^{18-20,24,26,33,34} The results were considered to be unsatisfactory by 121 (41.6%) of 291 patients.

Complications. An analysis of the complications was derived from 15 articles.^{10,14,15,17-21,23,24,26,29,33,34,36} (Table III). Infection was rarely reported, with only 12 cases of

Table III. Complications of hemiarthroplasty for proximal humeral fracture

Authors	Number of operations	Complications
Antuña et al ³³	57	3 re-operations, 1 symptomatic loosening (in an uncemented prosthesis)
Krause et al ¹⁰	58	2 aseptic loosening (revision), 1 peri-prosthetic fracture, 8 arthrolysis procedures for stiffness, 2 transient palsies of the axillary nerve, 13 dislocations of the tuberosities
Grönhagen et al ³⁴	46	24 superior migrations, 16 glenoid erosions, 25 ectopic bone formations, 5 displaced tuberosities
Kralinger et al ¹⁹	167	1 superficial infection, 1 deep infection, 3 anterosuperior subluxations
Christoforakis et al ¹⁴	26	3 injury-related injuries to the axillary nerve (2 recovered), 2 deep infections, 1 displacement and malunion of the greater tuberosity
Mighell et al ²⁰	72	16 tuberosity complications (most common malreduction in vertical plane), detachment of tuberosities (2 lesser), 1 deep wound infection, 1 aseptic loosening, 1 ankylosis of the glenohumeral joint, 1 reflex sympathetic dystrophy, 18 heterotopic ossifications (1 grade IV)
Robinson et al ²³	138	9 superficial infections, 3 reattachment procedures for tuberosities, 1 deep infection, 1 haematoma
Demirhan et al ¹⁵	32	2 superior placements of the humeral head, 3 insufficient reconstructions of the greater tuberosity, 1 inaccurate reduction of greater tuberosity, 2 superior migrations, 1 reflex sympathetic dystrophy, 1 transient palsy of the axillary nerve, 2 resorption of tuberosities
Boileau et al ²⁶	66	33 final tuberosity malpositions, 11 nonunions and 26 malunions of the tuberosities, 7 heterotopic ossifications, 15 proximal migrations, 3 transient palsies of the axillary nerve
Zyto et al ²⁹	27	2 post-operative infections managed with antibiotics, 1 peri-operative brachial plexus injury
Wretenberg and Ekelund ³⁶	18	1 re-operation for stiffness
Goldman et al ¹⁷	22	7 radiological loosening (3 asymptomatic), 3 superior subluxations, 3 small heterotopic ossifications, 1 superficial wound dehiscence
Hawkins and Switlyk ¹⁸	20	1 palsy of the axillary nerve, 1 malorientated prosthesis, 1 dislocation, 1 loosening (uncemented), 1 wire broken with bursitis, 1 revision to constrained prosthesis
Moeckel et al ²¹	22	1 mild superior subluxation, 1 glenoid erosion, 1 nonunion-migration of the greater tuberosity, 9 heterotopic ossifications
Tanner and Cofield ²⁴	16	1 haematoma, 4 nonunions of the tuberosities, 4 overtensionings of the rotator cuff, 5 mild ectopic ossifications

superficial and five of deep infection in 771 cases of hemiarthroplasty, a rate of 1.6% and 0.6%, respectively. Complications related to the fixation of tuberosities and healing were reported in 86 of 771 cases (11.2%). The estimated incidence of heterotopic ossification was 8.8%, but this was not found to be a significant factor limiting function of the shoulder. Only a few cases were found to have ectopic bone of any severity. The incidence of proximal migration of the humeral head was 6.8%.

Discussion

Complex fractures of the proximal humerus with severely-displaced three- and four-part fractures, fracture-dislocations, and those in which the humeral head has been split, are at risk of developing avascular necrosis, especially after internal fixation.^{38,39} If these complex fractures are managed conservatively, there is usually malunion but avascular necrosis leading to collapse of the humeral head occurs at lower rates than has been commonly believed.⁴⁰ Most patients eventually become able to perform daily activities with a relatively pain-free shoulder, although they are unable to elevate it above the horizontal position and have very limited rotation.⁴⁰ A pre-requisite for a joint-preserving surgical treatment for a fracture of the proximal humerus at risk of avascular necrosis is an anatomical reduction. If this cannot be obtained joint replacement should be considered.⁴¹ Hemiarthroplasty is currently the treatment of choice for these

complex fractures with the aim of achieving a superior outcome than with benign neglect or osteosynthesis.

The preferred surgical exposure has been through a deltopectoral approach taking care to preserve deltoid integrity.^{3,10,14,17,18,20,21,23,26,29,33,36} The anteromedial approach comprising a deltopectoral exposure and release of the clavicular and anterior acromial origins of the deltoid has been used in a few patients.^{18,24,33} The recently described anterolateral acromial approach for fractures of the proximal humerus has not been described in association with hemiarthroplasty.⁴² Early operation when the surgical anatomy is more easily displayed offers a technically easier procedure.^{3,43}

Several methods have been described for the fixation of the tuberosities around the prosthesis using either strong non-absorbable sutures^{10,17-21,23,24,26,33,34,36} or wires.^{9,10,18,19,23,24,33} The original technique as described by Neer,⁴⁴ may lead to the so-called butterfly effect which is due to the passage of sutures through the holes of the lateral fin of the prosthesis.⁴⁵ The fixation should be horizontally and vertically stable^{9,20,26,46} aiming at an anatomical appearance of the proximal humerus. Excessive retroversion of the prosthesis may result in failure of the tuberosities to heal with subsequent posterior migration of the greater tuberosity.²⁶ Failure to restore the length of the humerus after implantation may affect function of the deltoid and in cases of excessive lengthening the rotator cuff

will be stretched and squeezed under the acromion, resulting in superior migration of the prosthetic head because of failure of the rotator cuff.²⁶ The tendon of the long head of biceps is thought to depress the head of the humerus preventing superior migration in shoulders with tears of the rotator cuff.⁴⁷ The routine use of biceps tenodesis in hemiarthroplasty has been proposed because of derangement of the bicipital groove by the fracture and additional restriction of its physiological movement, making the tendon a potential source of pain.^{45,48} However, the most common complication with regard to the tuberosities was failure of fixation and nonunion. An intra-operative radiograph, before definite fixation of the tuberosities may help to reduce the incidence of malreduction.²⁶ The design of shoulder hemiarthroplasties should allow accurate positioning of the tuberosities to ensure a good functional outcome.¹¹

However, it needs to be recognised by the surgeon and patient that arthroplasty for degenerative arthritis leads to a more certain outcome than for fractures.⁴⁹

Articular fractures in general can result in a variable degree of stiffness of the joint.⁵⁰ In the shoulder this seems to be the rule. Our review illustrates that a normally functioning shoulder after a hemiarthroplasty for fracture is generally unachievable, even with an appropriately structured post-operative programme of rehabilitation.⁴⁷ Data from our review did not allow any judgement to be made on the ideal programme of rehabilitation but contrary to the classical protocol, some authors now suggest immobilisation of the shoulder until there is solid union of the tuberosities.⁵¹

Measurement of outcome is essential for evaluating any surgical procedure. However, since several scoring systems were used to assess function in the papers which we reviewed it was not possible to compare outcomes. Younger individuals have been reported to have a better prognosis than elderly patients.^{17,19,21-23,26,36} Hemiarthroplasty of the shoulder seems to result in either no or only mild pain in most patients, but this is also the result when benign neglect has been the treatment.⁴⁰ Early prosthetic replacement of the proximal humeral head after fracture leads to a better outcome than late replacement.^{46,52} Tanner and Cofield²⁴ stated that the incidence of complications was higher when surgery was delayed for more than three weeks. Mighell et al²⁰ found statistically significantly better function, judged by the American Shoulder and Elbow Surgeons score, in patients treated within two weeks in comparison with those treated more than two weeks after the initial injury. Other authors have described similar findings.^{15,21,27} By contrast, Goldman et al¹⁷ found no difference between the range of movement and the length of time to operation. Furthermore, Prakash et al²² found no significant difference in the range of movement in patients operated on within 30 days of injury compared with those operated on more than 30 days after injury. Movin et al²⁸ noted no difference in the Constant score in patients operated on within the first three weeks of injury and in those having surgery after three weeks.

These studies showed that many patients were dissatisfied following the procedure. Fortunately, severe complications such as infection, and revision due to prosthetic loosening, were unusual and heterotopic bone formation, although not uncommon, appeared to have a minimal effect on function.³⁴

Summarising the information derived from our study, it must be recognised that there is no strong scientific evidence to support the effectiveness of early hemiarthroplasty in the treatment of shoulder fractures. Our review examined case series and retrospective comparative studies which by their nature contain significant bias. The results were not presented in a manner which allowed further statistical calculation to strengthen the evidence by the use of meta-analysis. Despite these inherent weaknesses, a critical appraisal of the recorded information showed that most patients with early hemiarthroplasty for a fracture had no pain or only mild pain but also that the level of function before injury was almost never regained. The overall rate of complications was low. Although early post-operative passive movement was mainly recommended, its effect on the healing of the tuberosities was not known, which was a concern, given that malunion or nonunion was the principal problem with this procedure.

Further well-designed prospective, randomised controlled studies are necessary to answer certain questions about the value and effectiveness of hemiarthroplasty in comparison with alternative conservative or surgical treatments.

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