Relevance of the restoration of humeral length and retroversion in hemiarthroplasty for humeral head fractures

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Sixteen patients, with a fracture of the upper humerus treated with hemiarthroplasty, were followed-up for 45.7 ± 15.1 (20-72) months after surgery. The results were assessed using the Constant-Murley scale. The mean score was 75.8 ± 15.7 (54-96) points out of a possible maximum of 100. At the time of their last follow-up they underwent CT of the fractured and contralateral humerus. Humeral length and retroversion were measured and evaluated. A very good final outcome (Constant score more than 71) was achieved in patients with a difference in retroversion less than 10° and a difference in length less than 14 mm, between fractured and sound humerus. The mean difference in retroversion was 8.7° and the mean difference in length was 0.65 cm, between fractured and sound humerus. We attribute the very good clinical outcome in our series to the quality of the anatomical reconstruction that was performed.

INTRODUCTION

Most humeral head fractures are undisplaced or minimally displaced and are managed successfully by conservative means (1). The fracture type, as well as factors related to the specific characteristics of each patient, usually determine the selection of treatment. Osteosynthesis of these fractures is feasible using transcutaneous pins, or strong nonabsorbable sutures, or plates and screws. A prerequisite for a stable osteosynthesis is an efficient bone stock. Shoulder hemiarthroplasty is mainly used for the treatment of 4-part fractures and fracture-dislocations as well as for the treatment of the 3-part fractures in patients with diminished bone stock (6, 16).

After Neer's introduction of the hemiarthroplasty for fractures around the shoulder, some authors reported beneficial results with excellent pain relief and good function. In fact, there is no controversy regarding pain relief but many other authors reported poor results considering range of shoulder motion and physical activity (21, 23). The key to good functional results is believed to be anatomical reconstruction of the humeral head (2, 18).

The objective of this study was to assess whether restoration of the humeral length and retroversion, in shoulder hemiarthroplasty for fracture of the humeral head, is important for the final outcome.

PATIENTS AND METHODS

Between January 1996 and May 2001, 30 consecutive cemented shoulder hemiarthroplasties were performed

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Fig. 1. — Example of a four-part fracture dislocation of the humeral head and insufficient bone stock in a 75-year-old woman, requiring hemiarthroplasty.

Table I. — Classification of the fractures

Type of Fracture	Number of Patients
Three-part fracture	3
Four-part fracture	7
Four-part fracture dislocation	3
Head split	3
Total	16

Fig. 2. — Example of a cemented Aequalis prosthesis used for the treatment of a four-part fracture of the proximal humerus.

in patients with fracture or fracture-dislocation of the proximal humerus. Sixteen of them accepted to undergo CT scan of the fractured and the sound upper humerus, in order to evaluate the anatomical position of their prosthesis, and these patients are included in this study. There were 13 women and 3 men (mean age 62.7 ± 8.2 years, range 42 to 78 years), with a follow-up of 20 to 72 months (mean 45.7 ± 14.1 months). According to Neer's classification there were 7 four-part fractures, 3 four-part fracture dislocations (2 anterior and 1 posterior) (fig 1), 3 head splits and 3 three-part fractures (table I). Five Cofield, 7 Global and 4 Aequalis (fig 2) prostheses were implanted in these patients. All the procedures were performed between 0 and 17 days after the injury (mean 4.1 ± 4.6 days).

Under general anaesthesia, with the patient in a beach chair position, and the arm draped free beyond the edge of the table, the fracture was exposed using a deltopectoral approach. The deltoid was carefully kept intact, without damaging its origin or its fibers. The long biceps tendon was used as a guide for the groove between tuberosities. In the majority of the cases the fracture line between the tuberosities was found to be lateral to the bicipital groove. The fractured head was removed and the size of the prosthetic head was selected accordingly. Our goal was anatomic placement of the prosthesis as well as anatomic restoration of the tuberosities around the humeral prosthesis, fixing them with strong non-absorbable sutures. For most of our patients the prosthesis was implanted with the lateral fin 5 mm behind the posterior edge of the bicipital groove, in order to achieve the proper retroversion. For restoration of the length, the sound upper humerus was taken into account, but the final decision was taken intra-operatively. We used cement for implant fixation, over the whole length of the humeral stem, except the proximal part which was filled with bone grafts, in all cases. After implantation of the prosthesis, there was a full range of passive shoulder movements without any impingement.

The patients started passive shoulder flexion and external rotation the day after the surgery. The goal was

to achieve 140° passive flexion and 30° passive external rotation by the end of the 3rd postoperative week. All patients followed the same postoperative rehabilitation program at this period. When the tuberosities were healed, at 6 weeks, active shoulder motion was permitted. Thereafter it was not possible to follow a uniform rehabilitation program, due to the organisation of the rehabilitation centers in our region. Eleven patients did not follow any rehabilitation program, trying to achieve by themselves the demands of their daily living.

Temporary axillary nerve lesions, related to the injury, occurred in two patients but resolved completely.

All sixteen patients returned to the outpatient clinic and were available for an interview and a physical and radiographic examination. All were assessed using the Constant-Murley scoring system. At the time of the last follow-up, all patients underwent CT scan of the fractured and the sound humerus (3 sections on each) in order to evaluate the anatomical placement of the humeral prosthesis in relation to the sound humerus, using parameters such as retroversion of the humeral head and humeral length that were measured after image processing on CT images.

CT imaging and post processing image analysis

All 16 patients were scanned using a third-generation Computerized Tomography (CT) imager (TOMOSCAN LX, Philips). The patient's anatomical axes in all three dimensions are referred to as Head-Feet (HF), Right-Left (RL) and Anterior-Posterior (AP) axes. In all examinations patients were placed in lateral position with their HF axis parallel to the CT imager's gantry principal axis. They all entered the CT scanner head-first. Prior to any CT examination, patients were meticulously positioned on the equipment's couch. They were first positioned in lateral position with their normal arm and shoulder in contact with the equipment's couch surface. The operated arm was positioned parallel to the equipment couch surface and moved proximal to the body during the examination.

A 90° scout localiser scan was used thus depicting anatomy in the coronal plane. Two orthogonal axial slices of 3-mm thickness were obtained using the coronal localiser as a scout view. The first of the two slices was positioned at the middle of the humeral head. The second slice was positioned at the elbow. A standard high-resolution CT protocol was utilised for the acquisition of the slices (KV : 120, mA : 175, sec : 1.9). A square Field of View (FOV) covering an area of 350 X 350 mm^2 was used. The image reconstruction matrix was 512 X 512 pixels respectively to the FOV dimensions. Pixel size was therefore (350 / 512 = 0.7 mm), representing a square box of 0.7 mm size.

The whole procedure was repeated again by positioning patients in lateral position with their prosthetic humeral arm in contact with the equipment's couch surface. All patients entered again the CT scanner head-first with their normal arm meticulously positioned parallel to the equipment's couch surface.

All CT slices were transferred for further post processing analysis to an IBM compatible personal computer workstation. Spatial calibration, spatial filtering, image slice registration and overlays adequate for the purposes of this study were performed using a commercially available image processing software (Image-Pro plus, Media Cybernetics). The two corresponding slices for each humerus (fractured and sound) for each patient were then overlaid on a pixel by pixel basis in order to form a merged image for the fractured (fig 3) and the sound humerus (fig 4), with these two slices superimposed on each other.

Having these two sections on the same level the line AC is the perpendicular to the anatomical head line (LL'), the line AB the tangent elbow axis and the angle r is the retroversion of the humeral head, for the fractured humerus (fig 3). For the sound humerus (fig 4), AC is the perpendicular to the anatomical head line, the line AB the tangent elbow axis and the angle r is the retroversion of the humeral head. We used the tangent elbow axis, and not the transepicondylar axis, in our measurements, because the inter- and intraobserver variability were better using tangent elbow axis (better reproducibility of the measurements).

We calculated the length of the humerus using the scout localiser scan, for each humerus, in all patients who underwent CT evaluation.

RESULTS

Clinical evaluation

We had no complications or adverse effects during the follow-up period. The outcome was assessed during the last follow-up consultation using the Constant-Murley grade scale, by the first author. The mean score was 75.8 ± 15.7 % (54-96%). The mean flexion of the arm was 150° (90° -175°), the mean abduction was 145° (85° -170°), the mean external rotation was 30° (10° -45°). In the vast majority of cases the internal rotation cor-

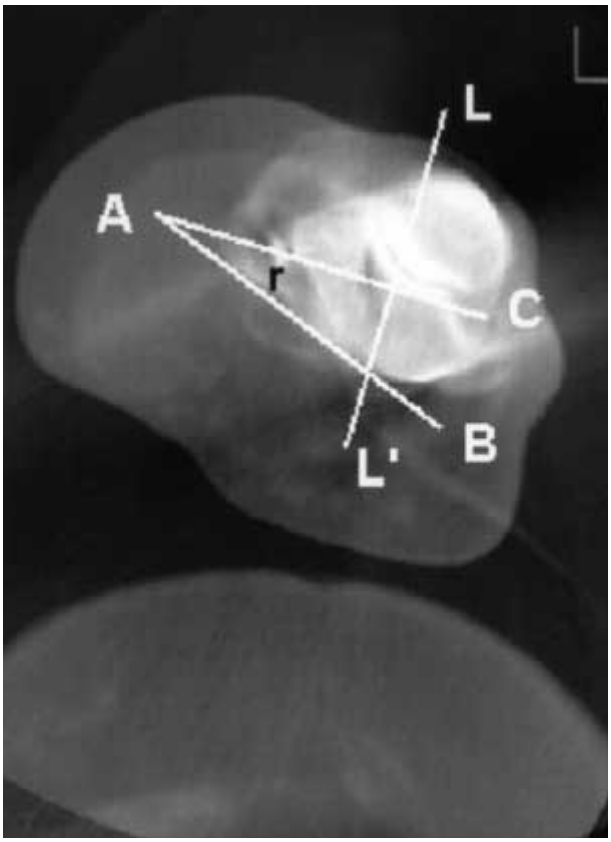

Fig. 3. — Measurement of the retroversion of the humeral prosthesis. Having the two slices on the same level the line AC is the perpendicular to the anatomical head line LL', the line AB is the tangent elbow axis and the angle r is the retroversion of the humeral head, for the fractured humerus.

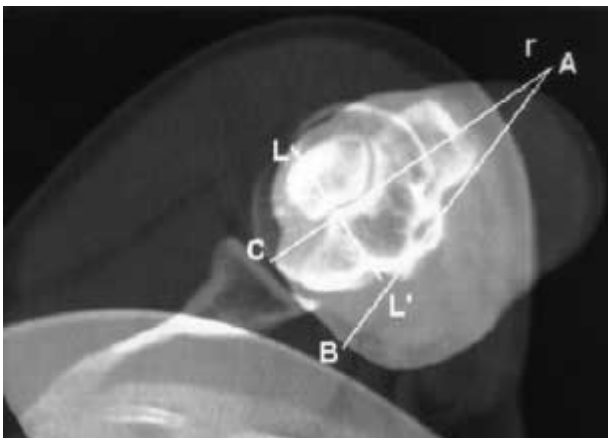

Fig. 4. — Measurement of the retroversion of the humeral head, for the normal humerus. AC is the perpendicular to the anatomical head line LL', the line AB is the tangent elbow axis and the angle r is the retroversion of the humeral head.

responded with a position of the dorsum of the hand at the L3 vertebrae.

Eleven patients (68.7%) had no pain, 4 (25%) patients had mild pain at the end of their daily activities, and one patient (6.3%) had severe pain when performing daily activities. Six months after the injury 12 out of the 16 patients (75%) had the same activity level as they had prior to the fracture. The strength of the limb of each patient was lower than the opposite healthy limb (70% of the healthy side) a fact which is generally attributed to the lack of a strengthening training program. For the patients who did not follow a formal rehabilitation program after the first six weeks postoperatively, an impairment of the clinical outcome was noted, mainly affecting the strength of the shoulder, which was less than 60% of the healthy side.

CT Evaluation

All patients underwent CT evaluation at the time of their last follow-up, 20 to 72 months (mean 45.7 ± 14.1 months) after their operation at the same day that they were evaluated with the Constant-Murley grade scale. The results of the CT imaging evaluation are summarised in table II.

DISCUSSION

The rate of avascular necrosis of the humeral head after 3- or 4-part fractures ranges between 12-25% and 41-59% respectively (10). This results in a loss of the rounded shape of the humeral head and inevitably in arthritis of the shoulder, associated with pain and limitation of function (12, 16, 17). Because of the reported high failure of both conservative treatment and resection arthroplasty, replacement of the humeral head with a prosthesis is advocated as a better alternative (16).

The results of shoulder hemiarthroplasty for fractures are very good according to some authors (4, 5, 19, 20). The Neer II humeral prosthesis has been used in the majority of cases but the use of other prostheses has resulted in similar outcomes (8, 9, 14). However, several authors report less predictable results after shoulder hemiarthroplasty

Table II. — Summary of the CT imaging results in 16 patients. Rf is the retroversion of the fractured humerus, Rs is the retroversion of the sound humerus, Lf is the length of the fractured humerus, Ls is the length of the sound humerus, Rdif is the difference in retroversion and Ldif is the difference in length between fractured and sound humerus

	Name	Constant Score(%)	Rf (°)	Rs (°)	Rdif (°)	Lf (cm)	Ls (cm)	Ldif (cm)
1.	T.E	87	32	24	8	26.7	27.1	0.4
2.	M.A	44	20	22	2	32.5	30.3	2.2
3.	K.E	89	45	44	1	29.3	29.2	0.1
4.	P.M	91	14	13.5	0.5	26	26.5	0.5
5.	S.M	63	78	26	52	27.7	27.9	0.2
6.	T.Z	59	41	19	22	34	34.8	0.8
7.	D.M	92	25	34	9	27.1	26.8	0.3
8.	B.T	84	26	23	3	26.2	26.8	0.6
9.	B.S	78	14	22	8	31.5	32.1	0.6
10.	L.P	56	29	25	4	26	27.4	1.4
11	M.K	88	40	31	9	26.4	26.5	0.1
12.	S.A	54	22	26	4	26.1	27.9	1.8
13.	P.N	71	32	26	6	32.4	31.9	0.5
14.	A.M	74	23	22	1	27.3	27.4	0.1
15.	G.M	96	32	39	7	27.6	28.2	0.6
16.	M.E	87	19	16	3	27.4	27.6	0.2
Mean		75.8	Mean Rdif : 8.7			Mean Ldif : 0.65		

for fractures or better results after conservative treatment (13, 22, 23). Despite the fact that there is satisfactory pain relief, the range of motion is not predictable after this procedure (21).

The surgical technique is the most significant factor for a good functional outcome. Poor quality of anatomical reconstruction has been correlated to poor functional results, even though there is no clinical study to confirm this opinion (2). Factors that deserve a closer look, owing to the biomechanical perturbations they generate within the glenohumeral joint and the frequency of technical errors correlated with them are : humeral height and humeral retroversion (2). In order to assess the contribution of each of these factors in the functional outcome of the shoulder after hemiarthroplasty, we performed CT evaluation in 16 of our patients who agreed to undergo this procedure, comparing these parameters in the fractured and sound upper humerus.

In our series, the difference in length between fractured and sound humerus, varied from 1mm to 22 mm (mean : 6.5 mm). Three patients with more than 14 mm difference in length between sound and fractured humerus had poor final outcome. The one patient with 22-mm lengthening had a Constant score of 44 with limited shoulder movements and severe pain on active anterior elevation or abduction. The two patients with 14-mm and 18-mm humeral shortening had a Constant score of 56 and 54 respectively, mainly due to the limited range of shoulder movements (table II). The pain score for these patients was satisfactory.

Restoration of the humeral height is essential for the proper action of the deltoid muscle, and satisfactory active abduction of the shoulder. Neer (15, 17) outlined the importance of the proper positioning of the shoulder prosthesis in regard to the height. Boileau *et al* showed that a tendency towards either shortening or lengthening the humerus exists and this influences the functional outcome (2). Evaluating our results (table II), we can note that lengthening or shortening of the humerus more than 14 mm significantly affects the Constant score, which is exponentially decreased. This is due to the improper deltoid lever arm, which does not allow normal active anterior elevation, in the case of humeral shortening. Humeral lengthening is even less well tolerated. It leads to pain and allows very limited mobility. There is

excessive impingement of the supraspinatus, which is squeezed between the prosthetic head and the coracoacromial arch (2, 18).

In terms of humeral retroversion, the difference between fractured and sound humerus, in our series, varied from 0.5 to 52° (mean : 8.7°). We have obtained good final outcome in all patients with a difference of less than 10° between sound and fractured humerus, except in those with excessive lengthening or shorthening of the humerus. For the patients with a difference in retroversion between sound and fractured humerus of more than 20°, there is deterioration in the range of movements of the shoulder. In our series, the patient with 52° and the patient with 22° excess in retroversion of the fractured humerus had limited range of movements of the shoulder but a pain free shoulder with excellent result considering pain relief.

Usually, there is a tendency to put the humeral prosthesis in excessive retroversion. This fact can be explained by three factors : the fear for anterior dislocation, the use of the forearm as a landmark, as there is a carrying angle of about 10°, but the angle may vary considerably, and failure to properly use the bicipital groove as a landmark (2, 7). It is generally recommended to select 30 to 40° of retroversion or to use the bicipital groove as a landmark for implant orientation (2, 3, 11). Excessive retroversion leads to poor reconstruction of the tuberosities with overtensioning of the posterosuperior cuff in the horizontal plane. Postoperatively the patient's arm is placed in internal rotation, which leads to pull out of the sutures and posterior migration of the greater tuberosity, with non-union and malunion (2).

In our series, it appears that patients with a difference in retroversion less than 10° and a difference in length less than 14 mm between fractured and sound humerus (11 of 16 patients, 68.7%) have obtained Constant scores higher than 71 (table II) which corresponds to a very good result. This is indicative of the great relevance of the restoration of humeral length and retroversion, in hemiarthroplasty for humeral head fracture, with respect to the final outcome.

Reviewing the literature, most of the functional results, measured using the Constant – Murley scale, for shoulder hemiarthroplasty after fracture of the upper part of the humerus are not satisfactory (21, 23). The clinical outcome in our series is one of the best outcomes in the literature. In our opinion this is mainly due to the quality of the anatomical reconstruction we achieved. In our series the mean difference in length was only 0.65mm and the mean difference in retroversion 8.7°, between the fractured and sound humerus.

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