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ORIGINAL ARTICLE

Hemiarthroplasty for proximal humerus fracture and consequences of a comminuted greater tubercle fragment

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Abstract
Background A prerequisite for a satisfying functional result in the treatment of comminuted fractures of the proximal humerus with hemiarthroplasty is anatomical reduction, fixation and healing of the tuberculi around the prosthetic neck in order to restore normal function of the rotator cuff.
Purpose This was a retrospective study to examine the outcome after hemiarthroplasty using a prosthetic stem designed to optimise re-attachment and healing of the tuberculi (Aequalis; Tornier and Global Fx, DePuy). A special emphasis was on the effect on outcome a comminuted greater tubercle might have.
Materials and methods At follow-up, clinical results were evaluated using the Constant score and WOOS index. All patients had radiographs taken of the injured shoulder. Quality of tubercle healing and prosthetic height were estimated; acromiohumeral distance was registered as well as greater tubercle comminution and resorption.
Results Thirty-four patients with 35 hemiarthroplasties were included. Mean age was 71 years (range 47–88) at the time of injury. At follow-up (mean 38 months, range 23–67), the mean Constant score was 44 points (range 18–87). The mean WOOS index was 58 (range 15–96). A comminuted tubercle was associated with tubercle resorption and superior migration of the arthroplasty. Also, there was a correlation for the functional Constant score, but for the WOOS index, there was none.
Conclusion Like several other studies, we generally saw a group of patients with limited pain but poor range of movement in the shoulder. Our hypothesis was that comminution of the greater tubercle would correlate with both rotator cuff arthropathic radiographical features and more detrimental functional scores than average. Thus, a subtype of fracture could be identified at the time of injury and perhaps be allocated to a different treatment than hemiarthroplasty. Due to a limited number of patients in this study, we are unable to make any strong statistically supported conclusions regarding this hypothesis.
Level of evidence Level 4 evidence.

Keywords Shoulder · Fracture · Tubercle · Comminution · Arthroplasty · Hemiarthroplasty

Introduction

Hemiarthroplasty is recommended for the treatment of patients with three- and four-part fractures with osteopenic bone of the humeral surgical neck, fracture dislocations and displaced fractures involving a large portion (>30 %) of the humeral head [1, 2]. Several papers have documented that the outcome of this treatment is influenced by patient age [3–7], time from fracture to surgery [1, 4] and the ability to achieve healing of the tuberculi in an anatomical position [3, 5–9]. Other papers indicate that outcome also is influenced by the ability to reconstruct correct anatomical humeral length [3, 10] and perhaps prosthetic design is important, too [5, 9, 11].

Thus, the prerequisite for a satisfying functional result is an anatomical reduction and fixation of the tuberculi around the prosthetic neck in order to restore normal function of the rotator cuff [3, 6, 9]. The Aequalis and Global Fx hemiarthroplasties are designed to optimise re-

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attachment and healing of the tuberculi. Bone grafting is necessary to facilitate tubercle healing.

In this retrospective study, we evaluated outcome after the use of hemiarthroplasty in the treatment of patients with three- and four-part fractures of the humeral surgical neck. We report and assess results and outcome for 34 patients with 35 shoulders operated on during a 9-year period with an emphasis on the role of greater tubercle comminution on outcome. To our knowledge, this is the only study so far which has specifically addressed the possibility of a comminuted major tubercle fragment to correlate with outcome of hemiarthroplasty for complex proximal humerus fractures.

Materials and methods

During a 4-year period from January 2004 to December 2007, we used the Aequalis fracture stem for all patients operated with a hemiarthroplasty for fracture dislocations and comminuted fractures of the humeral surgical neck. From January 2008 to December 2011, the Global Fx hemiarthroplasty was used instead due to a change in medicotechnical buying policies.

All patients operated within 4 weeks after the injury were included at the time of follow-up. Eighty-seven patients were operated, 34 of whom were available for a clinical and radiographical review to evaluate the effect of the operation. Eight patients had died, three patients with pseudoparalysis and severe pain were reoperated within the first 2 years after surgery having the hemiarthroplasty exchanged to a reverse prosthesis due to early failure, 27 did not wish to participate, and 15 patients were not possible to locate, leaving 34 patients for clinical follow-up one of which had both shoulders operated on.

There were 11 men and 23 women. Mean age was 71 years (range 47–88) at the time of injury. According to Neer's classification [12], the group included 8 three-part fractures, 12 four-part fractures, 12 three- or four-part fracture dislocations and 3 headsplit fractures. Twenty-five of the patients were operated within 2 weeks after injury; nine were operated within 3–4 weeks after injury. The mean follow-up period was 38 months (range 23–67).

The patients were operated by five surgeons. The surgical procedure was performed according to the recommendations published by Krishnan and Boileau [13]. However, we did not use an external fracture jig for estimation of prosthetic height and retroversion. The height and retroversion of the prosthesis were judged without instrumentation [14, 15]. The patients were referred to rehabilitation supervised by local municipal physiotherapists outside the hospital. The rehabilitation programme was designed according to the recommendations by Neer [16] who stressed early passive range of motion exercises guided by a physiotherapist. In accordance, patients started active range of movement 6 weeks after surgery if an X-ray revealed an unchanged position of the greater tubercle. Healing of the greater tubercle was observed with radiographical examinations at 2, 6 and 12 weeks after surgery and at the time of follow-up.

At follow-up, clinical results were evaluated using the Constant score and WOOS index [17, 18]. The WOOS index reflects the patient's own perception of changes in health status and thus is an indicator of the success of treatment. The questionnaire contains 19 items, each with a visual analogue response option for the 4 domains: pain and physical symptoms (six questions), sport, recreation and work (five questions), lifestyle function (five questions) and emotions (three questions). Since 2005, the WOOS index has been used in the Danish National Register for Shoulder Arthroplasty [19]. The WOOS index offers a subjective evaluation of quality of life following treatment, and we found it to be useful as a supplement to the Constant score. Like Constant score values, the WOOS index values are adjusted and reported as a percentage of normal.

All patients had two X-rays taken of the injured shoulder including anterior-posterior projections in neutral and internal rotation and 1 anterior-posterior projection in neutral rotation of the contralateral shoulder. A metal ruler was affixed to both upper arms to measure relative lengths of the upper arms. Prosthetic height was considered correct when the difference between humeral lengths was less than 10 mm [3, 10]. The acromiohumeral distance (AH) was measured from the summit of the prosthetic head to a line of sclerosis at the under-surface of the acromion. AH was measured on an AP view in neutral rotation. When the AH was less than 7 mm, the rotator cuff was considered deficient [3].

Healing of the greater tubercle was considered anatomical when positioned 5–10 mm below the summit of the prosthetic head and visible on the AP-projection in neutral rotation [3]. When the greater tubercle had healed in a non-anatomical position relative to the prosthesis or was seen only on the internally rotated projection, the healing was considered a malunion. In cases where the greater tubercle was seen on neither neutral nor internal rotation projections, the greater tubercle was considered resorbed. Comminution of the greater tubercle was defined as the fragment being separated in two or more parts with the smaller fragment amounting to at least 25 % of the tubercle on any projection. X-rays were independently evaluated by authors SH and AU with full interobservational consistency.

Results

Data on 34 patients operated with a hemiarthroplasty for a comminuted, displaced fracture of the proximal humerus are presented in Table 1. At follow-up, the mean Constant score and WOOS index values for the whole group were 44 (range 22–87) and 58 (range 15–96). For the following subgroups, the Constant and WOOS values were: 26 shoulders operated on within 2 weeks, 46 (range 22–87) and 60 (range 15–95), respectively; 9 shoulders operated 2–4 weeks post-injury, 41 (range 33–54) and 57 (range 38–95); 21 shoulders above 70 years, 43 (range 33–87) and 59 (range 38–95); 14 shoulders below 70 years, 40 (range 22–76) and 56 (range 15–77); two patients developed a non-union of the greater tubercle; 21 shoulders displayed union or malunion of the greater tubercle, 46 (range 21–87) and 57 (range 27–95); and 27 shoulders with a comminuted greater tubercle, 42 (range 18–76) and 58 (range 15–96).

In 12 shoulders, the greater tubercle resorbed; 36 (range 18–54) and 62 (range 35–77). Of the 12 shoulders with

Table 1 Patients and results

ID	Sex	Age	F–S	GT	GT comminution	Migration	Length	Constant score	WOOS index	AAE
1	Female	73	7	Mal	−	−	2	87	95	140
2	Male	71	8	Union	+	−	−1	76	95	110
3	Female	81	15	Resorb	+	+	14	54	57	55
4	Male	74	3	Mal	+	+	8	55	59	50
5	Female	88	22	Non	+	+	40	33	38	50
6	Female	60	2	Mal	+	+	−4	64	67	75
7	Female	86	19	Union	+	+	−2	52	49	60
8	Female	61	21	Resorb	+	+	−5	50	77	45
9	Male	68	11	Non	+	+	8	22	15	25
10	Male	47	1	Mal	+	+	5	34	42	65
11	Female	63	7	Resorb	+	−	−9	29	56	55
12	Male	81	14	Union	+	+	12	56	51	110
13	Female	72	9	Mal	+	+	29	43	51	80
14	Female	84	5	Mal	+	−	−2	38	41	75
15	Male	57	14	Union	−	−	22	49	33	85
16	Male	63	16	Resorb	−	−	17	46	67	70
17	Female	66	6	Union	−	+	10	76	66	115
18	Female	72	21	Resorb	+	+	23	43	58	50
19	Male	75	7	Mal	+	+	18	42	55	55
20	Female	63	5	Union	−	−	5	32	27	71
21	Female	63	8	Mal	+	+	−16	45	96	92
22	Female	74	26	Union	−	+	13	21	43	24
23	Female	67	15	Resorb	+	+	6	43	76	40
24	Male	72	19	Mal	−	−	−3	28	48	74
25	Male	87	4	Mal	−	+	18	28	80	32
26	Female	79	2	Resorb	+	+	0	18	35	71
27	Male	77	14	Resorb	+	+	3	26	61	45
28	Male	77	14	Resorb	+	+	0	22	61	30
29	Female	59	5	Union	+	−	20	50	47	104
30	Female	71	3	Union	+	+	7	64	92	132
31	Female	78	2	Resorb	+	+	14	33	18	33
32	Female	48	11	Resorb	+	+	11	41	46	73
33	Female	79	7	Union	+	+	0	44	72	83
34	Female	77	14	Union	+	−	8	33	94	115
35	Female	59	2	Resorb	+	+	6	30	61	70

F–S, fracture to surgery (days); GT, greater tubercle; Union, union; Mal, malunion; Resorb, resorption; Non, non-union; Migration, migration of the prosthesis; −, no migration (AH < 7 mm); +, superior migration (AH > 7 mm). GT comminution: +, greater tubercle fractured into more than one segment; −, no comminution. Length, length difference in millimetres (healthy-fractured arm); AAE, active anterior elevation (degrees)

resorption of the greater tubercle, 11 had a comminuted tubercle (92 %). Twenty-three of 27 (85 %) shoulder arthroplasties with a comminuted greater tubercle had migrated superiorly at follow-up. Three of eight (38 %) shoulder arthroplasties with non-comminuted greater tubercles had migrated superiorly at follow-up. The average age in the comminuted greater tubercle group was 69 years (range 48–81).

The mean Constant score values for pain for all patients was 9.8 out of 15 (range 3–15 points). Only one patient reported severe pain, and five patients reported no pain. For ADL, the mean score was 7.4 out of 20 points (range 8–20) and for ROM 8.7 points out of 40 (range 4–34) with an average active anterior elevation (AAE) of 70° (range 24–140). Mean value for strength was 5.5 out of 25 (range 0–22). For shoulder arthroplasties with a comminuted greater tubercle, the mean Constant score for strength was 4.9 (range 0–22). Shoulder arthroplasties with non-comminuted greater tubercles had a mean Constant score for strength of 7.6 (range 0–18). Mean WOOS score value for symptoms was 67 (range 30–98), for recreation and work 46 (range 0–95), for lifestyle 51 (range 17–100) and for emotions 58 (range 0–100).

Complications

One patient had a superficial infection requiring antibiotics, and one patient had a deep infection requiring debridement of the joint followed by prolonged antibiotic treatment. One patient with a fracture dislocation sustained a lesion to the axillary artery and nerve plexus due to the trauma. After implantation of the hemiarthroplasty, the patient was immediately transferred to another hospital for vascular surgery. The circulation was successfully restored. The neurological injury partially healed leaving a sensory deficit to the ulnar nerve.

Statistics

Because of the small sample size, we cannot regard the distributions of data to be normal. Also, there were only eight patients with a non-comminuted tubercle which is too small a sample for a statistically viable comparative study. The study was under-powered. Therefore, the results are reported in a descriptive way.

Discussion

The Aequalis fracture stem has potential design benefits; a smaller implant with less metal proximally and fenestration in the prosthetic metaphysis to allow solid bone grafting and better bony tuberosity contact and increased medial stem offset to provide more space for positioning of the tuberosities without increasing tension in the rotator cuff. Results published by Krishnan et al. [20] show significantly better results in patients treated with the Aequalis fracture stem. In that study and in the later results published by Boileau et al. [21], patients obtained more than 130° AAE and an 80–90 % healing rate of the greater tubercle.

Other studies by Kralinger and Loew [6, 9] using the Aequalis fracture prosthesis have not been able to reproduce the same results shown in the studies mentioned above. They only found a 50 % healing rate of the greater tubercle. The patients in the study by Loew [9] had an average AAE below horizontal and a Constant score of 44.6. Our results for the Aequalis prosthesis are similar to those results and others using different prostheses [11, 22]. Comparing the two used fracture stems, the Constant score and WOOS index for the Aequalis stem were 50 and 56 versus 35 and 68 for the Global Fx stem.

Based on a systematic review, Kontakis [23] concluded that normal range of motion was not regained by far for the patient group regardless of type of fracture hemiarthroplasty, but most patients had only mild or no pain. Our 35 shoulders had a mean Constant score of 44, with an average AAE of 70° and a greater tubercle healing rate of 60 %, but only 52 % of these healed in an anatomical position. Thirty-four per cent of greater tubercles resorbed.

Possible reasons for inferior results compared to Krishnan and Boileau [20, 21] could be the small number of procedures performed by some of the surgeons. In our study, the 87 procedures were performed by five surgeons, only two of whom did more than four procedures per year. Kralinger [6] found that surgeons performing less than four procedures per year had a significantly worse healing rate of the greater tubercle. In Krishnan's study [20], all 170 patients were treated by one surgeon.

The Aequalis group recommends the use of an external fracture jig to estimate the height and retroversion of the prosthesis [13]. Using their external fracture jig, Boileau et al. [13] found that it allowed positioning of the prosthesis within a precision of +5 to −5 mm, while "eyeballing" positioning allowed less precision ($p = 0.025$). During implantation of the prosthesis, we estimated height and retroversion by "eyeballing". An anatomical study [10] concluded that length of the reconstructed humerus was to be considered normal if the difference to the contralateral humerus was plus/minus 10 mm or less. In this respect, we were only able to reproduce a correct humeral length in 21 out of 35 patients using "eyeballing" technique. Of the remaining 14 patients, 13 had a prosthesis that was set too low. One of our patients had a prosthesis that was positioned too high.

Early onset and correct post-operative rehabilitation are important to obtain a good outcome [16]. In our study, the

rehabilitation was supervised by local primary care physiotherapists. The frequency of supervised training was unknown. The quality of the rehabilitation and the compliance of these elderly patients were unknown and therefore questionable.

Judged from preoperative radiographs, we found a comminuted fracture of the greater tubercle in 27 out of the 35 shoulders (77 %). At follow-up, the greater tubercle was resorbed in 12 of these patients (44 %). Of the 27 hemiarthroplasties with a comminuted greater tubercle, 23 migrated proximally (85 %). In our study, a comminuted fracture of the greater tubercle had a negative impact on radiographical migration of the prosthesis and tubercle bone healing due to a high resorption rate. These observations correlated somewhat on functional outcome with Constant scores but not on a WOOS index. Also, a comminuted fracture of the greater tubercle had a negative impact on the Constant score for strength.

Preoperatively, our X-rays were described by a radiologist and the surgeon and were graded according to the Neer classification system. Classification was interesting but did not change the indication for surgery per se where important selection criteria were a relevant history, severe shoulder pain and no comorbidities or mental deficiencies precluding surgery.

Our results bring the recommendations by Neer [2, 12] into question whether all surgically treated comminuted fractures of the proximal humerus should be treated with a hemiarthroplasty. Recent studies [24–27] indicate that a reverse prosthesis might be an option for patients above 75 years of age who sustain this severe fracture, but further studies are needed to elucidate this problem.

Conclusion

Like in several other studies [4, 6–8, 23], we generally saw a group of patients with little or no pain, but with a poor range of movement. Our study contains a limited number of patients, and we therefore are unable to draw any certain conclusions or recommendations concerning treatment of these difficult fractures.

The problem with comminution is that it is technically challenging to fix the tubercle to the stem. Also, comminution is a result of a particularly significant trauma to a weak, likely osteopenic bone that could be associated with more devastating destruction of the local blood supply than in non-comminuted fractures. Our hypothesis was that comminution of the greater tubercle would correlate with both rotator cuff arthropathic radiographical features and more detrimental functional scores than average. Thus, a subtype of fracture might be identified at the time of injury that could have a predictable particularly inferior outcome. Perhaps such fractures could then be allocated to a different treatment than hemiarthroplasty.

Comminution features showed a correlation with rotator cuff arthropathic features and bone resorption. We find this important because those findings demonstrate how the head of the humerus could not be centred in the cavitas in that patient group, in reality indicating a dysfunctional rotator cuff. Also, there was some correlation functionally on Constant scores with a tendency towards particularly inferior outcomes for the fractures with comminuted greater tubercles. To our knowledge, this is the only study which has addressed the possibility of a comminuted major tubercle fracture fragment to specifically correlate with inferior outcome results of hemiarthroplasty after complex proximal humerus fractures.

We find that more high-level statistical studies with a higher rate of inclusion are relevant to determine an association as hypothesised with more certainty. If the presented tendency could be supported statistically from a high-yield, large randomised study, this could point surgeons towards choosing other options for such a subtype such as no surgery or a reverse arthroplasty [28–30]. Such information would also give the surgeon and patient with such a fracture a more clear and precise prognosis for outcome.

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Compliance with ethical standards

Conflict of interest None.

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