



# Reverse shoulder arthroplasty for acute fractures in the elderly: is it worth reattaching the tuberosities?

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**Hypothesis:** Reverse Shoulder Arthroplasty (RSA) may be indicated in displaced proximal humerus fractures in elderly patients. We hypothesized that tuberosity fixation and healing around the prosthesis would result in better outcomes and patient satisfaction.

**Methods:** Thirty-eight acute displaced or dislocated 3- and 4-part fractures in elderly patients were treated with reattachment of the tuberosities around a RSA. The mean age at surgery was  $80 \pm 4$  years (range, 70–88 years). A specific reverse fracture stem that incorporated a cancellous bone autograft (harvested from the fractured head) and a standardized suturing technique for tuberosity fixation were used in all operations. Patients were evaluated and radiographed with a minimum 2-year follow-up (mean  $36 \pm 8$  months).

**Results:** The tuberosity union rate was 84% (32 of 38). There were 4 tuberosity resorptions and 2 tuberosity migrations with nonunion, which were associated with significantly lower subjective results (Subjective Shoulder Value of 65% vs. 83%,  $P = .029$ ) and lower active mobility in forward elevation ( $115^\circ \pm 26^\circ$  vs.  $141^\circ \pm 25^\circ$ ,  $P = .023$ ) and external rotation ( $11^\circ \pm 12^\circ$  vs.  $27^\circ \pm 12^\circ$ ,  $P = .010$ ). Among the 5 disappointed patients, 3 presented with tuberosity resorption and 2 with tuberosity migration and nonunion.

**Conclusions:** Despite the advanced age of the patients, tuberosity reattachment and use of bone graft results in a high rate of tuberosity healing. Tuberosity reconstruction and healing in reverse shoulder arthroplasty for fractures improves active forward elevation, external rotation, and patient satisfaction.

**Level of evidence:** Level III; Retrospective Cohort Design; Treatment Study

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**Keywords:** Proximal humeral fractures; reverse shoulder prosthesis; tuberosity nonunion; malunion or migration; complications; elderly patient

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The results of hemiarthroplasty (HA) for displaced 3- and 4-part proximal humeral fractures (PHFs) in patients older than 70 years have been disappointing and unreliable.<sup>3,7,11,22</sup> This has been attributed to poor tuberosity healing, associated comorbidities, and inability to comply with rehabilitation.<sup>24</sup> As a result, reverse shoulder arthroplasty (RSA), originally designed to treat shoulder pseudoparalysis associated with cuff tear arthropathy,<sup>1,6,12,19</sup> has been more and more indicated to treat displaced 3- and 4-part PHFs in the elderly population.<sup>8,9,11,12,16,21,23-25,27,29-31,33</sup> However, preliminary data have suggested that in case of tuberosity malunion, migration, or resorption (up to 50%), restoration of external rotation strength is rarely achieved, making all activities of daily living (ADLs) difficult, if not impossible.<sup>6-8,9,11,12,16</sup>

The main advantage of the RSA over HA, when treating acute displaced PHFs in the elderly is that even in the absence of tuberosity healing, the patient remains able to elevate or abduct the arm, or both.<sup>8,21,23-25,27,29,33,35</sup> Some authors have recommended not reattaching or even excising the tuberosities when treating PHFs with a RSA<sup>11,12,16,21</sup>; however, severe complications, such as instability, infection, and implant loosening, have been reported when the tuberosities do not heal around the reverse stem.<sup>9,16,21,23,24,27-29,34,35</sup> Although recent studies have shown that tuberosity healing in the elderly is associated with better range of motion and function,<sup>13,17,20,32</sup> the rates of tuberosity healing vary from 40% to 84% in this elderly population. Thus, a question still remains and needs to be answered: is it worth reattaching the tuberosities in RSA for acute fractures in the elderly?

This study was undertaken to investigate whether tuberosity fixation and healing would result in better outcomes in an elderly population presenting with displaced PHFs treated with RSA. We hypothesized that tuberosity healing could be reproducibly obtained even in elderly patients and would result in improved shoulder function and patient satisfaction.

## Materials and methods

### Study design

A retrospective cohort study was performed. The inclusion criteria were (1) a dislocated or displaced acute 3- and 4-part fracture (according to the Neer classification<sup>26</sup>), (2) in patients at least 70 years old, (3) treated with a specific reverse-fracture stem with bone grafting and a standardized technique of fixation, and (4) a minimum clinical and radiologic follow-up of 24 months. Patients with fracture sequelae (fractures older than 6 weeks), failed previous open reduction and internal fixation, or failed previous HA for fractures were excluded.

From July 2008 to April 2011, 54 consecutive patients (55 shoulders) aged older than 70 years met the inclusion criteria and underwent RSA to treat an acute dislocated or displaced 3- or 4-part PHF. Of these patients, 12 (22%) died before the 2-year follow-up, 9 were too weak to come back, and 6 were lost to follow-up. Overall, 37

patients (38 shoulders) were reviewed and radiographed with a minimum 2 years of follow-up.

### Surgical procedure

All surgeons used the Aequalis Reverse-Fracture prosthesis (Tornier, Edina, MN, USA). Prosthesis implantation was performed with the help of a specific instrumentation to control height (with a sliding ruler) and retroversion (with a version rod aligned on the forearm). A standardized technique for tuberosity fixation with 4 horizontal cerclages and 2 vertical tension-band sutures was used.<sup>3-5,7</sup>

The design modifications of the reverse-fracture stem (compared with the conventional reverse stem) are as follows: (1) there is less metal at the level of the neck, with a window to allow incorporation of a cancellous bone graft (harvested from the fractured head); (2) the medialized and low-profile design allows more room for lateral bone grafting and for lateral anatomic placement of the greater tuberosity (GT); (3) the medial neck is smooth and polished (to prevent abrasion and breakage of cerclage sutures), and (4) the lateral neck is hydroxyapatite coated to allow osseointegration and bone healing around the stem. The instrumentation includes a version rod and a sliding ruler, enabling restoration of humeral retroversion and length.

The prosthesis was implanted through a superior transdeltoid approach in 34 patients and a deltopectoral approach in 4. The supraspinatus tendon was systematically excised and the long head of biceps tendon tenodesed. Two specially shaped cancellous bone grafts were harvested from the fractured head using specific instruments. One graft was placed into a specially shaped window in the prosthesis and the other graft between the GT fragment and the fin of the prosthesis at the tuberosity repair (Fig. 1). Six double-looped NiceLoops sutures (Tornier) were used for tuberosity fixation: 2 were placed in the infraspinatus, 2 in the teres minor, and 2 in the diaphysis through drill holes made in the lateral humerus.

After careful retraction of the tuberosities, reaming of the glenoid surface was performed with a cannulated reamer inserted over a guidewire, and a central hole for the glenoid peg was drilled. The baseplate was impacted and secured in place with 4 screws (2 compression and 2 locking). The diameter of the glenosphere was chosen to best fit the patient's anatomy: a 36-mm-diameter glenosphere was generally used in women and smaller men, and a 42-mm glenosphere was used for larger men. The stem diameter corresponded to the diameter of the last broach used. The retroversion was set at 20° by aligning the version rod to the forearm.

The GT fragment was reduced on the lateral aspect of the stem by pulling on the 4 horizontal sutures placed in the external rotator cuff tendons. The prosthetic height was determined according to the GT reduction: the optimal prosthetic height was achieved when the summit of the prosthesis (ie, the metallic cup) was positioned level with, or just above, the reduced GT. Once the correct height had been determined, the sliding ruler was used to reproduce this height for the definitive prosthesis. After confirming all measurements, the definitive implant (with the 2 shaped cancellous grafts) was placed on the fracture jig and distally cemented into the humeral diaphysis.

The tuberosity reconstruction and fixation were performed with the 6 sutures previously placed and was made in 3 steps (Fig. 2): (1) reattaching the GT with 2 horizontal cerclage sutures, (2) joining



**Figure 1** Bone grafting around a specific reverse-fracture stem. Two shaped cancellous bone grafts (harvested from the fractured humeral head) are used: 1 graft is inserted inside the fenestration, and the other is sutured laterally to the fin of the specific reverse-fracture stem.

the lesser and greater tuberosities with 2 additional horizontal cerclage sutures, and (3) neutralizing the construct with 2 vertical tension-band sutures (1 stabilizing each tuberosity).

The 4 horizontal cerclage sutures already passed through the cuff tendons were passed around the neck of the stem before prosthesis reduction. The arm was placed in neutral rotation, a clamp was used to pull on the GT to its anatomic (lateral) position over the stem, and the sutures were tightened with the arm in neutral rotation. The 2 remaining horizontal sutures were then passed through the subscapularis tendon and used to perform 2 additional horizontal cerclages. Two tension-band sutures were then performed with the sutures placed in the diaphysis: 1 tension-band was anterior for the subscapularis and the other was posterior for the infraspinatus. Finally, the anterior deltoid was securely reattached to the acromion using absorbable transosseous sutures (Looped PDS; Ethicon, Somerville, NJ, USA).

### Postoperative care

A standardized postoperative protocol with early passive motion was used. The arm was rested in a neutral rotation sling to minimize tension on the tuberosity and deltoid repairs for 4 weeks. Self-directed rehabilitation with pendulum exercises was started at day 1 (5 times a day, 5 minutes each session). The sling was removed after 4 weeks, and formal rehabilitation with a physiotherapist began. Pool therapy was encouraged. No heavy lifting was allowed until 12 weeks postoperatively to ensure that solid bony union of the tuberosities had been obtained. Return to all activities, including

gardening and leisure sports, such as golf, tennis, and hunting, was permitted 3 to 6 months postoperatively.

### Clinical assessment

All patients were evaluated at 3, 6, 12, and 24 months after the operation and then annually. Active mobility was recorded in active forward elevation and internal and external rotation. Shoulder function was assessed using the Constant scoring system and the Subjective Shoulder Value (SSV).<sup>14,15,18</sup> Overall subjective patient's satisfaction was evaluated using a 4-grade scale (very satisfied, satisfied, disappointed, very disappointed).

### Radiologic assessment

Routine postoperative radiographs of the operated-on shoulder were obtained at each visit, including anterior/posterior and lateral views. The bone graft and tuberosity healing was analyzed according to the radiologic criteria that has been used for tuberosity union in HA.<sup>3,7</sup> The GT was considered as anatomically consolidated when it was visualized on the anteroposterior view in neutral rotation and united with the humeral shaft. In addition, 15 patients agreed to a computed tomography scan (performed at least 6 months after surgery) to confirm tuberosity healing. Radiographs were also examined for evidence of radiolucent lines around the components and inferior ossification or spurs. Inferior scapular notching was classified according to the Nérot-Sirveaux system.<sup>30,31</sup>

### Statistical analysis

The distribution of data was analyzed with the d'Agostino-Pearson test. Due to the relatively small sample size, a nonparametric test (Mann-Whitney) was used to determine the differences in clinical outcome and active ROM between the group with GT anatomic healing and the group with GT migration/resorption. The significance level was set at 0.05.

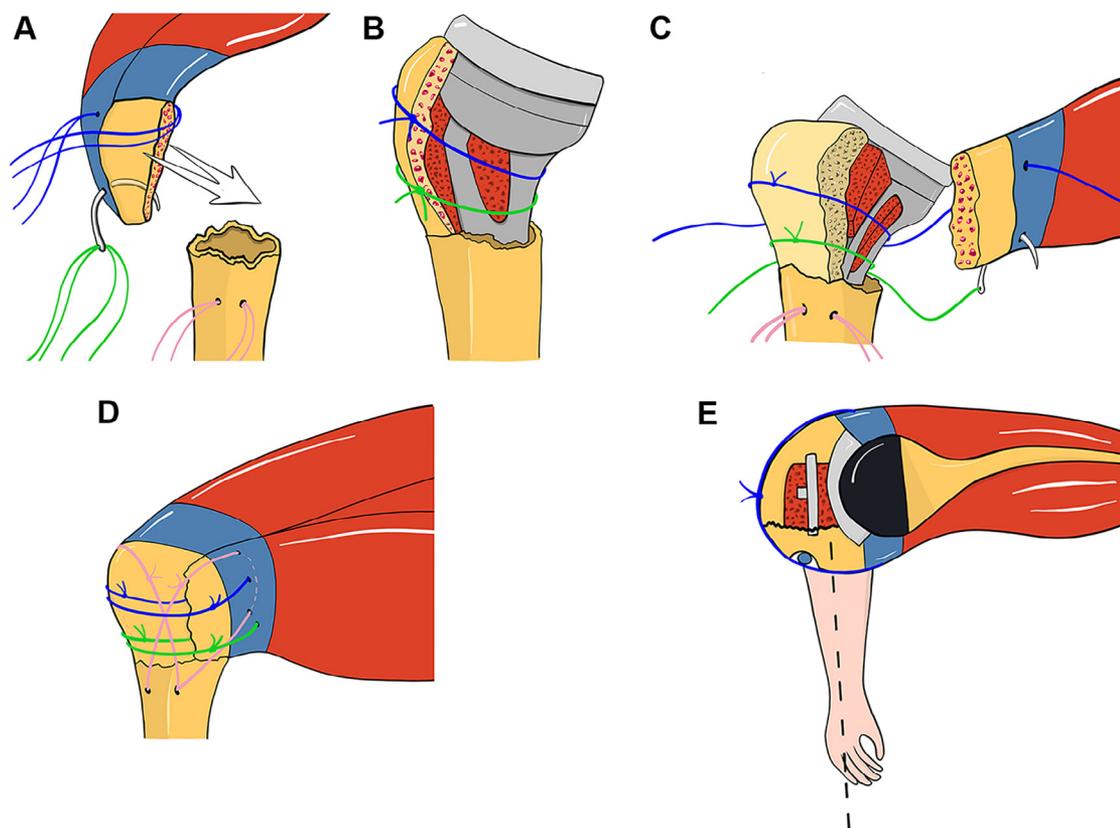
## Results

### Patient population

Thirty-seven patients (38 shoulders) aged older than 70 years underwent RSA to treat acute displaced PHFs and were evaluated and radiographed with a minimum 2 years of follow-up. The mean follow-up was  $36 \pm 8$  months (range, 24-59 years). There were 33 women (92%) and 4 men with a mean age at surgery of  $80 \pm 4$  years (range, 70-88 years). The interval between injury and surgery averaged  $7 \pm 5$  days (range, 0-23 days). The dominant side was involved in 24 shoulders (63%). According to the Neer classification, the fracture was 4-part in 32 shoulders, and 3-part in 6.

### Complications

Two temporary early postoperative complications occurred, and both were treated medically: 1 patient had a hematoma



**Figure 2** Tuberosity fixation around a reverse-fracture shoulder arthroplasty. (A) Two loop sutures are passed through the infraspinatus and 2 others (of different colors) through the teres minor to perform 4 horizontal cerclages, and 2 sutures are passed through holes drilled in the diaphysis. (B) The first 2 cerclages are used to fix the greater tuberosity. (C) The remaining sutures are passed through the tendon of the subscapularis to fix the lesser tuberosity. (D) Final intraoperative aspect with the 4 horizontal cerclages and the 2 vertical tension-band sutures. (E) Axial view shows that the greater tuberosity fragment must be placed on the lateral fin of the prosthesis (ie, it must not be left posterior).

along the upper limb, and another had a pulmonary embolism. At the last follow-up, no other complication was recorded: no prosthetic instability, infection, or implant loosening was encountered, and no patients required further surgery.

### Functional results

The functional outcomes for the 38 shoulders are summarized in [Table I](#). Nine patients had some comorbidity (diabetes mellitus in 5, Parkinson disease in 1, and Alzheimer disease in 3). With the numbers available, none of these comorbidities had any influence on the functional results.

### Tuberosity healing

Despite the advanced age of the patients, the use of bone graft incorporated inside a specific reverse fracture stem resulted in a high rate of tuberosity healing and good functional results: 32 of the 38 shoulders (84%) had complete GT healing ([Fig. 3](#)). Four patients presented with tuberosity osteolysis and 2 with tuberosity migration and nonunion ([Fig. 4](#)). Radiolucent lines were observed around the humeral implant in

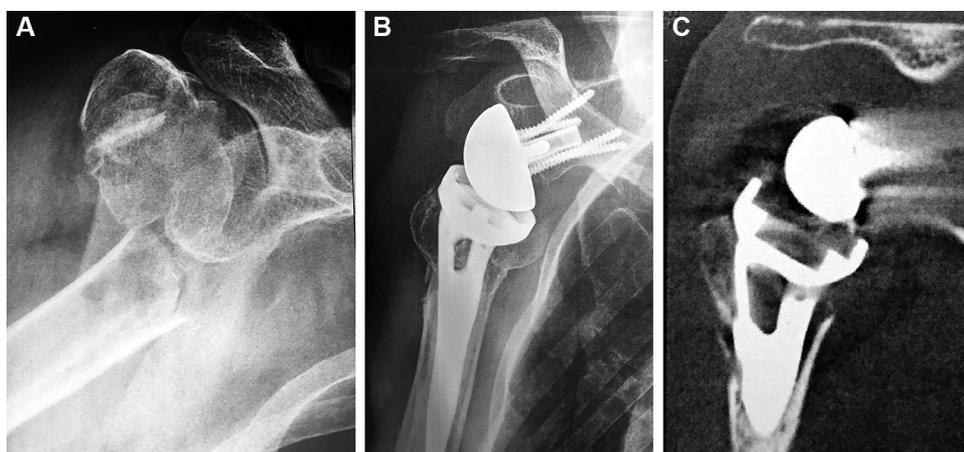
**Table I** Functional results

Variable	Mean $\pm$ SD (range)
Constant and Murley scores	
Pain	14 $\pm$ 3 (7-15)
Activity	16 $\pm$ 4 (9-20)
Mobility	27 $\pm$ 8 (12-40)
Strength	7 $\pm$ 5 (0-20)
Constant score	64 $\pm$ 15 (25-80)
Adjusted Constant score, %	93 $\pm$ 23 (45-142)
Active shoulder mobility	
Anterior elevation, $^{\circ}$	135 $\pm$ 29 (40-180)
External rotation, $^{\circ}$	24 $\pm$ 14 (0-50)
Internal rotation, points*	5 $\pm$ 3 (2-10)

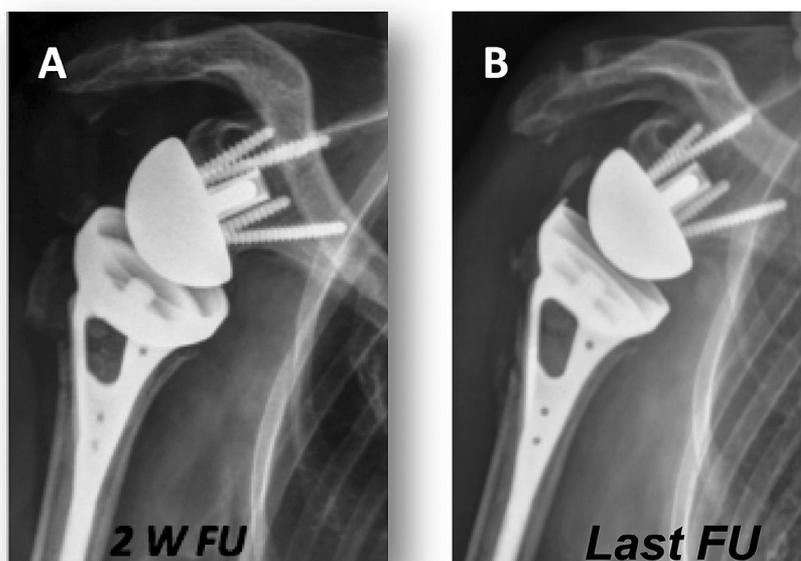
SD, standard deviation.

\* Active internal rotation scored as greater trochanter = 0; but-tocks = 2; sacrum = 4; L3 = 6; Th12 = 8; Th7-8 = 10.

2 patients: 1 demonstrated partial lines, and the other had a complete radiolucent line (<1 mm) around the prosthesis. However, the radiolucent lines did not progress over time in these 2 patients, and no stem migration occurred.



**Figure 3** Example of tuberosity reconstruction and healing. (A) Four-part fracture in a 82-year-old patient. (B) Postoperative anteroposterior radiograph and (C) axial computed tomography scan cut demonstrate complete tuberosity healing after reverse-fracture prosthesis with tuberosity grafting and fixation. The cancellous bone grafts placed in the prosthetic window and create a lateral bone bridge between the tuberosities to facilitate their healing.



**Figure 4** Example of tuberosity migration and lysis after reverse shoulder arthroplasty for acute fracture. (A) The greater tuberosity is present on postoperative x-ray images 2 weeks after surgery. (B) At 36 months after surgery, the greater tuberosity has migrated posteriorly and is partially lysed.

The difference in functional results between the patients with anatomic GT healing compared with those in whom it migrated, resorbed, or nonunited are summarized in [Table II](#). Patients with tuberosity nonunion or osteolysis achieved lower active forward elevation and external rotation.

### Patient satisfaction

At the last follow-up, 87% (32 of 37) of patients were satisfied or very satisfied with the results of the procedure. Five

patients were disappointed: 3 presented with tuberosity osteolysis and 2 with tuberosity nonunion. Their main complaint was an inability to maintain elevation, either in flexion or abduction.

### Scapular notching and spur formation

Eighteen cases of inferior glenoid notching (grade 1 or 2) were identified, and glenoid spur formation was observed in 10 patients. There was no significant difference in shoulder mobility

**Table II** Functional results according to greater tuberosity healing

Variable	Greater tuberosity		P value
	Anatomically healed (n = 32)	Migrated/resorbed (n = 6)	
Age at surgery, yr	79 ± 4 (70-88)	81 ± 4 (78-88)	.28
Female, %	88	100	1
Constant score			
Pain	14 ± 1 (11-15)	13 ± 2 (9-15)	.11
Activity	16 ± 8 (0-20)	13 ± 6 (7-20)	.90
Mobility	28 ± 7 (6-38)	22 ± 10 (10-32)	.015*
Strength	6 ± 3 (0-12)	3 ± 2 (0-6)	.06
Constant score (/100 points)	64 ± 15 (28-80)	51 ± 12 (30-73)	.018*
Adjusted Constant score, %	92 ± 22 (45-142)	84 ± 30 (52-132)	.62
Subjective Shoulder Value, %	83 ± 15 (50-100)	65 ± 15 (40-80)	.029*
Satisfied or very satisfied	75	20	.014*
Active shoulder mobility			
Anterior elevation, °	141 ± 25 (50-170)	115 ± 26 (90-150)	.023*
External rotation, °	27 ± 12 (0-50)	11 ± 12 (0-30)	.010*
Internal rotation, points <sup>†</sup>	5.2 ± 2.7 (2-10)	4.3 ± 1.5 (2-6)	.42

Continuous data are presented as mean ± standard deviation (range) and categorical data as percentage of patients.

\* Statistically significant result ( $P < .05$ ).

† Active internal rotation scored as greater trochanter = 0; buttocks = 2; sacrum = 4; L3 = 6; Th12 = 8; Th7-8 = 10.

and function in these patients when compared with the rest of the series.

## Discussion

The unreliable results achieved with HA in elderly patients have prompted attempts at treating these patients with the RSA.<sup>8-11,13,17,20,22-24,27,29-34</sup> The need and potential benefits of tuberosity fixation and healing around such implants remain controversial, and low rates of tuberosity healing (as low as 40%)<sup>8,13,17,20,32</sup> have been reported in some published series of RSA for fractures in the elderly population. Moreover, because the RSA can overcome cuff deficiency,<sup>2</sup> some authors have recommended not reattaching or even excising the tuberosities in RSA for displaced PHFs.<sup>9,11,12,16,21</sup> This study was undertaken to investigate the effect of tuberosity fixation and healing in RSA for displaced PHFs in an elderly population.

The most pertinent findings of our study are that (1) tuberosity healing in RSA for fractures can reproducibly be obtained even in elderly patients and that (2) tuberosity reconstruction and healing improves active forward elevation and external rotation as well as patient satisfaction. Despite the advanced age of the patients (mean, 80 years; range, 70-88 years), fixation and healing of the tuberosities associated with bone graft (harvested from the fractured head) results in a high rate (84%) of tuberosity healing and good functional results. Our results confirm those of Levy and Badman,<sup>24</sup> who reported an 86% union rate after performing a bone graft in a small series of 7 patients. Garofalo et al<sup>17</sup> used a similar technique and implant in

patients with a mean age of 76 years (range, 61-90 years). At a minimum 2-year follow-up, they observed a healing rate of 75%, with nonunion occurring preferentially in older women (mean age, 78 years). A significant advantage in active forward elevation and external and internal rotations was found when the tuberosities healed. We agree with these authors that the use of a specific low-profile reverse-fracture stem is advantageous because it provides more room for graft placement. Furthermore, such reverse-fracture stems allow anatomic repair of the GT fragment, which is mandatory to obtain the best arc of rotation and the strongest external rotation force.<sup>3,5,7,24</sup> As mentioned by Levy and Badman<sup>24</sup> and Gallinet et al,<sup>16</sup> posterior positioning of the GT (frequently seen with bulky prostheses) leads to a reduced impingement-free arc of external rotation and a lessened force vector.

Our series demonstrates that restoration of better active forward elevation and external rotation and better subjective results can be expected after tuberosity reconstruction and healing. The fact that tuberosity migration, resorption, or nonunion is associated with lower subjective results is not surprising. Among the 6 patients in our series in whom the tuberosity did not heal, 4 complained about difficulties with ADLs that require active external rotation because of a dropping arm or Hornblower sign, or both.

As previous authors have mentioned, maintenance of functional independence appears to be difficult in elderly patients when the infraspinatus and teres minor muscle are both absent or deficient.<sup>5,23,24</sup> Our surgical technique offers a reproducible way of performing a RSA for acute displaced PHFs in the elderly population (Fig. 2). If the tuberosities heal, the

strength of active external rotation can be restored, and the ADLs are facilitated.

An additional advantage of successful tuberosity healing relates to the avoidance of complications after RSA. In the absence of tuberosity repair and healing, high rates of complications (up to 40%) have been reported in some previous series of RSA for fractures.<sup>8-12,16,21,23-25,27-30,33</sup> Cazeneuve et al,<sup>11</sup> in a series of 30 acute fractures treated with a RSA without tuberosity reattachment, reported 2 patients with instability, 2 with implant loosening, 1 with infection, and 7 with proximal humeral bone lysis. Klein et al<sup>20,21</sup> reported 2 early infections and 2 dislocations in a series of 20 fractures treated with a RSA and excision of the tuberosities. Gallinet et al<sup>16</sup> compared 18 patients with tuberosity healing in an anatomic position vs. 24 without tuberosity repair or with nonunion or malunion of the tuberosities. They reported 2 infections and 1 anterior dislocation of the implant in the group without tuberosity repair. We did not observe these complications in our series. It is our interpretation that reconstructing a bony and soft tissue envelope around the reverse prosthesis prevented those postoperative complications in our patients.

Based on our surgical experience, our opinion is that tuberosity reconstruction and healing in RSA for fractures provides at least 3 advantages. First, the risk of joint instability is potentially reduced because of reconstruction of the anterior and posterior soft tissue walls and restored humeral length. Second, the risk of infection is reduced because the periprosthetic dead space is minimized and the surrounding bone and soft tissues are better vascularized. Third, the probability of humeral implant loosening is decreased because the stem is not solely reliant on distal fixation; the reconstructed bony envelope provides an additional proximal fixation for the semiconstraint prosthesis.<sup>6</sup>

The limitations of our study are inherent to any retrospective study without a control group. A comparison group operated on with a conventional RSA could have reinforced our results. By contrast, our study has several potential strengths, including its design, monitoring a well-defined study population (only patients older than 70 years) with a well-defined type of fracture (only displaced 3 and 4-part PHFs), and clinical and radiologic review of patients with a minimum 2 years of follow-up. In addition, the surgeons used the same reverse-fracture stem implant, the same instrumentation (for accurate control of prosthesis height and retroversion), used a standardized suture technique to securely reattach the tuberosities to the shaft, systematically used a bone graft, and ensured the same postoperative care for all patients.

## Conclusion

Despite the advanced age of the patients, the use of a specific reverse-fracture stem that incorporates bone graft results in a high rate of tuberosity healing and good

functional results. Tuberosity reconstruction and healing in RSA for fractures improves active mobility in forward elevation and external rotation as well as patient satisfaction. In case of tuberosity migration or resorption, patients have difficulties accomplishing many ADLs. Furthermore, reattaching the tuberosities around a RSA for fracture is mandatory to avoid secondary complications. The bony and soft tissue envelope reconstructed around the reverse prosthesis protects from severe postoperative complications such as instability, infection, and prosthetic loosening.

## Disclaimer

Pascal Boileau, François Sirveaux and Luc Favard receive royalties from Tornier/Wright. Philippe Clavert is consultant for Tornier/Wright. The other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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