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Original article

Reverse shoulder arthroplasty for recent proximal humerus fractures: Outcomes in 422 cases

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BACKGROUND

The ageing of the population is steadily increasing the frequency of displaced proximal humerus fractures (PHFs) in elderly patients. The last decade has seen a shift from hemi-arthroplasty (HA) to reverse shoulder arthroplasty (RSA) in these patients. The primary objective of this study was to assess short- and long-term outcomes of RSA in a large cohort of elderly patients with recent PHFs. The secondary objectives were to evaluate radiological outcomes and short- and long-term morbidity and mortality rates.

Hypothesis: Outcomes of RSA to treat PHFs in older patients are satisfactory, reliable, and sustained over time.

Material and methods: This retrospective multi-centre study included 898 patients with a mean age of 79 years, among whom 422 underwent a standardised clinical and radiological evaluation at least 1 year after RSA. Some patients were re-evaluated twice. An evaluation within the first 5 years was available for 420 patients (≤ 5-Y group), whereas 119 patients were re-evaluated more than 5 years after RSA (> 5-Y group). Some patients had one re-evaluation either within or after 5 years and others had both an early and a late re-evaluation; thus the total number of re-evaluation was greater than the number of patients.

Results: Mean active forward elevation was 115° ± 29°, mean external rotation with the elbow by the side was 17° ± 19°, mean internal rotation (hand-to-back) was 4.3 ± 2.5 points, mean absolute Constant score was 57 ± 15, and mean Subjective Shoulder Value was 70% ± 18%. Re-implantation of the tuberosities followed by healing in the anatomical position was associated with significantly better outcomes, notably regarding rotations. Even in the absence of healing in the anatomical position, tuberosity repair was associated with better clinical outcomes compared to tuberosity excision. Humeral loosening occurred in 3.5% of patients and was associated with tuberosity excision. Glenoid loosening was seen in 3.5% of patients and was associated with superior tilt of the glenoid component. The main complication was prosthesis instability, which occurred in 2.5% of patients, a proportion similar to that seen in the general population. Post-operative patient survival was not significantly different from that in the general population of the same age. Prosthesis survival was 91% after 20 years.

Conclusion: Clinical outcomes of RSA for PHF in elderly patients were not only satisfactory but also reproducible and sustained over time. Tuberosity re-implantation around the prosthesis is the key step for optimising the functional outcomes, notably by restoring rotations and decreasing the risk of complications (prosthesis instability and humeral loosening).

Level of evidence: IV, retrospective observational study.

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1. Introduction

The proximal humerus is the third most common fracture site after the hip and distal radius in older individuals [1]. Surgery is generally believed to be required in only about 20% of patients with proximal humerus fractures (PHFs) [2]. In recent years, the ageing of the population has increased the frequency of PFHs [1,2] to within the range defining a public health issue. Surgical indications in elderly patients with displaced PHFs are changing gradually, with a shift from hemi-arthroplasty (HA) to reverse shoulder arthroplasty (RSA) [3]. Published data [4–8] establish that, compared to HA, RSA provides significantly better and more reliable functional outcomes in terms of forwards elevation (FE), abduction, and the Constant score. In contrast, the ranges of active rotation were smaller with RSA [9]. Re-implantation of the tuberosities around the prosthesis followed by their healing in the anatomical position may improve rotations [10]. Furthermore, even when the repaired tuberosities failed to heal the functional outcomes remained satisfactory, whereas major functional impairments were seen after HA [7,9,11].

Unfortunately, the level of the available evidence is low, with a single level 2 publication [11], few studies having more than 50 re-evaluated patients [12,13], and virtually no long-term data (a single cohort study had a mean follow-up longer than 5 years [14]).

The primary objective of this study was to assess short- and long-term outcomes of RSA in a large cohort of elderly patients with recent PHFs. The secondary objectives were to evaluate radiological outcomes and short- and long-term morbidity and mortality rates. The working hypothesis was that outcomes of RSA to treat PHFs in older patients are satisfactory, reliable, and sustained over time.

2. Material and Methods

This retrospective multicentre study included patients managed at 14 centres specialised in shoulder surgery. The study sponsor was the French Society for Orthopaedic and Trauma Surgery (*Société Française de Chirurgie Orthopédique et Traumatologique*, SoFCOT). The study was authorised by the appropriate ethics committee (CCTIRS-16-003) and the French Data Protection Authority (*Commission Nationale de l'Informatique et des Libertés*, CNIL) responsible for handling personal data collected for purposes of research on standard care.

2.1. Inclusion criteria

Males and females who underwent RSA within 6 weeks after a displaced PHF were eligible. Among them, those with available data from a clinical and radiological evaluation performed at least 1 year after RSA were included in the study.

2.2. Study population

Table 1 reports the main features of the 898 eligible patients, among whom 422 were evaluated at least 1 year after RSA. For some patients, complete data on a clinical and radiological evaluation were already available at the time of the re-evaluation for the study. We therefore distinguished two groups of re-evaluation data based on whether time since RSA was ≤ 5 years ($n = 420$) or > 5 years ($n = 119$). Some patients had a re-evaluation either within or after 5 years, whereas others had both an early and a late re-evaluation; thus, the number of re-evaluations is greater than the number of patients.

Table 1
Epidemiological data on the overall population of 898 patients.

Age, years, mean (range)	79 (46-98)
Sex, % females	82%
Dominant side involved, % patients	58%
Body mass index, kg/m^2, mean (range)	26 (16-64)
ASA score 3 or 4, % patients	40%
Comorbidities, % of patients	
Cardiovascular	66%
Diabetes	19%
Cognitive impairments	8%
Fracture type in the Neer classification	
Four	73%
Three	23%
Two	4%
Other fracture	18%

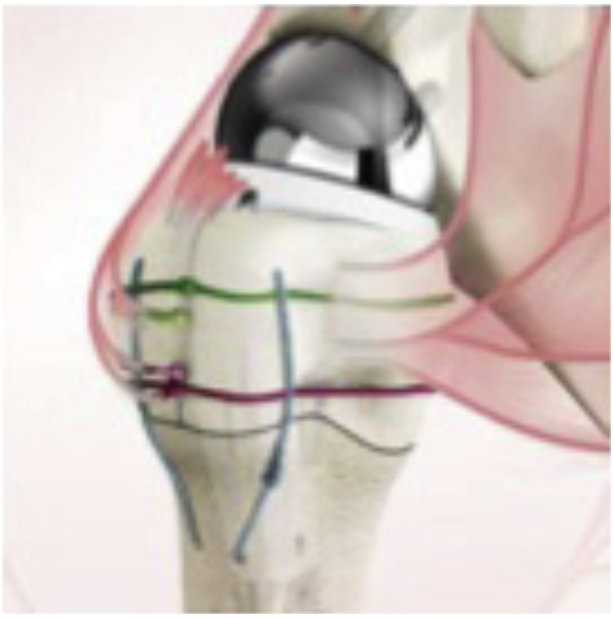

Fig. 1. The tuberosities are sutured around the reverse prosthesis.

2.3. Operative technique

Mean time from injury to RSA was 5.6 days (range, 0–42 days). The supero-lateral approach was used in 75% of cases. Mean operative time was 95 minutes (range, 30–270 minutes).

For the humerus, a dedicated fracture stem was used in 71% of patients (filling stem, 31% and non-filling stem, 40%). The stem was cemented in 90% of patients. Metaphyseal inclination was 155° in two thirds of patients and less than 155° in the remaining third. A retentive polyethylene insert was implanted in 29% of patients.

The glenoid component measured 36 or 38 mm in diameter in 92% of cases. Lateralisation within the glenoid component was performed in 3% of patients and lateralisation via the bony increased offset technique (BIO-RSA) in 2% of patients.

2.3.1. Tuberosities

The supra-spinatus was removed in 82% of patients. The tuberosities were re-implanted around the prosthesis in 69% of patients, using four horizontal and two vertical single (39%) or looped (30%) cerclage wires (Fig. 1). In the remaining 31% of patients, the tuberosities were removed completely.

2.3.2. Concomitant procedures

Biceps tenodesis or tenotomy was performed in 91% of patients and acromioplasty in 13% of patients.

2.3.3. Post-operative care

Immobilisation in a splint was used in 75% of patients. Active upper limb movements were started immediately after surgery in 55% of patients. The remaining patients either performed gentle passive pendulum exercises or received delayed rehabilitation therapy. Mean hospital stay length was 7 days (range, 1–60 days).

2.4. Clinical assessment

The objective Constant–Murley score [15] and Subjective Shoulder Value (SSV) [16] were determined. Active range of motion was measured for forwards elevation (FE), external rotation with the elbow by the side (ER1), external rotation with the arm abducted at 90° (ER2), and internal rotation with the hand behind the back (IR). The spinal level reached during IR measurement was converted to a numerical value via the Constant score to allow a statistical evaluation.

2.5. Imaging studies

All patients underwent a standard radiographic assessment including antero-posterior views in the externally rotated, neutral, and internally rotated positions; a trans-scapular (Y) view; and an axillary view. The humerus was examined for linear radiolucencies, evidence of stem loosening, and evidence of tuberosity union in the anatomical position if the tuberosities were repaired (greater tuberosity healed and visible on the antero-posterior radiograph in neutral rotation). The glenoid was assessed for the position and orientation of the glenoid component and for the presence of scapular notching classified according to Sirveaux–Nérot [17], of a scapular spur, of a surrounding radiolucent line, and of glenoid component loosening.

2.6. Statistical analysis

The statistical analysis was performed by the Biostatistics Department of the Lille University Hospital, Lille (France). Qualitative data were described as number (%) and quantitative data as mean ± SD after normality of their distribution was verified using graphs and the Shapiro–Wilk test.

Groups were compared by applying the chi-square or Fisher exact test for qualitative variables and the Student or Mann–Whitney test for quantitative variables. The Kaplan–Meier method was used to assess survival. Values of $p \leq 0.05$ were taken to indicate significant differences. The statistical tests were performed using SAS software version 9.4 (SAS Institute, Cary, NC, USA).

3. Results

3.1. Clinical outcomes

In the short term, re-evaluations performed within 5 years after RSA were available for 420 patients with a mean age of 78 ± 8 years. Mean time from RSA to re-evaluation was 28 months (range, 12-60 months). Table 2 reports the clinical data. Both the objective and the subjective clinical parameters were better overall in the patients managed with tuberosity repair, the only exception being IR with the hand behind the back. When tuberosity repair was performed but was not followed by healing in the anatomical position (malunion, non-union, resorption, or migration), the clinical parameters were not as satisfactory as when anatomical healing occurred but were nevertheless significantly superior over those obtained after complete tuberosity excision (Table 3).

Other factors significantly ($p < 0.05$) associated with better short-term outcomes (Constant score) included three patient-related factors, namely, a body mass index < 30 kg/m^2, an American Society of Anesthesiologists (ASA) score of 1 or 2, and absence of comorbidities; and five technical factors, namely, use of a non-filling fracture stem, lateralisation of the glenoid component (within the implant or using the BIO-RSA technique), absence of a retentive insert, immobilisation in abduction or neutral rotation, and delayed rehabilitation or immediate passive pendulum exercises. None of the following factors was associated with the short-term outcome: time from injury to surgery, smoking status, surgical approach, and whether rehabilitation therapy in a dedicated centre was provided.

In the long term, re-evaluations performed more than 5 years after RSA were available for 119 patients with a mean age of 79 ± 8 years. Mean time from RSA to re-evaluation was 92 months (range, 60–228 months). Table 4 reports the clinical data. Again, the objective and subjective clinical parameters were better in the patients managed using tuberosity repair. For all study parameters, the earlier improvements were sustained over time ($p > 0.05$).

3.2. Radiographic outcomes

3.2.1. Healing of the tuberosities

Among patients who underwent tuberosity repair, 71% experienced healing of the greater tuberosity, 57% in the anatomical position and 14% in an abnormal position (greater tuberosity healed but not visible on the antero-posterior view in neutral rotation). The remaining 29% of patients experienced migration, non-union, or resorption of the greater tuberosity.

Factors significantly associated with tuberosity healing were use of a non-filling fracture stem ($p = 0.01$) and immobilisation in neutral rotation or abduction ($p = 0.03$).

3.2.2. Humeral radio-lucencies and loosening

In 33% of patients, a partial humeral radio-lucent line chiefly located around the proximal stem was visible and progressed significantly over time ($p = 0.0001$), although no clinical symptoms developed. Complete loosening of the humeral stem occurred in 3.5% of patients.

Factors significantly associated with the development of a radiolucent line were tuberosity excision ($p < 0.05$), cementation of the stem, and longer follow-up ($p < 0.05$).

3.2.3. Scapular notching and glenoid component loosening

A glenoid spur was visible in 44% of patients but was not associated with any clinical symptoms. No scapular notch was visible in 56% of patients. A grade I or II notch was seen in 37% of patients and a grade 3 or 4 notch in 7% of patients. Presence of a notch was not associated with the clinical outcome. Factors associated with absence of scapular notching were humeral component inclination below 155° ($p = 0.03$), absence of superior glenoid tilting ($p = 0.02$), glenoid baseplate at the inferior rim of the glenoid cavity ($p = 0.03$), and glenoid lateralisation within the component or using the BIO-RSA technique ($p < 0.05$).

A radiolucent line completely surrounding the glenoid component (indicating potential loosening) was seen in 4% of patients and complete migration of the glenoid component in 2.2% of patients (11% within 5 years after RSA and 1.1% more than 5 years after RSA).

3.3. Complications

The complications were assessed in the overall population of 898 patients.

Table 2
Clinical outcomes within 5 years after reverse shoulder arthroplasty.

Mean ± SD Population	FE,°	ER1,°	ER2,°	IR, points	Absolute Constant score, points	Weighted Constant score, %	SSV, %
Overall population	115 ± 29	17 ± 19	32 ± 25	4.3 ± 2.5	57 ± 15	86 ± 23	70 ± 18
Excision of the tuberosities, 104 patients	101 ± 25	7 ± 7	18 ± 6	4 ± 2	53 ± 15	80 ± 24	57 ± 18
Tuberosity repair, 316 patients	120 ± 30 $p = 0.0001$	20 ± 18 $p = 0.0001$	39 ± 28 $p = 0.0001$	4.4 ± 3 $p = 0.17$	58 ± 15 $p = 0.004$	88 ± 23 $p = 0.006$	73 ± 17 $p = 0.0001$

FE: forwards elevation; ER1: external rotation with the elbow by the side; ER2: external rotation with the arm abducted at 90°; IR: with the hand in the back; SSV: Subjective Shoulder Value

Table 3
Clinical outcomes within 5 years after reverse shoulder arthroplasty in the patients without union of the tuberosities.

Mean ± SD Population	FE,°	ER1,°	ER2,°	IR, points	Absolute Constant score	Weighted Constant score, %	SSV, %
No tuberosity repair	101 ± 25	7 ± 7	18 ± 6	4 ± 2	53 ± 15	80 ± 24	57 ± 18
Failed tuberosity repair	114 ± 30 $p < 0.001$	17 ± 20 $p < 0.001$	33 ± 27 $p < 0.001$	4 ± 2.5 $p = 0.14$	55 ± 15 $p < 0.001$	82 ± 22 $p < 0.001$	69 ± 18 $p < 0.001$

FE, forwards elevation; ER1, external rotation with the elbow by the side; ER2, external rotation with the arm abducted at 90°; IR: with the hand in the back; SSV, Subjective Shoulder Value.

Table 4
Clinical outcomes more than 5 years after reverse shoulder arthroplasty.

Mean ± SD Population	FE,°	ER1,°	ER2,°	IR, points	Absolute Constant score, points	Constant score, %	SSV, %
Global	118 ± 34	20 ± 19	32 ± 25	4 ± 2	57 ± 15	88 ± 25	71 ± 21
Excision of the tuberosities (37 patients)	100 ± 38	6 ± 8	14 ± 9	3 ± 2.5	50 ± 18	76 ± 26	6 ± 26
Tuberosity repair (82 patients)	126 ± 31 $p = 0.0005$	21 ± 18 $p = 0.0001$	46 ± 27 $p = 0.0001$	4.4 ± 2.7 $p = 0.01$	60 ± 14 $p = 0.004$	93 ± 23 $p = 0.0005$	73 ± 20 $p = 0.004$

FE: forwards elevation; ER1: external rotation with the elbow by the side; ER2: external rotation with the arm abducted at 90°; IR: with the hand in the back; SSV: Subjective Shoulder Value.

3.3.1. Intra-operative complications

Intra-operative complications occurred in 18 (2%) patients and consisted of glenoid fractures ($n = 8$), humerus fractures ($n = 8$), and axillary injuries ($n = 2$).

3.3.2. Post-operative complications

Post-operative complications were recorded in 12.5% of patients. They are listed below in decreasing order of frequency:

- instability of the prosthetic shoulder (2.5% of patients). The instability developed within 3 months after RSA in 87% of cases. After simple reduction under general anaesthesia, stability was achieved in a single case. In contrast, revision surgery was followed by stability in 77% of cases. The only factor significantly associated with instability was excision of the tuberosities ($p < 0.0001$);
- aseptic loosening of the humeral component (1.5% of patients) was significantly associated with a longer follow-up, use of a cemented stem, and excision of the tuberosities ($p < 0.05$);
- peripheral nerve injury (1.3% of patients) was consistently followed by a full recovery;
- infection (1.3% of patients). One-third of infections occurred within the first month after RSA. No factors significantly associated with infection were identified;
- aseptic loosening of the glenoid component (1.2% of patients) was associated with superior tilt of the glenoid component ($p < 0.001$);
- peri-prosthetic fracture (0.9% of patients). Plate fixation in the event of displacement or non-operative treatment in the absence of displacement was consistently followed by healing of the fracture;
- complex regional pain syndrome type I (0.7% of patients);
- medical complications (3.1% of patients) included exacerbation of previous heart and/or lung disease, deep vein thrombosis, confusion, and stiffness.

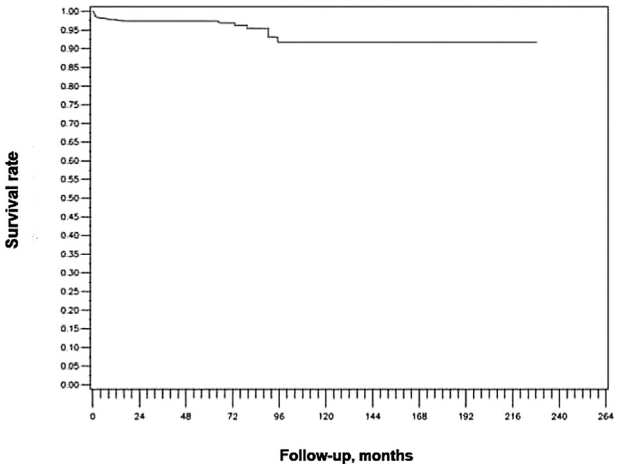

Fig. 2. Prosthesis survival curve.

3.3.3. Revision surgery

Overall, 5% of patients required further surgery, for the following reasons: instability (2.4% of patients), infection (1% of patients), loosening of the glenoid or humeral component (1% of patients), and peri-prosthetic fracture (0.6% of patients). The prosthesis survival rate with revision as the endpoint was 91% after a follow-up of 238 months (Fig. 2, e-component 1).

3.3.4. Mortality

The mortality rate within the first year after RSA was 6%. Mean time from RSA to death was 4 months (range, 0–12 months). Factors significantly associated with mortality were age older than 80 years ($p < 0.001$), ASA score 3 or 4 ($p < 0.004$), and presence of cognitive impairments ($p < 0.0001$). The 5-year mortality rate was 21%. After

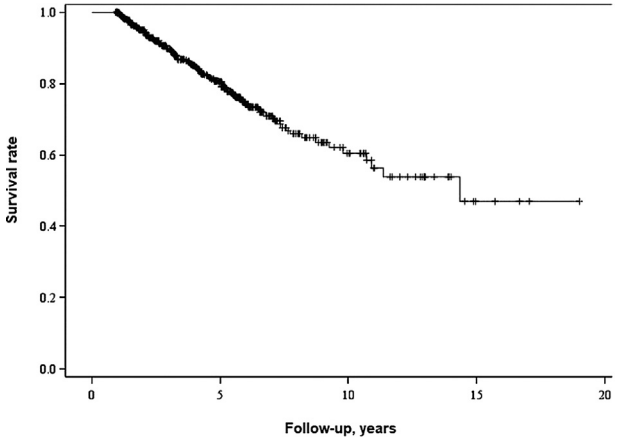

Fig. 3. Post-operative patient survival curve.

238 months, the patient survival rate was 47% (Fig. 3, e-component 2).

4. Discussion

The short-term clinical outcomes in our study were consistent with earlier reports [4–6,9]. Thus, upper limb function was restored (mean overall Constant score, 57) and perceived as useful by the patients (mean SSV, 70%). The key determinant of a good outcome was re-implantation of the tuberosities around the reverse prosthesis. For many years, resection of the tuberosities was the standard of care, because the reverse prosthetic joint is mobilised by the deltoid muscle [7,18,19]. However, with this technique, despite functional outcomes that were often better and more reliable than with HA, incapacitating deficits in arm rotation precluded upper-limb control in space [7]. Tuberosity repair was then identified as a means of avoiding rotation deficits and providing rotation ranges similar to those seen after HA for PHFs [8,10,11]. Our study confirms this effect of tuberosity in a far larger sample size. It also identified additional advantages of re-implanting the tuberosities around the prosthesis:

- even when the re-implanted tuberosities fail to heal in the anatomical position, the overall functional outcome, although poorer than after anatomical healing, was nevertheless significantly better than after excision of the tuberosities;
- tuberosity repair was associated with a decreased risk of post-operative instability, which was the most common complication in our study;
- the long-term risk of humeral component loosening was decreased by tuberosity repair, due to the restoration of a metaphyseal bony region capable of withstanding the mechanical torque forces applied to the stem.

The 71% tuberosity healing rate, with 57% of patients healing in the anatomical position (Fig. 4), is highly satisfactory and consistent with earlier reports [5,8,11,20–22], despite the risk of non-union related to the advanced age of the population, as demonstrated for HA [23]. Our results show that the same tuberosity-protective methods used for HA should be applied to maximise the tuberosity healing rate and, consequently, the clinical outcome of RSA [23]: a non-filling humeral stem should be used, the shoulder should be immobilised in abduction or neutral rotation, and post-operative care should involve either immediate gentle pendulum exercises or deferred rehabilitation therapy.

Another finding from our study is that the outcomes achieved within the first post-operative year are sustained over time. The

Fig. 4. Antero-posterior radiograph in neutral rotation showing healing of the tuberosity in the anatomical position.

only other study reporting RSA outcomes after more than 5 years, by Cazenave and Cristofari, showed similar stability over time [14], although its authors reserved their opinion regarding RSA for PHFs based on worrisome rates of aseptic loosening of the humeral or glenoid component. Importantly, tuberosity repair was not performed in this study [14]. In our study, significant progression towards humeral component loosening occurred only in the patients managed without tuberosity repair.

Thus, particularly in younger and more active patients, it is important to obtain post-operative mechanical loads similar to those produced by HA, in order to achieve full tuberosity healing and, consequently, optimal short- and long-term clinical outcomes. When the tuberosities are repaired but fail to heal, the outcomes, although less good, remain acceptable, in contrast to the major functional impairments reported after HA [4–8,11,23].

The complication rate was 12.5% overall and 5% for complications requiring revision surgery, in keeping with previous data [4–6,9]. Instability of the prosthetic joint was the most common complication. Among cases of instability, 87% developed within 3 months. Excision of the tuberosity was associated with a higher risk of instability. Shortening of the humerus, although classically reported [24], did not occur in any of our patients. Interestingly,

closed reduction under general anaesthesia was followed by recurrent instability, whereas 77% of shoulders remained stable after revision surgery (e.g., humeral insert exchange, height adjustment, lateralisation of the glenoid component). Aseptic loosening was less common than might have been expected (humeral component, 3.5%; glenoid component, 2.4%). Loosening of the humeral component may be largely prevented by primary tuberosity repair. Decreasing the risk of scapular notching and glenoid component loosening requires the same precautions as described for the initial indications of RSA [17,25–28]: humeral inclination < 155°, no superior tilt, glenoid baseplate at the lower rim of the glenoid cavity, and lateralisation of the glenoid component within the implant or using the BIO-RSA technique. Interestingly, the classically reported neurological and infectious complications [4–6,9] were not prominent in our population.

Post-operative mortality is important to consider when assessing the outcomes of elderly trauma patients. Among studies of RSA for PHFs in older individuals, only one evaluated post-operative mortality [29], which was 3.5% after 1 year, compared to 6% in our study. Further epidemiological studies are needed to better delineate this parameter. However, mortality after RSA for PHFs seems considerably lower than after hip arthroplasty for femoral neck fractures [30], although the risk factors for mortality seem similar (ASA score 3 or 4 and cognitive disorders). Patient survival in our population was still 47% after 12 years. Thus, compared to femoral neck fractures, the adverse impact of PHFs on immediate mortality and loss of self-sufficiency seems far less [31,32].

The main limitation of this study is that fewer than half the patients were re-evaluated. As expected in an elderly population, many patients died, were lost to follow-up, or were confined to bed. Nevertheless, the 422 re-evaluated patients make ours the largest study by far. Other limitations include the retrospective review of the clinical and imaging study data, the differences in operative techniques and post-operative care programmes related to the multi-centre recruitment, and difficulties in performing the clinical evaluation due to the advanced age of some of the patients.

5. Conclusion

In elderly patients with recent PHF, RSA provides outcomes that are not only globally satisfactory but also, and importantly, reliable and sustained over time. Tuberosity re-implantation around the prosthesis is the key step of the procedure that improves the functional outcome by restoring rotation ranges and decreasing the risk of complications (instability of the prosthesis and loosening of the humeral component). Despite the advanced age of the population, the impact of surgery on immediate mortality and loss of self-sufficiency seemed far less than after hip arthroplasty to treat femoral neck fractures. Thus, these elderly patients will continue to enjoy many years of life with their RSA, whose outcomes will not deteriorate over time. The main goal of the procedure is to achieve healing of the tuberosities in the anatomical position. To this end, the operative technique must be optimal: use of a non-filling fracture stem, anatomical reduction and stable fixation of the tuberosities, positioning of the glenoid component at the lower rim of the glenoid cavity with no superior tilt, post-operative immobilisation (if possible, in neutral rotation or slight abduction), and either deferred rehabilitation therapy or immediate gentle pendulum exercises.

Disclosure of interest

D. Gallinet: Conmed, L. Obert: FX solutions, Zimmer, Medartis, Evolutis, Wright Medical.

N. Bonnevialle: Smith & Nephew, Wright Medical, Stryker, Conmed.

Ph. Valenti: FH Orthopaedics.

P. Boileau: Wright Medical, Smith & Nephew, Conmed.

The other authors declare that they have no competing interest.

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Authors' contributions

David Gallinet: re-evaluated patients, headed the symposium, and wrote the manuscript.

Jean-François Cazeneuve: re-evaluated patients and wrote the manuscript.

Etienne Boyer: re-evaluated patients.

Laurent Obert: analysed the data.

Xavier Ohl: re-evaluated patients and analysed the data.

Nicolas Bonnevialle: re-evaluated patients and analysed the data.

Philippe Valenti: headed the symposium.

Pascal Boileau: headed the symposium.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.otsr.2019.03.019.

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