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Long-Term Clinical and Radiological Outcome in Primary Hemiarthroplasty for Comminuted Humeral Head Fractures in the Elderly: A 5 - 10 Years Follow-Up Prospective Study

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Abstract

Objective: In the constantly growing population of people beyond the age of 60 years, the incidence of complex comminuted humeral head fractures increases, thus increasing the need for prosthetic replacement. The purpose of this study was to determine the long-term results after primary hemiarthroplasty in patients older than 60 years. Methods: From 08/2010 to 12/2015 a prospective study of 54 patients (mean age 75 years) with complex humeral head fracture was performed at the University Hospital Rostock. 24 patients were available for follow-up after 5 - 10 years. Pain, the Karnofsky-index, and the range of motion were obtained as well as radiographs in two planes. The Constant-Murley score and the UCLA rating system were evaluated for functional assessment. Results: 15 patients were painfree. The Karnofsky index deteriorated from 94 preoperatively to 70. The Constant-Murley score of the operated extremity reached 47 points out of possible 100, the uninjured side scored 82 points. The age-specific Constant-Murley score showed more favorable results. The UCLA rating system values leveled up to 22 out of 35 points for the replaced shoulder and 33 points for the other arm. Radiologically, more than 50% of the implants were classified as non-centered and the acromio-humeral space diminished significantly. Conclusions: Primary hemiarthroplasty helps to restore a situation of little or no pain whereas functional and radiological outcome remains limited. Revision surgery or conversion to reverse shoulder arthroplasty was not indicated in any case supporting the clinical value of hemiarthroplasty.

Keywords

Primary Hemiarthroplasty, Proximal Humeral Fracture, Prospective Study,

Functional Outcome

1. Introduction

A United Nations survey estimates that by 2050, approximately 2 billion people worldwide have attained a minimum age of 60 years. With age, the risk of osteoporosis falls and fractures increases [1] [2]. Remaining functional deficits after fracture treatment in the elderly often lead to an institutionalization in a nursing home [3]. Proximal humeral fractures account for 4% - 5% of all fractures in adults. 30% of these fractures occur in patients older than 60 years mostly after low-energy trauma and are clearly related to osteoporosis [4]. Older patients tend to suffer a more complex fracture pattern such as Neer three- or four-part fractures with dislocation and humeral head-splitting [5]. The optimal treatment of these fractures has not been clarified conclusively. Even non-surgical treatment might represent a viable option in defined displaced fracture types of the humeral head with an acceptable clinical outcome which is not inferior to that after surgical intervention [6]. Fracture fixation reaches its limits in the presence of reduced bone quality, advanced degeneration of the rotator cuff, dislocation or headsplit. Consecutive failure of fracture fixation with cut-out of the screws and re-displacement occurs more often than in younger patients. Complications such as humerus head necrosis also reduce the mid-term postoperative success and call for a change of therapeutic strategy requiring secondary prosthetic replacement [7].

Even though Charles Neerfirst reported on primary hemiarthroplasty for humeral head fractures in 1953, fracture endoprothesis is still not considered a standard operating procedure in clinical practice due to insufficient cuff repair, tuberosity mal- or non-union, loss of tuberosity reduction and bone resorption which may contribute to an inferior outcome [7] [8] [9].

In a prospective study, we evaluated the clinical and radiological results 5 - 10 years after primary hemiarthroplasty for displaced and comminuted proximal humeral fractures in patients older than 60 years. A subpopulation of the study collective had been examined 1 and 2 years after the implantation of the humeral head prosthesis [10]. An improved version of modular humeral head prosthesis was used allowing anatomic reconstruction of the humeral head applying infinitely variable modularity to restore the functional center of rotation and the humeral offset correctly [11]. The purpose of this study was to evaluate long term functional and radiological results in primary fracture hemiarthroplasty, to determine if there are still substantial arguments to use primary hemiarthroplasty, in particular in the knowledge of more recent recommendations for inverse arthroplasty in a geriatric population with fractures of the humeral head [12] [13] [14].

2. Patients and Methods

From August 2000 to December 2005, 54 patients with complex humeral head

fractures were treated with primary hemiarthroplasty and were evaluated prospectively. The study was approved by the local ethics committee and the patients gave their written informed consent to participate in the study. The average age of the operated patients accounted for 75 ± 10.7 years (range 60 - 92 years). Inclusion criteria for primary hemiarthroplasty were subjects aged 60 years or above affected by 4 part fractures with a complex fracture pattern that were considered not reconstructable due to poor bone stock, fracture dislocation, destroyed humeral articular surface or head-splitting. Exclusion criteria included circumflex nerve lesion, neurological disorders with palsy of the upper extremity and injury of the contralateral shoulder or humerus.

The 4th generation of a modular humeral head prosthesis (EPOCA C.O.S.®, Fa. Argomedical, Gifhorn, Germany) with a double eccentric adjustable headboard was used in all cases. In this particular endoprosthesis type the posterior and medial offset can be selected according to the anatomical conditions. The coupling of head and stem is achieved by an intermediary eccentric frictional cone connector. The tuberosity fragments were reconstructed using braided cable cerclages of one millimeter in diameter with a steal lead-wire seal ensuring an extremely stable reattachment of the tuberosities maintaining a low risk of cut-out and loss of reduction [11] [15].

2.1. Surgical Technique

Patients were placed in a half-sitting position and received antibiotic prophylaxis as a single dose. The anteromedial deltoideo-pectoral approach was used. After exposure of the fracture site, the tuberosities were identified and retracted via 1 - 0 polyester sutures that were passed through the tendon-bone junctions. The humeral head was extracted and measured to select the matching size of the prosthetic head. Then the humeral shaft was prepared for stem implantation. The exact shaft size, depth of implantation, the retroversion angle and the offset were evaluated by insertion of a trial endoprosthesis. All stems were fixed via PMMA bone cement. After placing an absorbable blocker into the medullary cavity of the humeral shaft and application of bone cement (Refobacin-Palacos®, Heraeus, Hanau, Germany) with a cement gun, the prosthesis was inserted. The tuberosities in connection to the rotator cuff were fixed to the prosthesis by 1mm braided cable cerclages as recommended by the developer of the endoprosthesis [15].

From day one after surgery a continuous passive motion device mobilized the shoulder. Additionally, physiotherapy was performed as active assisted exercises restricted to 90˚ of abduction and elevation while avoiding external rotation for 6 weeks. Weight-bearing was encouraged 6 weeks after the operation.

2.2. Data Collection

Patient data, operative and postoperative complications, general complications, duration of the surgical procedure and length of stay in hospital were docu-

mented. All patients were invited to a clinical and radiological assessment 1 year and 5 to 10 years after primary surgery. Early outcome had been reported previously [10].

2.3. Clinical Examination

Pain level was recorded using a numeric analogue scale ranging from 0 - 10, 0 meaning no pain at all and 10 meaning inconceivable pain. The Karnofsky-index [16] and the subjective assessment of the patients were obtained. The Karnofsky performance status scale was initially described to assess the symptom-related limitation of activity, self-care and self-determination in patients with malignant tumors. It ranges from a maximum of 100 percent (no restrictions) to 0 percent (death). The graduation is usually done in 10-point steps. Thus, the abstract and elusive concept of quality of life can be operationalized and standardized with a certain approximation. Additionally, the patients were asked for their subjective satisfaction. Active and passive range of motion of the operated shoulder and the opposite side were measured using a standard goniometer. The Constant and Murley score was used as a measuring instrument for organ-specific shoulder joint function [17]. The score includes subjective and objective criteria which represent a picture of the shoulder function with an emphasis on range of motion. Additionally, the UCLA (University of California at Los Angeles) rating system was obtained [18]. This score contains questions on pain, patient satisfaction and function as subjective parameters and registers active forward flexion and strength of forward flexion as objective parameters. UCLA-shoulder rating scale numbers of more than 27 are generally considered as good and excellent results whereas scores of less than 27 are classified as fair or poor.

2.4. Radiological Examination

Fractures were classified using the Neer-classification described in 1970 [19]. Radiographs were taken in two plains, a true antero-posterior and a Y-view before hospital-discharge, after 1 year and at the final follow-up visit. It was ensured that all X-rays were taken under standardized conditions in order to facilitate a comparison of the radiographs. X-rays were rated concerning the healing of the tubercles, distance between the upper edge of the prosthesis and the lower acromial rim and centering of the prosthetic head in the glenoid joint socket [20]. To classify the centering of the prosthetic head in the glenoid, the glenoid surface was divided into 5 sections. The prosthesis was assessed as well centered if the center of the prosthetic head projected abeam of the middle portion of the glenoid. Accordingly, the prosthesis was classified as distinctly decentered if the center of the prosthetic head projected to the two adjacent portions of the glenoid and as severely decentered if the center of the prosthetic headprojected abeam of the two outer glenoid portions or beyond. Loosening of the prosthetic stem was judged by the width of the radiolucent zone around the cemented base of the stem.

2.5. Statistics

Results were given as mean ± standard deviation. Comparisons between values were performed by Wilcoxon rank sumtest as nonparametric test (SigmaStat, Jandel, San Rafael, California, United States). Statistical significance was set at $p < 0.05$.

3. Results

From August 2000 to December 2005 54 comminuted and displaced fractures of the humeral head were treated with hemiarthroplasty. The average stay in hospital amounted to 19 ± 10 days (range 9 - 45 days). The average operation time amounted to 142 ± 30 min (range 92-209 min). Postoperative blood transfusion was not necessary in any case. A 92-year-old patient died 11 days after surgery due to multi-organ failure following paralytic ileus with subsequent electrolyte imbalance. One patient developed pneumonia, which healed without consequences under antibiotic therapy. In another patient a superficial wound infection was observed which healed after a single wound revision (hospital stay 39 days). Axillar nerve damage did not occur in any patient neither before nor after the operation. 23 patients had deceased at the one year follow-up interval, each more than 3 months after hospital discharge. Five additional patients had died by the final assessment date, so that a total of 24 patients (19 women, 5 men) were available at the 5 - 10 year interval. A minimum of 62 and a maximum of 125 months had elapsed after surgery, the median follow-up time being 89 ± 19 months.

Revision surgery such as removal of the prosthesis due to infection, periprosthetic fracture or conversion to complete or reverse shoulder arthroplasty was not necessary in any case throughout the observational period. Fracture classification for the 24 patients is shown in Table 1.

At final review, 54% of the patients stated to be free of pain, 33% reported some pain with specific movements or loads with a mean of 2.3 ± 1.5 on the visual analogue scale. One patient reported moderate pain and classified its level at 6 on the VAS, whereas 66% reported to be free of pain one year postoperatively. To classify the implications of this result, it has to be kept in mind that 15% of the patients indicated pain in the contralateral shoulder at the same time (Table 2).

Table 1. Fracture classification according to Neer for the 24 patients at final follow-up.

Fracture type	n
V/4	15
VI/4	-
Anterior dislocation	6
Posterior dislocation	1
Head split fracture	2

Table 2. Pain levels measured by visual analogue scale (VAS), range of motion, Constant and Murley score, UCLA rating score in comparison of injured and uninjured extremity.

	Operated side	Uninjured side
Pain		
None	13 (54%)	17 (85%)
Low	8 (33%)	3 (15%)
Moderate	3 (13%)	0 (0%)
Severe	0 (0%)	0 (0%)
Adduction and Internal Rotation		
Yes	18 (75%)	20 (100%)
No	6 (25%)	0
Abduction and External Rotation		
Yes	9 (38%)	20 (100%)
No	15 (62%)	0
Constant-Morley Score (max. 100 points)		
Mean (±SD)	47 (±16)*	82 (±16)
UCLA Rating System (max. 35 points)		
Mean (±SD)	23 (±6)*	33 (±4)

*$p < 0.05$ vs. uninjured side.

The Karnofsky-index deteriorated from 93.8 ± 8.2 pre-traumatically to 70.4 ± 18.9 after 5 - 10 years. Asked for their subjective appraisal, 88% of the patients graded the long-term outcome of the surgery as "very good" whereas two patients were disappointed.

The range of motion of the replaced shoulder joint improved after hospital discharge but remained impaired significantly throughout the whole period affecting abduction and elevation in particular. Measured active abduction reached a range of 35˚ - 150˚ with a mean of 83˚ ± 28˚ (Figure 1). The patients achieved a mean active elevation of 89˚ ± 30˚ (Figure 2).

The Constant-Murley score of the operated extremity reached 47.2 ± 15.6 out of possible 100 points. The uninjured side scored a mean of 82.2 ± 15.9 points (Table 2). As expected the age-specific Constant-Murley score showed more favorable results with a mean of 70.1 ± 8 points (Figure 3).

The UCLA rating system values leveled up to 22.6 ± 5.8 points out of 35 possible points for the replaced shoulder as opposed to 32.7 ± 4.3 points for the other arm (Table 2).

Radiological Results

All 24 prostheses were examined radiologically. Healing or displacement of the tubercules, the positioning of the prosthetic head and loosening of the stem was measured (Table 3).

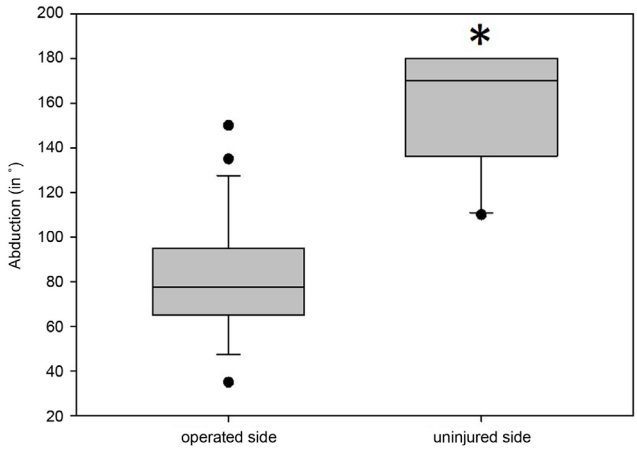

Figure 1. Box-and-Whiskers-Plot of abduction at follow up, the box representing the 25th and 75th, the whiskers representing the 10th and 90th percentile; outlying values are marked as dots. The median (50th percentile) is shown as horizontal line within the box. *p < 0.05 vs. operated side.

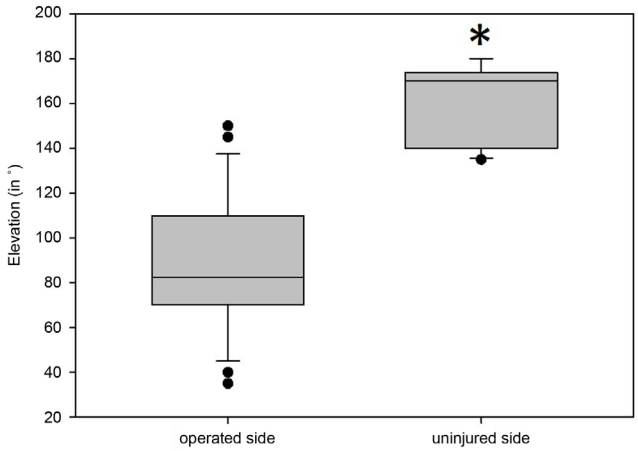

Figure 2. Box-and-Whiskers-Plot of elevation at follow up, the box representing the 25th and 75th, the whiskers representing the 10th and 90th percentile; outlying values are marked as dots. The median (50th percentile) is shown as horizontal line within the box. *p < 0.05 vs. operated side.

Table 3. Radiological parameters (positioning of the tubercules, positioning of the prothetic head and radiological signs for loosening of the stem) for the 24 patients at final follow-up.

		n	%	Findings at hospital demission n (%)
Positioning of the tubercles	Complete dislocation	0	0	0
	Healing in correct position	5	21	0
	No bony healing/lysis	19	79	0
Positioning of prosthetic head	Well centered	10	43	13 (5)
	Caudally displaced	2	7	5 (19)
	Cranially displaced	12	50	6 (25)
Loosening of the stem	Radiolucency 0 mm	20	90	24 (100)
	Radiolucency 2 mm	2	5	0 (0)
	Radiolucency > 2 mm	2	5	0 (0)

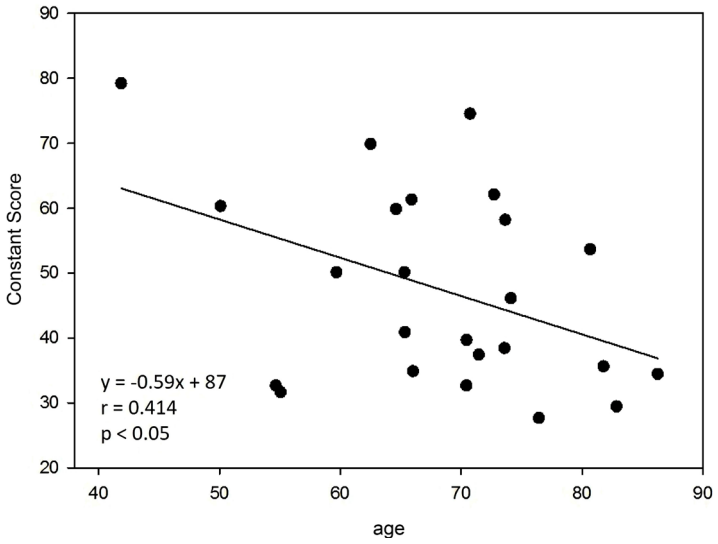

Figure 3. Regression analysis between age and Constant Score at follow up. r: regression coefficient.

Compared with the postoperative status a significant successive narrowing of the subacromial space took place ($p < 0.05$).

4. Discussion

Considering the limited level of most existing clinical studies on various treatment modalities following humeral head fractures according to the rules of evidence-based medicine there is no convincing proof yet, that any type of surgical intervention leads to superior functional outcome than nonsurgical treatment [21]. But, as the authors admit, this general statement might not hold true in case of specific fracture types as head split fractures and fracture dislocations. Further, there is lacking evidence from existing randomized controlled trials to decide between different choices of non-surgical and surgical treatment [21]. Thus, surgical treatment of complex proximal humeral fractures is a topic of controversial discussion particularly in the elderly. Fracture fixation in the presence of poor bone stock has been demonstrated to increase the risk of functional impairment due to implant loosening or humeral head necrosis [8] [13] [22] [23]. In addition to fracture reduction and fixation as a reconstructive method, the primary replacement of the humeral head with a fracture prosthesis appears to be a valuable treatment option especially in complex fractures with a high risk for an avascular humeral head fragment [5] [10] [15] [21] [23].

In this study, the indication for primary prosthetic replacement was seen in 4-fragment fractures with destruction of the humeral head or head split of elderly patients in accordance with other authors [5] [14] [16]-[22]. Primary hemiarthroplasty promises to avoid typical problems of osteosynthesis in poor bone stock like non-union, malunion, avascular necrosis of the humeral head calling for revision surgery and producing poor functional outcome. New developments in the prosthetic design with continuously variable offset enables exact recon-

struction of the anatomical configuration of the humeral head. In the wake of this development the primary prosthetic replacement of the humeral head after comminuted humeral head fractures in the elderly is becoming increasingly important. For this study the EPOCA-C.O.S.-humeral head prosthesis, a "4.th generation"—design, was used which offers a maximum modularity in the a.-p.—and lateromedial plane.

7.4 years after implantation of a shoulder hemiprosthesis due to an acute fracture the level of pain as reported by the patients in this study was considerably low and correlated with a high degree of overall patient's satisfaction. The results regarding the pain level distribution are well comparable with the short- to mid-term outcome after hemiarthroplasty in a multicentre study [20] and the previously reported pain levels 1 and 2 years after index surgery [10].

Apart from one in-hospital fatality which had not been related to the index surgery and one surgical revision due to superficial wound infection without the need for implant removal no consecutive surgical interventions were necessary during the whole observation period which certainly strengthens the indication for primary shoulder hemiarthroplasty in complex fracture situations of the humeral head.

The deterioration of the Karnofsky index within the observation period reflects the development in a geriatric collective and is in line with the literature [24].

Despite the improved design and the theoretical advantages of the prosthetic system used in this study, the average Constant-Murley score was only 47 points in the investigated patient population after a median of 7.4 years of postoperative follow-up. A part of the study collective had been examined 1 year after index surgery with a mean Constant-Murley of 56 points demonstrating a further functional deterioration within the following years [10]. Thus, the patients achieved barely 57% of the score they reached for the uninjured opposite side. These unsatisfactory functional results are consistent with current literature. A Constant-Murley score of 52 - 70 points has been reported for comparable groups of patients after hemiarthroplasty [13] [14] [21] [23] [25] [26] [27]. However, due to small group sizes and short follow-up periods, the comparison of different models of prostheses is not possible due to considerable variance between the studies. Especially older patients show a significantly poorer functional outcome measured by the Constant-Murley score. This can not necessarily be attributed to local factors, as Choo and coworkers showed in a prospective study that concomitant lesions of the rotator cuff become manifest in just about 8% of the cases after humeral head fractures, even in the elderly. But it can be suggested that elderly patients have significantly restricted mechanisms of muscular compensation after traumatic injuries at the proximal humerus and therefore generally achieve poorer functional results than younger patients [21] [28].

Most authors paid close attention to tuberosity healing after posttraumatic hemiarthroplasty of the shoulder. Stable fixation of the tubercles to the prosthesis is thought to be essential for successful healing [20] [27] [29]. If the necessary

stability cannot be achieved, early dislocation of the tubercles and malfunction is impending. Despite the required high primary stability, biological principles must be considered in order to preserve the vascularity of the fragments. Evidently it is important to preserve the periosteal connection between the fragments and not to destroy them during implantation of the prosthesis [21]. The problems of absorption or lack of healing of the tuberosities with consecutive insufficiency of the rotator cuff remains unsolved. In two thirds of our study population resorption of the tuberosities was observed so that the tuberosities were no longer visible on the X-rays obtained 5 - 10 years after the fracture. Although stable reattachment of the tuberosities with the cable cerclages could prevent cranial dislocation of the tubercles in most cases, this was not associated with an improved healing of the tubercles to the humeral shaft. In a multicenter study Kralinger *et al.* showed that there was a highly significant correlation between tuberosity healing and functional outcome measured by the Constant-Murley score [20]. This could not be confirmed by the results presented, most likely due to the small number of patients and the high rate of non-healed or resorbed tubercles. Along with the absorption of the tubercles which must be regarded as increasing insufficiency of the rotator cuff, a gradual migration of the prosthetic head could be observed. In the course of follow-up assessments, there was both a significant reduction of the subacromial space as well as an increasing decentralization of the prosthetic head in the cranial plane. Apart from this, aseptic stem loosening or periprosthetic fractures were no major issues in our collective with PMMA bone cement fixation in all cases where newer recommendations speak in favour of cementless stem fixation [29].

Due to these disadvantages of the anatomical prosthesis, reverse shoulder arthroplasty is favoured by an increasing number of authors in complex humeral fractures, particularly for patients older than 70 years. In the last years, more and more authors reported clinical results using reverse shoulder endoprosthesis for comminuted humeral head fractures as a means to prevent complications due to tuberosity malunion and secondary rotator cuff insufficiency [9] [14] [25] [30] [31] [32] [33]. Although this procedure provides adequate pain relief, functional outcome respectively range of motion is not always satisfactory. Given implant failure, salvage procedures for reverse arthroplasty remain limited [33]-[38]. But functional outcome was reported to be more favourable than that of hemiarthroplasty by several authors [13] [14] [25] [31] [37] [38]. Most authors report higher Constant scores for the reverse arthroplasty group, however the DASH scores for both groups were identical [14] [25] [38]. Tuberosity healing seems to be less important for functional outcome in reverse arthroplasty [14]. The increased rate of dislocation reported for the first generations of this type of prosthesis could be reduced with newer models and modified surgical technique [21]. Some authors report that although reverse arthroplasty results in adequate pain relief, the range of motion, especially in terms of rotations, is limited which leads to unsatisfied patients [7] [32]. Anyhow, in a prospective case-control study comparing anatomical and reverse shoulder arthroplasty regarding outcome and com-

plications in the non-fractures situation, the mid-term results and complications of both procedures were comparable [39]. In a recent review article comparing hemiarthroplasty and reverse arthroplasty for humeral head fractures, Mata-Fink *et al.* concluded that reverse shoulder arthroplasty offers improved functional outcome and forward flexion but long-term results are still amiss concerning implant survival and outcome [37].

The inherent weakness of our study is the small number of patients available for long-term follow-up. The high rate of losses to follow-up represents a problem frequently encountered when dealing with study participants older than 60 years, especially if long-term follow-up is intended [40] [41]. The fact that 29 out of 53 patients had deceased meanwhile reflects the principally geriatric composition of our study collective.

5. Conclusions

Despite the development of various new implant systems, the surgical approach to comminuted humeral head fractures is still a major challenge for the surgeon. Due to many possible biological complications such as osteoporosis or humeral head necrosis with a high risk for subsequent implant failure in case of primary reconstruction, the primary prosthetic replacement of the humeral head appears to be a meaningful alternative treatment option. A decisive advantage certainly represents a high proportion of pain-free patients after implantation of humeral head prosthesis even in the long run. Probably this fact also accounts for the high subjective satisfaction of the operated patients, in spite of the moderate functional outcome. A further and relevant advantage is represented by the complete missing of any secondary revisions during the 5 to 10 years observation period. Despite technical improvements, the functional and radiological long-term results with the E.P.O.C.A prosthesis fell short of expectations, in particular with reference to the preservation of the tubercles.

Nevertheless, hemiarthroplasty appears as the smaller intervention with less blood loss and less perioperative risk compared to extended procedures as reverse shoulder arthroplasty. The fact that there had not been a single case affording surgical revision or conversion to reverse shoulder arthroplasty in the long run speaks in favor of this treatment option. In case of implant failure reverse shoulder arthroplasty remains a viable withdrawal option in contrast to the primary generous use of reverse shoulder arthroplasty without any reasonable exit strategy in a geriatric population.

Of course, there is a strong need for prospective randomized clinical studies comparing different treatment options including shoulder hemiarthroplasty to achieve a higher level of scientific proof regarding the decision-making in complex fractures of the humeral head in an aging population.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Kannus, P., Palvanen, M., Niemei, S., Parkkari, J., Jarvinen, M. and Vuori, I. (2000) Osteoporotic Fractures of the Proximal Humerus in Elderly Finnish Persons: Sharp Increase in 1970-1998 and Alarming Projections for the New Millennium. *Acta Orthopaedica Scandinavica*, **71**, 465-470. https://doi.org/10.1080/000164700317381144

[2] Granacher, U., Muehlbauer, T., Gschwind, Y.J., Pfenninger, B. and Kressig, R.W. (2014) Assessment and Training of Strength and Balance for Fall Prevention in the Elderly: Recommendations of an Interdisciplinary Expert Panel. *Zeitschrift für Gerontologie + Geriatrie*, **47**, 513-526. https://doi.org/10.1007/s00391-013-0509-5

[3] Thonnes, M. and Jakoby, N.R. (2011) Where Do People Die? On the Question of Dying in Institutions. *Zeitschrift für Gerontologie + Geriatrie*, **44**, 336-339. https://doi.org/10.1007/s00391-011-0181-6

[4] Ismail, A.A., Pye, S.R., Cockerill, W.C., Lunt, M., Silman, A.J., Reeve, J., *et al.* (2002) Incidence of Limb Fracture across Europe: Results from the European Prospective Osteoporosis Study (EPOS). *Osteoporosis International*, **13**, 565-571. https://doi.org/10.1007/s001980200074

[5] Murray, I.R., Amin, A.K., White, T.O. and Robinson, C.M. (2011) Proximal Humeral Fractures: Current Concepts in Classification, Treatment and Outcomes. *The Journal of Bone and Joint Surgery. British Volume*, **93**, 580-585. https://doi.org/10.1302/0301-620X.93B1.25702

[6] Lange, M., Brandt, D., Mittlmeier, T. and Gradl, G. (2016) Proximal Humeral Fractures: Non-Operative Treatment versus Intramedullary Nailing in 2-, 3- and 4-Part Fractures. *Injury*, **47**, 14-19. https://doi.org/10.1016/S0020-1383(16)30848-8

[7] Russo, R., Cautiero, F., Fontanarosa, A. and Della Rotonda, G. (2015) Reconstruction Techniques in Comparison for Reverse Shoulder Trauma Prosthesis in the Elderly: A Follow-Up between 2 and 4 Years. *Archives of Orthopaedic and Trauma Surgery*, **135**, 905-912. https://doi.org/10.1007/s00402-015-2221-y

[8] Neer, C.S., Brown, T.H. and McLaughlin, H.L. (1953) Fracture of the Neck of the Humerus with Dislocation of the Head Fragment. *The American Journal of Surgery*, **85**, 252-258. https://doi.org/10.1016/0002-9610(53)90606-0

[9] Merschin, D. and Stangl, R. (2016) Proximal Humeral Fractures in the Elderly: Quality of Life, Clinical Results and Institutionalisation Following Primary Reverse Fracture Arthroplasty. *Archives of Orthopaedic and Trauma Surgery*, **120**, 1015-1022. https://doi.org/10.1007/s00113-015-0009-8

[10] Gierer, P., Simon, C., Gradl, G., Ewert, A., Vasarheyi, A., Beck, M. and Mittlmeier, T. (2006) Complex Proximal Humerus Fractures-Management with Humeral Head Prosthesis? Clinical and Radiological Results of a Prospective Study. *Orthopade*, **35**, 834-840. https://doi.org/10.1007/s00132-006-0954-6

[11] Fialka, C., Stampfl, P., Arbes, S., Reuter, P., Oberleitner, G. and Vécsei, V. (2008) Primary Hemiarthroplasty in Four-Part Fractures of the Proximal Humerus: Randomized Trial of Two Different Implant Systems. *Journal of Shoulder and Elbow Surgery*, **17**, 210-215. https://doi.org/10.1016/j.jse.2007.07.002

[12] Acevedo, D.C., Vanbeek, C., Lazarus, M.D., Williams, G.R. and Abboud, J.A. (2014) Reverse Shoulder Arthroplasty for Proximal Humeral Fractures: Update on Indications, Technique, and Results. *Journal of Shoulder and Elbow Surgery*, **23**, 279-289. https://doi.org/10.1016/j.jse.2013.10.003

[13] Wang, J., Zhu, Y., Zhang, F., Chen, W., Tian, Y. and Zhang, Y. (2016) Meta-Analysis Suggests That Reverse Shoulder Arthroplasty in Proximal Humerus Frac-

tures Is a Better Option than Hemiarthroplasty in the Elderly. *International Orthopaedics*, **40**, 531-539. https://doi.org/10.1007/s00264-015-2811-x

[14] Cuff, D.J. and Pupello, D.R. (2013) Comparison of Hemiarthroplasty and Reverse Shoulder Arthroplasty for the Treatment of Proximal Humeral Fractures in Elderly Patients. *The Journal of Bone and Joint Surgery*, **95**, 2050-2055. https://doi.org/10.2106/JBJS.L.01637

[15] Krause, F.G., Huebschle, L. and Hertel, R. (2007) Reattachment of the Tuberosities with Cable Wires and Bone Graft in Hemiarthroplasties Done for Proximal Humeral Fractures with Cable Wire and Bone Graft: 58 Patients with a 22-Month Minimum Follow-Up. *Journal of Orthopaedic Trauma*, **21**, 682-686. https://doi.org/10.1097/BOT.0b013e31815917e0

[16] Péus, D., Newcomb, N. and Hofer, S. (2013) Appraisal of the Karnofsky Performance Status and Proposal of a Simple Algorithmic System for Its Evaluation. *BMC Medical Informatics and Decision Making*, **13**, 72. https://doi.org/10.1186/1472-6947-13-72

[17] Constant, C.R. and Murley, A.H.G. (1987) A Clinical Method of Functional Assessment of the Shoulder. *Clinical Orthopaedics and Related Research*, **214**, 160-164. https://doi.org/10.1097/00003086-198701000-00023

[18] Ellman, H., Hanker, G. and Bayer, M. (1986) Repair of the Rotator Cuff. End-Result Study Factors Influencing Reconstruction. *The Journal of Bone and Joint Surgery. American Volume*, **68**, 1136-1144. https://doi.org/10.2106/00004623-198668080-00002

[19] Neer, C.S. (1970) Displaced Proximal Humeral Fractures. I. Classification and Evaluation. *The Journal of Bone and Joint Surgery. American Volume*, **52**, 1077-1089. https://doi.org/10.2106/00004623-197052060-00001

[20] Kralinger, F., Schwaiger, R., Warmbacher, M., Farrell, E.T., Menth-Chiari, W., Lajtai, G., Hübner, C. and Resch, H. (2004) Outcome after Primary Hemiarthroplasty for Fracture of the Head of the Humerus. A Retrospective Multicentre Study of 167 Patients. *The Journal of Bone and Joint Surgery. British Volume*, **86**, 217-219. https://doi.org/10.1302/0301-620X.86B2.14553

[21] Handoll, H.H., Keding, A., Corbacho, B., Brealey, S.D., Hewitt, C. and Rangan, A. (2017) Five-Year Follow-Up Results of the PROFHER Trial Comparing Operative and Non-Operative Treatment of Adults with a Displaced Fracture of the Proximal Humerus. *The Bone & Joint Journal*, **99**, 383-392. https://doi.org/10.1302/0301-620X.99B3.BJJ-2016-1028

[22] Kirchhoff, C. and Biberthaler, P. (2013) Indication for Primary Fracture Prosthesis of the Shoulder. *Der Unfallchirurg*, **116**, 1015-1029. https://doi.org/10.1007/s00113-013-2423-0

[23] Tauber, M., Magosch, P. and Habermeyer, P. (2013) Humeral Head Replacement in Acute Proximal Humerus Fractures. *Der Unfallchirurg*, **116**, 691-697. https://doi.org/10.1007/s00113-013-2409-y

[24] Crooks, V., Waller, S., Smith, T. and Hahn, T.J. (1991) The Use of the Karnofsky Performance Scale in Determining Outcomes and Risk in Geriatric Outpatients. *The Journals of Gerontology*, **46**, 139-144. https://doi.org/10.1093/geronj/46.4.M139

[25] Schairer, W.W., Nwachukwu, B.U., Lyman, S., Craig, E.V. and Gulotta, L.V. (2015) Reverse Shoulder Arthroplasty versus Hemiarthroplasty for Treatment of Proximal Humerus Fractures. *Journal of Shoulder and Elbow Surgery*, **24**, 1560-1566. https://doi.org/10.1016/j.jse.2015.03.018

[26] Spross, C., Platz, A., Erschbamer, M., Lattmann, T. and Dietrich, M. (2012) Surgical Treatment of Neer Group VI Proximal Humeral Fractures: Retrospective Comparison of PHILOS and Hemiarthroplasty. *Clinical Orthopaedics and Related Research*, **470**, 2035-2042. https://doi.org/10.1007/s11999-011-2207-1

[27] Solberg, B.D., Moon, C.N., Franco, D.P. and Paiement, G.D. (2009) Locked Plating of 3- and 4-Part Proximal Humerus Fractures in Older Patients: The Effect of Initial Fracture Pattern on Outcome. *Journal of Orthopaedic Trauma*, **23**, 113-119. https://doi.org/10.1097/BOT.0b013e31819344bf

[28] Choo, A., Sobol, G., Maltenfort, M., Getz, C. and Abboud, J. (2014) Prevalence of Rotator Cuff Tears in Operative Proximal Humerus Fractures. *Orthopedics*, **37**, e968-e974. https://doi.org/10.3928/01477447-20141023-52

[29] Boyer, E., Menu, G., Loisel, F., Saadnia, R., Uhring, J., Adam, A., Rochet, S., Clappaz, P., Baudouin, E., Lascar, T., Cermeno, R. and Obert, L. (2017) Cementless and Locked Prosthesis for the Treatment of 3-Part and 4-Part Proximal Humerus Fractures: Prospective Clinical Evaluation of Hemi- and Reverse Arthroplasty. *European Journal of Orthopaedic Surgery & Traumatology*, **27**, 301-308. https://doi.org/10.1007/s00590-017-1926-8

[30] Besch, L., *et al.* (2009) Hemiarthroplasty of the Shoulder after Four-Part Fracture of the Humeral Head: A Long-Term Analysis of 34 Cases. *The Journal of Trauma*, **66**, 211-214. https://doi.org/10.1097/TA.0b013e31815d9649

[31] Lebus, V.G.F., Mir, H.R. and Bushnell, B.D. (2017) Reversetotal Shoulder Arthroplasty for Complex Three- and Four-Part Proximal Humerus Fractures in Elderly Patients: A Review. *Journal of Surgical Orthopaedic Advances*, **26**, 75-80. https://doi.org/10.3113/JSOA.2017.0075

[32] Garofalo, R., Flanagin, B., Castagna, A., Lo, E.Y. and Krishnan, S.G. (2015) Reverse Shoulder Arthroplasty for Proximal Humerus Fracture Using a Dedicated Stem: Radiological Outcomes at a Minimum 2 Years Follow-Up: A Case Series. *Journal of Orthopaedic Surgery and Research*, **10**, 129. https://doi.org/10.1186/s13018-015-0261-1

[33] Smith, G.C., Bateman, E., Cass, B., Damiani, M., Harper, W., *et al.* (2017) Reverse Shoulder Arthroplasty for the Treatment of Proximal Humeral Fractures in the Elderly (ReShAPE Trial, Study Protocol for a Multicentre Combined Randomised Controlled and Observational Trial). *Trials*, **18**, 91. https://doi.org/10.1186/s13063-017-1826-6

[34] Hussey, M.M., Hussey, S.E. and Mighell, M.A. (2015) Reverse Shoulder Arthroplasty as a Salvage Procedure after Failed Internal Fixation of Fractures of the Proximal Humerus: Outcomes and Complications. *The Bone & Joint Journal*, **97**, 967-972. https://doi.org/10.1302/0301-620X.97B7.35713

[35] Cho, C.H., Song, K.S. and Koo, T.W. (2017) Clinical Outcomes and Complications during the Learning Curve for Reverse Total Shoulder Arthroplasty: An Analysis of the First 40 Cases. *Clinics in Orthopedic Surgery*, **9**, 213-217. https://doi.org/10.4055/cios.2017.9.2.213

[36] Boileau, P. (2016) Complications and Revision of Reverse Total Shoulder Arthroplasty. *Orthopaedics & Traumatology*: *Surgery & Research*, **102**, S33-S43. https://doi.org/10.1016/j.otsr.2015.06.031

[37] Mata-Fink, A., Meinke, M., Jones, C., Kim, B. and Bell, J.E. (2013) Reverse Shoulder Arthroplasty for Treatment of Proximal Humeral Fractures in Older Adults: A Systemic Review. *Journal of Shoulder and Elbow Surgery*, **22**, 1737-1748. https://doi.org/10.1016/j.jse.2013.08.021

[38] Van der Merwe, M., Boyle, M.J., Frampton, C.M.A. and Ball, C.M. (2017) Reverse Shoulder Arthroplasty Compared with Hemiarthroplasty in the Treatment of Acute Humeral Fractures. *Journal of Shoulder and Elbow Surgery*, **26**, 1539-1545. https://doi.org/10.1016/j.jse.2017.02.005

[39] Kiet, T.K., Feeley, B.T., Naimark, M., Gajiu, T., Hall, S.L., Chung, T.T. and Ma, C.B. (2015) Outcomes after Shoulder Replacement: Comparison between Reverse and Anatomic Total Shoulder Arthroplasty. *Journal of Shoulder and Elbow Surgery*, **24**, 179-185. https://doi.org/10.1016/j.jse.2014.06.039

[40] Stappaerts, K.H., Deldycke, J., Broos, P.L., Staes, F.F., Rommens, P.M. and Claes, P. (1995) Treatment of Unstable Pertrochanteric Fractures in Elderly Patients with a Compression Hip Screw or with Vandeputte (VDP) Endoprosthesis: A Prospective Randomized Study. *Journal of Orthopaedic Trauma*, **9**, 292-297. https://doi.org/10.1097/00005131-199509040-00004

[41] Gierer, P., Landes, J., Grubwinkler, M., Gradl, G., Lob, G. and Andres, H.J. (2002) The Femoral Neck Fracture in the Elderly Patient-Cemented or Cementless Hip Arthroplasty? *Zentralblatt Fur Chirurgie*, **127**, 514-518. https://doi.org/10.1055/s-2002-32612