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Hemiarthroplasty in complex proximal humeral fractures: preserving unity of the tuberosities with the cap technique improves clinical outcome

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Abstract

Objectives: The outcome of primary hemiarthroplasty for complex proximal humeral fractures is highly dependent on the position and survival of the tuberosities. Preserving the cuff–tuberosity complex as a unit (named cap technique) is thought to improve the reduction and stability of the tuberosities. We present the first report of the cap technique and compare it with the common intertubercular split technique.

Design: Comparative retrospective study on consecutive patients.

Design: Setting: Urban level 1 trauma center.

Patients/Participants: Included were all patients treated between May 2010 and August 2019 with the Affinis Fracture (Mathys, Switzerland) hemiarthroplasty for complex shoulder fractures. The cap technique was used from February 2015 onward. Minimum follow-up of 11 months. Dementia was an exclusion criterium.

Outcome Measure: Clinical evaluation by (normalized) Constant-Murley score, DASH score, and EQ5D-VAS score. Radiological outcomes according to the criteria of Boileau.

Results: The cap-technique group consisted of 26 patients. One patient had revision surgery; 23 patients could be evaluated at a mean follow-up of 28 months. The control group consisted of 26 patients. Three patients had revision surgery. Ten patients could be scored at a mean follow-up of 101 months. A statistically significant difference in Constant-Murley score ($P = .0121$) could be observed between case and control group. There were no significant differences between radiological scores and between revision rates.

Conclusion: The cap technique significantly improves clinical outcome in comparison with the intertubercular split technique. However, there was no significant difference in radiographic appearance of the tuberosities.

Keywords: cap technique, complex proximal humeral fractures, hemiarthroplasty

1. Introduction

Hemiarthroplasty (HA) treatment of proximal humeral fractures (PHF) is a common and well-documented technique indicated in fracture types with a compromised humeral head survival, mainly seen in severely displaced 4-part fractures.[1–3] In contradiction to the excellent outcomes reported by Neer et al[1] for both range of motion and pain relief, numerous others have reported dichotomous outcomes with very good or very poor functional outcomes.[2,4,5]

Crucial for the results of HA is normal rotator cuff functioning, which depends on achieving anatomic repositioning and healing of the tuberosities.[6–12] Several authors showed that the application of cerclage wire is a superior way of fixating the tuberosities to the prosthetic neck.[13–15] Improved clinical and radiographic results were published using the cerclage technique in combination with a low-profile fracture-specific prosthesis and autograft.[9,14,16–18] However, these reported improved results have not been repeated by other authors, with mal- or nonunion of the tuberosities still the principal problem, especially in the elderly.[19–22]

These less predictable results have led to a major shift from HA toward reversed arthroplasty (RSA) over the last decade.[23] After RSA the clinical outcome is theoretically less dependent on the functioning of the rotator cuff tuberosity complex.[24] Increasing literature reports suggest that primary RSA may provide better pain control and functional restoration with a lower revision rate especially in the elderly.[23,25,26] However, with a mean Constant-Murley score (CMS) ranging between 50 and 57 after RSA reported in a recent meta analysis,[26] hemiarthroplasties with anatomically consolidated tuberosities still outperform RSA, with scores above 60 and an increased external rotation force, which is important in many activities of daily living (ADL).[12,20,27,28]

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Here, we hypothesized that avoiding the routinely performed intertubercular split may facilitate an anatomical reconstruction and improve primary stability. We present the clinical and radiological results of a novel technique where we preserve the tuberosity soft tissue unity and pull the rotator cuff-tuberosity complex as a cap over the prosthetic head after having preloaded the nonmounted metaphyseal part with cerclage sutures (which we refer to as the cap technique). We hypothesized that this might be associated with an improved functional and radiological outcome.

2. Methods

2.1. Ethical considerations

A retrospective clinical case-control study where the common intertubercular split technique was compared with the cap technique. Patient identity data were prospectively collected, their medical files were retrospectively analyzed, and patients were finally invited for clinical assessment. Research protocols adhered to the tenets of the Declaration of Helsinki and were approved by the ethical committee of AZ groeninge, Kortrijk (B396201940409). Written informed consent was obtained of all patients included in this study.

2.2. Patient cohort

Retrospective review of clinical records identified patients who underwent the intertubercular split technique with subsequent cerclage fixation of the tubercula from May 2010 and ended in November 2014. Seven patients died from unrelated causes and 2 patients suffered from dementia and were not able to complete questionnaires, leaving 13 patients to be included in the control group. Three patients had revision surgery, meaning that 10 patients underwent clinical scoring. Equally, patients operated using the cap technique from 2015 to 2019 were identified. Two patients died meanwhile and 1 patient suffered from dementia and was excluded from the study. One patient had revision surgery, leaving 23 patients available for clinical scoring. Demographic data retrieved from the clinical records include age, gender, and fracture type.

2.3. Surgical technique

All patients were operated on by a single surgeon in a level 1 trauma center. An intact rotator cuff was a prerequisite to proceed with the cap technique. The humeral calcar (when present) was used as a reference guide to determine the height of the prosthesis and reconstruction of the tuberosities. An image intensifier was each time used. The prosthesis used in all cases was the Affinis shoulder fracture prosthesis (Mathys Ltd, Bettlach, Switzerland) (Supplemental Digital Content Figure 1, http://links.lww.com/OTAI/A28).

The patient is placed in the beach-chair position with the lower arm fixed in a trimano arm holder. A deltopectoral approach was used in all patients. After tenodesis of the bicipital tendon a split of the rotator interval is performed without disrupting the intertuberosity soft tissue sleeve allowing the cuff-tuberosity unit to be viewed as a cap (Fig. 1).

After the removal of the humeral head and preparation of the humeral shaft, a corresponding stem is cemented onto which a small size metaphyseal part is provisionally mounted at a neutral level, with the medial part of the collar resting on the humeral calcar using it as a reference guide to determine the height of the prosthesis. An encircling heavy nonabsorbable suture (Supplemental Digital Content Figure 2, http://links.lww.com/OTAI/A29) is introduced first through the lower anterior cuff, the calcar suture hole of the unmounted metaphyseal part, and finally through the lower posterior cuff. A second suture wire is introduced first through the upper anterior cuff, the footplate suture hole, and finally through the upper posterior cuff (Fig. 2).

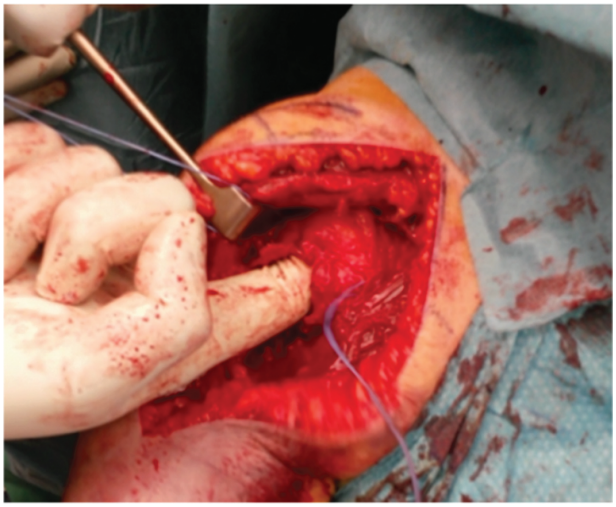

Figure 1. Humeral head has been removed while preserving integrity soft-tissue sleeve between tuberosities = CAP technique.

The tagged metaphyseal part is fixed onto the cemented stem with a tightening screw, making sure that the collar rests on the humeral calcar in a retroversion angle of 25° relative to the forearm axis. Once the ceramic head is mounted (Supplemental Digital Content Figure 3, http://links.lww.com/OTAI/A30), the prosthesis is reduced toward the glenoid through a combination of pulling on the rotator cuff tagging sutures and pushing the humeral head toward the glenoid in progressive abduction, allowing the cap to slide as a whole over de prosthetic humeral head (Supplemental Digital Content Figure 4, http://links.lww.com/OTAI/A31). The 2 transprosthetic encircling sutures are sequentially tightened, temporarily fixed with suture holders (Supplemental Digital Content Figure 5, http://links.lww.com/OTAI/A32) and if visual and fluoroscopy control is satisfactory, the 2 encircling transprosthetic sutures are definitively tightened (Supplemental Digital Content Figure 6, http://links.lww.com/OTAI/A33).

Two transosseous shaft sutures are vertically tightened to the superoposterior cuff and 1 extra transtendinous interfragmentary horizontal suture is added. The rotator interval is left open.

Postoperatively, patients are encouraged to perform immediate self-directed active rehabilitation for the first 4 weeks in combination with pendulum exercises. When the clinical and radiographic evolution is deemed satisfactory, passive mobilisation is started by the physiotherapist, avoiding strengthening exercises. Return to full activity was permitted after 3 months postoperatively.

2.4. Study design

There was no age limit. An intact rotator cuff was a prerequisite. Dementia at the time of follow-up was an exclusion criterium. All eligible patients were invited to the out-patient clinic to fill in the questionnaires and undergo a clinical examination

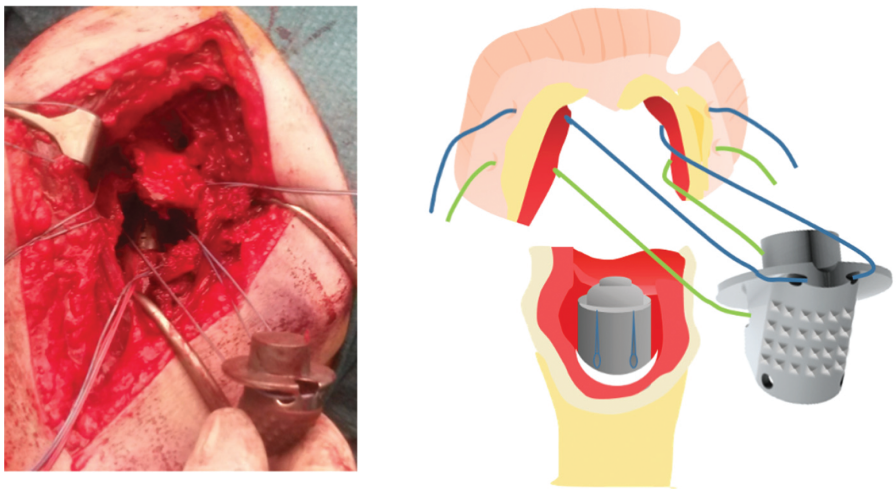

Figure 2. Preloading of the nonmounted metaphyseal part with 2 circular suture wires passing through the anterior cuff exiting both slots, and passing through the posterior cuff. Images provided by G. Putzeys, Kortrijk, Belgium.

performed by the data nurse. If they were not able to come, the author went to their home. The outcome measurements are the (normalized) CMS, which is a clinician measured functional outcome measure, the Disability of the Arm, Shoulder, and Hand (DASH) score as a patient-reported functional outcome measure and EuroQol-5D (EQ-5D) as a general health status measure.[29] Normalization of the CMS was done according to Katolik et al.[30] The external rotation force in a neutral arm position was separately documented and graded as weak, moderate, or strong.

Radiological images were evaluated according to Boileau et al.[13] Vertical tuberosity position (overreduction = head to tuberosity distance (HTD) > 10 mm, good position = HTD between 5–10 mm, underreduction = HTD > 5 mm), horizontal tuberosity position (visible vs not visible), secondary migration and tuberosity detachment (malunion, nonunion, bone resorption) were determined on first and last radiograph available.

2.5. Statistical analysis

Descriptive statistical analysis was performed using calculation of the mean, median, standard deviation, and 95% confidence interval where applicable. The demographic data of the 2 patient groups were compared using the unpaired *t* test and chi-squared test. Clinical outcome scores were compared between the 2 groups using the Mann–Whitney test. Radiological scores were compared between the 2 groups using the Mann-Whitney test and the chi-squared test where applicable. All tests were 2-tailed. Significance threshold was set at 0.05. The GraphPad Prism 8 software was used for statistical analysis.

3. Results

The first patient treated with this modified technique was in February 2015. Aiming for at least 11 months follow-up, inclusion was stopped after August 2019. Twenty-seven consecutive patients have been treated with the cap-technique during the predetermined time period. One patient was excluded due to dementia at the time of surgery. Two patients were deceased. One patient had revision surgery. Twenty-three patients were clinically and radiologically evaluated as 1 patient refused participation. In the control group, there were 26 consecutive patients treated with the common intertubercular split technique. Seven patients were deceased, 4 patients were excluded due to dementia, 1 patient could not be traced, 1 refused, and 3 patients had revision surgery. Ten patients underwent radiological and clinical scoring. The treated arm was in 62.5% of cases the dominant arm in the cap group, compared to 61.54% of cases in the control group (*P* = .9541). There were 7 men and 17 women with a mean age at time of surgery of 68.67 years in the cap group.

In the control group, 9 women and 4 men were included, with a mean age at the time of surgery of 72.62 years. For all of the demographic data mentioned above, no significant differences between both groups could be detected (Table 1).

Patients from the cap group presented with 3 types of fractures: 1 headsplit 3-part fracture, 3 severely displaced 3 part, and 20 four-part fractures. Patients from the control group presented with 2 headsplit 3-part fracture, 2 severely displaced 3-part, and 9 four-part fractures. Mean follow-up was 28.29 months and 101.2 months for the cap and control group respectively (Table 1). There were no infections.

3.1. Prosthetic revision surgery

There were 3 out of 26 HA that were revised to RSA (painful restriction of movement at 7 months postop; anterior dislocation

Table 1

Demographic data of the 2 patient groups

	CAP group	Control group	*P* value
Age (years)*	68.67 (SD 11.66)	72.62 (SD 10.22)	.3252
Females/males (no.)	17/7 (70.8%/29.2%)	9/4 (69.23%/30.77%)	.9189
Dominant arms (%)	62.5%	61.54%	.9541
Follow-up (months)*	28.29 (SD 15.18)	101.2 (SD 15.53)	<.0001

P values were calculated using the unpaired *t* test (age at the time of surgery and follow-up) and chi-squared test (ratio females/males and dominant arms). No significant difference was identified for difference in age, the gender ratio, and the percentage of dominant arms between the 2 groups. A significant difference was identified between the mean follow-up in both groups.
SD = standard deviation.
* = mean values.

at 1 month postop, disengagement of the ceramic humeral head at 1 month postop) in the no cap group and 1 out of 26 HA (painful restriction of movement at 1year postop) in the Cap group which is statistically not significant (P=.6098)

3.2. Clinical outcome

Clinical outcome measures were the DASH, EQ5D-VAS, CMS, and normalized CMS. Normalization was done according to Katolik et al.[30] No statistically significant differences could be identified between the cap and control group for the DASH and EQ5D-VAS score. However, when comparing CMS between cap and control group, a significant ($P=.0121$) difference could be observed, whereby patients treated with the cap technique score significantly better (mean values 65.76 and 48.55 respectively) (Table 2). This significance increases even more when applying the normalized CMS, whereby normalization is done according to age and gender ($P=.0073$, with mean normalized CMS of 78.01 and 57.49 respectively) (Table 2 and Supplemental Digital Content Figure 7, http://links.lww.com/OTAI/A34).

Upon further comparison of the CMS between cap and control group, we identified a mean anterior elevation score of 7.22 and 5.56 respectively ($P=.0281$), mean endorotation score of 7.48 and 4.6 respectively ($P=.0016$), mean exorotation scores of 7.73 and 5.71 respectively ($P=.0114$), and strength score (measured at 90° lateral abduction) of 9.72 and 5.00 respectively ($P=.0148$). All other values (pain, ADL, abduction) were not statistically significant.

3.3. Radiological scores

Radiological images were evaluated according to criteria of Boileau et al.[13] However, no statistical significance could be identified between cap and control group for AHI, HTD, vertical and horizontal tuberosity position and tuberosity detachment (Table 3).

There was neither a significant difference in the evolution of AHI between the postop and last X-ray between the cap and control group ($P=.9092$).

4. Discussion

Although HA for the treatment of PHF is a controversial technique due to unpredictability of the clinical results with dichotomous outcomes,[4,31] depending on the recovery of a normal functioning rotator cuff,[2,7,8,32] we were able to

Table 2

Clinical scores of the 2 patient groups

	CAP group	Control group	*P* value
DASH	29.46 (SD 24.38)	43.08 (SD 15.75)	.1115
EQ5D-VAS	0.68 (SD 0.24)	0.53 (SD 0.31)	.2707
C-M	65.76 (SD 19.18)	48.55 (SD 12.05)	.0121*
Normalized C-M	78.01 (SD 22.18)	57.49 (SD 14.06)	.0073*

Mean values and the corresponding standard deviation are represented. *P* values were calculated using the Mann-Whitney test. No significant difference was identified for the DASH and EQ5D-VAS scores. However, both Constant-Murley (C-M) score and normalized C-M score, where corrections for age and gender are applied, showed a significant difference between the CAP group and the control group. SD = standard deviation.

* = statistically significant *P* values ($P<.05$).

Table 3

Radiological scores of the 2 patient groups

Postoperative X ray	CAP group	Control group	*P* value
AHI (mm)*	15	12	.1614
HTD (mm)*	11 (SD 5.23)	10 (SD 6.17)	.1270
Vertical tuberosity position	8 overreduction 1 underreduction 14 good position	3 overreduction 7 good position	.4665
Horizontal tuberosity position	23 visible	10 visible	No difference between groups
Last X ray, follow-up (months)*	**CAP group**	**Control group**	***P* value**
AHI (mm)*	7.8	5.5	.1429
HTD (mm)*	11.26 (SD 5.57)	11.11 (SD 6.25)	.5319
Vertical tuberosity position	6 overreduction 1 underreduction 13 good position 3 no RX available	3 overreduction 6 good position 1 no RX available	.9304
Horizontal tuberosity position	20 visible 3 no RX available	9 visible 1 no RX available	No difference between groups
Tuberosity detachment	1 nonunion 19 union 3 no RX available	9 union 1 no RX available	.5299

First and last RX images were compared between patient and control groups. Vertical tuberosity position: overreduction when HTD > 10 mm, good position when HTD = 5–10 mm, underreduction when HTD < 5 mm. Horizontal tuberosity position: visible vs not visible. Tuberosity detachment: malunion, nonunion, or bone resorption. *P* values were calculated with the Mann–Whitney test (HTD) and the Chi-squared test (vertical and horizontal tuberosity position and tuberosity detachment).

AHI = acromion to head interval, HTD = head to tuberosity distance, RX = medical prescription, SD = standard deviation.

* = mean values.

demonstrate in this retrospective, case control study that in the subgroup of HA using the cap technique, the mean CMS score was at a minimum FU of 11months clearly superior to the subgroup treated with the common technique. The poorer clinical outcome of our common technique corresponds with results published in the literature on HA using cerclage fixation and the fracture-specific prosthesis with mean CMS sores ranging between 40 and 60.[7,10,11,13,19,20,33–35]

To the best of our knowledge all the technical and clinical papers reporting on the use of a HA in the treatment of PHF and all the company surgical technique manuals illustrate routinely a separation between the tuberosities before implanting the prosthesis and subsequently reconstruct the separated tuberosities around the prosthesis.[9,17,36,37]

It seems that the cap technique, by preserving the rotator cuff tuberosity complex as 1 unit, enables a more anatomical and stable reconstruction of the tuberosity complex improving the survival rate of the tuberosities and subsequently better clinical results. Out of 23 scored patients using the cap technique, we had 2 functional failures (CMS score of 28 and 29) but the patients did not complain of pain. In both cases, a postop X-ray showed an early superior migration of the greater tuberosity. Both patients were known for severe alcohol dependence.

In the presence of a continuous cuff-tuberosity complex, it is from a surgical perspective crucial to be able to run the suturewire in a controlled manner under direct view from the anterior cuff through the medial slot and subsequently through the posterior cuff, which is only feasible with a modular nonmounted metaphyseal part, a possibility offered by some modular fracture-specific prostheses as is the case with the Affinis prosthesis (Mathys Ltd, Bett-lach) used in our cohort.

There are only a few clinical reports on the Affinis and its predecessor, the Articula fracture prosthesis, using the standard cerclage fixation of the separated tuberosities showing similar clinical results as other fracture-specific prostheses with mean CMS scores of respectively 50,[27] 53.8,[18] and 59.[17] These results are all below our clinical results, suggesting that the cap technique makes the difference. This significant better clinical result in our series was however not reflected in the X-ray analysis.

X-ray has been shown in case of an invisible major tubercle on an AP view to miss the presence of tubercula in front or posterior to the metaphysis. CT can account for this deficit as has been shown by Greiner et al[28] but in our series postop CT was only performed in 1 case confirming the findings of Greiner et al.

Singh et al[38] suggested that horizontal reduction (between tuberosities) is more important to tuberosity healing than vertical reduction but the former is difficult to assess with X-ray.[7] This could explain the better clinical results in the cap group without being able to prove a better horizontal reduction on X-ray.

There was a 3-fold greater revision rate in the non-CAP group, but this was not statistically significant. This may represent a type-II statistical error due to the small number of patients. Increasing the number of patients is likely to show a statistically significant difference in favor of the CAP technique.

In view of these results one can question the recent major shift over the last decade from HA toward RSA for these fractures.[23] RSA perform less well than hemi's if tuberosities are anatomically healed, especially in the younger population preserving much better rotational force and capacity which is important for many ADL.[39–42]

Our study has several limitations. It is retrospective, in nature not allowing us to control for confounding factors. It is a small group with subsequent lack of power. Additional analysis within the subgroups was therefore not performed. Almost half of the patients within the cap group had to be scored in their home environment which was only acceptable and feasible for most patients if done by the treating surgeon introducing bias from a nonindependent investigator. A radiological follow-up was incomplete lacking long-term follow-up in some patients.

On the other hand, study strengths are the use of the same implant, the same surgical technique by the same experienced shoulder surgeon. The surgical procedure was performed early after injury (in the first 3 weeks) to avoid lower functional outcomes observed when performed late. The length of follow-up was with a mean of 28 months comparable to many other studies reporting on results of HA.[25] One of the major strengths of the study is that all, except one, eligible patients in the cap group could be evaluated.

5. Conclusion

We conclude, with respect to the limitations of our study and the low patient number, that the cap technique for the fixation of tuberosities, preserving the tuberosities as a unit, using a modular fracture-specific prosthesis with a separate metaphyseal part seems to be a more reliable procedure compared with the common technique providing a high patient satisfaction, better range of motion and low risk of secondary procedures. A more extensive and more scientifically sound designed clinical study is indicated to prove this assumption.

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