Proximal humeral endoprosthetic reconstruction for tumour defects

clinical outcomes of 165 patients from the MUTARS Orthopedic Registry Orthopedic Registry Europe (MORE)

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Aims

Tumour defects of the proximal humerus can be reconstructed using hemiarthroplasty, reverse shoulder arthroplasty (RSA), or anatomical total shoulder arthroplasty (TSA). This study aimed to evaluate clinical and functional outcomes of reconstructions of proximal humeral tumour defects with MUTARS endoprostheses.

Methods

A total of 165 reconstructions were included: 98 (59%) hemiarthroplasties, 61 (37%) RSAs, and six (4%) TSAs. Median age was 54 years (IQR 31 to 68). Median follow-up time was 5.9 years (IQR 2.83 to 10.50). Competing risks models were employed to estimate the cumulative incidence of revision (CIR) for mechanical reasons and infection with local recurrence and mortality as competing events. The range of motion was reported using descriptive statistics.

Results

Axillary nerve preservation and deltoid muscle reattachment were observed in 89% and 96% of cases, respectively, without significant differences between implant types. Rotator cuff refixation was less frequent in RSA (78%) compared to hemiarthroplasty (91%). Overall, 26 implants (16%) were revised for mechanical complications (dislocation n = 11, loosening n = 2, periprosthetic fracture n = 3) and infection (n = 10). Patients with previous surgery at the same site had a higher revision risk due to instability (cause-specific hazard ratio 3.7; 95% CI 1.3 to 10.8). The CIRs for mechanical reasons (Henderson 1 to 3) in the entire population at two, five, and ten years were 7% (95% CI 3 to 11), 11% (95% CI 6 to 17), and 13% (95% CI 7 to 20), respectively. For periprosthetic joint infection (Henderson 4), the CIRs were 5% (95% CI 2 to 10), 7% (95% CI 3 to 12), and 7% (95% CI 3 to 12). Compared with hemiarthroplasty, RSA offered superior median anteflexion (73° (IQR 40 to 90) vs 30° (IQR 5 to 45)), abduction (70° (IQR 38 to 90) vs 30° (IQR 5 to 45)), and external rotation (15° (IQR 0 to 28) vs 5° (0 to 19)).

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Conclusion

MUTARS proximal humerus reconstruction outcomes are satisfying, particularly in terms of mechanical failure. RSA and hemiarthroplasty exhibit comparable revision risks, with previous surgery at same site as a prognostic factor for revision due to dislocation. RSA appears to provide the best functional outcome.

Take home message

- This study demonstrates that MUTARS endoprosthetic reconstruction of the proximal humerus provides satisfactory long-term outcomes with relatively low rates of mechanical complications and implant loosening.
- Reverse shoulder arthroplasty offers superior functional results compared to hemiarthroplasty, particularly in cases without rotator cuff reattachment, without an increased risk of revision.
- Prior surgery at the same site significantly increases the risk of dislocation, highlighting the importance of careful surgical planning in previously operated patients.

Introduction

The proximal humerus is relatively frequently affected by primary bone sarcomas and metastatic lesions.[1,2] Wide resection of tumours around the shoulder compromises crucial structures for shoulder stability and function, which include the axillary nerve, deltoid muscle, rotator cuff, and bone.[3-6] Consequently, it is challenging to obtain a well-functioning reconstruction, and functional outcomes may be limited in terms of stability range of motion (ROM).

The choice of reconstruction method can vary depending on the tumour extent, although a reconstruction consensus is lacking.[4,7,8] Endoprostheses are commonly used after proximal humeral tumour resection, particularly for reconstruction following Malawer type I (intra-articular proximal humeral resection) and Malawer type V (extra-articular humeral and glenoid resection).[9,10] However, the risk of complications such as dislocation (4% to 23%), aseptic loosening (0% to 5%), and infection (3% to 9%) remains substantial.[4,11-13] MUTARS (Implantcast, Germany) offers a modular system for reconstructions of the proximal humerus. Due to its rarity, there are no large systematic studies on the clinical outcomes of individual proximal humerus endoprostheses. As mentioned, there is currently no consensus on when to use hemiarthroplasty, reverse shoulder arthroplasty (RSA), or anatomical total shoulder arthroplasty (TSA), although some studies suggest that RSA may result in superior functional results in case the rotator cuff is to be resected.[3,4,12,14,15]

This study aims to assess the clinical outcomes of MUTARS proximal humeral reconstructions for oncological indications, using data from the MUTARS Orthopedic Registry Europe (MORE).[16] We evaluated the complications and reasons for implant revision,[1] and the associated risk factors,[2] the cumulative incidence of revision (CIR) of the implant at two, five, and ten years, and the functional outcomes in terms of ROM for hemiarthroplasty, RSA, and TSA.[3]

Methods

In this international multicentre observational retrospective study, data from the MORE was used. Patients who underwent a MUTARS proximal humerus reconstruction for an oncological indication between January 2001 and August 2023 were included, from eight participating centres in six countries. Patients with a follow-up of less than 24 months or with custom-made shoulder reconstructions were excluded.

A total of 165 patients (51% female) were included, with a median follow-up of 5.9 years (IQR 2.83 to 10.50), estimated using the reverse Kaplan-Meier method.[17] The median age was 54 years (IQR 31 to 68) for the entire cohort, 57 years (IQR 36 to 68) for those with hemiarthroplasty, 47 years (IQR 22 to 61) for those with RSA, and 59 years (IQR 20 to 68) for those with TSA. Hemiarthroplasty was performed in 98 patients (59%), while 61 (37%) underwent RSA and six (4%) TSA (Table I). Reconstruction with hemiarthroplasty or RSA was guided by tumour extent and rotator cuff status. In general, hemiarthroplasty was preferred for intact rotator cuffs without glenoid involvement, while RSA was used for cases with glenoid involvement or rotator cuff dysfunction, requiring an intact deltoid muscle. Additionally, a relative requirement for RSA is an intact deltoid muscle. The indication for proximal humerus resection was a primary bone tumour in 106 patients (64%), while 54 (33%) were treated for metastatic carcinoma. Among the 165 reconstructions, 106 (64%) were uncemented, 57 (35%) were cemented, and for two (1%) it was unknown. Additionally, 73 patients (44%) received a silver-coated implant, 67 (41%) did not, and for 25 (15%) it was unknown. The majority of the cemented reconstructions (74%) were performed for metastatic lesions. A total of 19 patients (12%) underwent prior surgery to the same site, consisting of a previous reconstruction (n = 10, 6%), osteosynthesis for oncological reasons such as prophylactic fixation (n = 1, 1%), osteosynthesis for a pathological fracture (n = 1, 1%), osteosynthesis after trauma (n = 1, 1%), and excision or curettage of a tumour (n = 6, 4%). The median resection length was 12 cm (IQR 10 to 16).

Prosthetic details

The MUTARS system is a modular endoprosthetic system, using a hexagonal stem that is available in different sizes, both for uncemented and cemented fixation. Uncemented press-fit fixation of a hydroxyapatite coated stem was preferred, unless adequate primary stability could not be obtained (for example, in the case of poor bone quality). Extension pieces can be used to obtain the appropriate length in 1 cm increments, with or without silver coating. In the majority of cases, tendons and muscle insertions were attached to the prosthesis using a Trevira tube (Implantcast, Germany).

Variables

Demographics, surgical and prosthesis details, and complications were obtained from the (electronic) patient records. Implant revision was defined as any surgical procedure in which (part of) the implant was removed or replaced. Complications and the reason for implant revision were scored according to the Henderson classification.[18]

Table I. Study population.

Variable	Value
Sex, n (% of total)	165 (100)
Male	81 (49)
Female	84 (51)
Median age, yrs (IQR)	54 (31 to 68)
ASA grade, n (% of total)	156 (95)
I	38 (24)
II	82 (53)
III	35 (22)
IV	1 (1)
Smoking, n (% of total)	97 (58)
Yes, currently	15 (16)
Yes, former (stopped > 6 mths ago)	10 (10)
Diabetes, n (% of total)	11/108 (10)
Indication for reconstruction, n (% of total)	165 (100)
Primary malignant tumours	106 (64)
Chondrosarcoma	53 (32)
Osteosarcoma	41 (25)
Ewing's sarcoma	4 (2)
Soft-tissue sarcoma	3 (2)
Multiple myeloma	2 (1)
Other high-grade sarcomas	3 (2)
Metastatic carcinoma	54 (33)
Benign aggressive lesions	5 (3)
GCTB	2 (1)
Osteoblastoma	2 (1)
Intraosseous hemangioma	1 (1)
Previous surgery at same site	19 (12)
Previous reconstruction	10 (6)
Osteosynthesis for oncological reasons	2 (1)
Osteosynthesis after trauma	1 (1)
Curettage or excision of (benign) tumour	6 (4)
Soft-tissue involvement	98/149 (66)
Pathological fracture at diagnosis	63/163 (39)
Neoadjuvant chemotherapy	43/159 (27)
Neoadjuvant radiotherapy	9/156 (6)
Adjuvant chemotherapy	55/157 (35)
Adjuvant radiotherapy	21/155 (14)

ASA, American Society of Anesthesiologists; GCTB, giant cell tumour of bone.

Table II. Surgical and prosthesis details.

Variable	Value
Type of reconstruction, n (% of total)	165 (100)
Hemiarthroplasty, n (% of total)	98 (59)
Reverse shoulder arthroplasty, n (% of total)	61 (37)
Anatomical total shoulder arthroplasty, n (% of total)	6 (4)
Surgical approach, n (% of total)	162 (98)
Deltopectoral, n (% of total)	157 (97)
Deltoid flap, n (% of total)	2 (1)
Other, n (% of total)	3 (2)
Median resection length, cm (IQR)	12 (10 to 16)
Median surgical duration, hrs (IQR)	3 (2.5 to 3.8)
Median blood loss, l (IQR)	0.6 (0.3 to 0.9)
Silver coating, n (% of total)	73/140 (52)
Cemented prosthesis, n (% of total)	57/163 (35)
Metastastatic carcinoma as indication, n (% of total)	42/57 (74)
Trevira tube, n (% of total)	136/164 (83)
Sacrifice (part of) axillary nerve, n (% of total)	17/161 (11)
TSA, n (% of total)	0/6 (0)
RSA, n (% of total)	8/59 (14)
Hemiarthroplasty, n (% of total)	9/96 (9)
Partial or complete deltoid reattachment, n (% of total)	133/139 (96)
TSA, n (% of total)	3/4 (75)
RSA, n (% of total)	52/55 (95)
Hemiarthroplasty, n (% of total)	78/80 (98)
Partial or complete rotator cuff reattachment, n (% of total)	131/152 (86)
TSA, n (% of total)	5/5 (100)
RSA, n (% of total)	45/58 (78)
Hemiarthroplasty, n (% of total)	81/89 (91)

RSA, reverse shoulder arthroplasty; TSA, total shoulder arthroplasty.

Study ethics

This study was approved by the scientific committee of the Leiden University Medical Centre, and waived informed consent (W.22.005/2022-031). Participating centres obtained approval from their local ethical review board.

Statistical analysis

Descriptive statistics were employed for baseline characteristics, the incidence of complications, and functional outcomes. Univariate cause-specific hazards regression models were employed to study the effect of possible prognostic risk factors on implant revision. Cause-specific hazard ratios (HRcs) and 95% CIs are reported. Two competing risks models were used to estimate the CIR.[19] In model 1, the CIR among the entire study population for mechanical reasons and for infection was estimated considering revision for local

Table III. Univariate Cox proportional hazards regression model for possible prognostic factors on the occurrence of dislocation (left) and perisprosthetic joint infection (PJI) (right) along with the 95% CI.

Possible risk factors	Dislocation	PJI
	HR (95% CI)	**HR (95% CI)**
Sex		
Female		
Male	1.02 (0.37 to 2.80)	1.50 (0.56 to 4.04)
Age	1.00 (0.98 to 1.03)	0.98 (0.95 to 1.00)
BMI	N/A	0.92 (0.81 to 1.04)
ASA grade		
I + II		
III + IV	1.86 (0.50 to 6.93)	0.64 (0.14 to 2.83)
Previous surgery at same site		
No		
Yes	3.70 (1.26 to 10.84)	0.94 (0.21 to 4.15)
Type of reconstruction		
Reverse arthroplasty		
Hemiarthroplasty	0.94 (0.34 to 2.71)	0.83 (0.28 to 2.41)
Resection length, cm	0.88 (0.77 to 1.01)	1.03 (0.94 to 1.14)
Surgical duration, hrs	0.78 (0.47 to 1.32)	1.21 (0.78 to 1.87)
Blood loss, L	N/A	1.00 (0.99 to 1.00)
Use of silver coating		
No		
Yes	N/A	1.42 (0.51 to 3.99)
Use of Trevira tube		
No		
Yes	0.40 (0.14 to 1.18)	1.39 (0.31 to 6.16)

*Reference category.
ASA, American Society of Anesthesiologists; HR, hazard ratio; N/A, not applicable; PJI, periprosthetic joint infection.

recurrence and death as competing events. In model 2, the CIR due to mechanical reasons and infection was estimated, for RSA and hemiarthroplasty separately, with revision for local recurrence and death as competing events (Figure 1). The median active anteflexion, abduction, and external rotation in patients reconstructed with hemiarthroplasty and RSA were compared using the Mann-Whitney U test. Data analysis was performed using SPSS v. 25.0 (IBM, USA) and R-studio v. 4.2.1 (RStudio, USA). The R-studio package 'cmprsk' was used to estimate the CIR. The level of significance was set at a p-value < 0.05.

Results

The axillary nerve was spared in 89% of resections (144/161, with four missing data), 96% of the patients (133/139) had a partial or complete reattachment of the deltoid muscle, and 86% of the patients (131/152) had a partial or complete reattachment of the rotator cuff (Table II). Fewer patients with RSA (45/58, 78%) had a partial or complete reattachment of their rotator cuff compared to hemiarthroplasty (81/89, 91%) and TSA (5/5, 100%). In total, 40 patients (24%) experienced one or more complications during the follow-up period.

Dislocation(s) (Henderson 1A) occurred in 15 patients (9%). Among the 15 patients with one or more dislocations, six were initially reconstructed with RSA (6/61, 10%) and nine with hemiarthroplasty (9/98, 9%). The first dislocation occurred within six months in three cases (20%), between six and 12 months in two (13%) cases, and between one and eight years in ten cases (67%). Among the six dislocated RSAs, two were revised to adjust component size and orientation, one required an offset adjustment, and one underwent closed reduction only. One patient underwent three revisions for recurrent instability, ultimately leading to a conversion of the RSA to a hemiarthroplasty without glenoid reconstruction nine years after the initial implantation. Another patient required multiple revisions for periprosthetic joint infection (PJI), along with three revisions for recurrent instability, ultimately resulting in a conversion to a constrained design. Of the nine dislocated hemiarthroplasties, six were revised to RSA, two were managed with a stabilizing soft-tissue procedure, and one required an open reduction.

In total, ten out of 147 patients (7%) without previous surgery at same site suffered from (recurrent) dislocations. In contrast, five out of 19 patients (26%) with previous surgery at same site experienced (recurrent) dislocations requiring reoperation. Among these five patients, one had previously undergone reconstruction with an allograft prosthetic composite (APC) which required revision due to local recurrence. The other four had previously undergone curettage or excision of a tumour and suffered from local recurrence. Patients with previous surgery at same site had a higher dislocation risk (HRcs 3.7, 95% CI 1.3 to 10.8) compared to those without. No other prognostic factors were identified (Table III).

Aseptic loosening (Henderson 2) was observed in three patients (3/165, 2%), all hemiarthroplasties. Two uncemented stems loosened (2/106, 2%) after nine months, of which one was revised to an uncemented RSA and one was revised to a cemented stem (which loosened again after two years and was again revised with a new cemented stem). One cemented stem (1/57, 2%) loosened after 14 years and was revised to a new cemented stem. Implant breakage or wear (Henderson 3A) was not observed. Periprosthetic fractures (Henderson 3B) were observed in four patients (2%). One occurred during primary implantation and was managed with cerclage wires. Two fractures resulted from trauma: one at nine months post implantation in a hemiarthroplasty, treated with open reposition and internal fixation using an allograft, strut graft, and cerclage wires; and one in RSA at 42 months, treated with conversion to a total humerus prosthesis. The last case was a hemiarthroplasty with a pathological periprosthetic fracture due to local recurrence at nine months, for which revision to a cemented stem was performed.

PJI (Henderson 4) was observed in 16 patients (10%), eight hemiarthroplasties (8%), six RSAs (10%), and two TSAs (33%). Two infections (13%) occurred within the first month after implantation, three (19%) between one and six months, five (31%) between six and 12 months, and six

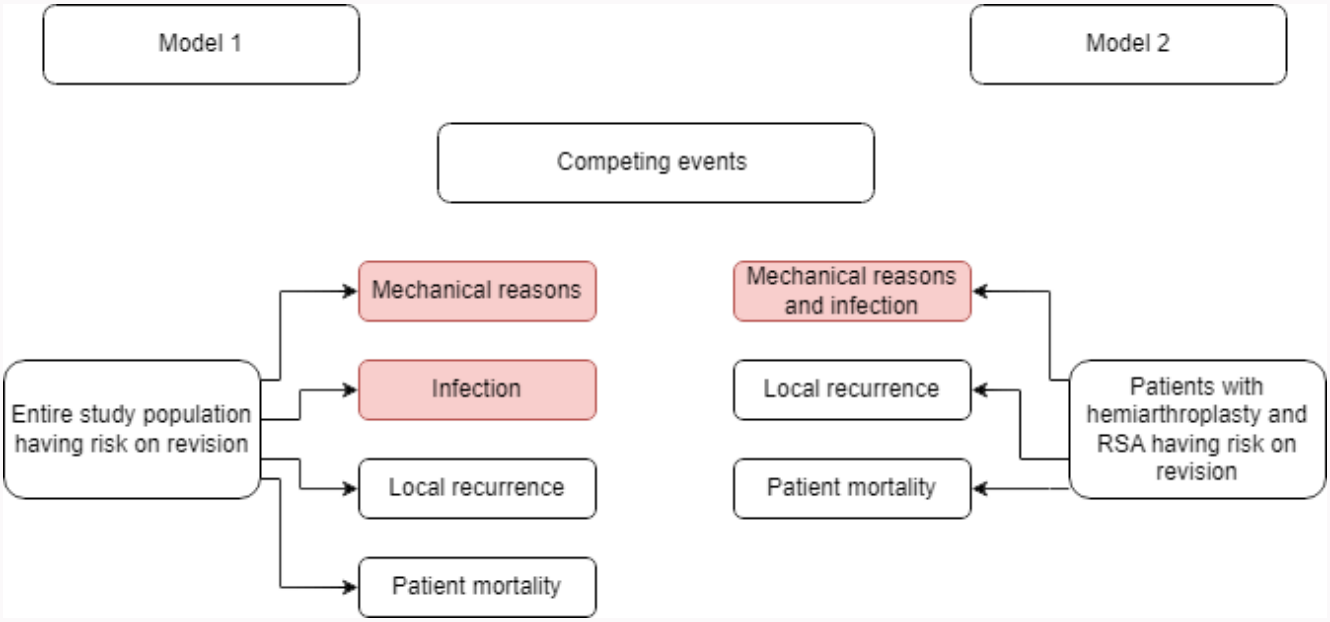

Fig. 1
Competing risk model with four competing events (left panel), and with three competing events (right panel). RSA, reverse shoulder arthroplasty.

Table IV. Functional outcomes of patients reconstructed with a MUTARS proximal humerus reconstruction. Data presented as medians (IQRs).

Variable	RSA	Hemiarthro-plasty	p-value*	RSA without reattachment rotator cuff	Hemiarthroplasty without reattachment rotator cuff	p-value*
Patients, n	42/61†	56/98†		12/13†	5/8†	
Anteflexion, °	73 (40 to 90)	30 (5 to 45)	< 0.001	80 (66 to 102)	52 (35 to 59)	0.006
Abduction, °	70 (38 to 90)	30 (5 to 45)	< 0.001	81 (63 to 90)	51 (38 to 65)	0.026
External rotation, °	15 (0 to 28)	5 (0 to 19)	0.192	15 (10 to 18)	10 (10 to 10)	0.232

*Mann-Whitney U test.
†Available cases for analysis of functional outcomes.
RSA, reverse shoulder arthroplasty.

(38%) > 12 months postoperatively. In one patient, the PJI followed after a revision procedure for loosening 14 years post implantation. In the remaining 15 patients, the reoperation for PJI was their first reoperation. Four PJIs were successfully treated with one DAIR, and seven PJIs were successfully treated with one-stage or two-stage procedures. Five PJIs necessitated implant removal, without further reconstruction. No significant risk factors for PJI were identified (Table III).

Local recurrence (H5B) was observed in ten patients (6%). Among these, eight underwent amputation, while two underwent re-resection and received a revision implant.

Cumulative incidence of implant revision and reconstruction status at final follow-up

The CIRs for mechanical reasons (Henderson 1 to 3) among the entire study population at two, five, and ten years were 7% (95% CI 3 to 11), 11% (95% CI 6 to 17), and 13% (95% CI 7 to 20), respectively. For PJI (Henderson 4), these were 5% (95% CI 2 to 10) 7% (95% CI 3 to 12), and 7% (95% CI 3 to 12) (Model 1, Figure 2). Specifically for RSA, the CIRs for mechanical reasons and infection (Henderson 1 to 4) at two, five, and ten years were 9% (95% CI 3 to 18), 22% (95% CI 11 to 37), and 24% (95% CI 11 to 37). For hemiarthroplasty, these were 13% (95% CI 7 to 21), 16% (95% CI 9 to 24), and 18% (95% CI 10 to 27) (Model 2, Figure 3). The number of TSAs (n = 6) was too small to provide an adequate estimation of the CIR. At final follow-up, 153 patients (93%) had a (revised) implant in situ.

Functional outcome

In patients with RSA, the median active anteflexion, abduction, and external rotation were 73° (IQR 40 to 90), 70° (IQR 38 to 90), and 15° (IQR 0 to 28), respectively (data available for 42 patients (69%)). For those with a hemiarthroplasty, these were 30° (IQR 5 to 45), 30° (IQR 5 to 45), and 5° (IQR 0 to 19), respectively (data available for 56 patients (57%)). Additionally, a subanalysis of patients without a reattached rotator cuff in both the RSA and hemiarthroplasty groups showed that RSA led to better functional outcomes (Table IV). The sample size for TSAs was too small to provide an adequate estimation of the ROM.

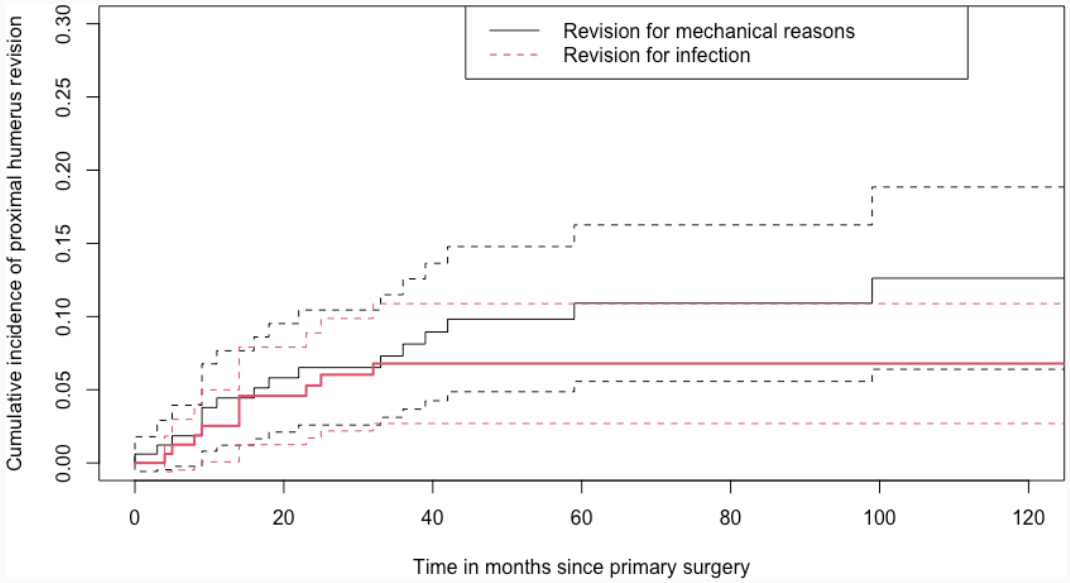

Fig. 2
Cumulative incidence of revision for mechanical reasons or infection.

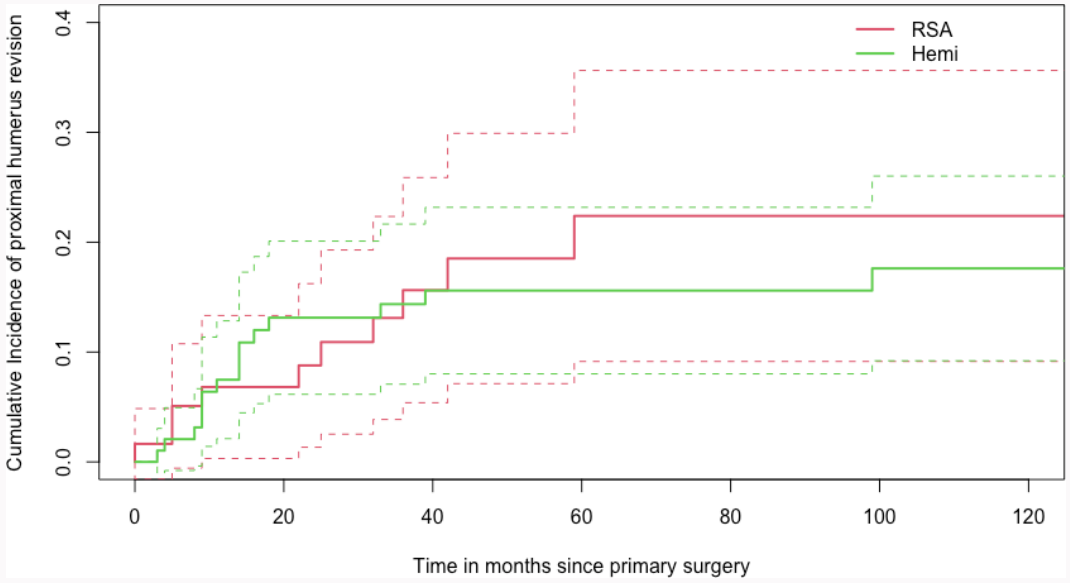

Fig. 3
Cumulative incidence of revision for both mechanical reasons and infection as event of interest, by type of proximal humerus reconstruction. Hemi, hemiarthroplasty; RSA, reverse shoulder arthroplasty.

Discussion

This study evaluates the clinical outcomes of proximal humeral reconstructions for a tumour defect with a MUTARS hemiarthroplasty, RSA, or (anatomical) TSA. It represents the largest series of proximal humerus reconstructions to date. We found satisfactory mechanical complication rates, although dislocation and infection remain relatively frequent causes for implant revision. RSA demonstrated good functional outcomes despite the fact that the rotator cuff was more often sacrificed in these patients.

Our dislocation rate (9%) is consistent with Raiss et al,[20] who reported a 10% dislocation rate in 39 patients with MUTARS proximal humerus endoprostheses. Our results are favourable compared to other studies on MUTARS hemiarthroplasty and RSA, ranging from 18% to 23%.[4,12,21] We identified previous surgery at the same site as a prognostic factor for revision due to dislocation. Other studies, possibly due to smaller sample sizes, did not identify any possible risk factors for dislocation. Sharma et al[22] reported a 14% dislocation rate in 21 cemented Stryker endoprostheses, and Kumar et al[7] described a 2% reoperation rate for dislocation in 100 Stanmore custom-made endoprosthetic reconstructions. Our results are equal to or favourable in comparison to alternative reconstructive techniques. Teunis et al[23] reviewed the literature and found a 0% to 31% dislocation rate among proximal humeral endoprostheses, 0% to 62% among allografts, and 0% to 21% in APCs. They concluded that there was no significant difference in dislocation

rates between reconstruction techniques. However, caution is warranted when interpreting these findings, as sample sizes of the studies in the review were typically limited.

We found loosening in 2% of our patients, which is in line with the findings of Raiss et al[20] (3% in 39 uncemented MUTARS prostheses). Trikoupis et al[4] reported a 5% loosening rate in a cohort of 40 patients reconstructed with either hemiartroplasty or RSA. Similarly, Trovarelli et al[21] documented one case of loosening in an uncemented stem in their cohort of 22 patients, of which ten were uncemented. Streitbuerger et al[12] and Guven et al,[24] on the other hand, observed no loosenings, although the follow-up in their studies was short and sample sizes were small. Kumar et al[7] observed three loosenings in 100 patients reconstructed with cemented custom-made Stanmore endoprostheses, while Sharma et al[22] found no loosenings in 21 cemented Stryker endoprostheses. Our results are favourable compared to the loosening rates in endoprostheses (0% to 20%) and APCs (0% to 17%) described by Teunis et al.[23]

Our PJI risk (10%) was somewhat higher compared to other publications with infection rates of 0% to 6% in MUTARS endoprosthetic reconstructions.[4,12,20,21,24] A possible explanation is a longer follow-up period, as we observed that 38% of our PJIs occurred later than one year postoperatively. Trovarelli et al[21] noted that they had no PJIs in silver-coated implants. Although we present the largest series to date, we found no difference for silver coating, nor did we identify other risk factors, which might be attributable to the multifactorial cause of PJI. van de Sande et al[6] identified comparable infection rates for allografts (1/13 patients, 8%), and APCs (1/10 patients, 10%), whereas Rödl et al[25] observed a 27% (4/15 patients) infection rate in clavicula pro humeri reconstructions. Our PJI risk is comparable or favourable to the infection rate in endoprosthesis (0 to 20%), allografts (0 to 25%), and APCs (0 to 13%) as described by Teunis et al.[23] However, it is important to note that there is substantial variability and uncertainty regarding complication rates due to limited sample sizes and heterogenous study populations. The ten-year CIRs for mechanical reasons and infection for hemiarthroplasty and RSA were 18% and 24%, respectively, which is in line with other studies reporting a 5% to 32% implant revision rate. However, comparisons are difficult due to differences in statistical methodology: we employed competing risks models to estimate the CIR, while others use the Kaplan-Meier method. In addition, most previous studies had shorter follow-up periods.[4,12,20,21,24] Interestingly, a plateau in the risk of revision over time can be observed in our cohort, suggesting that patients have a relatively low risk of revision once they have passed the initial postoperative years without revisions. As for alternative reconstructive techniques, van de Sande et al[6] reported a poor five-year implant survival of 9% for osteoarticular allografts, and 60% for APCs with implant revision as the endpoint. With implant removal as the endpoint, the five-year implant survival for osteoarticular allografts was 61%, and 90% for APCs. Rödl et al[25] reported a ten-year cumulative survival of 79% for the clavicula pro humeri procedure, 75% for osteoarticular allografts, and 83% for endoprostheses. In the systematic review by Teunis et al,[23] the survival rates of endoprostheses (38% to 100%) were comparable to those for osteoarticular allografts (33% to 100%) and APCs (33% to 100%). As previously reported, RSAs seem to offer significantly better functional results compared to anatomical reconstructions, particularly for those with killed rotator cuff muscles.[4,24,26] This improvement can be attributed to the fact that the centre of rotation is moved medially and inferiorly, which increases the deltoid muscle's moment arm.[27] Another factor could be an indication bias favouring RSA, as these patients were generally younger and potentially more active. The ROM after RSA in our study was comparable to those in other studies with active flexion ranging from 88° to 117°, abduction from 80° to 103°, and external rotation of 13°.[4,12,21,24] Similarly, the ROM of patients with hemiarthroplasty or anatomical reconstructions was comparable with other studies, showing active anteflexion ranging from 34° to 60°, abduction from 33° to 55°, and external rotation of 12°.[4,20] Several limitations must be acknowledged. First, the relatively small number of TSA cases limits the generalizability of the findings related to this implant type. However, there is limited indication for TSA in oncological patients, as TSAs require an intact rotator cuff to function properly, while the cuff is often sacrificed during tumour resection. Second, the MORE focuses on complications requiring reoperation, which likely leads to an underestimation of the true incidence of complications, most notably dislocations. Nevertheless, patients who do not choose or require revision for instability often continue to live well despite having an unstable shoulder joint. Third, despite the fact that we present the largest series to date, the limited number of events per complication hampered the multivariate analyses. At last, the absence of patient-reported outcome measures (PROMs) prevented their use in this study. To effectively evaluate patient outcomes, centres should systematically collect PROMs as a standard of care. This is the largest series on proximal humerus reconstructions to date and could serve as a benchmark for future studies, given the current lack of large-cohort comprehensive studies with adequate follow-up on these reconstructions. Clinical outcomes are satisfying, particularly in terms of mechanical failure. RSA and hemiarthroplasty exhibit comparable revision risks. The risk of dislocation is higher in patients with previous surgery at the same site. RSA appears to provide good functional outcomes, even in the absence of a functioning rotator cuff. These findings suggest that clinicians should consider using RSA over hemiarthroplasty, given its comparable revision risk and superior functional outcomes.

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Data sharing

The study protocol can be requested at the corresponding author. Anonymized data are available on request.

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