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ORIGINAL PAPER

Composite reverse shoulder arthroplasty can provide good function and quality of life in cases of malignant tumour of the proximal humerus

Cyril Lazerges[1] · Louis Dagneaux[2] · Benjamin Degeorge[1] · Nicolas Tardy[3] · Bertrand Coulet[1] · Michel Chammas[1]

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Abstract
Purpose Management of proximal humeral tumours remains a surgical challenge. No study to date has assessed the quality of life scores following the composite reverse shoulder arthroplasty for this indication. We, therefore, evaluated function and quality of life following reconstruction with allograft for malignant tumour of the humerus.
Methods A series of six cases of humeral tumour treated by a single surgeon in a single centre was reviewed after a mean follow-up of 5.9 years. The tumours included two chondrosarcomas, one plasmocytoma and three metastases. Resection involved bone epiphysis, metaphysis and diaphysis in five cases (S3S4S5A) and epiphysis and metaphysis in one case (S3S4A). For reconstruction, an allograft composite reverse shoulder arthroplasty was used in all the cases. Outcomes were assessed with range of motion, the QuickDash score and the Short Form 12 (SF-12) Health Survey. Radiographs assessed osseointegration and complications.
Results At the final follow-up, the mean shoulder range of motion were respectively 95°, 57° and 11° for forward flexion, abduction and external rotation. Mean QuickDASH score improved from 28 to 41 and VAS-pain scores improved from 5.1 to 2.3. The post-operative MSTS score was 73% and the Constant score was 46.1/100. The SF-12 PCS and MCS scores were also improved, respectively from 44.4 and 39.7 to 45.5 and 56.1. The mean satisfaction score was 8.1/10.
Conclusions Composite reverse shoulder arthroplasty is a viable alternative for reconstruction after resection of malignant humeral tumour. Although total tumour resection was the most important objective, the functional and quality of life scores were satisfactory.

Keywords Tumour · Quality of life · Reverse shoulder arthroplasty · Composite prosthesis · Reconstruction · Allograft

Introduction

The proximal humerus is the most frequent location of bone tumours in the upper limb [1]. Wide resection with free margins is the overriding concern and this often requires sacrifice of muscle [2], depending on tumour extension. Management of humeral tumours thus remains a surgical challenge as the twofold goal is tumour resection and the preservation of shoulder function and patient quality of life. Several methods for bone reconstruction are possible: metal arthroplasty [1, 3], reverse shoulder arthroplasty (RSA) [4–7], composite arthroplasty [6, 8, 9], scapulohumeral arthrodesis [10] and allograft alone [11, 12]. The choice depends on the size of the tissue resection: De Wilde et al. [4] therefore proposed RSA for this indication, given the frequency of rotator cuff resection.

It is difficult to assess the impact of this surgery as it requires a high level of specialisation and the studies to date have been based on small series. Reconstruction with

✉ Cyril Lazerges
c-lazerges@chu-montpellier.fr

[1] Hand and Upper Extremity Surgery Unit, Lapeyronie University Hospital of Montpellier, 191 avenue du Doyen Gaston Giraud, 34295 Montpellier cedex 5, France

[2] Hip, Knee and Foot Surgery Unit, Lapeyronie University Hospital of Montpellier, 191 avenue du Doyen Gaston Giraud, 34295 Montpellier cedex 5, France

[3] Centre ostéo articulaire des Cèdres, 21 Rue Albert Londres, 38432 Échirolles, France

composite prostheses preserves good mobility post-operatively and the implants are long-lasting despite the sizeable bone resection [6, 7]. Only two studies have assessed the consequences of reconstruction using anatomic prostheses on the quality of life [9, 13]. The authors reported that the overall mobility of the affected limb was satisfactory, with compensation by the underlying joints and the use of the contralateral limb, thereby ensuring a good quality of life. Recently, other authors have reported that RSA is a beneficial alternative [5–7]. However, no study has yet investigated the quality of life of patients who have received this implant. The aim of our study was, therefore, to evaluate quality of life with the SF-12 score and functional status after resection of a humeral tumour and composite RSA.

Material and methods

A series of six patients from a single centre was reviewed, all of whom had undergone resection and reconstruction for malignant tumour of the proximal humerus by a single surgeon between 2008 and 2013. The data were prospectively collected from four men and two women, with a mean age of 65.5 years (41–79). The diagnoses were as follows: two chondrosarcomas, one plasmacytoma and three cases of metastatic disease (from lung cancer in one case and kidney cancer in two cases). The dominant side was affected in four cases. Radiotherapy was given in four cases, chemotherapy in one case, and they were associated in two cases. All adjuvant treatment began within two months post-surgery. Three patients presented pre-operative pathological fractures: two with metastatic disease and one with plasmacytoma. All patients were followed clinically in a specialised cancer treatment centre. Each subject signed an approved consent form for publication.

Surgical technique The surgeon used a deltopectoral approach. An en bloc resection including the biopsy track was performed in all cases (Fig. 1). The resection was evaluated according to the criteria of the Musculoskeletal Tumor Society (MSTS), as described by Enneking et al. [14] in 1990: epiphysis-metaphysis-diasphysis with sparing of the abductor muscles (S3S4S5A) in five cases and epiphysis-metaphysis with sparing of the abductor muscles (deltoid) (S3S4A) in one case (Fig. 2). Tumour resection with wide margins was always restricted to the proximal humerus. Deltoid muscle management was as follows: distal deltoid sparing in all cases, anterior deltoid resection in one case and deeper deltoid resection in one case. Sparing of the posterior rotator cuff (teres minor and infra spinatus) was possible in four cases. The upper part of the medial triceps was resected in two cases. The reconstruction used an RSA with reverse composite with cemented fixation in all cases: two Aequalis® Reversed prostheses (Tornier, Montbonnot Saint Martin, France) and four XTend® prostheses (DePuy Synthes, Warsaw, IN, USA). The average length of the bone resection was 13 cm (11–16). All the patients also received a humeral allograft after extended resection to restore humeral height and to facilitate muscle reinsertion (Fig. 3): distal deltoid by anchor and posterior rotator cuff through the tendinous insertion of the allograft.

Clinical and radiological evaluation Our standard follow-up protocol included clinical assessment and X-ray acquisitions at three and six months, and then every year. Data were collected by the senior surgeon. Pain assessed with a visual analogue scale (VAS), clinical function with the QuickDASH, and quality of life with the SF-12 questionnaire [Physical Component Summary (PCS) and Mental Component Summary (MCS)] [15] were evaluated pre-operatively and at the last follow-up visit. Functional evaluations were performed over the course of follow-up and at the last visit with clinical examination of the shoulder: passive and active mobility in forward flexion, abduction, internal rotation and external rotation (elbow to the body). Muscle strength at 45° of abduction was evaluated using the Medical Research Council (MRC) scale for muscle power. Subjective instability was evaluated with an analogue scale. Clinical QuickDASH, MSTS [16] and

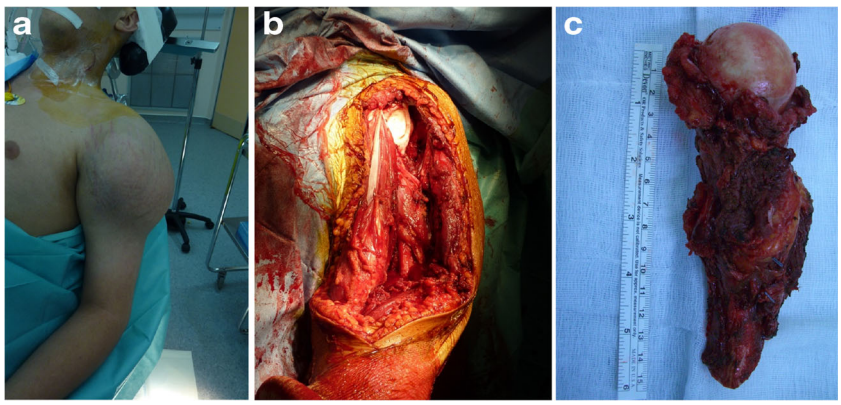

Fig. 1 Photographs showing the shoulder malignant tumour (**a**), view of the deltopectoral approach (**b**) and extended tumoural resection S3S4S5A (**c**)

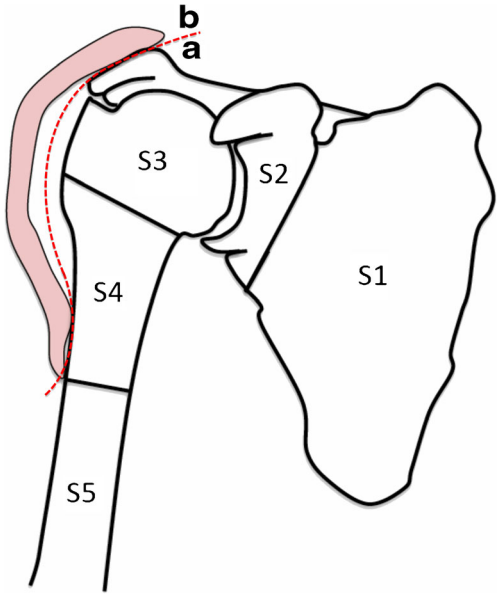

Fig. 2 Classification of skeletal resection around the shoulder girdle, according to the Musculoskeletal Tumor Society by Enneking et al. [14] with (**a**) or without (**b**) preservation of the abductor muscles

Constant scores were assessed, and the latter score was compared with the score for the healthy contralateral shoulder. The aim of our study was, therefore, to evaluate quality of life after resection of a humeral tumour and composite RSA. Our primary criterion was the SF-12 questionnaire. The secondary criterion was the functional status in order to correlate the quality of life with shoulder function. Radiographs were examined to assess osseointegration of the prosthesis, secondary displacement, non-union of the allograft-host junction and scapular notching according to the Sirveaux classification [17].

Statistical evaluation All statistical tests were performed using SPSS 22.0 software® (IBM Corporation, Armonk, NY, USA). Functional and quality of life scores were compared using a non-parametric test (Wilcoxon test). A p value of <0.05 was considered significant.

Results

The six patients were followed for an average of 5.9 years (2.7–7.8). One tumour-related death was recorded (patient 5, follow-up 2.7 years) 3.5 years post-surgery. Three patients were retired and two were working, one performing heavy physical work and the other performing light physical work. One patient presented with recurrent prosthetic dislocation during the early follow-up period, requiring surgical revision at one month post-surgery to increase the humeral length (patient 6). No tumour recurrence was observed.

Clinical evaluation at the final follow-up visit The mean VAS-pain scores at rest and during activity were respectively 1.2/10 (0–4) and 2.3/10 (0–4). Pain at rest and during activity improved significantly (respectively, $p = 0.035$ and $p = 0.033$). Mean passive mobility in abduction, forward flexion and external rotation was, respectively, 75° (40–110), 113° (90–150) and 31° (0–50). The mean passive internal rotation was to L4. Mean active mobility in abduction, forward flexion and external rotation was, respectively, 57° (30–90), 95° (70–130) and 8° (0–15), with mean internal rotation to L4. The mean QuickDASH score was 41/100 (7.5–70). We observed no significant difference between the pre-operative and post-operative QuickDASH scores ($p = 0.093$). The mean functional Constant score was 46.1/100 (14–70) on the operated side and 85.8/100 (83–90) on the healthy side ($p = 0.035$). The mean MSTS score was 67% (57–73). No patient complained of a feeling of shoulder instability. Mobility and functional scores according to deltoid muscle sacrifice are presented in Table 1. Patients who underwent partial resection of the deltoid appeared to have lower mean scores of mobility in abduction and forward flexion than the others: respectively, 35° and 65° versus 70° and 107°.

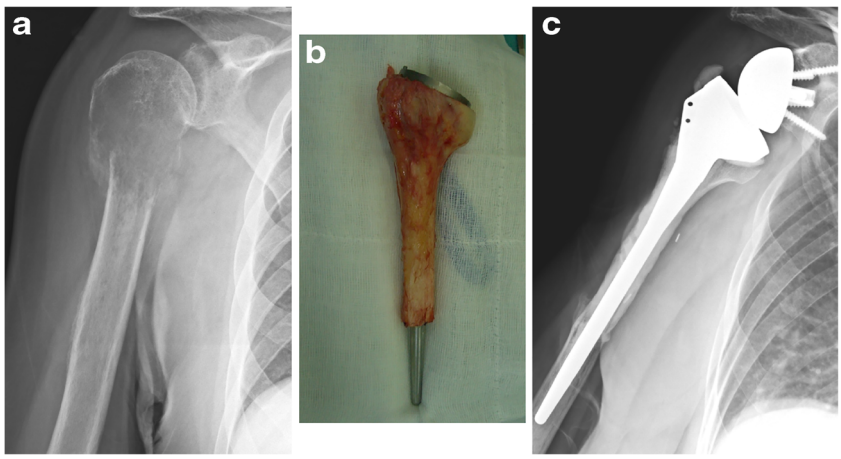

Fig. 3 Radiographs showing proximal humeral pathological fracture in plasmocytoma (**a**), view of the allograft composite reverse shoulder arthroplasty (Aequalis Reversed prosthesis®; Tornier, Montbonnot Saint Martin, France) (**a**) and radiograph showing the shoulder reconstruction at 6.1 years' follow-up (**c**)

Table 1 Shoulder mobility and functional scores according to deltoid sacrifice with mean and range

	Abduction (°)	Forward elevation (°)	MSTS score [18]	Constant score	QuickDASH score
Total	57 (30–90)	95 (70–140)	73 (57–90)	46.1 (14–55)	41.2 (7.5–61)
Partial deltoid sacrifice	35 (30–40)	70 (70–70)	70 (57–83)	26 (14–38)	42 (14–70)
Deltoid sparing	65 (40–90)	107 (80–140)	74 (57–90)	56.3 (50–70)	40.8 (7,5–61)

Evaluation of quality of life The mean SF-12 PCS score increased from 44.4 (35.6–51.1) to 45.5 (35.2–52.5) at the last follow-up visit (Table 2). Similarly, the mean SF-12 MCS score increased from 39.7 (27.5–49.9) to 48.4/100 (49.9–61.2). The difference between the pre (Table 2) and post-operative scores for the physical component was not significant ($p = 0.68$), but the difference between scores for the mental component was ($p = 0.031$).

Final radiographic evaluation No secondary displacement was observed. No lysis in the allograft or prosthetic loosening occurred. The allograft-host junction was consolidated in five cases. Non-union of the allograft was observed in one case (patient 1). Two glenoid notches were visible: a stage 1 (patient 1) and a stage 4 (patient 2) according to the Sirveaux classification.

Discussion

The proximal humerus is the fourth most common site for tumours and the first site for malignant tumours of the upper limb. Cancer surgery requires a wide en bloc tumour resection. The muscle sacrifice depends on the degree of tumour invasion. Obtaining clear margins is the priority and is correlated with better survival [19]. The type of reconstruction is thus based on the size, type and location of the tumour, the ability to obtain clear surgical margins, and the surgeon's experience. We think that in the complex case of reconstruction, allografts can be used to reproduce the glenohumeral anatomy, thereby allowing the reinsertion and healing of the abductor apparatus and achieving better functional recovery [12]. A series of six cases of composite RSA was reviewed, with follow-up comparable to that of most of the series reported by Teunis et al. [18] in their literature review (mean follow-up of 6 years). In line with the results in the literature, the extent of resection and muscle sacrifice clearly influenced the functional shoulder outcome [11].

Several reconstruction techniques are possible following resection of a tumour of the proximal humerus [1, 3–12]. RSA, which was initially designed for the arthritic shoulder with rotator cuff tear, operates through the mechanical action of the deltoid muscle, which raises the arm. Its use in shoulder reconstruction after tumour resection seems logical, given the sacrifice of the rotator cuff muscles. De Wilde et al. [20] reported that post-operative mobility was improved with RSA

Table 2 Evaluation of the quality of life with SF-12 PCS and MCS scores and SF-12 scores according to deltoid sacrifice with mean and range

	Pre-operative PCS	Post-operative PCS	Pre-operative MCS	Post-operative MCS
Patient 1	51.1	50.9	35.6	57.7
Patient 2	46.4	52.5	48.3	61
Patient 3	35.6	38.1	33.3	61.2
Patient 4	46.4	35.2	27.5	52.6
Patient 5	48.3	46.4	43.3	49.9
Patient 6	38.6	49.9	49.9	54.2
Significance	$p = 0.68$		$p = 0.031$	
Total ($n = 6$)	44.4 (35.6–51.1)	45.5 (35.2–52.5)	39.7 (27.5–49.9)	56.1 (49.9–61.2)
Partial deltoid muscle sacrifice ($n = 2$)	41 (35.6–46.4)	45.3 (38.1–52.5)	41.9 (35.6–48.3)	59.4 (57.7–61)
Deltoid muscle sparing ($n = 4$)	46.1 (38.6–51.1)	45.6 (35.2–50.9)	38.5 (27.5–49.9)	54.5 (49.9–61.2)

Table 3 Shoulder mobility and functional scores according to the type of prosthetic reconstruction in literature with mean and range

Type of prosthetic reconstruction	Author	Inclusion (number)	Deltoid muscle resection	Mobility (°)		Constant score
				Forward elevation	Abduction	
Anatomic prosthesis	Abdeen et al. [8]	10	No	70 (42–98)	72 (51–93)	–
		11	Partial	59 (46–72)	52 (41–53)	–
		13	Total	23 (19–26)	19 (17–21)	–
RSA	Bonnevialle et al. [7]	10	No	122 (40–170)	–	52 (7–84)
	Guven et al. [5]	3	No	140 (100–160)	133 (90–160)	71 (44–96)
		7	Partial	77 (30–130)	68 (30–110)	46.2 (22–63)
	King et al. [6]	2	Partial	114 (108–120)	95 (90–100)	62.7

with a mean abduction of 157°. However, little is known about the results in cases of partial resection of the deltoid and for young subjects. Abdeen et al. [8] notably described a decrease in mobility in abduction and forward flexion, depending on the degree of deltoid sacrifice. In another study, Kumar et al. [3] insisted on the preservation of an innervated deltoid, as denervation greatly reduces the functional outcome. Thus, the respective mean mobility in abduction and forward flexion was 72° and 70° with preservation of the abductor apparatus, 52° and 59° with partial sacrifice, and 19° and 23° with total sacrifice of the deltoid. The MSTS score was satisfactory regardless of the type of resection, but did not satisfactorily discriminate the influence of muscle sacrifice. In a review of the literature on reconstructions with composite prostheses, Teunis et al. [18] found a majority of MSTS scores between 60 and 79%, equivalent to our findings. The QuickDASH and Constant scores were altered by this surgery, but they did not appear to be specific to the muscle sacrifice secondary to the surgery. Few studies have sought to determine the difference in postoperative function between anatomic arthroplasty and RSA. However, RSA tends to provide better mobility in forward flexion and abduction, as summarised in Table 3. Although our series was too small to highlight a difference between sacrifice and sparing of the abductor apparatus, a better functional outcome with preservation seems likely. In addition, the functional result is also dependent on specialised physiotherapy to teach patients how to use the affected limb. Physiotherapy is well known to improve the autonomy of patients with cancer and their quality of life [21].

The cumulative complication rate in our series was 33%: one case of dislocation and one case of non-union of the allograft-host junction. The dislocation occurred early on, within the first three months post-surgery. A wide resection is known to destabilise the glenohumeral joint. Intra-operative testing and the use of a larger polyethylene insert therefore seem indispensable in cases of instability. Gebhardt et al. [11] found the complication rate specific to allografts to be 67% (one case of non-union, one case of instability, seven cases of graft fracture and infection) and Mourikis et al. [22] reported a similar rate. In a comparative study, Potter et al. [23] found superior function and a lower complication rate with allograft composite RSA than with either an allograft or RSA alone. King et al. [6] described increased prosthetic stability with the use of allograft composite RSA compared with other types of reconstruction. Although the complication rate was high in our series, it seems to have had no impact on long-term function at six years of follow-up.

Quality of life scores were assessed to test our hypothesis that reconstruction by RSA would maintain the quality of life of patients after tumour resection. In the general French population, the mean SF-12 scores for PCS and MCS are respectively 51.2 (±7.4) and 48.2 (±9.4) [15, 24]. In our series, the postoperative PCS score was, as expected, slightly lower than the mean score for the general population, which was not the case for the MCS score. Reconstruction by allograft composite RSA therefore seems to provide satisfactory quality of life, as confirmed by the SF-12 physical and mental scores (PCS and MCS). Pre-operative and post-operative PCS scores were similar, but MCS was significantly improved post-operatively. Moreover, subgroup analysis was not reliable because of the small number of cases, but quality of life did not seem to be linked to the muscle sacrifice necessary for oncological resection. In the two cases of partial deltoid resection, improvement in the SF-12 MCS scores was still observed. Our study nevertheless has several limitations: the small number of cases, the relatively short follow-up period (mean, 5.9 years), and the heterogeneity

of the series. Although it is difficult to conclude as to a difference in quality of life due to muscle sacrifice, this finding has been reported by other authors for anatomical prosthetic reconstructions for tumour [9, 13]. Black et al. [9] reported similar results with the SF-36. The mean MCS score increased post-operatively (pre-operative: 48.3 versus 57.5 at the last follow-up visit), indicating an improved psychological state post-surgery despite diminished physical capacities, as indicated by the decrease in the mean PCS score (46.8 pre-operatively versus 41.5 at the last visit). Kiss et al. [13] suggested that the enhanced quality of life after resection was due to the increased use of the contralateral limb to provide partial compensation and the good dexterity and mobility of the distal limb. Damron et al. [25] and Witting et al. [26] reported that the dexterity and strength of the forearm and hand of the affected limb were acceptable, although slightly lower than on the contralateral side. In our series, patient satisfaction scores were high (8.1/10) despite lower active glenohumeral mobility and were associated with low VAS-pain scores (1.75/10). Several studies have reported the negative influence of low functional outcome on quality of life [27, 28]. The declines in mobility were well accepted by the patients, probably because of the initial cancer diagnosis and fear of amputation. They therefore reported a good quality of life at the last follow-up visit. These patients had nevertheless undergone major surgery and one might wonder about the sustainability of our results. Kumar et al. [3] reported a 20-year survival rate of 86.5% following prosthetic reconstruction and Witting et al. [26] reported 100% at 10 years. Very long-term quality of life now needs to be assessed to determine whether it changes. Also, the lack of cancer recurrence is another parameter that should be considered from a psychological point of view [29]. Indeed, total tumour resection is the primary outcome measure of surgical success and affects the quality of life of patients.

Conclusions

This study of a small series of patients with malignant tumours of the proximal humerus does not provide statistical evidence on the outcome of composite reverse shoulder arthroplasty. It, nevertheless, shows that this alternative seems to be reliable, including functional recovery and quality of life. The quality of life seems to be more related to oncological remission than to range of motion.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval For this type of study, formal consent is not required.

Informed consent Informed consent was obtained from all individual participants included in the study.

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