Custom-made endoprosthetic total humerus reconstruction for musculoskeletal tumours

Mayil Natarajan · Mohamed Sameer · Dheep Kunal · Navin Balasubramanian

Received: 25 January 2011 / Accepted: 24 June 2011 / Published online: 28 July 2011
© Springer-Verlag 2011

Abstract

Purpose We analysed 11 patients with malignant musculoskeletal tumours of the humerus who underwent limb salvage surgery with total humeral custom endoprosthesis from 1990 to 2009.

Methods There were six male and five female patients, with a mean age of 17 years. The most common diagnosis was osteosarcoma. The average follow-up period was 66 months, with the maximum being 180 months. Functional and oncological outcomes were analysed.

Results The one and five year cumulative survival (Kaplan–Meier method) rates were 90.9% and 77.9 %. The average Musculoskeletal Tumour Society Score (MSTS) was 80%. Two patients died due to metastasis. One patient had a forequarter amputation for local recurrence. The procedure provides fast recovery and relatively good restoration of elbow function, whereas active shoulder movements remain limited

Conclusion Total humeral custom endoprosthetic replacement represents a viable treatment option in indicated patients, providing reliable and reasonable function of the upper limb, with a low complication rate.

Introduction

The humerus is a common site for malignant musculoskeletal tumours. With advances in effective adjuvant chemotherapy, diagnostic imaging and improved surgical methods, limb-salvage surgery is now an accepted treatment modality, with

functional and oncological outcomes better than limb ablation [1–4]. In particular, salvage of the upper limb provides better emotional and social acceptance of patients due to forearm and hand preservation.

The use of allografts, alloprosthetic composites and prosthetic replacements to reconstruct the proximal humerus after tumour resection and associated complications have been well described [5–9, 11]. However, extensive tumours of the humerus, large tumours of the diaphysis and local recurrent disease after limb-salvage surgery present unique problems with respect to reconstruction options. Despite extensive experiences with prosthetic replacements for bone tumours, there are few reports on limb-salvage surgery using total bone replacements in such difficult situations, especially so in the humerus [12, 13].

We therefore present our results for one of the first consecutive case series of custom-made total humerus endoprosthesis in order to evaluate oncological, surgical and functional outcomes.

Patients and methods

Eleven patients with primary malignant bone tumours involving part or the entire humerus underwent endoprosthetic replacement using a custom-made total humerus endoprosthesis between May 1991 and April 2009 (patient details outlined in Table 1). There were six male and five female patients with a mean age of 17 (median 16; range 6–27) years. The most common diagnosis was osteosarcoma, which occurred in nine patients. One patient had Ewing's sarcoma, and the remaining patient had recurrent fibromatosis of the upper arm.

The origin of malignancy was the proximal third of the humerus in five patients and of the diaphysis in six. Four

M. Natarajan · M. Sameer · D. Kunal (✉) · N. Balasubramanian
Madras Medical College, Orthopaedics,
Madras, India
e-mail: drkunalatheep@gmail.com

Table 1 Patient clinical data of patients. Endoprosthetic total humerus replacement for humeral tumours: long-term results

Case no.	Age	Gender	Histopath. diagnosis	Stage	Type of prosthesis	Preop. chemotherapy cycles	Preop. RT	Period of FU(months)	Functional results (%)	Oncological outcome	Remarks
1.	18	M	OS	IIA	PH	3	No	144	66	NED	TH– done for PH implant failure 01/1997 Ulnar stem blow out 07/2007
2.	18	F	AF	IIA	TH	0	No	180	76	NED	
3.	27	F	OS with PF	IIB	TH	3	No	72	73	NED	
4.	25	M	OS with PF	IIA	TH	3	No	60	86	NED	
5.	16	M	OS	IIA	TH	3	No	13		Local recurrence 07/05 Systemic metastasis DOD	Amputation 07/2005; Death due to systemic spread
6.	15	M	OS	IIB	TH	3	No	18		Systemic metastasis DOD	Death due to systemic spread
7.	25	F	OS with PF	IIA	TH	3	No	24	79	NED	
8.	12	M	OS	IIA	TH	3	No	24	86	NED	
9.	6	F	OS	IIA	TH ext	3	No	12	83	NED	
10.	15	M	OS with PF	IIB	TH ext	3	No	12		Local recurrence NED	Forequarter amputation done
11.	12	F	ES	IIA	TH	3	Yes	12	86	NED	

Histo. histopathological, *RT* radiotherapy, *FU* follow-up, *preop.* preoperative, *TH* total humerus endoprosthesis replacement, *PH* proximal humerus endoprosthesis replacement, *OS* osteosarcoma, *OS with PF* osteosarcoma with pathological fracture, *ES* Ewing's sarcoma, *AF* aggressive fibromatosis, *A* alive, *D* dead, *NED* no evidence of disease, *DOD* died of disease

patients had a pathological fracture at presentation. Patients required a custom-made total humerus endoprosthesis, as they had involvement of more than one third of the humerus either by tumour extension, fracture haematoma or recurrence. These specific conditions precluded retention of any portion of the humerus for stable anchorage of the custom-made proximal humerus or intercalary endoprosthesis. The diagnosis was confirmed by needle biopsy in all but three patients, who were referred to us after open biopsy at another institution. All patients underwent standard radiographic examination, including computed tomography (CT) and magnetic resonance imaging (MRI), and their disease was staged according to the American Musculoskeletal Tumour Society (AMTS) scoring system (Enneking system) [15]. Eight patients had stage IIA and three stage IIB tumours. One patient with osteosarcoma initially underwent tumour resection and reconstruction with a proximal humerus endoprosthesis. A periprosthetic diaphyseal fracture indicated secondary conversion to a total humerus implant (patient 1). All other patients received the custom-made total humerus implant during index surgery. No patient had distant metastasis at presentation. All patients with malignant tumours underwent (neo-) adjuvant chemotherapy according to respective protocols. Preoperative radiotherapy was given to the patient with Ewing's sarcoma (Fig. 1).

The prosthesis

The total humerus endoprosthesis used in this series was a custom-made implant individually designed for each patient to replace the humerus, shoulder and elbow (Fig. 2). The proximal component consisted of a unipolar head with provisions to attach abductors, and the elbow joint has a hinge with inherent flexion of 150°. Prosthetic dimensions were determined by taking anteroposterior and lateral radiographs of shoulder, humerus and elbow of the normal limb to avoid undue shortening or lengthening. The material used to manufacture the prosthesis was stainless steel 316 L in four patients and titanium alloy incorporating 6% aluminium and 4% vanadium in seven. Except for minor changes in the proximal humeral part, the prosthesis has remained largely unchanged over the last eight years. In two young patients, we used an expandable total humerus endoprosthesis.

Operative technique

An anterior approach to the humerus was chosen in all patients, including resection of the biopsy scar wherever indicated. The deltoid and rotator-cuff muscles were preserved as much as possible without sacrificing adequate tumour clearance. Neurovascular structures were identified,

Fig. 1 Preoperative X-ray (AP view) of a patient with left humeral osteosarcoma

isolated and preserved in all cases. The shoulder joint was disarticulated and the tumour removed in toto, along with part of the olecranon, preserving the triceps flap attachment. Resected margins were wide in nine patients and marginal in

Fig. 2 Total humeral custom mega prosthesis

two. The proximal ulna was reamed, and the intramedullary stem of the implant was inserted with cementation. The unipolar humeral head was reduced into the glenoid, and stainless steel wires were used for static suspension of the prosthesis to the acromion process through drilled holes in the first seven patients; Dacron tapes were used in the rest. A nonabsorbable mesh was used in four patients in the later part of our series, in addition to wires and tapes to provide a more stable shoulder joint (Fig. 3).

Results

Patients were followed monthly for the first three months, then biannually for the first year and annually thereafter to assess functional, surgical and oncological outcomes. Mean follow-up was 66 (median 18; range 12–144) months. Eight patients were disease free up to the latest follow-up. Two patients developed local recurrence at six and eight months after surgery, respectively: the first also developed pulmonary metastases and succumbed to the disease after palliative chemotherapy; the second underwent forequarter amputation and was disease free 12 months after index surgery (patient 10). Pulmonary metastases were diagnosed in another patient one year after surgery, who also died of disease after palliative chemotherapy. Survival analysis was performed according to Kaplan–Meier (Fig. 4). The five year

Fig. 3 Post operative X-ray (AP view) showing four year follow-up of the same patient

Fig. 4 Kaplan Meier analysis

overall survival of all patients was 78%, and the five year disease-free survival was 73% [20].

All patients had passive more than active movement, and none could actively elevate their arm above shoulder level. Some also had less than full extension of the elbow, but all had good hand function. All patients showed some degree of proximal migration or instability of the prosthetic head; only one patient suffered from painful impingement against the acromioclavicular joint, with restriction of movement. The unipolar head of the prosthesis alone was removed, leaving the proximal stem to articulate with the glenoid, resulting in pain-free movement at the shoulder. One patient with osteosarcoma who underwent a successful revision total humerus endoprosthesis for failure of the proximal humerus prosthesis experienced ulnar stem blow-out after seven years (patient 1). However, the patient declined ulnar stem revision, as he had a satisfactory and pain-free range of movement. Two young skeletally immature patients received an expandable prosthesis (patients 9 and 10). One underwent a forequarter amputation for local recurrence. The other showed a humeral shortening of 15 mm compared with the healthy contralateral side upon skeletal maturity. There were no cases of infections: two patients showed superficial wound-healing disturbance that resolved under conservative management. Functional outcome was assessed according to the MSTS score, including data on pain, function, emotion, hand position, manual dexterity and lifting ability [7, 12, 13]. Mean MSTS score for eight patients who had their limb salvaged was 80% (24 points).

Discussion

Endoprosthetic replacement of the proximal humerus offers a safe, feasible and reliable option. It provides fast recovery and relatively good restoration of elbow function, although active shoulder movements remain limited [7–9, 14, 16–18]. Though these patients have minimal movements at the shoulder, the technique allows them to gain a reasonable range of movement in the elbow and hand. Where bone resections for tumour clearance preclude using a proximal humeral or intercalary endoprosthesis for stable anchorage, using a total humeral custom endoprosthesis allows such patients to retain the limb with a functional elbow and hand. Replacing the entire humerus with prosthesis is a relatively new concept that presents unique difficulties in the form of complex articulation of the shoulder joint and the hinged elbow joint; significant loss of supporting structures, such as rotator cuff, deltoid and triceps during tumour resection, proximity of major neurovascular structures making dissection difficult. The major advantages are early functional recovery, a relatively low complication rate and high level of emotional acceptance. Full range of shoulder movements cannot be achieved by available methods of reconstruction after resections that sacrifice a part or all of the rotator cuff and deltoid [7–10, 14]. There was significant loss of shoulder abduction and flexion in all patients. They had good range of movements at the elbow and hand, enabling them to carry out activities of daily living. These patients constantly re-educate, reinvent and modify movements of the upper limb to comfortably suit their daily activities, as seen during their follow-up. Proximal migration of the prosthesis was observed throughout our series, as with any other series on proximal humeral replacement, due to extensive resection of rotator cuff muscles [7–10, 14]. Using SS wires and Dacron tapes to secure the prosthetic humeral head to the acromion was inadequate to provide optimum stability. However, in the latter part of our study, this problem could be limited to a great extent by using mesh to capture the prosthetic head [13, 21]. Patients with proximal migration were largely asymptomatic due to the limited shoulder function, and hence no revision was attempted.

It is our experience over the two decades we have used endoprosthetic replacement that the two main causes of failure in the lower limb—namely, infection and loosening with fracture—have not been apparent in the upper limb. This has also been substantiated by the Ayoub et al. study [13]. Achieving disease-free margins should be the prime concern in limb-salvage surgery for malignant lesions. We managed to achieve disease-free margins in nine patients. We had a local recurrence rate of 18% (two of 11 patients), which is higher in comparison with Malawar et al. and our own series on proximal humerus tumours [16]. This, we felt, was probably due to the extensive and aggressive

nature of the disease in this subset of patients, resulting in achieving inadequately wide margins in all cases. Using a lengthening prosthesis in the arm is controversial, since the main problem of arm-length discrepancy is cosmetic [19]. We used a lengthening prosthesis in two of our recent paediatric patients. One had a forequarter amputation for local recurrence, and we are yet to commence the lengthening procedure in the other patient [13].

Limitations of our study include its retrospective design and small number of patients. This is due to the fact that the indication for total humeral replacement is itself very rare. This reconstructive option should be employed after careful patient selection in indicated patients and after proper preoperative counselling with regards to limitations.

Conclusion

Total humeral custom endoprosthetic replacement is a reliable and useful therapeutic option in providing acceptable cosmetic and functional outcomes in patients with extensive diaphyseal tumours and in cases of revision prosthetic replacements of the arm.

References

1. Davis A, Devlin M, Griffin A, Wunder J, Bell R (1999) Functional outcome in amputation versus limb sparing of patients with lower extremity sarcoma: a matched case-control study. *Arch Phys Med Rehabil* 80(6):615–618
2. Simon MA, Aschliman MA, Thomas N, Mankin HJ (1986) Limb salvage treatment versus amputation for osteosarcoma of the distal end of femur. *J Bone Joint Surg* 68:1331–1337
3. Heisel C, Kinkel S, Bernd L, Ewerbeck V (2006) Megaprotheses for the treatment of malignant bone tumours of the lower limbs. *Int Orthop* 30:452–457
4. Yaw KM, Wurtz LD (1991) Resection and reconstruction for bone tumours in proximal tibia. *Orthop Clin North Am* 22:133–148
5. Unwin PS, Cannon SR, Grimer RJ et al (1996) Aseptic loosening in cemented custom mega prosthesis for malignant bone tumours of lower limb. *J Bone Joint Surg Br* 78:5–13
6. Matejovsky Z Jr, Matejovsky Z, Kofranek I (2006) Massive allografts in tumour surgery. *Int Orthop* 30:478–483
7. Asavamongkolkul A, Eckardt JJ, Eilber FR, Dorey FJ, Ward KG, Kelly CM, Wiraganowicz PZ, Kabo JM (1999) Endoprosthetic reconstruction for malignant upper extremity tumors. *Clin Orthop Relat Res* 360:207–220
8. Bos G, Sim F, Pritchard D, Shives T, Rock M, Askew L, Chao E (1987) Prosthetic replacement of the proximal humerus. *Clin Orthop Relat Res* 224:178–191
9. Wada T, Usui M, Isu K, Yamawakii S, Ishii S (1999) Reconstruction and limb salvage after resection of malignant bone tumor of the proximal humerus—a sling procedure using free vascularised fibular graft. *J Bone Joint Surg Br* 81:808–813
10. Damron TA, Rock MG, O'Connor MI et al (1977) Distal upper extremity function following proximal humeral resection and reconstruction for tumours: contralateral comparison. *Ann Surg Oncol* 4:237–246
11. Athwal GS, Chin PY, Adams RA, Morrey BF (2005) Coonrad-Morrey total elbow arthroplasty for tumours of the distal humerus and elbow. *J Bone Joint Surg Br* 87-B:1369–1374
12. Natarajan MV, Balasubramanian N, Jayashankar V, Sameer M (2008) Endoprosthetic reconstruction using total femoral custom mega prosthesis in malignant bone tumours. *Int Orthop* 33(5):1359–1363
13. Ayoub KS, Fiorenza F, Grimer RJ, Tillman RM, Carter SR (1999) Extensible endoprotheses of the humerus after resection of bone tumours. *J Bone Joint Surg Br* 81-B:495–500
14. Mayil Vahanan N, Paraskumar M, Sivaseelam A, Natarajan S (2006) Custom mega-prosthetic replacement for proximal humeral tumours. *Int Orthop Jun* 30(3):158–162
15. Enneking WF (1986) A system of staging musculoskeletal neoplasms. *Clin Orthop Rel Res* 204:9–24
16. Malawer MM, Chou LB (1995) Prosthetic survival and clinical results with use of large-segments replacements in the treatment of high grade bone sarcomas. *J Bone Joint Surg Am* 78:1872–1888
17. Rodl RW, Gosheger G, Gebert C, Lindner N, Ozaki T, Winkelmann W (2002) Reconstruction of proximal humerus after wide resection of tumours. *J Bone Joint Surg Br* 84:1004–1008
18. Wittig JC, Bickels J, Lellar-Graney KL, Kim FH, Malawer MM (2002) Osteosarcoma of the proximal humerus: long term results with limb sparing surgery. *Clin Orthop Rel Res* 397:156–176
19. Lavvy CBD, Briggs TWR (1992) Failure of growing endoprosthetic replacement of the humerus. *J Bone Joint Surg Br* 74-B:626
20. Kaplan EL, Meier P (1958) Nonparametric estimation from incomplete observation. *J Am Stat Assoc* 53:457–481
21. Ross AC, Wilson JN, Scales JT (1987) Endoprosthetic replacement of the proximal humerus. *J Bone Joint Surg Br* 69-B:656–661