The results of total humeral replacement following excision for primary bone tumour

A. Puri, A. Gulia
From Tata Memorial Hospital, Mumbai, India

Rarely, the extent of a malignant bone tumour may necessitate resection of the complete humerus to achieve adequate oncological clearance. We present our experience with reconstruction in such cases using a total humeral endoprosthesis (THER) in 20 patients (12 male and eight female) with a mean age of 22 years (6 to 59). We assessed the complications, the oncological and functional outcomes and implant survival. Surgery was performed between June 2001 and October 2009. The diagnosis included osteosarcoma in nine, Ewing’s sarcoma in eight and chondrosarcoma in three. One patient was lost to follow-up. The mean follow-up was 41 months (10 to 120) for all patients and 56 months (25 to 120) in survivors. There were five local recurrences (26.3%) and 11 patients were alive at time of last follow-up, with overall survival for all patients being 52% (95% confidence interval (CI) 23.8 to 74) at five years. The mean Musculoskeletal Tumor Society score for the survivors was 22 (73%; 16 to 23). The implant survival was 95% (95% CI 69.5 to 99.3) at five years.

The use of a THER in the treatment of malignant tumours of bone is oncologically safe; it gives consistent and predictable results with low rates of complication.

The advent of effective chemotherapy has made limb salvage an oncologically safe option for many bone tumours, without compromising long-term survival.\(^1\)\(^,\)\(^2\) The humerus is a common site for primary bone tumours\(^3\) and complete humeral resection may occasionally be required to achieve oncological clearance. Total humeral endoprosthetic replacements (THERs), in appropriate cases, provide the best balance between adequate oncological clearance and retaining function of the upper limb.

Few reports in literature address the use of THER.\(^4\)\(^,\)\(^6\) We present our experience of these implants after resection of primary malignant bone tumours. The oncological and functional outcome, and the complications and implant survival are presented.

Patients and Methods
We identified 20 patients from our database who underwent THER between June 2001 and October 2009. A modular THER with a constrained hinge (TMH-NICE/ResTOR; Sushrut-Adler, Devrukh, India) was used in 18 patients and an expandable prosthesis (ISIQU Orthopaedics, Capetown, South Africa) in two patients. The medical records, imaging, functional and current disease status were reviewed. There were 12 males and eight females with a mean age of 22 years (6 to 59) at the time of surgery. The diagnoses included osteogenic sarcoma in nine, Ewing’s sarcoma in eight and chondrosarcoma in three. Metastases were not present at time of diagnosis in any patient. Chemotherapy was administered according to the existing protocols. No patient received radiotherapy.

The primary goal of surgery was limb preservation with complete excision of the tumour while providing a functional forearm and hand. Surgery involved disarticulation of the shoulder and elbow with en bloc resection of the humerus and surrounding muscles involved with the tumour while preserving the vessels and nerves to maintain distal viability and function. The TMH-NICE/ResTOR total humeral system was a customised implant until 2006. Subsequently a modular implant was developed (Fig. 1). It comprises a side-specific proximal humerus component, central resection segments and a distal humeral component, which are designed to lock into each other with a self-locking taper. The central resection segments are available in various lengths. The distal component articulates with a side specific ulnar stem that is cemented into the proximal ulna. Restoration of length was based on preoperative radiological assessment and reconfirmed intra-operatively. In order to enhance the stability of the shoulder and prevent...
proximal migration of the prosthesis the residual shoulder capsule was reinforced with a polypropylene mesh, which was anchored circumferentially to the glenoid and extended to form a sleeve around the proximal part of the prosthesis. The mesh also served as an anchor for residual soft tissues that were sutured around the neck of the prosthesis.

The resected specimens were evaluated for surgical margins and to assess the histological response to chemotherapy wherever applicable. On the basis of the evaluation of necrosis of the tumour in response to pre-operative chemotherapy, the histological response was considered good when the extent of the necrosis was > 90% and poor when < 90%.

Post-operatively patients used a sling for six weeks. Range of movement exercises were performed to ensure full extension of the elbow while supporting the elbow to minimise distraction of the shoulder.

Patients were reviewed every three months for the first two years and six monthly thereafter. In all 19 patients were available for follow-up. Functional status was assessed at time of last follow-up using the Musculoskeletal Tumor Society score (MTSS),\textsuperscript{8} based on three general factors (pain, functional activities and emotional acceptance) and three factors specific to the upper limb (hand positioning, manual dexterity and lifting ability). For each of the six factors, values of 0 to 5 were assigned based on established criteria. The result was expressed as a sum total with a maximum score of 30 and as a percentage of the expected normal function for the patient.

**Statistical analysis.** Disease free survival (DFS) and overall survival (OS) rates were analysed using the Kaplan-Meier method with calculation of 95% confidence intervals (CI). DFS was calculated from date of surgery to the date of recurrence and overall survival from the date of surgery to the last date when the patient was documented to be alive or the known date of death.

A curve was plotted for survival of the implant, which was analysed with the starting point defined as the date of the operation and the endpoint being removal for whatever the cause. Patients were censored for statistical analysis (observation stopped before the event occurred) if removal had not occurred at the time the patient was last assessed.

**Results**

Two patients had positive tumour margins; both had an osteosarcoma that had responded poorly to chemotherapy. They were counselled for a subsequent amputation after the post-operative histopathology report, but refused.

Of the 17 patients who received chemotherapy, histological response was assessed in 16; seven had a good response and nine did not.

No patient had a nerve palsy or infection. Two intra-operative fractures of the ulna occurred on insertion of the ulnar component, and were identified on post-operative radiographs. One was managed conservatively with immobilisation for four weeks. The other occurred despite the use of a customised ulnar stem in a six-year-old girl. This needed further surgery to reposition the stem correctly. One expandable prosthesis failed to expand when lengthening was subsequently attempted.

One patient with Ewing’s sarcoma was lost to follow-up at 36 months leaving 19 patients available for study. The patient lost to follow-up was disease-free at time of last review. The mean follow-up for all patients was 41 months (10 to 120).

Five patients (26.3%) had a local recurrence, two in isolation and three with simultaneous disseminated disease. One of two patients with a positive margin and four of 18 patients with a negative margin had a local recurrence. Two of these five patients eventually had an amputation. In one patient the local recurrence was excised along with the involved radial nerve. The other two patients were offered palliative care as they had disseminated disease at the time of local recurrence.

Of the 16 patients in whom response to chemotherapy was assessed, all seven patients with a good response to chemotherapy were alive at the time of review at a mean of 41 months (25 to 88). Of the nine patients with a poor response, seven died, one is currently alive with disease and one is lost to follow-up.

In all, 11 patients are currently alive. The follow-up of the survivors was a mean of 56 months (25 to 120). Disease-free survival for all patients was 44% (95% CI 14.8 to 62.6) at five years, the overall survival for all patients was 52% (95% CI 23.8 to 74) at five years (Fig. 2).

After reconstruction of extensive humeral lesions, function of the shoulder is compromised due to sacrificing the axillary nerve and loss of the deltoid and rotator cuff.
musculature. Stability at the proximal end of the reconstruction ensures good hand and elbow function.\textsuperscript{9,10} Conventionally rather than use a measurement of range of movement of the shoulder, the focus is on function scores.\textsuperscript{11} All patients had limited shoulder function with passive movement exceeding 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. The mean MTSS score for all survivors was 22 (73\%; 16 to 23).

There was no case of implant breakage or failure. Implant survival was 95\% (95\% CI 69.5 to 99.3) at five years (Fig. 3).

**Discussion**

Reconstructing large defects after resection of a tumour has always been challenging. A forequarter amputation may be required in patients with a sarcoma of the humerus.\textsuperscript{12,13} The advent of better imaging modalities, more effective chemotherapy, better understanding of anatomy with continuous refinement in surgical techniques and advances in prosthesis design and materials have all played a part in making limb salvage possible even in extensive tumours that involve the entire bone.\textsuperscript{2,4,14-17} Limb salvage should not compromise patient survival while optimising function as early as possible post-operatively.\textsuperscript{18} The prostheses used must also have good long-term survival. When evaluating a reconstruction technique various factors need to be considered including its complications, functional outcome and durability. In populations where resources are limited cost often plays a role in the decision making.\textsuperscript{19}

A THER is reserved for situations where extensive disease precludes any attempt at salvaging the native joint at either end (Fig. 4). Even in tumours of the proximal humerus with extensive involvement of the diaphysis extending as far as the distal metaphysis we have successfully retained the elbow with durable long-term function and reconstructed the defect with custom-made plates.\textsuperscript{20}

Thus, resections requiring a THER are uncommon and this is borne out by the small number of series documenting the results following their use.\textsuperscript{4,6,21,22} Most series comprise a variety of aetiologies including primary malignant tumours.
tumours, benign lesions, metastatic disease, degenerative disease and failed joint replacements.\textsuperscript{4,5,21,22} Our study documents the largest series of THER for primary bone sarcomas.

Proximal migration is commonly reported with proximal humeral and total humeral replacements.\textsuperscript{4,5} Our use of an inexpensive polypropylene mesh to reinforce the capsule has helped avoid this. Some authors have used a more expensive mesh commonly used in cardiovascular procedures for a similar purpose.\textsuperscript{23}

We were fortunate not to have any nerve palsy or infection in our patients, although they have been found in other series.\textsuperscript{5,6,22} The absence of radiotherapy in our patients may have contributed to avoiding infection.\textsuperscript{24} Local recurrence is a reflection of adequacy of oncological clearance and the effectiveness of chemotherapy.\textsuperscript{17} We had five local recurrences (26.3\%). Tang et al\textsuperscript{6} found two of six primary malignant tumours with THER to have local recurrence, while Natarajan et al\textsuperscript{5} reported local recurrence in two of ten primary malignant tumours treated with a THER. Of our three patients with chondrosarcoma, two developed local recurrence. Of the other 17 patients (osteosarcoma and Ewing’s sarcoma), three had a local recurrence. None of the other series of THERs included a patient with chondrosarcoma. A total of three of the five local recurrences presented with simultaneous disseminated disease. It is possible that the inherent aggressive biology of these tumours could have contributed to local failure.\textsuperscript{22} Local recurrences often require ablative surgery to achieve adequate oncological clearance. Our experience has been similar to that of other authors who have performed a forequarter amputation for local recurrence after THER.\textsuperscript{5,6}

The mean MTSS functional score of 73\% in our study is encouraging when compared with other series.\textsuperscript{6,21,22} Patients reported good psychological acceptance after limb salvage with the THER despite having compromised shoulder function. All the patients preferred the option of limb salvage. Salvage of the upper limb provides better social acceptance.\textsuperscript{3} This is significant as the prostheses used were low-cost locally manufactured devices, costing approximately US$2000. In a population with limited resources the cost of prostheses can be a restrictive factor to limb salvage, especially in patients with a malignant tumours where the prognosis is guarded.\textsuperscript{24}

It can be argued that in young children, the use of an expandable implant could minimise the arm length discrepancy at skeletal maturity.\textsuperscript{4} This discrepancy is, however, mainly cosmetic.\textsuperscript{4,5} The absence of a cost-effective expandable implant precludes us offering this option to most of our patients. Expandable implants are not without their complications.\textsuperscript{25} The only expandable prosthesis in our series in which lengthening was attempted failed to expand. The other expandable prosthesis was used in a patient who died before lengthening was attempted. In Natarajan et al’s\textsuperscript{5} series both expandable THERs were not lengthened and in Ayoub et al’s\textsuperscript{4} series three of six were not lengthened.

The survival of the implant was 95\% (95\% CI 69.5 to 99.3) at five years, with removal as the endpoint. Though the incidence of implant-related complications can be expected to increase with a longer follow-up, the fact that these patients have compromised shoulder function and use their upper extremities less rigorously subjects the implant to less load and stress.\textsuperscript{22} The non-weight-bearing function of the humerus should also contribute to a lesser incidence of loosening and breakage when compared to the lower limb.\textsuperscript{5,5,11}

Although the numbers are small we believe that this study adds to the existing literature on use of massive endoprostheses in limb salvage in the upper limb, especially in primary malignant tumours. The successful use of locally manufactured prostheses demonstrates that cost constraints need no longer be an insurmountable barrier in populations with limited resources.

**Supplementary material**

A table giving further details on each of the patients is available with the electronic version of this article on our website www.bjj.boneandjoint.org.uk

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

**References**


