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Endoprosthetic replacement of diaphyseal bone defects. Long-term results

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Abstract We retrospectively studied 35 patients who underwent endoprosthetic reconstruction of diaphyseal bone defects after excision of primary sarcomas. The patients were treated between February 1979 and May 1999 and had more than 5 years follow-up. There were 22 males and 13 females and the median age at diagnosis was 29 (8–75) years. The bone defect measured a mean of 19 (10–27.6) cm. There were 29 femoral reconstructions, three tibial and three humeral. Cumulative overall survival for all patients was 65% at 10 years. Cumulative overall survival for prosthetic reconstruction, using revision surgery as an end point, was 63% at 10 years. Cumulative risk of failure of reconstruction, including infection, fracture, aseptic loosening, local recurrence and amputation, was 60% at 10 years. Tibial and humeral reconstructions fared less well than femoral. Endoprosthetic replacement is a useful method of reconstructing long intercalary defects, especially if situated in the femur.

Résumé Nous avons étudié rétrospectivement 35 malades qui ont subi une reconstruction endoprothétique après excision diaphysaire d'un sarcome primaire. Les malades ont été traités entre février 1979 et mai 1999 et avaient plus de 5 ans de suivi. Il y avait 22 hommes et 13 femmes et l'âge médian au diagnostic était de 29 (8–75) ans. Le défaut osseux mesurait en moyenne 19 (10–27.6) cm. Il y avait 29 reconstructions fémorales, trois tibiales et trois humérales. La survie totale cumulative pour tous les malades était 65% à 10 ans. La survie totale cumulative pour la reconstruction prothétique, en utilisant la chirurgie de révision comme élément final, était de 63% à 10 ans. Le risque cumulatif d'échec en incluant: l'infection, la fracture, le démontage aseptique, la récurrence locale et l'amputation étaient de 60%

à 10 ans. Les reconstructions tibiales et humérales sont allées moins bien que les fémorales. Le remplacement endoprothétique est une méthode utile pour reconstruire de longues pertes de substance intercalaires, surtout si elles sont situées sur le fémur.

Introduction

The options for reconstruction of diaphyseal bone defects after excision of bone tumours include structural autologous bone graft, allograft or prostheses. Structural autograft, such as fibula struts, are perfect for treatment of short bone segments but disadvantages include difficulty in matching, limited sources, prolonged time for rehabilitation and complication at the donor site [20]. Allograft allows the reconstruction of soft tissue and accurate match to the bone defect but the disadvantages are the risk of disease transfer to the host, a long period of non-weight bearing or immobility of the limb to allow union, relatively high risk of early infection, fracture and graft failure [4, 14, 16, 18]. Endoprostheses allow early mobilization, have a short operating time and hospital stay and allow immediate commencement of post-operative adjuvant therapy but infection and loosening remain major concerns. The early results of the outcomes of endoprosthetic replacement of diaphyseal bones have been published previously [1].

Patients and methods

We analysed 35 patients who underwent segmental wide resection of primary sarcomas in both lower- or upper-limb long bones and reconstruction with custom-made diaphyseal endoprostheses between February 1979 and May 1999. There were 22 males and 13 females with a median age at diagnosis of 29 (8–75) years. The mean follow-up was 107 (24–306) months. The most-often encountered diagnoses were Ewing's sarcoma and osteosarcoma. The remaining diagnoses are listed in Table 1. The primary tumour site was the femur ($n=29$), tibia ($n=3$) and humerus

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($n=3$). Median bone defect was 19 (10–27) cm. In 28 prostheses cement was used and 17 prostheses were coated with hydroxyapatite at the bone/prosthesis junction. The average operating time was 99 (78–137) min. Patients clinical details are shown in Table 1.

All patients were evaluated by clinical examination, plain radiography and radioisotope bone scans. All patients underwent a biopsy to determine the histology of the tumour. Prior to the advent of MRI in 1994, we used clearance biopsies carried out at the planned level of transection to ensure there was no tumour present. After 1994, MRI was used to determine the extent of the disease and the involvement of the surrounding soft tissues, especially the neurovascular bundle and the margin of bone transection.

Measurement radiographs were obtained to aid design of the custom-made prostheses. When appropriate, patients received neoadjuvant chemotherapy according to the national protocols in use at the time. The prosthesis took approximately 2 weeks to manufacture and had cemented

stems proximally and distally linked by a step-cut joint overlain by a ring with a bolt passing through both parts of the prosthesis (Fig. 1).

Surgical approach varied according to the site of the tumour and followed general principles of tumour surgery, ensuring that the tumour itself was never violated and that the bone was divided at the appropriate level. The segment of involved bone was then removed, with a surrounding cuff of normal tissue overlying the tumour. All patients received prophylactic antibiotics. In the tibia, a gastrocnemius muscle flap was used to cover the anterior surface of the prosthesis. Active physiotherapy was started on the second day after operation, with the patient being allowed to partially weight bear, progressing to full weight bearing by the time of discharge. Patients were usually discharged home 4–6 days after operation fully weight bearing.

Table 1 Details of 35 patients with diaphyseal tumour treated with endoprostheses. *MFH* Malignant fibrous histiocytoma, *Y* cemented, *N* uncemented, *HA* hydroxyapatite, *NO* uncoated with hydroxyapatite

Case	Age (years)	Site	Histology	Resected bone (cm)	Cement	Metal coating
1	15	Femur	Ewing's sarcoma	16	Y	NO
2	64	Femur	MFH	17.5	N	NO
3	9	Femur	Osteosarcoma	19	Y	HA
4	31	Tibia	Chondrosarcoma	10	Y	NO
5	8	Femur	Spindle cell sarcoma	16	Y	HA
6	32	Humerus	Osteosarcoma	12	Y	NO
7	16	Femur	Osteosarcoma	18	N	NO
8	43	Femur	Osteosarcoma	22	Y	HA
9	58	Femur	Osteosarcoma	16	Y	HA
10	58	Femur	Leiomyosarcoma	22	Y	HA
11	43	Femur	Osteosarcoma	22	Y	HA
12	26	Humerus	Ewing's sarcoma	12	Y	NO
13	10	Femur	Ewing's sarcoma	23	Y	HA
14	19	Femur	Osteosarcoma	16	Y	HA
15	14	Femur	Ewing's sarcoma	16	Y	NO
16	20	Femur	Ewing's sarcoma	27.6	Y	NO
17	25	Tibia	Ewing's sarcoma	17	N	NO
18	47	Femur	Ewing's sarcoma	18	Y	HA
19	18	Tibia	Ewing's sarcoma	19	Y	HA
20	34	Femur	Adamantinoma	23	Y	HA
21	17	Femur	Ewing's sarcoma	19	Y	HA
22	10	Femur	Osteosarcoma	24	Y	NO
23	42	Femur	MFH	13.5	Y	HA
24	25	Femur	Ewing's sarcoma	27	Y	NO
25	8	Humerus	Osteosarcoma	10	Y	NO
26	34	Femur	Leiomyosarcoma	26	Y	HA
27	42	Femur	Ewing's sarcoma	25	Y	NO
28	24	Femur	Chondrosarcoma	20	N	NO
29	30	Femur	Osteosarcoma	23	N	NO
30	15	Femur	Osteosarcoma	15	N	NO
31	15	Femur	Osteosarcoma	18	Y	HA
32	75	Femur	Spindle cell sarcoma	21	Y	HA
33	48	Femur	Synovial sarcoma	20	Y	HA
34	36	Femur	MFH	22	Y	NO
35	17	Femur	Ewing's sarcoma	24	N	NO

Fig. 1 Diaphyseal endoprosthesis showing how it is manufactured in two parts and the intramedullary stems are customised to fit the host bone.



Fig. 3 Fractured endoprostheses of the left femur.



Results

During the 20-year study, 13 patients died. The cumulative overall survival of all patients was 65% at 10 years (Fig. 2). Fourteen patients had a distant metastasis (lung, spine), and five had a local recurrence of whom one underwent amputation. The local recurrences arose in patients with Ewing's sarcoma, osteosarcoma and synovial sarcoma (one patient each) and in two patients with malignant fibrous histiocytoma; all of them were high-grade tumours with marginal resection of the tumours.

One prosthesis became infected 7.5 years after operation when the patient was involved in a road traffic accident and suffered a laceration over his tibial prostheses. One periprosthetic fracture arose in a young patient after a fall and there were two prosthetic fractures; one arose in a 15-year-old boy while playing football 7 years after his initial operation (Figs. 3, 4). Seven patients developed aseptic

loosening leading to a revision procedure (five femoral, one tibial and one humeral). In five, a new diaphyseal prostheses was used but in two, the prostheses was extended to replace the adjacent joint. The humeral endoprosthesis was revised 4 months post-operatively because a very short proximal stem led to early aseptic loosening. The patient age, the type of prosthesis, whether cemented or uncemented and length of defect did not influence prosthetic survival but the use of hydroxyapatite-coated prostheses improved the fixation dramatically, which led to a lower aseptic loosening rate. There were no amputations for prosthesis-related complications. The cumulative overall survival of all the prosthetic construction using revision as the end point was 63% at 10 years.

Fig. 2 Survivorship of the endoprostheses using revision or further surgery for any reason as the endpoint. *Dotted lines* show the 95% confidence limits

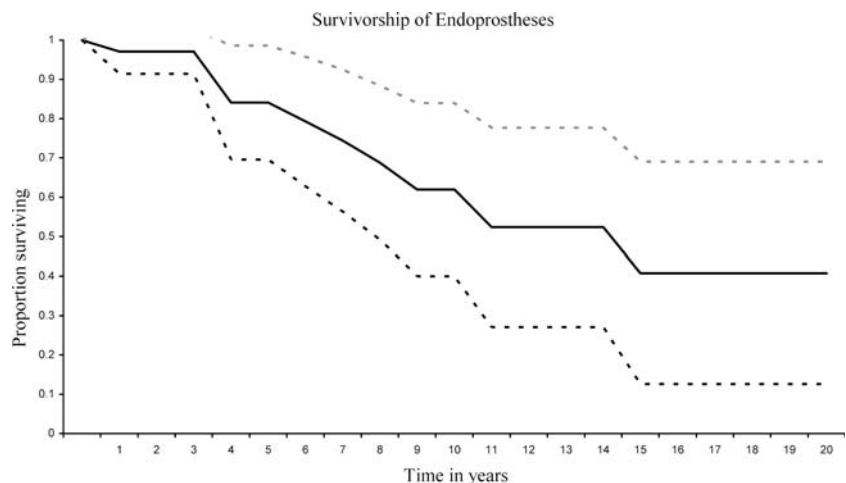


Fig. 4 Left femur 6 months after revision surgery.



Discussion

Diaphyseal tumours are relatively uncommon, and the ability to replace just the mid-part of the bone while preserving the joint above and below only arose in 2.8% of all patients undergoing endoprosthetic replacement in our centre. Options for replacing the mid-part of the bone include the use of an autograft, allograft or a metal endoprosthesis. Although there is a reasonable body of literature about the use of autografts, there is a general consensus that they are predominantly of use in children or in the upper limb [7, 8, 13]. A vascularised fibula graft is certainly of considerable biological attraction but in practice, whilst bone union usually takes place, hypertrophy of the graft sufficient to allow full weight bearing can take many years and in an adult, this can be a major disadvantage for an individual who wishes to get on with their life rather than being reliant on crutches for a prolonged and uncertain period of time. The published results of autograft reconstructions of the femur, for instance, show that the average time to full weight bearing was 19 months and the longer the segment to be replaced, the higher the incidence of complications [9].

Over the years, there has been considerable enthusiasm, particularly in Europe and North America, for the use of allograft bone to replace diaphyseal defects. There has been considerable discussion about the best method of fixing these bone replacements and various options include intramedullary nails and external plates. There is also debate about whether the graft should be filled with cement or with a vascularised fibula graft. There are certainly very impressive results for the combination of allograft with the vascularised fibula graft in the tibia and there is little doubt that this is now the treatment of choice at that particular site

[15]. In the femur, however, the results of allografts are less impressive and numerous papers have discussed the likely risk of complications following allograft surgery [4, 5, 14, 16, 18]. Whilst a diaphyseal defect is said to be the ideal one to reconstruct with an allograft, the incidence of complications, even in this situation, has varied from 18.5% [5] to 30% [6] for infection, 30% [19] to 63% [5] for non-union or delayed union and 19% [17] to 42% [22] for risk of graft fracture. Most of these complications will happen within the first 2–3 years and thereafter, grafts seem to do reasonably well [6, 19]. During the first few months, the patient must remain non- or partially weight bearing while the graft unites because the mean consolidation time for the diaphyseal allograft reconstruction is 16 months [21]. The complication rate increased significantly with the use of systemic chemotherapy, external radiotherapy [5, 6, 10] and in children [2].

Compared with these options, the use of a metal endoprosthesis has some attractions. Firstly, the surgery is relatively straightforward and the stay in hospital relatively short. There is a very low incidence of early complications and it is a significant attraction that the patient will leave hospital fully weight bearing and within 6 weeks will be independent of all walking aids. Patients will have an early return to their occupation and to a more-or-less normal life. The importance of this can be recognised for the 40% of patients who will not survive their tumour and in whom the median survival is 23 months. The ability to be fully weight bearing and leading a relatively normal life all this time cannot be overestimated.

One of the perceived problems with diaphyseal endoprostheses is the risk of late failure and the subsequent need for surgery. Our failure rate of the prosthesis—63% at 10 years—was higher than that reported for other endoprostheses used at other sites [11, 12, 23]. We believe that the reason for this high failure rate was the short segment fixation, which was frequently necessary in order to preserve the adjacent joint. With the passage of time, we have moved from the short-stem intramedullary fixation to increasing use of hydroxyapatite-coated extra-cortical plates to ensure fixation. It is still premature to say whether this will give better outcomes in the longer term [3].

Our results of tibial diaphyseal replacement have not been particularly encouraging and we would not recommend it nowadays except in a palliative situation—for instance, when treating metastatic bone disease. Similarly, the mid-humeral replacements have not fared well and in this situation, we would nowadays consider a vascularised fibula graft with appropriate fixation to be a sensible alternative option. We have, in this situation, used extracorporeal irradiation and re-implantation of bone with success in the short term.

We believe however that for tumours of the mid part of the femur, diaphyseal endoprosthetic replacements offer a sturdy and reliable limb salvage option with a low risk of complications in the short term and early restoration of near-normal function. The patient has to be aware of the likelihood of the need for revision surgery at some stage in the future, but in our current experience, this is rarely disabling and is usually straightforward. Diaphyseal endo-

prostheses remain an attractive option for long-segment replacement, especially in the femur.

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