Reimplantation of autoclaved tumour bone in limb salvage surgery

B. K. S. Sanjay, P. G. Moreau, D. A. Younge

Department of Orthopaedic Surgery, King Faisal Specialist Hospital and Research Centre, Riyadh, Saudi Arabia

Accepted: 2 July 1996

Summary. *This is a prospective clinical study of 7 patients with malignant bone tumours who were treated by resection of the tumour, followed with reconstruction by reimplantation of the resected autoclaved tumour bone. There were 3 male and 4 female patients between 10 and 36 years of age. All the tumours were Stage IIB. Five of the 7 were in the region of the knee joint. Histologically, 5 were osteosarcomas, 1 a recurrent chondrosarcoma and 1 a recurrent Ewing's sarcoma. All the patients were treated by en bloc resection of the tumour with wide margins. The resected length ranged from 13 cm to 28 cm. After removal of soft tissue and cartilage, the resected bone segment was autoclaved for 5 min at 132 °C and 29 pounds per square inch pressure (0.2 mega Pascal). This autoclaved segment of bone was then reimplanted and fixed with an appropriate implant. The average follow-up was 20 months with a range of 14 to 27 months. None of the tumours recurred and, at the most recent follow-up, all the patients were alive, 6 with no evidence of disease and one with a lung metastasis. Six of the 7 patients were available for radiological assessment. Solid bone union was seen in 4 patients, delayed union in 1 and nonunion in 1. This method of reconstruction using an autoclaved tumour bone graft is useful in countries where facilities for allograft or tumour prostheses are not available owing to financial, technical or sociocultural reasons.*

Résumé. *La reconstruction d'un membre après une résection large pour tumeur maligne présente toujours un problème majeur sur les os longs, car le segment osseux ressequé est souvent massif. Cette étude comporte 7 patients ou on a ré-implanté l'os tumoral comme greffon après une stérilisation par autoclave. Il s'agit de 3 patients masculins et 4 féminins, âgés de 10 à 36 ans. Toutes les tumeurs étaient de grade IIB selon la classification de Enneking. Dans 5 des 7 cas, la tumeur se situait dans la région du genou. Il y avait 5 ostéosarcomes, 1 chondrosarcome récidivé, et 1 sarcome d'Ewing. Tous les patients subirent une résection large. La longueur du segment enlevé variait de 13 à 28 cm. Après excision des tissus mous et curetage grossier de la tumeur, l'os a été autoclavé à 132 degrés pour 5 minutes. Le segment a été ensuite ré-implanté avec fixation interne appropriée. Le suivi est de 14 à 27 mois, avec une moyenne de 20 mois. Jusqu'à présent, tous les patients sont vivants, 6 sans aucune manifestation de tumeur, et un avec métastase pulmonaire. Il n'y a aucune récurrence locale. Nous avons pu étudier 6 patients par radiographie. Il y a consolidation chez 4 patients, un avec retard de consolidation, et un avec pseudarthrose. Ce dernier n'est pas encore guéri malgré deux interventions avec changement de fixation et greffe osseuse, et celui avec retard de consolidation a une chirurgie planifiée. Cette technique est très appropriée dans les pays où l'allogreffe ou la mégaprothèse n'est pas disponible pour des raisons économiques, techniques, ou socio-culturelles.*

Fig. 1. **a** Preoperation X-ray of chondrosarcoma of left proximal femur. **b** Postoperation X-ray at 2 weeks, **c** Postoperation X-ray at 3 months. **d, e** Postoperation X-ray at 15 months

Introduction

Reconstruction of the residual defect after wide resection of a malignant limb bone tumour is still a major problem in limb salvage surgery. The available procedures use autografts, allografts, tumour prostheses, cement and other composite reconstructions.

Autografting requires large amounts of bone to reconstruct the extensive defect. Allografting has

the problems of procurement, storage, immunological responses and possible HIV infection. Tumour prostheses may be unavailable and are expensive. Cement can reconstruct large defects, but is not a viable alternative in the long term.

In contrast to other methods, the use of an autoclaved bone graft following complete ablation of the tumour allows immediate and anatomical correct filling of the defect. It is technically and fi-

Fig. 2a, b, c. Postoperation X-ray of osteosarcoma of right distal femur at 9 months

nancially a simple, cost-effective and viable solution for these difficult problems.

Materials and methods

Seven patients with malignant bone tumours were treated by resection of the lesion and reconstruction by reimplantation of the resected autoclaved tumour bone between September 1992 and October 1993 [13]. There were 4 females and 3 males. Their average age was 16.8 years, ranging from 10 to 36 years. Six of the 7 patients were aged between 10 and 18 years. Five had an osteogenic sarcoma, 1 a chondrosarcoma, and 1 a Ewing's sarcoma. Three of the 7 patients had open epiphyses. According to Enneking's staging system, all tumours were Stage IIB [2], and all the patients with osteosarcoma received preoperative and postoperative chemotherapy. The patient with a chondrosarcoma and the patient with a Ewing's sarcoma only received preoperative chemotherapy. The patient with a chondrosarcoma had been diagnosed elsewhere as having an osteogenic sarcoma and had received preoperative chemotherapy. The patient with recurrent Ewing's sarcoma had been treated previously with 3 courses of chemotherapy followed by irradiation. The chemotherapy consisted of cis-platinum and adriamycin in all cases except the patient with Ewing's sarcoma who had received the vincristine, adriamycin and cyclophosphamide (VAC) regime.

Operative technique

The tumour was approached through a straight longitudinal incision whenever possible. The distal femur and proximal

tibia were approached anteriorly, and the proximal femur by a lateral approach. The previous biopsy scar was removed with the tumour and with a margin of at least 1.5 cm on each side. The tumour was removed enbloc with as wide a margin as possible. For the lesion at the distal femur we were able to save the rectus femoris muscle. At the knee, the resection was made with a wide margin except at the anterior part of the supracondylar region where the tumour is often covered with thin synovium. The menisci and the cruciate ligaments were removed from their tibial attachment when the tumour involved the distal femur, and from their femoral attachment when the tumour involved the proximal tibia. The medial head of the gastrocnemius was severed to expose the neurovascular bundle before making the posterior dissection around the knee. The proximal femur was resected enbloc. The capsule and ligamentum teres were divided at the acetabulum. The site of the proposed bone section was decided preoperatively after studying CT, MRI and bone scans. After resection of the tumour, the medullary canal of the distal femur was curetted to allow frozen section examination in an attempt to rule out the presence of tumour.

The cartilage and soft tissues were removed from the resected bone segment, and the tumour bone segment was then autoclaved for 5 min at 132 °C at 29 pounds per square inch pressure (0.2 mega Pascal). After cleaning and irrigation with normal saline, this autoclaved bone segment was then placed in the defect and fixed with a suitable implant, much like an allograft, usually using an intramedullary nail. When an interlocking nail was not available, the graft was also fixed at the knee joint with additional staples to prevent rotation. The host graft junction was supplemented by cancellous grafting in 2 cases, with a fibular graft in 2 cases, and with both

Fig. 3. Postoperation X-ray of osteosarcoma of right proximal tibia

cancellous and a fibular graft in 1. The autoclaved tumour bone was used as a composite graft prosthesis in 1 case (Fig. 1), an intercalary graft in 1 case, and a resection arthrodesis in 5 patients (Figs. 2, 3, 4).

Following the development of arterial spasm in 1 patient, we monitored the distal circulation by continuous pulse oximetry. There were no further vascular problems. The patients were mobilised with walking aids 2 days after surgery.

Results

The average follow-up was 20 months, ranging from 14 to 27 months. When last seen all the patients were alive, 6 with no evidence of the disease, and 1 with a lung metastasis. The patient with a below knee amputation following popliteal artery spasm was excluded. Six of the 7 patients were available for radiological assessment. Bone ingrowth and bone union were assessed by plain x-rays, tomograms and bone scans. Solid bone union was seen in 4 patients (Figs. 1, 2, 3), delayed union in 1 (Fig. 4) and nonunion in 1. None of the tumours recurred locally.

The 3 patients with open growth plates developed shortening of the operated limb and required a shoe raise. The average shortening was 6.4 cm. All the patients, except the one with a nonunion, were satisfied with this procedure and enjoyed their daily activities. None complained of pain.

The patient with a chondrosarcoma treated with a composite graft prosthesis procedure had an acceptable range of movement at the treated hip.

Complications

One patient developed popliteal artery spasm in the immediate postoperative period and this persisted for almost 6 h. Exploration of the artery was unsuccessful, and there was wound breakdown, muscle necrosis and infection. This infection was uncontrollable and necessitated below knee amputation [19]. The other patients had neither infection nor skin necrosis.

The lack of long locking nails led to inadequate fixation and implant failure in 2 patients. In 1 a short nail broke 14 months after the initial surgery, and in the other the fixation with a plate and screws became loose in the autoclaved bone 4 months after operation. Both these patients were treated by removal of the original implants, and fixation using appropriate long locking nails. One patient went on to bone union (Fig. 3), the other had delayed union at the proximal host graft junction (Fig. 4). Specimens removed during these repeat operations revealed histological evidence of bone ingrowth at the host graft junctions (Fig. 5a, 5b).

Discussion

There are reports in the literature of encouraging results following reconstruction of the defect using an autoclaved bone graft after tumour resection. There are no reports of tumour recurrence after reimplantation of the autoclaved tumour bone [1, 3–10, 12–18]. Freiberg et al. [4] reported a case of chondrosarcoma of the humerus which was treated with reimplantation of the autoclaved autogenous graft. A painful recurrent anterior subluxation of the shoulder developed and this was treated 6 years later by resection arthroplasty. The bone specimen taken during this procedure did not show any evidence of histological recurrence. Further examination 10 years after the first operation did not reveal any recurrence or metastasis of the tumour.

Further surgery was required in 4 of our patients: 1 for treatment of a nonunion, 1 for removal of painful staples, and 2 for implant failure. The complications of implant failure and bone healing were due to inadequate fixation as the necessary long interlocking nails were unavailable at the time of the first operation. These complications of bone healing could have been avoided if we had been

Fig. 4. **a** Postoperation X-ray at 1 month. NB bone grafting not done at host junction. **b** Postoperation X-ray at 15 months showing broken short nail. **c** Postoperation X-ray at 10 months (second surgery) showing long nail, union at the distal site but delayed union at the proximal site

able to use adequate stable osteosynthesis. Tissue taken for histological examination during the second operations showed no features of local tumour recurrence after periods ranging from 4 months to 27 months. Evidence of revascularisation at the host graft junction was seen histologically in 3 of the 4 cases.

Union between the autoclaved bone graft and the host bone can be improved by using an autogenous graft, and this can be either cancellous or fibular or both. The use of a vascularised fibular graft can give immediate stability and vascularity to the reconstructed limb [12, 16]. Taguchi et al. [16] reported 3 cases of osteosarcoma which were

Fig. 5. **a** Photomicrograph of autoclaved bone exhibiting coagulative necrosis (H & E $\times 160$). **b** Photomicrograph of reimplanted autoclaved tumour bone exhibiting osteoblastic and fibroblastic activity and new bone formation (H & E $\times 160$)

treated with autoclaved bone graft supplemented with a vascularised fibular graft. We have used an autogenous cancellous bone graft in 2 cases, a non-vascularised fibular graft in 1, and both a cancellous and a fibular graft in 1. All united. Two cases which were not supplemented with a bone graft at the first operation developed either delayed union or nonunion. The nonunion in 1 case can be attributed to the lack of cancellous bone graft in addition to the greater length of the resected bone segment, and to preoperative irradiation and inadequate internal fixation.

We believe that stable osteosynthesis and the use of an autogenous cancellous bone graft around the host graft junction and/or a fibular bypass graft are desirable to give the best chance of early and satisfactory host graft union. Similar views are expressed by other authors who used cancellous grafting at the time of the initial reconstruction [6].

Smith et al. [15] reported 7 cases of low grade chondrosarcoma of the proximal humerus and femur which were treated by resection, autoclaving of the excised segment and re-insertion of the segment together with a supplementary osteogenic graft. This report quoted a follow-up ranging from 14 to 22 years. A biopsy of the autoclaved segment was made in 1 patient 11 years after the first operation, and histological examination showed predominantly live bone. In Smith's study, the principal X-ray changes were visible by the end of the first year, but in our patient with chondrosarcoma significant X-ray changes were seen 1 month after operation.

Skin breakdown is a common problem after resection of tumours involving the proximal tibia and this leads to exposure of subcutaneous bone and infection. None of our patients had these complications. We used a gastrocnemius myoplasty routinely when dealing with tumours of the proximal part of the tibia whatever the histological diagnosis or the type of reconstruction. This technique has been suggested by other authors [11].

Four out of 7 autoclaved bone grafts showed infection in one study [17]. However, only one of our cases had this complication and this followed popliteal artery spasm.

Autoclaved bone grafts have many advantages as they do not require either sophisticated instrumentation, the special implants needed for prosthetic replacement, or a bone bank for storing allografts. Their use avoids any blood transmitted disease or the graft rejection problems which may follow use of allografts. However, they lack ade-

quate mechanical strength when the tumour is of a lytic type.

As with an allograft, autoclaved bone graft can also be used as an intercalary graft, a resection graft arthrodesis or a composite graft with a long stem prosthesis. It is therefore useful in developing countries where the resources for allograft or tumour prosthesis are rarely available.

References

1. Asada N, Tsuchiya H, Shimozaeki E, Shinokawa Y, Matsuda E, Tomita K (1995) Reconstruction using autoclaved bone grafts for limb salvage surgery. Proc 8th International Symposium on Limb Salvage, Florence
2. Enneking WF, Spanier SS, Goodman MA (1980) A system for the surgical staging of musculoskeletal sarcoma. Clin Orthop 153: 106–120
3. Evans JE, Harvey JP Jr, Nicket VL (1969) Follow-up notes on articles previously published in the Journal – a 19-year follow-up of chondrosarcoma of the proximal portion of the femur treated by resection, autoclaving and bone replacement. J Bone Joint Surg [Am] 51: 598–603
4. Freiberg AA, Saltzman C, Smith WS (1992) Re-implantation of an autoclaved, autogenous humerus in a patient who had chondrosarcoma. J Bone Joint Surg [Am] 74: 438–439
5. Harrington KD (1992) The use of hemipelvic allograft or autoclaved grafts for reconstruction after wide resection of malignant tumors of pelvis. J Bone Joint Surg [Am] 74: 331–341
6. Harrington KD, Johnston JO, Kaufer HN, Luck JV Jr, Moore TM (1986) Limb salvage and prosthetic joint reconstruction for low-grade and selected high-grade sarcomas of bone after wide resection and replacement by autoclaved autogenic grafts. Clin Orthop 211: 180–214
7. Hiz M, Uzel M, Erdogan F (1995) Composite autoclaved autograft prosthesis in the treatment of proximal femoral malignancies. Proc 8th International Symposium on Limb Salvage, Florence
8. Johnston JO, Carrion WV (1991) A late follow-up of 39 patients treated for neoplastic problems by wide resections with large autoclaved bone autograft. In: Brown KLB (ed) Complications on limb salvage. 6th International Symposium on Limb Salvage, Montreal
9. Johnston JO, Harries TJ, Alexander CE (1983) Limb salvage procedure for neoplasms about the knee by spherocentric total knee arthroplasty and autogenous autoclaved bone grafting. Clin Orthop 181: 137–145
10. Kohler P, Krekbergs A (1993) Chondrosarcoma treated by reimplantation of reserved bone after autoclaving and supplementation with allogenic bone matrix: a case report. Clin Orthop 294: 281–284
11. Malawer MM, McHale KA (1989) Limb sparing surgery for high grade malignant tumours of the proximal tibia: surgical technique and a method of extensor mechanism reconstruction. Clin Orthop 39: 231–248
12. Pho RWH, Taguchi R, Kour AK, Satku K, Kumar VP (1995) Knee joint preservation with autoclaved bone reconstruction augmented with vascularised fibular graft and bone marrow transplantation. Proc 8th International Symposium on Limb Salvage, Florence

13. Sanjay BKS, Moreau PG, Younge DA (1995) Reconstruction of defect after resection in malignant tumours by reimplantation of autoclaved tumour bone. Proc 8th International Symposium on Limb Salvage, Florence
14. Sato K, Sugaira H, Yamamura S, Nakanishi K, Iwata H (1995) Autogeneous autoclaved bone graft in tumor surgery – clinical application in 13 cases with scintigraphic evaluation. Proc 8th International Symposium on Limb Salvage, Florence
15. Smith WS, Struhel (1988) Reimplantation of an autoclaved autogeneous segment of bone for treatment of chondrosarcoma. J Bone Joint Surg [Am] 70: 70–75
16. Taguchi Y, Pho RWH, Kour AK, Kumar VP, Satku K, Lee YS (1993) Limb salvage method using autoclaved autograft supplemented with vascularised fibular graft. Proc 7th International Symposium on Limb Salvage, Singapore
17. Thompson VP, Steggall CT (1956) Chondrosarcoma of the proximal portion of the femur treated by resection and bone replacement. A six year result. J Bone Joint Surg [Am] 38: 357–367
18. Uzel M, Hiz M, Kasabaigil A, Okkam S (1993) Non-autoclaved autograft reconstruction of bone defects in the musculoskeletal tumor surgery. Proc 7th International Symposium on Limb Salvage, Singapore
19. Younge D, Kadhi M, Sanjay B (1993) The use of composite bone flap to make BK amputation possible after extensive resection of the tibial diaphysis. Proc 7th International Symposium on Limb Salvage, Singapore