Allograft reconstruction for bone sarcoma of the tibia in the growing child

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The outcome of tibial allograft reconstruction after resection of a tumour is inconsistent and has a high rate of failure. There are few reports on the use of tibial allografts in children with open growth plates. We performed 21 allograft reconstructions (16 osteoarticular, five intercalary) in 19 consecutive patients between seven and 17 years of age. Two had Ewing's sarcoma, one an adamantinoma and 16 osteosarcoma, one with multifocal disease.

Five patients have died; the other 14 were free from disease at the time of follow-up. Six surviving patients (eight allograft reconstructions) continue to have good or excellent function at a mean of 59 months (14 to 132). One patient has poor function at 31 months. The other seven patients have a good or excellent function after additional procedures including exchange of the allograft and resurfacing or revision to an endoprosthesis at a mean of 101 months (43 to 198). The additional operations were performed at a mean of 47 months (20 to 84) after the first reconstruction.

With the use of allograft reconstruction in growing children, joints and growth plates may be preserved, at least partially. Although our results remain inconsistent, tibial allograft reconstruction in selected patients may restore complete and durable function of the limb.

The tibia is a common site for osteosarcoma and Ewing's sarcoma, the most frequent malignant primary bone tumours in children; 27% of all osteosarcomas¹ and 8% of Ewing's sarcoma² arise at this site.

Although radiotherapy may achieve local control, complete resection gives better oncological results.^{2,3} If adequate resection margins are achieved after local excision of the tumour, limb reconstruction can be performed by endoprosthetic replacement,⁴ expandable endoprosthetic replacement⁵⁻⁷ or biological reconstructions such as shortening and rotation-plasty,^{7,8} free microvascular bone transfer⁹ with or without allografts¹⁰⁻¹² or allografts alone.¹³⁻²¹ Additionally, a technique for joint-sparing resection using physeal distraction has been introduced by Canadell, Forriol and Cara,²² and San-Julian et al.^{23,24} With endoprosthetic reconstruction the knee joint is resected. Fixation of the prosthesis affects the growth plate of the distal femur even if the stem crossing the physis is smooth.

Limb-length discrepancy with the loss of the proximal tibial physis at a skeletal age of eight years can be expected to be about 4 cm at maturity, while the additional loss of the distal femoral physis gives a shortening of about 9 cm.²⁵

Allografts have long been an important method of segmental and articular bone reconstruction,²⁶ allowing precise replacement. However, tibial allografts have shown inconsistent results and high rates of failure¹⁴⁻¹⁷ in studies mainly of adults. Few reports on tibial allografting concentrate on children with open growth plates.^{15,27-29} We believe that the results may be more favourable in children and describe our experience with this reconstruction technique.

Patients and Methods

We performed 21 allograft reconstructions (16 osteoarticular, five intercalary) in 19 consecutive patients with primary bone sarcomas of the tibia. Two had Ewing's sarcoma, one an adamantinoma and 16 had osteosarcoma. One patient with osteosarcomas involving both legs (distal and proximal tibial metaphysis, and the opposite tibial diaphysis) received three allografts. The age range at operation was between seven and 17 years, and the growth plates remained open to a varying extent in all patients. Examination included a structured interview, physical examination and radiological documentation using the ISOLS Allograft Radiographic evaluation protocol.³⁰ The final results were graded according to the

Table I. Clinical and radiological results in the 19 patients

Case	Age (yrs)	Gender*	Diagnosis	Local complications	Management	Time to revision (mths)	Non-weight-bearing (mths)	Leg-length discrepancy (cm)	Fracture union (mths)	Follow-up (mths)	Final result
1	14	M	Osteosarcoma right [†]	Local wound healing	Soft-tissue revision	Post-operative	6	1.5	6	14	Good
2	10	M	Osteosarcoma right [†]	Infection	Soft-tissue revision	Post-operative	0	–	None	17	Died from disease
3	13	F	Osteosarcoma right [†]	Allograft fracture	Converted to alloprosthesis	63	17	1	17	97	Excellent
4	13	F	Osteosarcoma right [†]	Local recurrence	Excision of recurrence, allograft replacement	30	9	0	None	30	Died from disease
5	17	F	Osteosarcoma right [†]	Arthritis	None	–	8	–	8	31	Poor
6	17	F	Osteosarcoma left [†]	Allograft fracture	Allograft replacement	20	15	–	15	198	Good
7	14	F	Osteosarcoma left [†]	Allograft fracture	Allograft replacement	55	Brace	–	None	65	Good
8	13	M	Osteosarcoma right [†]	Local recurrence	Amputation	31	19	–	19	31	Died from disease
9	16	M	Osteosarcoma right [†]	None	–	–	16	0	16	72	Died from disease
10	13	F	Osteosarcoma right [†]	Arthritis	Alloprosthesis	84	14	1	14	96	Good
11	13	F	Adamantinoma right [†]	None	–	–	5	0	5	81	Excellent
12	12	F	Osteosarcoma left [†]	Allograft fracture	Oncological prosthesis	20	21	2	21	43	Good
13	13	F	Osteosarcoma right [†]	Fracture/arthritis	Allograft replacement/resurfacing	48/120	2.5	2	16	150	Excellent
14	9	M	Ewing's sarcoma left [†]	Allograft fracture	Osteotomy	96	2	2	24	132	Excellent
15	10	F	Osteosarcoma left [†]	Local wound healing	Soft-tissue revision	Post-operative	2	0	12	25	Died from disease
16	8	M	Osteosarcoma dist tibia right [†]	None	–	–	1.5	–	7	96	Excellent
			Osteosarcoma right [‡]	Local wound healing	Soft-tissue revision	Post-operative	7	–	None	24	Good
			Osteosarcoma left [‡]	None	–	–	4	–	7	24	Excellent
17	7	M	Osteosarcoma right [‡]	None	–	–	1.5	2.5	7	73	Excellent
18	12	F	Ewing's sarcoma right [‡]	Infection	Removal and shortening	40	6	–	None	57	Good
19	8	M	Osteosarcoma left [‡]	Local wound healing	Soft-tissue revision	Post-operative	1.5	1	19	31	Excellent

* F, female; M, male

† osteoarticular allograft

‡ intercalary allograft for transepiphyseal resection

method of Mankin, Doppelt and Tomford.³¹ Peri-operative chemotherapy was based on the COSS 86/C, COSS 91, COSS 96, EICESS 92 and EURO Ewing 99 protocols.

In all cases the resected specimen had uncontaminated margins confirmed by histological examination.

All the allografts were fresh frozen, stored in liquid nitrogen gas phase and thawed immediately before implantation. They were radiologically matched to the recipient using a technique which had been previously described.³² Allografts from children with open physes were excluded as being unsuitable for transplantation since fractures have been seen to occur at the physes. All proximal tibial allografts were covered by a local proximally pedicled medial gastrocnemius flap for soft-tissue cover and restoration of the extensor apparatus.

Full weight-bearing was allowed when fusion between the allograft and host bone was radiologically confirmed.

The allograft replacement was longer in several patients than the resected part of the tibia when the soft-tissue situation allowed for this to minimise anticipated limb-length discrepancy.

Results

The mean follow-up was for 66 months (14 to 198). All surviving patients were satisfied with the results regarding their body image, the retained limb and overall function (Table I). Five patients died from their disease, one of whom required amputation because of local recurrence. Six surviving patients (eight allograft reconstructions) continued to have a good or excellent function of their primary recon-

Fig. 1a

Fig. 1b

Fig. 1c

Fig. 1d

Radiographs of a proximal tibial osteoarticular allograft in a patient with Ewing's sarcoma showing a) the reconstruction at seven months after surgery, b) at 42 months after the primary reconstruction osteolysis of the medial tibial plateau and infraction, c) eight months later with bracing and protected weight-bearing modelling of the medial tibial plateau and continuing healing of the fracture and d) five years after valgus osteotomy with interposition of an autologous iliac-crest bone block, with healing, correct alignment and retained joint spaces.

struction at a mean of 59 months (14 to 132). One had poor function after 31 months due to arthritis. The remaining seven surviving patients required additional operations at a mean of 47 months (20 to 84) after the primary procedure. The revision operations included exchange of allografts, autografting with corrective osteotomy, resurfacing of the allograft with an endoprosthesis or replacement of the allograft with a reconstruction prosthesis. After these supplementary operations good or excellent function was achieved at a mean of 101 months (43 to 198) after the revision procedure. Even in these patients, in whom no revision surgery was required to the allograft, there was a high incidence of local problems with wound healing for which additional operative treatment was needed. The ten-year result of a patient with an Ewing sarcoma is shown in Figure 1.

Leg-length discrepancy developed in most patients as a result of loss of the physis. The extent of the inequality depended on the age at first treatment in accordance with the findings of Anderson et al.²⁵ The adjacent distal femoral physis continued to grow normally and maintain congruence with the transplant. At the end of skeletal growth, any small mismatch between the retained normal femoral epiphysis and the tibial osteocartilaginous allograft was asymptomatic provided that the allograft did not develop degenerative changes. We found that in transepiphyseal resection the retained epiphysis maintained the potential to grow in width and degenerative joint changes did not occur. However, osteoarticular allografts produced variable results from no degenerative change to advanced arthritis requiring resurfacing arthroplasty (Table I).

The mean time to radiological union at the graft-host junction was 10.5 months (5 to 24). Two patients died at 17 and 30 months, respectively, before visible fusion.

Discussion

Transepiphyseal resection and allograft replacement gave excellent results as expected with retention of the knee. Only a few similar cases have been reported in the literature^{20,22} making comparison with endoprosthetic reconstructions difficult. Intercalary allografts appear to have better results than osteoarticular allografts.¹⁶ In our series there was no obvious difference between the five osteoarticular and the 16 intercalary allografts in any of the parameters studied. An advantage over endoprosthetic reconstruction is the preservation of the physis of the distal femur, accounting for about 33% of the total limb growth. Limb-length discrepancy greater than 2.5 cm occurred only rarely and was managed by shortening of the contralateral limb except in one patient for whom limb lengthening is proposed.

In the literature the high rate of complications after tibial allograft reconstruction has resulted in their limited use. High rates of infection, fractures and arthritis have been reported.^{13,14,17,32,33} Rödl et al¹³ in a series of seven patients, found that in five of the six who survived the

allograft required revision to an endoprosthetic replacement. Allograft reconstruction in the growing child is controversial. Rödl et al¹³ considered this treatment to be at best a temporary solution. By contrast, Alman et al²⁷ found allograft reconstruction to be useful in skeletally immature individuals, but observed more frequent complications in children as compared with adults. Cara and Canadell¹⁵ reported that patients undergoing alloprosthetic composites had fewer complications and better functional results than those with osteoarticular allograft reconstruction. The results in the literature dealing specifically with children with an open physis appear to be more encouraging. Manfrini et al¹⁰ reported good results in nine of ten surviving patients who had tibial allograft reconstruction.

In our study, seven allografts in 14 disease-free patients failed partially or completely at longer follow-up, but salvage was possible. The patients received a second allograft and/or a subsequent resurfacing procedure. Preservation of bone stock was an important factor in allowing subsequent revision surgery. In our series amputation was performed in only one patient. When revising the salvaged limb because of allograft fracture additional bone could be added to correct limb-length inequality.

One failure was probably attributable to post-operative local radiotherapy with damage to the host bone and soft tissue. Six patients retained eight allografts (four osteoarticular, four intercalary) at follow-up at one to 11 years, which functioned well and allowed full weight-bearing. Our results are similar to those of Manfrini et al.¹⁰

However, osteointegration is unpredictable and the use of added microvascular bone transfer may be a useful adjunct to improve allograft host integration.¹⁰ The outcome of tibial allograft reconstruction remains uncertain with results ranging from excellent with full incorporation and osseointegration of the allograft and long-lasting joint function to failure with accelerated and advanced arthritis, fractures, nonunion and infection.³²

In children, the potential to perform transarticular resection with preservation of the proximal growth plates for further growth, or to spare the joint surface by replacing an intercalary segment after transepiphyseal or transphyseal resection when appropriate, make allografting an appealing option in the management of this unpleasant disease. However, a high rate of failure requiring additional surgery has to be accepted and complications are common even with a successful outcome.

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