TOTAL RESECTION OF DISTAL FEMUR OR PROXIMAL TIBIA FOR BONE TUMOURS

AUTOGENOUS BONE GRAFTS AND ARTHRODESIS IN TWENTY-SIX CASES

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Resection of the distal femur or proximal tibia *en bloc* has been performed on twenty-six patients with primary bone tumours. The gap was filled with autogenous bone grafts stabilised with a long intramedullary nail, thus arthrodesing the knee. In two cases temporary stabilisation with a Küntscher rod and acrylic cement was adopted because of adjuvant chemotherapy.

Union was achieved in twenty-four cases (92 per cent). Infection was the main and practically the only major complication, occurring in five (19 per cent) of the cases: it healed with union in three, healed with non-union in one, and led to an above-knee amputation in the fifth case. Follow-up has been from one to eight years with an average of four years.

The aim of repair after partial resection of one condyle of the femur or tibia at the knee is to preserve movement; for this the patella from the same knee with supporting cortico-cancellous autogenous grafts can be used (Merle d'Aubigné and Alexandre 1966; Fineschi 1975) or a massive homogenous articular graft can be substituted for the excised part (Campanacci, Giunti and Olmi 1975).

When, however, the whole distal end of the femur or proximal end of the tibia has to be resected any attempt to save movement of the knee may prove to be too ambitious and should be reserved for rare and selected cases. The percentage of good results from replacement of the whole end of a femur or tibia using an homogenous massive graft is low, no more than 25 per cent (Parrish 1966, 1973; Gui, Manes and Luppino 1976); the operation is hampered by several complications which make the attainment of a sufficient range of movement unlikely, and moreover there is a high risk of resorption and fracture of the grafted epiphysis. On the other hand, the use of a total hinged prosthesis is only rarely indicated. Also, while total prostheses are suitable substitutes for the distal femur, in a case of resection of the proximal tibia the covering of soft tissue would be sparse and it would be impossible to reattach the quadriceps tendon.

For these reasons we feel that the usual repair after resection of a half-joint at the knee should be by arthrodesis using an intramedullary rod and autogenous bone grafts. This operation, even at the price of sacrificing the movement of the knee, is in our opinion the safest procedure for obtaining a fairly constant and

definitive result. The technique we have used derives from the Putti-Juvara procedure as modified by Merle d'Aubigné (Juvara, 1921, 1929; Putti 1928; Merle d'Aubigné and Dejouany 1958; Merle d'Aubigné, Meary and Thomine 1966; Wilson and Lance 1965; Merle d'Aubigné *et al.* 1968; Koskinen 1973; Meary *et al.* 1975; Merle d'Aubigné and Mazas 1976). Our technique differs from that of Merle d'Aubigné in that we use only autogenous grafts, cut the bone at an angle of 45 degrees to the diaphysial axis, and arrange for a long surface of contact between the main graft and the hemidiaphysis of the host.

CLINICAL MATERIAL

Between 1971 and 1977 twenty-six consecutive patients were operated on using the above-mentioned technique (Table I). In two of the cases acrylic cement was used as an intermediate stabilising agent before the bone-grafting procedure, for the reasons given later. All the twenty-six operations were done by the same surgeon (M.C.) in a conventional operation theatre without laminar air flow. The age of the patients ranged from ten to fifty-nine years with an average of thirty years.

All the tumours were histologically confirmed. There were nineteen giant-cell tumours, two parosteal osteosarcomata, and one each of conventional osteosarcoma, low-grade central chondrosarcoma, periosteal osteosarcoma (Dahlin 1977), malignant haemangio-pericytoma and malignant fibrous histiocytoma.

Among the giant-cell tumours, ten were recurrent when operated on, fourteen were radiographically Grade II (active) and five were Grade III (aggressive) (Campanacci *et al.* 1975). All were histologically typical giant-cell tumours, with no evidence of malignancy.

All tumours involved the distal end of the diaphysis or metaphysis. The epiphysis was either involved to such an extent that it was impossible to spare part of the articular surface, especially in

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Table 1. Clinical details and results of treatment

Case number	Age (years)	Sex	Diagnosis	Site	Treatment	Complications	Further treatment	Result
1	16	F	G.C.T., Grade II	Distal femur	P.J.	At 14 months: removal of Küntscher rod. At 18 months: fracture of the grafts	At 18 months: new Küntscher nailing (blind)	At 8 years: union. Shortening 2 centimetres
2	23	M	G.C.T., Grade III	Distal femur	P.J.	—	—	At 3½ years: union. Shortening 2 centimetres
3	15	F	Parosteal osteosarcoma	Distal femur	P.J.	—	—	At 2½ years: union
4	40	F	G.C.T., Grade II	Distal femur	P.J.	At 4 months: mild localised infection of upper tibia	At 20 months: removal of Küntscher nail	At 3 years: union. Infection healed. Shortening 2 centimetres
5	18	F	Parosteal osteosarcoma	Distal femur	P.J.	—	—	At 2½ years: union
6	31	F	G.C.T., Grade II	Proximal tibia	P.J.	—	—	At 3½ years: union
7	30	M	G.C.T., Grade II	Distal femur	P.J.	At 15 months: breaking of the Küntscher rod	At 15 months: new Küntscher nailing and autogenous bone grafts from the ilium	At 2½ years: union
8	25	F	G.C.T., Grade III	Proximal tibia	P.J.	—	—	At 3 years: union
9	37	M	G.C.T., Grade III	Proximal tibia	P.J.	—	—	At 4 years: union
10	21	F	G.C.T., Grade II	Distal femur	(Curettage and grafting elsewhere.) At 13 months: recurrence and pathological fracture. At 15 months: P.J.	—	—	At 3 years: union
11	37	F	Central chondrosarcoma (histological grade 1-2)	Distal femur	(Curettage elsewhere.) At 1 month: P.J.	At 1 month: severe deep infection	At 14 months: removal of nail and screws	At 15 months: above-knee amputation
12	21	M	G.C.T., Grade II	Distal femur	Curettage and grafting. At 13 months: recurrence. At 13 months: P.J.	At 24 months: slight fracture of the grafts. At 29 months: breaking of the Küntscher rod and non-union	At 29 months: new Küntscher rod and autogenous bone grafts from the ilium	At 4 years: union. Shortening 2 centimetres
13	26	M	G.C.T., Grade II	Distal femur	(Curettage elsewhere.) At 4 months: P.J.	—	—	At 2½ years: union
14	25	F	G.C.T., Grade II	Proximal tibia	(Curettage and grafting elsewhere.) At 29 months: recurrence. At 33 months: P.J.	—	—	At 4½ years: union
15	39	F	G.C.T., Grade III	Distal femur	(Curettage and grafting elsewhere.) At 3 years: recurrence. (Second curettage and grafting elsewhere.) At 6 years: recurrence. At 7 years (12 years after the first diagnosis): P.J.	—	—	At 1½ years: union
16	26	M	G.C.T., Grade III	Distal femur	(Biopsy elsewhere.) At 3 months: P.J.	At 12 months: local recurrence in the soft tissues (scar of previous biopsy not excised at the time of resection because medially located)	At 12 months: excision of the recurrence (small single module)	At 3½ years: union
17	30	M	G.C.T., Grade II	Distal femur	(Curettage and grafting elsewhere.) At 2½ years: recurrence. At 3 years: P.J.	At 20 months: breaking of three screws and telescoping of the grafts	—	At 6½ years: union. Shortening 5 centimetres

18	15	M	Periosteal osteosarcoma	Proximal tibia	(Local excision elsewhere.) At 9 months: recurrence. Resection of a diaphyseal segment and homogenous massive graft. At 30 months: recurrence. Resection of the entire proximal half (20 centimetres) of the tibia and P.J.	—	—	At 1 year: union
19	33	F	G.C.T. Grade II	Proximal tibia	(Curettage and grafting.) At 4 months: recurrence. Resection of the anterior two-thirds of proximal tibia and massive homogenous graft. At 2 years: second recurrence. At 4 years: P.J.	—	—	At 1 year: union
20	32	M	G.C.T. Grade II	Distal femur	(Biopsy and 3000 rads radiotherapy elsewhere.) At 2 years: tumour still active. P.J.	—	—	At 3 years: union
21	28	F	G.C.T. Grade II	Proximal tibia	(Biopsy and 4500 rads radiotherapy elsewhere.) At 2 months: P.J.	At 3 months: infection	At 7 months: removal of the screws. At 16 months: removal of the Küntscher rod	At 3 years: union with partial resorption of the anterior graft. Infection healed
22	31	F	G.C.T. Grade II	Proximal tibia	(Biopsy and 6000 rads radiotherapy elsewhere.) At 7 months: tumour still active. P.J.	At 6 months: infection. Small area of skin necrosis. scarring of soft tissues	At 12 months: removal of the Küntscher rod and screws, and of necrotic bone. Plating and autogenous iliac grafts	At 3 years: non-union. Infection healed. At 4 years: union
23	59	M	G.C.T. Grade II	Proximal tibia	(Biopsy and 4600 rads radiotherapy elsewhere.) At 1 year: tumour still active. P.J.	—	—	At 3 years: union
24	46	F	Malignant haemangiopericytoma	Distal femur	Biopsy. At 20 days: because of infection of the wound, resection and temporary stabilisation with acrylic cement. At 8 months from the apparent healing of infection: P.J.	At 4 months: infection	At 6 months: removal of Küntscher rod and screws	At 1½ years: large resorption of the grafts, non-union. Shortening 4 centimetres. Infection healed
25	10	F	Osteosarcoma	Distal femur	Resection and temporary stabilisation with Küntscher rod and acrylic cement. Adjuvant chemotherapy. At 14 months: P.J.	—	—	At 1 year: union
26	22	F	Malignant fibrous histiocytoma	Distal femur	(Biopsy elsewhere.) At 2 months: resection and temporary stabilisation with Küntscher nail and acrylic cement. Adjuvant chemotherapy. At 8 months: P.J.	At 14 months from the resection: small recurrence in the soft tissue	Excision of local recurrence (small single nodule)	At 1 year: union

G.C.T. = giant-cell tumour (Grades II and III are radiographical grades—see text).

P.J. = "Putti-Javara" operation (see text).

giant-cell tumours, or was too close to the edge of a malignant tumour for preservation with safety.

The distal femur was involved in seventeen cases, the proximal tibia in nine cases.

The length of the resected bone ranged between 8 and 20 centimetres (average 11 centimetres), being usually shorter in the tibia.

In ten cases the resection was the primary procedure, diagnosis being confirmed during the operation by frozen sections. In the remaining sixteen cases, resection was secondary to one or more previous procedures: open biopsy, curettage with or without bone grafting, and even resection (Cases 18 and 19). Four patients (Cases 20, 21, 22, 23) had been treated with a course of radiation (3000 to 6000 rads) before the resection procedure.

All patients have been subsequently followed-up for between one and eight years with an average of four years.

Indications for operation. There were two main groups of tumours: giant-cell tumours which had undefined limits, were radiographically active, aggressive (Campanacci *et al.* 1975) or recurrent and where involvement of more than half the diameter of the epiphysis and wide resorption of the bone underneath the articular cartilage made curettage or even partial epiphyseal resection unfeasible or unsafe; and low-grade malignant tumours such as parosteal osteosarcoma, periosteal osteosarcoma and low-grade chondrosarcoma. In malignant central tumours with minimal invasion of the cortex and periosteum (osteosarcoma, malignant fibrous histiocytoma), the decision to perform a radical resection rather than amputate raised a series of problems and represented a calculated risk of which the patient and his relatives had to be made aware.

In those rare cases (as our Cases 25 and 26, of osteosarcoma and malignant fibrous histiocytoma respectively) under adjuvant chemotherapy, we feel that the use of bone grafts should be postponed to the end of treatment for several reasons: to avoid the shock of a long operation on a patient with a high risk of metastases and in order not to depress his immunological defences; to spare the patient from a procedure requiring a long period of immobilisation in plaster which might be useless if metastases appear soon after the operation; and because chemotherapy increases the risk of infection and may possibly impair the incorporation of the grafts. In these cases we approached the problem by giving the limb temporary stabilisation with an intramedullary rod and bone cement.

The same temporary stabilisation, with cement only (as in our Case 24) or with an external fixation device, is indicated when local infection is suspected or ascertained at the time of a resection performed after previous operative treatment.

OPERATIVE TECHNIQUE

The whole limb is prepared, including the iliac wing in the field of operation. A sterile tourniquet is applied at the groin.

The cutaneous incision is posterolateral at the thigh and anterolateral at the leg. (Only in one case of osteosarcoma—Case 25—where it was necessary to resect the distal femur *en bloc* with the whole vastus medialis muscle, was the incision anteromedial at the thigh). This incision does not require any debridement of the subcutaneous fat and fascia and preserves muscle fibres; the wound heals beautifully and scar tissue is minimal.

The procedure continues with incision of fascia lata, of the capsule

Fig. 1

Fig. 2

Figure 1—Scheme of arthrodesis after resection of distal femur. Figure 2—Scheme of arthrodesis after resection of upper tibia.

laterally to the patella and detachment of the patellar tendon (with the tuberosity of the tibia when this is not involved by the tumour). The vastus lateralis is separated from the aponeurosis, perforating vessels are ligated and the femur is exposed extraperiosteally as necessary.

Segmental resection (of the distal femur or proximal tibia) is performed, always extraperiosteally and, depending upon the tumour, *en bloc* with the synovial membrane and part of the capsule, muscular layers or entire muscle thickness, part of the proximal fibula and tibiofibular joint, and the skin wound or scar from any previous operation.

Fig. 3
Lateral view of the femur immediately after operation. Note the oblique cut and the good contact between the host diaphysis and the graft.

The cut at the diaphysis is angled at 45 degrees to the diaphysal axis. This is intended to avoid right-angled steps (stress raisers with the possibility of fractures) and to provide wide and intimate contact between host bone and grafts.

When it is the distal femur which has been resected, the articular surface of the tibia is removed and an anterior hemicylindrical half of the tibia is taken as a graft. It is necessary to cut this graft very straight and exactly in the frontal plane; the length has to be 3 to 4 centimetres in excess of double the length of the resected bone (Fig. 1). Therefore the maximum resection suitable for this procedure is from 12 to 15 centimetres. This depends on the length of the limb and has to be evaluated by radiography before operation. When the resection involves the proximal tibia, the articular surface of the femur is removed and the anterior hemicylindrical graft is taken from the femur (Fig. 2). In both cases, the diaphysal end of the graft has to be cut at an angle of 45 degrees to its long axis.

A second anterior hemicylindrical graft is now taken from the remaining diaphysis of the resected bone. This graft has to be half a centimetre longer than the excised specimen. Because it is cut at an angle of 45 degrees this graft has two sharp extremities (Figs. 1 and 2). It is important that, when taking the grafts, the periosteum is lifted from both diaphyses only in the anterior half of their circumferences and that the posterior halves of the bones are left undisturbed.

The tourniquet is removed, haemostasis is secured, and a Küntscher rod is inserted from the greater trochanter to the distal tibia. We perform moderate reaming of the medullary canals and use rods of 11 or 12 millimetres. The gap between the resection surface at the diaphysis and the opposite epiphysal surface cleaned from the articular cartilage has to be half a centimetre less than the length of the resected bone; therefore the limb will be shortened by about 1 centimetre, as in an arthrodesis of the knee.

The two bone grafts are put in place, the shorter one posteriorly the longer one (reversed upside down) anteriorly (Figs. 1 and 2). Using strong forceps it is easy to get good contact and fit between the rod, the host bones and the dual graft (Fig. 3). The grafts are fastened to the host bones and to each other with compressing screws. The limb is now very solid.

Spongy autogenous bone taken from epiphyses is packed around, particularly at the contact between the host diaphysis and the grafts. The articular cartilage of the patella is excised and tibial tuberosity is reinserted with a screw or stitches.

The wound is closed with at least two drains, and a long

pelvi-podalic cast is applied. Between 1 and 2 litres of blood are transfused during the operation, which takes two to three hours. In the first two days after operation the drains should be opened at intervals, under careful medical control, to avoid an excessive loss of blood from the medullary canals and spaces.

After two months a groin-to-ankle plaster is applied for four more months, allowing partial weight-bearing with crutches. At six months union is usually well advanced; full weight-bearing is allowed, with a contour-fitting brace with an ischial seat and a free ankle, for six more months. At one year all external supports are discontinued and full but not strenuous activity is permitted.

The Küntscher rod is not removed because we cannot be sure of the degree of regeneration (see Fig. 9) and the strength of the grafts even after several years. For this reason, the proximal end of the rod should emerge from the exact tip of the greater trochanter no more than 1 to 2 centimetres.

Modified technique for long resections. In one patient (Case 18) we excised 20 centimetres of the proximal tibia (Fig. 4). The hemifemoral graft was 27 centimetres long; 3 centimetres were applied to the distal femoral epiphysis while 4 centimetres were set on the remainder of the tibial shaft, anteriorly to the Küntscher rod. Posteriorly, a cortical graft 20 centimetres long taken from the other tibia was applied. Abundant cancellous bone was packed around and between the cortical grafts.

A similar technique was used in the two temporary stabilisations with acrylic cement, where in both cases (Cases 25 and 26) the length of the resected distal femur was 15 centimetres, and in another case (Case 19) where the resection length was 13.5 centimetres.

Temporary stabilisation without bone grafts. In the operations to give temporary stabilisation during adjuvant chemotherapy we use a

Fig. 4

Scheme of arthrodesis when resection exceeds 13-15 centimetres. The posterior bone graft is taken from the other tibia.

Fig. 5
Scheme of the temporary stabilisation with intramedullary rod and cement, when there is adjuvant chemotherapy

Küntscher rod and fill the resection gap with a "sausage" of acrylic cement, which embeds the nail and enters the medullary canal of the diaphysis for a short distance and also fills a prepared hole in the epiphysis around the entrance of the rod (Fig. 5). This gives good stability; plaster is not used and the patient is able to walk with crutches a few days after the operation. One of our patients walked without even a cane for six months, before having the bone grafts.

Once the chemotherapy had been completed, the grafting procedure can be carried out one to two years after the first operation.

When infection is the reason for temporary stabilisation, as in our Case 24, we use the cement without the rod. This obviously requires plaster. Probably a better system would be to use an external fixation device.

COMPLICATIONS

Infection. This was virtually the only serious complication. We had five cases over twenty-six procedures (19 per cent).

One patient (Case 11—central chondrosarcoma) had undergone curettage one month earlier and was our first for this operation. The infection was severe, did not clear with the removal of the rod and screws, and eventually led to above-knee amputation. Two patients (Cases 21 and 22) had previously been treated by

Fig. 6

Fig. 7

Fig. 8

Case 12. Figure 6—Twenty-four months after the resection—arthrodesis there is apparent union, but the broken screw is an indication of telescoping, a suspicious sign of non-union of the grafts. Figure 7—Twenty-nine months after the resection—arthrodesis the intramedullary rod suddenly broke while the patient was playing tennis; non-union at the middle of the grafts is clearly shown in the radiograph. Figure 8—Ten months after insertion of a new rod and autogenous bone grafts (from the ilium) around the non-union there is satisfactory union. The limb was solid twenty months after this last operation.

Fig. 9

Histological section of the tibial graft in Case 12 twenty-nine months after the resection-arthrodesis. The bone is viable and well vascularised. (Haematoxylin and eosin, x125.)

curettage and radiotherapy. Their infection healed with the removal of the rod and screws, in one case with no further complication and in the other with partial resorption and non-union of the grafts, which was successfully treated by plating and autogenous iliac grafts. One patient (Case 24) had been given temporary stabilisation with cement because at the time of resection there was infection from a previous biopsy. The grafts were applied eight months after apparent healing; the infection recurred but subsequently healed after removal of the rod and screws. The grafts resorbed producing non-union and shortening. This patient has a brace, but further grafts will possibly be tried when a year without infection has elapsed. The fifth patient with infection (Case 4) had resection and grafts as a primary procedure. Her infection was mild and localised, it

cleared soon after removal of the rod only and did not interfere with a good union.

These reports show how essential it is to take every possible precaution against infection before, during and after the operation; previous operation or radiotherapy seem to increase the risk of infection, and since adjuvant chemotherapy may also add to this risk our policy of postponing the grafts would appear to be justified.

Non-union. As pointed out, there was non-union in three of the cases with infection. Another patient (Case 17) had non-union and telescoping of the grafts with a 5-centimetre shortening. However, the nail did not break, and the limb was fully weight-bearing and solid six and a half years after operation. In this case there had been a technical error: the tibial graft was too short and did not fit in properly with the femur. The patient in Case 12 (Figs. 6 to 9) had a fatigue fracture and pseudarthrosis in the middle of the grafts, with subsequent sudden breaking of the nail at the same level, more than two years after the operation, while playing tennis (Fig. 7). Insertion of a new nail, with excision of the pseudarthrosis and repair with abundant autogenous iliac grafts led to union with a shortening of 2 centimetres (Fig. 8). In Case 7 the nail broke at the junction between the grafts and the epiphysis of the tibia fifteen months after the operation. A new nail was inserted, autogenous iliac bone was packed around it, and at fourteen months there was a satisfactory result. We removed the nail fourteen months after one operation (Case 1); at eighteen months there was a fracture of the grafts (Figs. 10 and 11). A new nail was inserted blindly through the greater trochanter and union was rapidly achieved (Figs. 12 and 13).

Fig. 10

Fig. 11

Fig. 12

Fig. 13

Case 1. Figures 10 and 11—Eighteen months after the resection-arthrodesis and four months after removal of the intramedullary rod there is a fracture of the grafts. Figures 12 and 13—Eleven months after the insertion of a new rod blindly through the greater trochanter the fracture has united. The limb was perfectly solid eight years after the resection-arthrodesis.

Local recurrence of the tumour. We had two cases of recurrence. There was a small recurrence of a giant-cell tumour in the soft-tissue scar of a previous curettage (Case 16). This scar had not been excised at the time of the resection because it was located medially. The recurrence was easily managed with a limited excision of the nodule. A small nodule of local recurrence in the scar was excised from another patient (Case 26—malignant fibrous histiocytoma); this was a recent case.

Shortening. As indicated, a shortening of 1 centimetre is deliberate at operation. Shortening of 2 centimetres was measured in four cases. One patient (Case 17) had a 5-centimetre shortening due to telescoping of grafts. Another patient had a shortening of 4 centimetres and non-union (Case 24) due to infection.

Peroneal nerve palsy. In two cases there was an incomplete and totally transient palsy.

RESULTS

Altogether, among twenty-six cases, there were twenty primary unions, four secondary unions, one non-union and one amputation. If we exclude the cases with infection, among twenty-one cases there were only three non-unions: two were easily repaired with a second and simple operation, and the other patient's grafts eventually consolidated without another operation. To summarise: union eventually occurred in twenty-four (92 per cent) of the twenty-six cases; in the absence of infection, primary union occurred in 86 per cent of the cases, secondary union in 100 per cent.

All the patients with union had free and full weight-bearing one to two years after operation, and some of them went back to heavy work and to sports (Figs. 14 to 17). However, since it is difficult to assess the security of the union radiologically, the degree of regeneration and the mechanical strength of the grafts, even several years after operation, the patient should avoid excessive stress on the limb for the first three years.

Removal of the rod is not indicated for several years after the operation.

In the event of non-union, repair is not usually a difficult problem.

DISCUSSION

We are certainly satisfied with this procedure as an alternative to massive homografting of a half joint, a total prosthesis and sometimes even amputation.

The results, although only a part of them are long-term, seem to indicate that this technique is very adequate as far as immediate solidity and uneventful definitive consolidation are concerned. Enneking and Shirley (1977) reported on twenty patients operated on with a technique where the hemidiaphysal graft is more limited than in our procedure and the fibula is used as an additional autogenous graft. They had no case of

infection, but did have a considerable number of fractures of the grafts and problems with consolidation.

The only serious complication in our series was infection (19 per cent). Tomeno, Istria and Merle d'Aubigné (1978), who reported on thirty-eight

Fig. 14

Fig. 15

Fig. 16

Fig. 17

Case 2. Giant-cell tumour. Figures 14 and 15—Anteroposterior and lateral views before operation. Figure 16—Lateral view five months after grafting procedure. Figure 17—Lateral view three years after operation: note slight bone-filling of the gap in the anterior of the tibia, where the graft was taken from.

operations with a technique similar to ours, had fifteen infections (39 per cent). We suggest that if the patient has had previous operations at the site of the tumour antibiotics should be administered before operation and, when indicated, samples obtained for culture

during the resection procedure. Meticulous preparation of the skin, gentle dexterity during the operation, careful haemostasis, and the use of a laminar air flow in the operation theatre will lessen the incidence of this complication.

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