Expanding prostheses in conservative surgery for lower limb sarcoma

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Summary. *Conservative resection of bone sarcoma in the lower limbs in children is very likely to be followed by a progressive problem of leg length inequality resulting from removal of the growth cartilage. To overcome this we have been using an expanding prosthesis and we report our experiences during the period 1985–1996. The prostheses are made of titanium and comprise 3 parts: an articular component, an expanding mechanism, and tibial and femoral stems. The degree of possible lengthening of the prostheses is virtually unlimited, and they can be inserted in children of 5 or more years of age. We report the use of 28 prostheses in patients aged from 5 to 18 years, of which 4 were tibial, 5 total femur, and 16 distal femur. There were 6 Ewing's sarcoma, 21 osteosarcoma, and 1 synovial sarcoma. The average follow-up was for 5 years. Five patients died from their disease, and 21 benefited from an average lengthening of 2.6 cm (range: 2 mm–120 mm). Using the Société Européenne des Tumeurs Osseuses (EMSOS) criteria, the functional results were excellent or very good in 16, fair in 7 and bad in 5. Five patients developed an infection; one required amputation and the others received a new expanding prosthesis. We conclude that an expanding prosthesis is an excellent alternative to amputation in young children. However, the risk of infection associated with repeat surgery has led us to develop a prosthesis which can be lengthened externally, without the need for reopening the wound.*

Résumé. *La résection du sarcome osseux des membres inférieurs chez l'enfant est très souvent suivie par une inégalité progressive de longueur des membres résultant de la perte du cartilage de croissance. Pour maîtriser ceci nous avons utilisé une prothèse expansive et nous rapportons notre expérience durant la période 1985–1996. Les prothèses sont en titane et comprennent 3 parties: le composant articulaire, le mécanisme d'expansion et les tiges fémorale et tibiale. La possibilité d'allongement de la prothèse est, théoriquement, sans limite et elle peut être implantée chez l'enfant de 5 ans ou plus. Nous rapportons une série de 28 prothèses chez des patients âgés de 5 à 18 ans. 5 étaient pour résection tibiale, 5 pour fémur total et 16 pour résection du fémur distal. Il y avait 6 sarcomes d'Ewing, 21 ostéosarcomes et 1 synoviosarcome. Le délai moyen d'observation était de 5 ans. 5 patients sont décédés de leur maladie et 21 ont bénéficié d'un allongement moyen de 2,6 cms (2 mm–120 mm). En utilisant les critères de la Société Européenne des Tumeurs Osseuses (EMSOS), les résultats fonctionnels ont été trouvés excellents ou très bons dans 16 cas, moyens dans 7 et mauvais dans 5. 5 patients ont eu des suites infectieuses, ce qui a nécessité l'amputation dans 1 cas et chez les autres, une réintervention avec implantation d'une nouvelle prothèse expansive. Nous concluons qu'une prothèse expansive est une très bonne alternative à l'amputation chez le jeune enfant. Cependant, le risque d'infection lié à la chirurgie répétée nous conduit à développer une prothèse qui puisse être allongée de façon externe, sans nécessiter de nouvelle intervention chirurgicale.*

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Fig. 1. Expanding prosthesis in a child aged 5 years after resection of an osteosarcoma of the distal femur

Fig. 2. The 'non-expanding' tibial component. Note the narrow stem, the absence of cement, and the small size of the antirotation 'wings' which do not damage the growth cartilage

Fig. 3. The use of a 'collar' when there has been 5 cm lengthening

Fig. 4. The use of two 'collars' allows lengthening of more than 10 cm

Introduction

Improvements in chemotherapy have increased the survival of the majority of children with bone sarcoma, and this has necessitated the development of treatments which give a better quality of life than that following amputation. Excision of the tumour and prosthetic replacement as used in adults results in considerable leg length discrepancy when employed in growing children. Consequently, some children suffer amputation, disarticulation, or other 'mutilating' but reconstructive procedures. In order to avoid loss of function and the associated psychological trauma we have been using an expanding prosthesis, and we report our results since its introduction in 1985.

Patients, materials and methods

Patients

Between 1984 and June 1996, expanding prostheses have been used in 28 patients with a sarcoma aged between 5 and 18 years. There were 20 osteosarcoma, 7 Ewing's, and 1 synovial sarcoma. In this series there were 14 boys and 14 girls. Twenty-three were fresh cases of whom 20 had a localized tumour and 3 had metastases. Five patients had already been treated elsewhere; 1 was in remission but suffered pain and had 7 cm shortening, 1 presented with a recurrent Ewing's tumour 3 years after radiotherapy, and 3 were referred to us with progressive metastatic disease which appeared after a lengthy period of preoperative chemotherapy. The average length of the tumour resection was 15 cm. The expanding prosthesis was used to replace the lower part of the femur in 21 cases of which 5 were part of a total femoral replacement, in the upper tibia in 4, and in the upper femur in 3. In 10 patients an expanding prosthesis was inserted at the time of the tumour resection, its manufacture having been started as soon as the biopsy result was available. In the other 18 patients the prosthesis was inserted later, either when the leg length discrepancy started to

become apparent (15 cases), after a late infection (1 case) or as a result of the loosening of a prosthesis inserted during the original resection.

The prostheses

The 28 prostheses inserted between January 1985 and June 1996 included 3 for the hip, 5 for the entire femur, and 20 for the knee.

The knee prostheses consist of a tibial and femoral component joined by a metal on polyethylene hinge. The lengthening mechanism is contained in the part of the prosthesis which replaces the tumour (Fig. 1). The tibial part of the implant rests on articular cartilage and sub-chondral bone and has a long stem which is always less than 8 mm in diameter. Rotation is prevented by 3 flanges which are embedded in the articular cartilage (Fig. 2). The femoral component of the joint is prevented from rotating by contact with the posterior part of the femoral condyles.

The upper femoral prosthesis articulates with a cemented polyethylene cup. The diaphyseal portion has a titanium stem which is either cemented or fixed by screws in order to prevent rotation. It is attached to the expanding mechanism by means of a Morse taper. While this reduces lengthening potential by 1.5 cm it allows easy adjustment of the apparatus in order to increase elongation (Figs. 3 and 4).

All the prostheses have been made of titanium as this metal is light, elastic, allows magnetic resonance imaging and does not produce tissue damage. The size of the epiphyseal parts is sufficiently small to allow insertion in young children

During the 12 years of this study we have used 4 different mechanisms to produce elongation:

The 'open sky' prosthetic mechanism (Generation I). This involved using a threaded rod which was turned by a screwdriver inserted into the knee in the line of the femur. However, this was insufficiently stable to maintain position, and had to be reinforced by using a wedge of acrylic cement. This involved a 15 cm incision and thus a risk of infection. This hazard encouraged us to limit the number of lengthening procedures by making maximum correction at each operation (2–3 cm), but this produced pain and stiffness.

Arthroscopic prosthesis (Generation II). The active parts of the second generation prostheses also use a threaded screw, but a better anti-collapse device. Elongation is produced arthroscopically using small puncture incisions. Trauma to the skin and muscles, and the period spent in hospital are reduced, as is the risk of infection. This technique allows 'little and often' elongation, which is closer to physiological growth.

Magnetic prosthesis (Generation III). These prostheses depend on a compressed spring which can be adjusted by using electromagnetic stimulation applied externally. As there is no need for any incisions, and the operation is often performed without anaesthesia, lengthening can be achieved in stages, each of a very few millimetres. This helps to produce quasi-physiological growth both longitudinally as well as in thickness.

Rotatory prosthesis with lengthening by external manoeuvre (Generation IV). This mechanism can be lengthened by an external mechanical manoeuvre. A short anaesthetic is wise, but no special apparatus is needed. Again normal limb growth can be simulated.

Fig. 5a–c. A large Ewing's sarcoma which necessitated removal of the femur. Reconstruction by a total femoral prosthesis, reinforced by a bone bank allograft, and incorporating an expanding mechanism distally. A radiograph 6 years later showing 5 cm lengthening

Methods

Frequency of lengthening. We advised lengthening with the 'open sky' prosthesis when the leg length discrepancy interfered with function (more than 2–3 cm). Arthroscopic lengthening started with a discrepancy of 1.2 cm. Electromagnetic, or rotatory manipulations are repeated every 1–3 months in order to reproduce physiological growth of the normal limb.

Twenty-one of our 28 patients have had at least one lengthening (2.6 cm on average). The size of the lengthening varied between 1 mm (external manipulation prosthesis) to 30 mm ('open sky'). The Morse taper allows unlimited lengthening, as extra rods can be introduced and each allows a gain of a further 5 cm. For example, one limb was lengthened by 12 cm, and this involved 8 interventions.

Monitoring. The patients were followed by the chemotherapist and the surgeon. Examination included a clinical assessment, standard radiographs, and bone scans of the whole body, the lungs and the local area, and were repeated every 3 months for 2 years, every 6 months for the next 2 years, and then annually. Orthopaedic examination included clinical assessment, standard radiography and measurement of the lower limbs.

In December 1997 the average follow-up was for 60 months (range: 16–150).

Results

There was a relatively high rate of complications, particularly with the open technique used in the early days of our series.

Early complications, resulting from the insertion or the replacement of a prosthesis, were acute ischaemia (1 case), lateral popliteal nerve palsies (2 cases), and infection (1 case). The vascular and neurological problems resolved completely in 1–2 years.

Secondary complications were related to the presence of the prosthesis, more specifically to the lengthening mechanism, or the actual lengthenings.

Three fractures occurred either proximal or distal to the stem of the prosthesis; 1 fracture of the femoral neck required pinning, 1 fracture of the tibial shaft was managed by inserting a tibial component with a long stem which acted as a nail and 1 fracture was treated conservatively. All united without complications.

Loosening of the prosthesis occurred in 4 patients, and was probably related to mechanical forces which appear during lengthening. Two involved the standard component, one of the acetabulum which was followed by dislocation of the hip and the other a tibial component. Two were localized on the lengthening mechanism bearing component.

Complications associated with actual lengthening all occurred with the 'open sky' prosthesis. Three patients developed stiffness arising from periprosthetic fibrosis. This stiffness interfered with further lengthening, and had to be managed by exchanging the apparatus to one which allowed this to be done more gently and more often. In contrast, no lengthening produced ischaemia, or even transitory neurological problems, presumably due to the protective action of the increased muscular tension on the nerves and vessels.

Complications of the actual lengthening have been rare with prostheses using a threaded pin (Generations I, II, IV). Failure of the 'anti-collapse' mechanism occurred in the first procedure on the first patient. This has since been prevented by using a cement wedge. With prostheses using a central threaded pin, whether arthroscopic or manipulative, no failure of materials has occurred. However, the electromagnetic prostheses have given various problems; three refused to lengthen, 1 lengthened spontaneously and then fractured.

Infection. Infection is the most troublesome complication and occurred in 5 out of 28 patients (17%), one after insertion of the prosthesis and 4 after a lengthening. Removal was necessary in every case in order to treat the infection, and it was then possible to insert a new prosthesis. One in-

fection persisted and led to amputation. The other infections were controlled, and after using a musculocutaneous flap to cover the wound it was possible to insert a new prosthesis. The high incidence of infection indicates the need for using a technique which does not require relatively frequent reoperation.

Functional result. The functional result was assessed at the last consultation using the criteria of the Société Européenne des Tumeurs Osseuses (EMSOS). They were excellent or very good in 16 patients, average in 7, and poor in 5. Only 3 patients had finished their growth at final review.

With the 'open sky' prosthesis, the length of the limb can be restored, but there is damage to muscle which reduces the size of the limb. This follows the considerable force needed during lengthening with this type of prosthesis and should therefore be less significant with more gently but more frequent lengthening (Generations III and IV).

Discussion

Attempts to improve the quality of life of the majority of patients with osteogenic sarcoma by conservative surgery result from the advances that have been made in the chemotherapy of these malignant tumours. Since 1982 the proportion needing an amputation has steadily fallen to less than 10% in our series of 400 sarcomas. Conservation of the limb, when the tumour is managed by a multidisciplinary approach, has not significantly lowered the rate of survival.

Conservative surgery depends on making a monobloc resection of the bone tumour with a surrounding zone of healthy tissue. In our series, the average length of bone removed was 17 cm, and the restoration of function demands a reconstructive procedure in 90% of cases. There are 5 possible modes of treatment namely autograft, allograft with bank bone, reconstruction with an inert material such as acrylic cement, a massive prosthesis, or the use of a prosthesis with a long stem together with an allograft.

On the whole the functional results of these techniques are good and, according to several authors, 75–90% are excellent or good after a reasonable time. However, these methods are not very satisfactory in young children when the resection involves a growth cartilage in the lower limb, which is likely to lead to significant leg length inequality at skeletal maturity.

In these circumstances certain authors suggest using a cartilage distraction technique employing

the Ilizaroff apparatus. However, as yet, there are no adequate published results, and present experience suggests that bone regeneration is very slow, possibly relating to postoperative chemotherapy. Currently it seems that the use of an expanding prosthesis remains the best technique available in conservative surgery.

To the best of our knowledge the first expanding prosthesis was used in Birmingham during 1976. It consisted of a uni-compartmental prosthesis which slowly dislocated, and finally fractured. The death of the child after 2 years prevented further study. More modern expanding prostheses appeared in 1981 with the Mark 2 model [4]. This is a bi-compartmental prosthesis with an expanding femoral part, articulating with a tibial prosthesis. Lengthening is produced by the insertion of metal ball bearings into a tube which has a lateral orifice. Some 60 of these prostheses were used by Sneath between 1982 and 1988. He then preferred to use a distractor for lengthening, and held correction with collars clamped in place. The need to reduce the trauma of lengthening, in 1984, led to a further change to a system using an apparatus which has a resemblance to our mechanical Generation II prosthesis.

In 1983, Lewis of New York inserted his first expanding prosthesis [2, 3]. This apparatus was made of titanium and used a threaded rod which was 'lengthened' by a screwdriver inserted laterally. This type of prosthesis has been used in several American centres, and the results have been reviewed recently by Eckardt [1]. However, the mechanism was fragile, with considerable titanium debris found at further operations, and in about half the patients this caused symptoms.

Eckardt reported fracture of the prosthesis during the first two postoperative years.

Since then several authors have reported expanding prostheses but all of these required further operations to achieve lengthening.

Our experience is similar but numerically inferior to that of the British [5] although we have noted more bone fractures, and less loosening or failure of the expanding prostheses. Infection is the most serious complication, and this encourages us to use mechanisms which require minimal surgical re-intervention (Generation II), or no further open surgery (Generations III and IV). Only more experience, and greater follow-up, will establish whether our prostheses which can be lengthened without further operation have been successful. A reconstruction procedure for a tumour in a child can only be adequately assessed when growth has finished, or at 10–15 years after insertion.

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