30 Reconstructive Surgery for Bone Tumors

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Reconstructive Surgery for Malignant Bone Tumor

The diagnosis and management of bone tumours has been largely covered in the chapter by Mr SR Cannon, but it is important to discuss other recent advances in this field. These include computer assisted surgical techniques and alternatives to endoprosthetic reconstruction. Amputations are less frequently required now than previously, but there are some important considerations in children that need highlighting. Finally, rotationplasty as an alternative to amputation will be discussed. There are parts of the world, for example Europe and North America where this procedure is more widely performed than in other countries, for example the UK. For the correct patient with the correct indications, it can be very successful.

Computer Assisted Navigation in Sarcoma Surgery

A prerequisite for successful tumour surgery is complete removal of the tumour itself. Sometimes defining the limits of the lesion is straightforward using images from staging studies, particularly MRI scans. In certain circumstances it can be very difficult to translate the information from scans to the patient. This is particularly the case when attempting removal of pelvic tumours. Computer assisted surgery is a rapidly evolving field within orthopaedic surgery and is used principally in joint replacement, spinal surgery and cruciate ligament reconstruction to ensure accurate placement of implants. In tumour surgery the navigation techniques can be used to guide bone cuts and to ensure a clear margin. There are a number of different techniques but the principles are similar. Imaging studies are used to identify the boundaries of the tumour and to plan the resection margins. Figure 30.1 shows the result of fusing CT and MR images of a pelvic tumour. Landmarks on the skeleton are identified either preoperatively or intraoperatively, in order to orientate the images. Motion sensors can be attached to surgical instruments (drills and osteotomes) which will show the precise location of the tip of the instrument on the fused CT/MRI image in three dimensions. A recent paper suggests that using computer navigation may improve tumour clearance, but controlled studies have not been published [1].

Advances in Biological Limb Reconstruction Following Resection of Malignant Tumours in Children

There is no doubt that advances in endoprosthetic (EPR) design have improved implant survival and function. Modular systems are available for implantation in adults – EPR components of differing sizes can be kept in theatre and assembled during the procedure to ensure that the final device fits perfectly. In paediatric practice it is more common to have to rely on custom-made implants as modular components of the correct size are less freely available. These implants can be designed to incorporate growth. Implants remain very costly and therefore are not available in all healthcare systems. Failures of endoprosthetic reconstructions are common.

In a review of 2367 EPRs, Henderson et al. examined why EPRs fail. The overall failure rate was 25 % with a mean time to failure of 47 months. The most common reason for failure was infection which occurred in 8 % of all cases but accounted for 34 % of all failures. Other causes were aseptic loosening, periprosthetic fracture and tumour progression [2]. In a series of patients who had an endoprostheses implanted for more than 20 years previously, Grimer et al. found that there was an amputation rate of 12 % and also a cumulative risk of deep infection of 1 % per year

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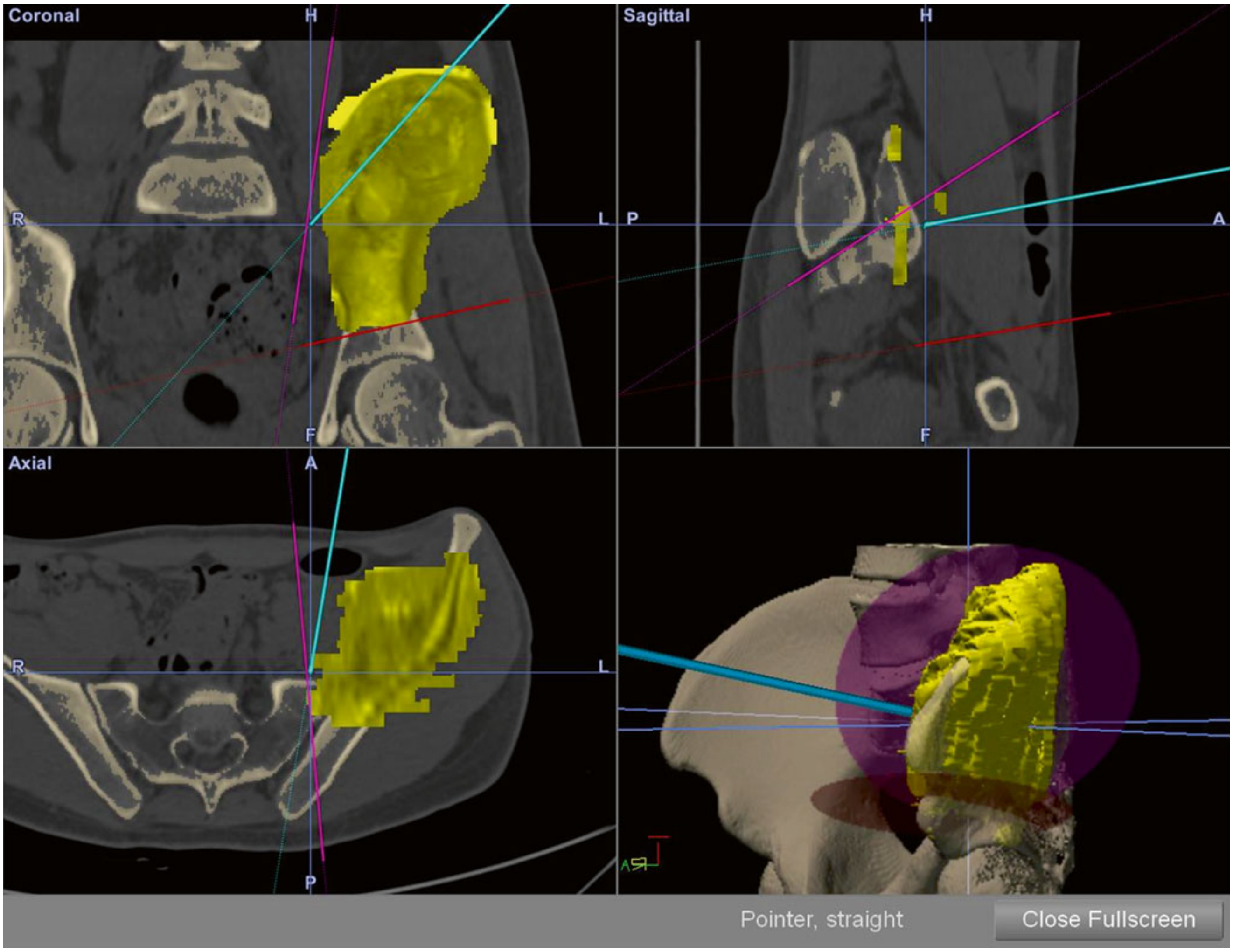

Fig. 30.1 Screen shot from intraoperative resection of a pelvic sarcoma using computer navigation. The intended resection (*yellow*) is planned from both preoperative MRI and CT scans. The planes of resection have been identified and marked (*red and purple lines*). The *blue line* represents the position of a surgical instrument, attached to a motion sensor, being used to resect the tumour (Images courtesy of Mr Ashish Mahendra, Glasgow Royal Infirmary, Glasgow UK)

(Personal communication British Orthopaedic Oncology Society Leicester 2012). Fracture around an endoprosthesis is a concern as long as the EPR is in place and full normal sporting activities, particularly high impact or contact sports, are generally discouraged. Revision of an EPR for fracture is complicated and increases the risk of infection.

Types of Biological Reconstruction

The use of bone to reconstruct defects following tumour resections has been studied for many years in the hope that this will provide a more durable 'biological' reconstruction. The options are to use bulk autograft (vascularised or non vascularised), allograft, a composite reconstruction using both bone and an EPR, or distraction osteogenesis. The latter option has not gained great popularity in the management of malignant tumours outside certain large centres because of the perceived risks of pin-related infection and poor bone formation in a child undergoing chemotherapy. Two recent reports, one on growth plate (physeal) distraction and another on external fixation with or without distraction, suggest that these fears may have been overestimated [3, 4]. It has been found that the use of allograft bone to reconstruct defects which include joint surfaces has not provided a long term solution, with early failure of the articular surface requiring revision. A way around this is to combine allografts and EPRs to create a composite reconstruction. Whether these produce better results in the long term when compared to endoprostheses alone remains to be seen.

Pure biological reconstruction techniques tend to be limited to situations where the host joint surfaces can be retained without compromising the surgical margins. For metaphyseal tumours, the physis may need to be sacrificed.

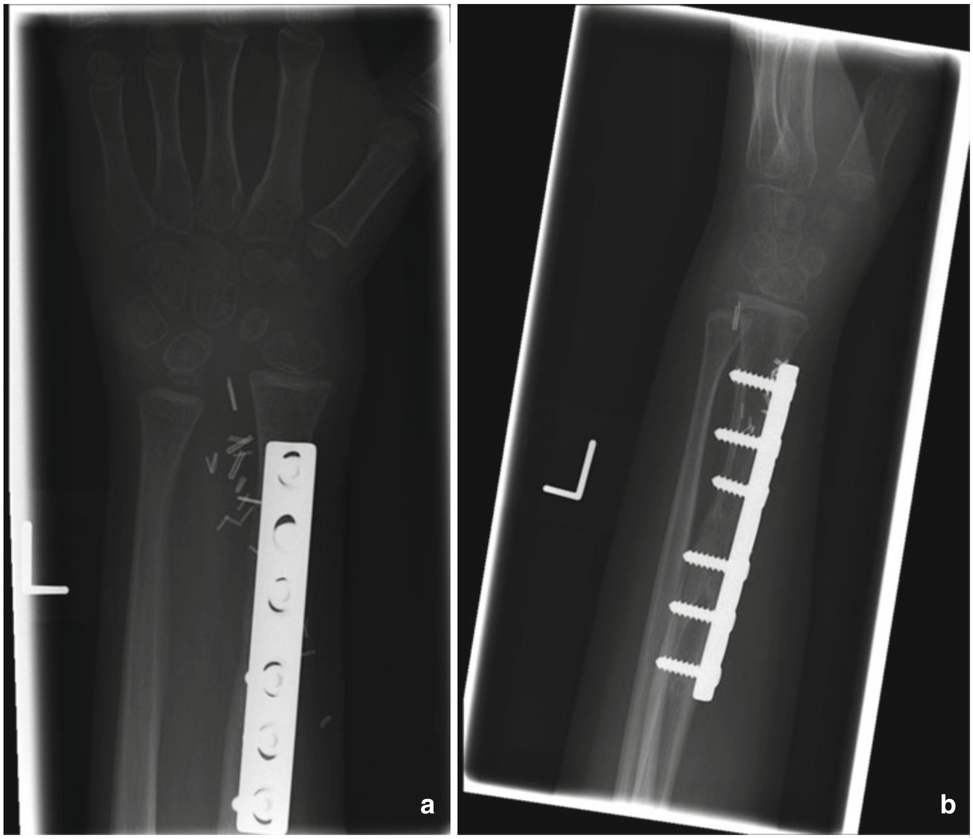

Fig. 30.2 (**a**, **b**) Radiographs from an 8 year old boy who had free transfer of his proximal fibula to the wrist following resection of a recurrent aneurysmal bone cyst. The fibula was mobilised on the anterior tibial artery in order to preserve the physeal blood supply. A faint Harris line can be seen indicating that the transplanted fibula is growing

In certain situations it is possible to reconstruct a defect using a vascularised autograft in which the physeal blood supply is retained. It is therefore possible that the limb will continue to grow. By harvesting the proximal fibula whilst preserving the physeal vessels, the vascularised graft can be used to reconstruct the distal radius for example [5] (Fig. 30.2).

Bulk allografts or autografts can be used in the following circumstances; diaphyseal resections, metaphyseal resections where preservation of the physis is not required (in the older child for example) and following certain pelvic resections. There are cultural objections to allografts is certain parts of the world. Allografts are expensive and not widely available outside centres will well established tissue banks. The use of vascularised autografts is common, with the fibular graft raised on the pedicle of the peroneal artery, being the mainstay. There is a high union rate and it is relatively resistant to infection, but the procedure is technically demanding and can be complicated by late fatigue fracture [6]. The grafts hypertrophy after implantation, but this can take a long time, requiring protected weight bearing or protection with an orthosis. Vascularised fibular grafts can be used for joint arthrodesis (Fig. 30.3).

Extracorporeal Irradiation and Reimplantation

There has been a lot of recent interest in the use of irradiated autografts. The technique of extracorporeal irradiation and reimplantation was first reported in the late 1980s [7]. It involves resection of the malignant tumour with a cuff of normal tissue in order to achieve a wide surgical margin. The specimen is then packed in a sterile container and then irradiated with at least 50 Gy. The original report recommended 300 Gy, but doses between 50 and 300 Gy are reported [6–11]. The soft tissues are removed from the bone either before or after irradiation, the tissues sent for pathological evaluation and the bone is then reimplanted (Figs. 30.4 and 30.5). The dose of irradiation is enough to kill all cells in the host bone, including the tumour cells and delivers a dose which is considerably higher than could be safely delivered by conventional means. The bone is then reimplanted. Plating of the graft is recommended, with either one or two plates [8]. There does not appear to be an increased risk of local recurrence, with rates reported to be less than 10 %. Infection remains a problem, up to 32 % [8], but one group [9] found that the use of vancomycin impregnated cement seemed to be associated with fewer infections.

Ipsilateral or contralateral vascularised fibular transfers have been used to fill the medullary canal – in theory this should encourage union, and may speed up the incorporation of the irradiated autograft. One small study compared irradiated autograft reconstruction with allografts [9]. They found a similar rate of infection and fracture rate, but the non union rate was much higher in the allograft group than the autograft (43 % vs 7 %). The three fractures in the autograft group were treated with casts, but the allografts fractures were fixed and grafted.

A significant criticism of extracorporeal irradiation and reimplantation is that it does not allow complete pathological

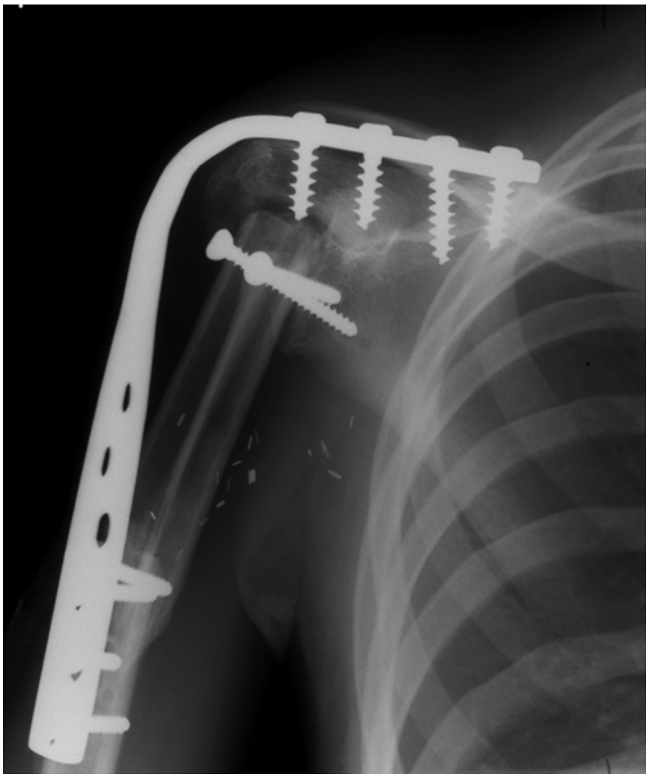

Fig. 30.3 Radiograph of a reconstruction of the shoulder following an intraarticular resection of the proximal humerus for Ewings sarcoma. An arthrodesis was performed using a free vascularised fibular graft, and a contoured plate

Fig. 30.5 Radiograph of a 9 year old boy who had resection, extracorporeal irradiation and reimplantation of the tibial diaphysis with an ipsilateral vascularised fibular transfer for an adamantinoma

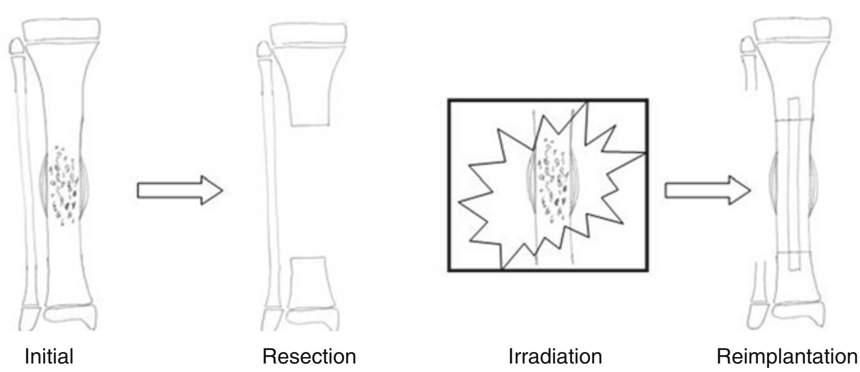

Fig. 30.4 Schematic diagram of the process of resection, extracorporeal irradiation and reimplantation of the tibial diaphysis, with reconstruction incorporating an ipsilateral vascularised fibular transfer

evaluation of the specimen. The soft tissues and marrow from the resection margins can be evaluated, but the estimation of the percentage necrosis is likely to be unreliable. This is a prognostic indicator in those who have had preoperative chemotherapy and, in several clinical trials, used to guide postoperative chemotherapy.

Several other questions also remain such as whether the long term risk of infection is different from that of EPRs, and whether biological reconstructions will eventually become strong enough to permit unrestricted sporting activities. Infection remains a huge problem, but the use of antibiotic impregnated bone grafts is encouraging [12].

Alternatives to Limb Sparing Surgery

Limb sparing surgery is not always feasible in children with malignant tumours of the limb girdles. The primary aim of local treatment for sarcoma is complete tumour clearance including a surrounding cuff of normal tissue. The reconstruction of the resulting defect should result in a well perfused and sensate limb which will allow the child to function as they wish to and which looks good. Ideally the reconstruction should be long-lasting with the risk of as few complications as possible. The majority are treated by limb sparing surgery. Many families expect that their child will be able to take part in normal activities after limb sparing surgery, but this is not always the case. Activity restriction is usually advised after implantation of an endoprosthesis and after biological reconstruction. This may not be easy for children and their families to accept. A fracture following limb salvage can result in an extremely challenging problem, with a significant risk of complications.

An amputation may result in a quality of life which is comparable to that after limb sparing surgery, with little impact on employment, educational attainment, marriage and psychological status. Most large studies have found that physical functioning scores are less for amputees than those having limb salvage, but the differences are much smaller than one might expect [13, 14]. Measuring the health related quality of life of survivors of childhood cancer is more difficult than one might imagine because of the limitations of the tools that are in use and also because of the mechanisms young people adopt to cope with their diagnosis and treatment [15]. The difference in physical functioning between childhood cancer survivors and the normal population becomes more apparent with time [16] which makes it challenging to organise studies with long term follow up. Bone cancer survivors have consistently worse physical functioning scores than other cancer groups [16]. The effect of the type of surgery (limb sparing or amputation) on this particular outcome measure is not yet clear. Again the differences between those undergoing limb salvage, and those undergoing amputation are smaller than one might expect.

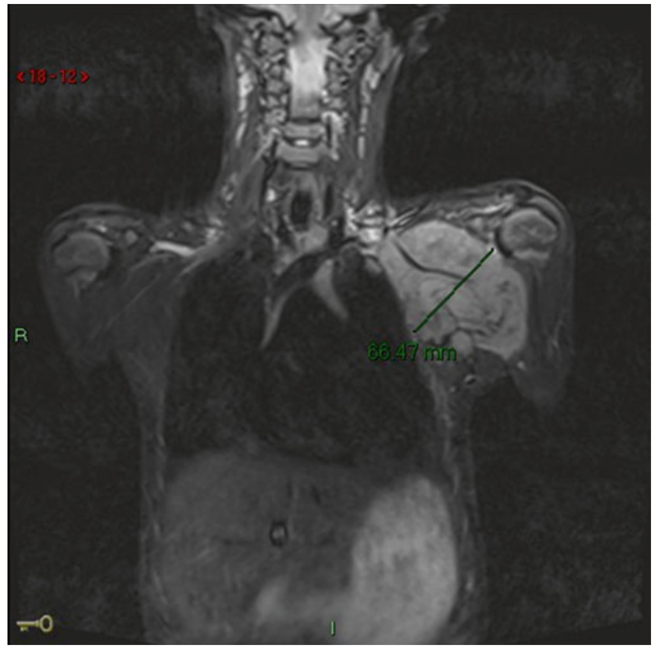

Fig. 30.6 Coronal plane MRI scan of an epithelioid sarcoma of the axilla with the axillary vessels passing straight through the tumour. This tumour could not be treated with limb salvage and the child underwent a modified fore-quarter amputation

In situations where safe removal of the tumour will involve resection of major nerves and vessels or where large amounts of muscle need to be sacrificed, amputation may be the only option for surgical clearance (Fig. 30.6). This is a difficult situation to discuss with families. It is helpful to have a good working relationship with the local prosthetic and psychology services. Children who are being considered for amputation should be offered the opportunity to meet with the prosthetic team pre-operatively and to meet someone who has undergone a similar procedure at a similar age. The best way to utilise psychology services has not been defined – it can be difficult to predict beforehand how children and their families will adjust to the loss of the limb. Some do much better than expected and others do not. One group found that children accept amputation more readily if the child has pain or functional loss before surgery [17]. Throughout treatment for cancer, a supportive family is important. If the family are positive about the amputation as being a curative procedure then this is likely to help the child come to terms with it as well as helping friends and other family members.

Amputation is a particularly difficult issue to discuss with teenagers at a time where concerns regarding body image are heightened. Some will refuse point blank to agree to amputation when limb sparing surgery is not advisable. It is essential to have frank, but sensitive, discussions with the young person to make sure that, if there is a serious risk that the tumour might not be completely removed, they understand the full implications of their decision to refuse amputation. The risks are of local recurrence and further surgery with the attendant complications. The chances of cure may also be reduced.

Amputation is occasionally performed for recurrent benign disease where there have been multiple attempts at local resection and limb sparing.

Amputations in Children – Surgical Issues

Amputations in adults are most often performed for complications of peripheral vascular disease and for trauma. Careful selection of amputation level and skin flaps is important because of impaired perfusion to the skin. In children who require amputation for cancer, the tissues are usually healthy and wound healing problems are less of a concern. The main surgical difficulty is to provide a stump which is covered by healthy skin and muscle whilst obtaining complete tumour clearance. It is important to liaise with the prosthetic services to ensure that the remaining stump length is adequate for prosthetic fitting. We use 10 cm as the minimum length for a below knee amputation. An alternative is disarticulation through the knee. An ankle disarticulation (Syme's amputation) is an option for children who have tumours of the foot, but the heel pad must be preserved to provide a durable end-bearing stump.

In children with tumours, soft tissue coverage is usually not a problem although sometimes careful planning of the skin flaps is required. The major problem, which is particularly a concern in younger children is that of bone overgrowth. This is common and occurs in between 4 and 35 % of children [18]. It is particularly common after transtibial amputation where it may occur in up to 15 %. After the age of 12 years of age stump overgrowth is less of a problem [19]. It is also less common following transfemoral amputation. It occurs as a result of appositional bone growth. In a sense the bone also appears to outgrow the soft tissue envelope (Fig. 30.7). The padding over an amputation stump reduces over a remarkably short period of time and can result in pain, difficulty in wearing the prosthetic limb and infection of the stump. The incidence of overgrowth can be

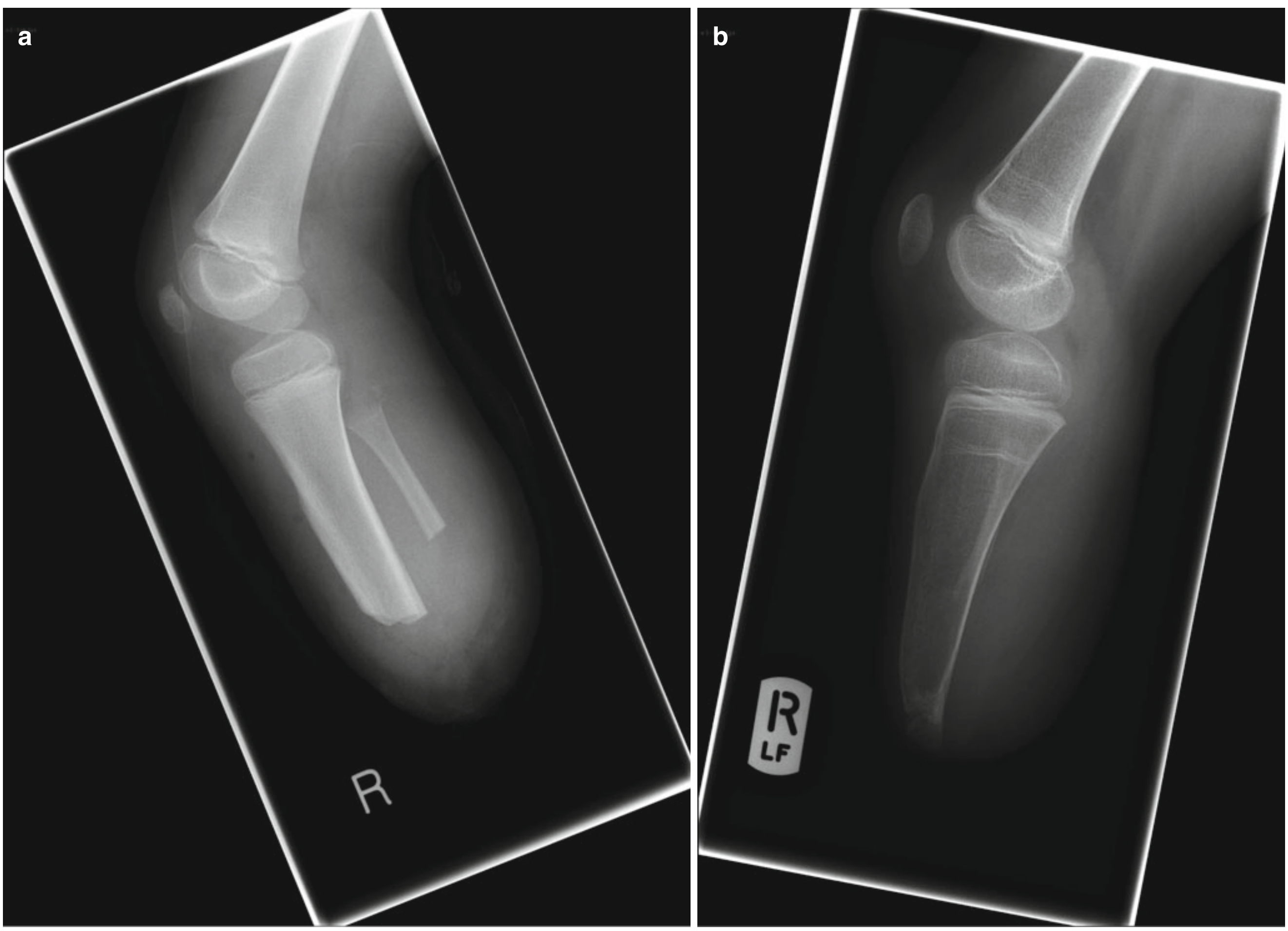

Fig. 30.7 (**a**, **b**) Radiographs of a boy who had a transtibial amputation with capping for an undifferentiated extracompartmental sarcoma of the calcaneus. Note the large soft tissue envelope distal to the tip of the tibia (**a**) and the amount of growth that had occurred 11 months later (**b**) with subsequent reduction in the soft tissue coverage

reduced, but is not abolished, by capping the stump either with autograft from the iliac crest, using a synthetic cap. In a comparative study the rates of revision surgery after simple resection, synthetic capping and biological capping were 86 %, 29 %, and 29 % respectively [20]. Another effective technique is to create a synostosis between the tibia and the fibula (the Ertl procedure) [21].

Rotationplasty

Rotationplasty can be regarded as either a form of amputation or limb salvage of the lower limb. The aim of the procedure is to preserve a functional joint at the level of the opposite knee. The energy involved in walking afterwards is approximately 30 % above normal which is comparable to a below-knee amputation and much better than after an above knee amputation (approximately 70 % more energy utilised compared with normal gait) [22]. It involves resection of a limb segment and rotation of the distal part of the lower limb, placing the ankle joint at the level of the contralateral knee. A prerequisite is that the foot and ankle must retain normal sensation and power after surgery. Vascular resection and reanastomosis can be performed if the femoral or popliteal vessels are involved by tumour, but the common peroneal and posterior tibial components of the sciatic nerve must be preserved. It is most commonly performed for distal femoral tumours as an alternative to above knee amputation, but can also be used for proximal tibial and even tumours of the proximal femur.

It is a valuable reconstructive option in children. A trans-femoral amputation involves sacrifice of the distal femoral growth plate, from which the majority of femoral growth occurs. In a child who has growth remaining in the lower limb, the proximal segment of the amputated lower limb will therefore become relatively shorter over time – an initially adequate stump length will become less. This will have implications for suspension of a prosthesis and lower limb function. Initially, the child may function as expected for a trans-femoral amputee, but with time function may become more like that after a hip disarticulation. Rotationplasty preserves a joint at the level of the knee, so the child will function more like a below knee amputee. An obvious disadvantage is the appearance of the limb. Some suggest that these individuals will have psychological problems because of the appearance of the limb, but this is not supported in the literature. One study of twenty-two patients, studied at least 10 years after surgery, showed values of contentment relating to friends, partnership and sex which were comparable to the normal population. They also had comparable quality of life measured using the EORTC QOL-C30 tool [23]. The mental component scores of the SF-36 tool for measuring quality of life in rotationplasty patients were, in some respects, better than the normal population in one study [24]. Half of one group of young people who had undergone rotationplasty felt that they had no difficulty in initiating intimate relationships or having an active sex life, although some did have concerns. The authors of this study pointed out that problems in this area are not uncommon among conventional amputees [25]. The importance of family, friends and healthcare professionals in facilitating acceptance cannot be over-stressed.

With expert prosthetic management these children can function very well. A study on the sports activity and endurance capacity of sixty-one patients with rotationplasty revealed higher levels of participation in sports than the general population. Most took part in activities such as swimming and cycling, but also soccer and volleyball. Some took part in Alpine skiing, horse riding and badminton. Their findings confirmed the findings of others that their oxygen consumption was higher than that of healthy subjects, but is lower than that of other patients with amputations [26]. Bekkering et al. used an activity monitor and a questionnaire and found no difference in physical activity levels between groups who had undergone limb salvage or amputation/rotationplasty, but the limb salvage patients were better at a timed test on stairs and various walking activities including stepping over 20 cm obstacles [27].

In summary, rotationplasty is a valuable option for treating certain children with malignant disease, particularly those in whom the alternative is an above knee amputation, or where a significant leg length discrepancy is predicted at the end of growth. The recent review by Gupta et al. [28], and descriptions by Winkelmann [29] and Kenan et al. [30] will provide readers with more detailed information regarding the surgical technique.

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