The role of allografts in tumour surgery

Peter F M CHOONG

Department of Orthopaedics, St. Vincent's Hospital, 41 Victoria Parade, Fitzroy 3065, Victoria, Australia. Tel 61-3-9288-3980, Fax 61-3-9416-3610. e-mail peterchoong@c031.aone.net.au

The effectiveness of current multimodal therapy has placed greater demands on the practice of limb sparing surgery. This technique employs a variety of mobile and immobile reconstructions that are biological, artificial or a combination of both. Allografts have an established role in reconstructive tumour surgery (Mankin et al. 1996) and the availability of sterile allograft tissue in plentiful supply, the ease of anatomical matching, the possibility of long storage periods and biologic integration make the use of allografts an attractive alternative to prosthetic reconstruction or amputation. This use was recognised even as early as the turn of the century when hemijoint transplantations were already in use (Lexer 1908). Since then the successful application of allografts has been frequently reported (Gitelis et al. 1987, Voggenreiter et al. 1995, Mankin et al. 1996, Weiner et al. 1996, Zehr et al. 1996). The disadvantages of allografts, however, include possible transmission of disease, infection, rejection, fracture, nonunion and deterioration of the articular surface (Rosenberg et al. 1994). These complications are not insignificant and represent major causes for the failure of allograft reconstruction. This paper reviews the main applications of bone allografts following tumour resection.

Types of allografts

Nonstructural allografts

Nonstructural allografts consist of morsellised bone which is used to fill cavities in host bone (Figure 1) to strengthen the latter, and tend to undergo greater incorporation than structural allografts, but this may depend upon the size of the cavity filled and the amount of grafts employed. Morsellised allograft chips are applicable after curretage of tumours. The most common use of this technique is in the treatment of giant cell tumours, simple and aneurysmal bone cysts. Its use for malignant tumours is limited, although it may be applicable after thorough currettage of grade 1 chondrosarcomas.

The success of this technique as a filler depends upon complete removal of the tumour, otherwise recurrence of the process usually results in graft destruction. Therefore, wide saucerisation of the lesion is mandatory to provide adequate visualisation of the tumour and to prevent recurrences just behind the edge of the cortical window. Aggressive curretage combined with the use of a dental burr and followed by phenolisation of the cavity and irrigation with a water pick is a method which minimises the risk of tumour recurrence. If the cavity is large enough to pose a risk of pathological fracture, the addition of internal fixation may be useful.

The advantages of this technique are that the procurement of morsellised allograft bone is easy, the morbidity of harvesting autograft from the host is nonexistent and the size of the allograft chips may be varied. The disadvantages are that of all allografts,

Figure 1. A. Chondromyxoid fibroma of proximal tibial metaphysis. B. Curretage, burring, phenolisation and bone grafting.

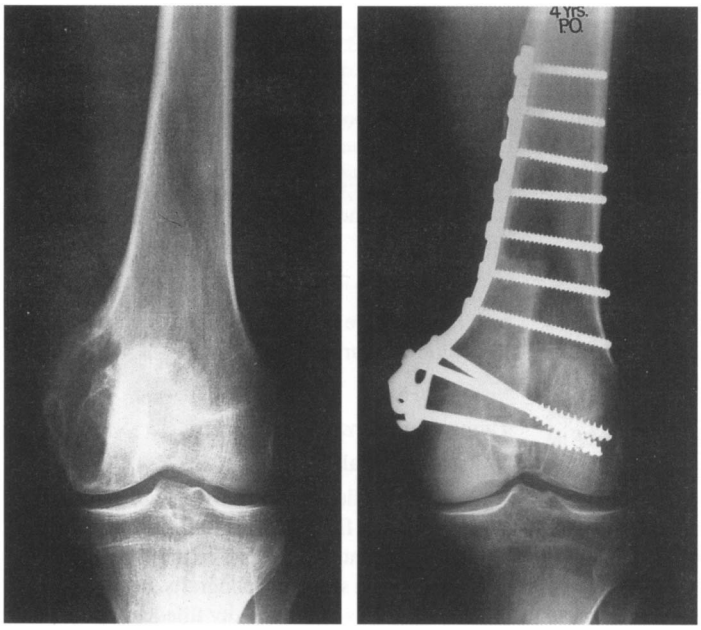


Figure 2. A. Giant cell tumor of medial femoral condyle. B. Hemicondylar osteoarticular allograft. Note protection of graft and osteotomy site with plate.

namely disease transmission, although with adequate screening this may be minimised. Cost may also be a limiting factor as in Australia the cost of a femoral head is in excess of $1000 and several specimens may be required.

Structural allografts

Structural allografts are sturdy corticocancellous bone which are used to bridge defect in host bone and through which load is transferred, such as with intercalated allografts. Structural allografts are usually only incorporated for a small distance from its junction with host bone and their strength is reliant upon the grafts' avascular state. Significant revascularisation is usually accompanied by graft dissolution and fragmentation. Structural allografts include hemi- or total condylar osteoarticular allografts, intercalary allografts, and composites of prostheses and allograft.

I) Hemicondylar osteoarticular allografts. Anatomic specific hemicondylar allografts may be used to reconstruct defects in medial or lateral condyles of the distal femur or proximal tibia, and additionally, have the potential to replace the biologic surface of the joint (Figure 2). Because of the size of hemicondyles, their use is limited to benign lesions which may, if required, be excised intralesionally. They are less commonly used for malignant tumours because of the need for wider margins, although small tumours may be an indication for its use.

Success of the technique depends upon accurate size matching and placement of the chondral surface at the true joint line. By doing so, proper ligmanentous tension is maintained which is important for avoiding instability or excessive stresses across the allograft surface. Allografts placed further away from the anatomic joint line permit the development of valgus or varus deformities, while allografts that cross the normal level of the joint line increase the stress at the surface of the allograft.

The broad osteotomy surface of hemicondylar allografts rarely make union a problem. The diaphyseo-metaphyseal junction is the weakest part of the construct and this requires adequate protection in the form of a plate to prevent fracture. A standard large fragment compression plate or a clover leaf shaped plate would be suitable for reinforcing this construct.

II) Total condylar allografts. Total condylar allografts are used to replace one half of a joint (Figure 3). Replacement of the distal femur or proximal tibia represent the more common use of this allograft, although it is also used for the proximal humerus, distal radius and occasionally the proximal femur. This technique is suitable for malignant and aggressive, but benign lesions.

Technically, the success of the procedure depends upon proper ligamentous reconstruction as stability appears to be an important factor in the longevity of the graft. Adequate size matching is also important as size mismatching may result in abnormal joint kinematics which may lead to ligamentous laxity and instability. Internal fixation is usually in the form of rigid plate and screw fixation with the plate extending up to the level of the condyles to prevent stress fractures at the level of the metaphysis.

An advantage of total condylar allografts is that the size matching as required for hemicondylar allografts is not required. Disadvantages of this technique are the failure of the articular surface which may occur as an early event, and the difficulties in achieving ligamentous stability. Failure of the joint surface, however, may be corrected with a joint replacement directly onto allograft bone.

The function following reconstruction with os-

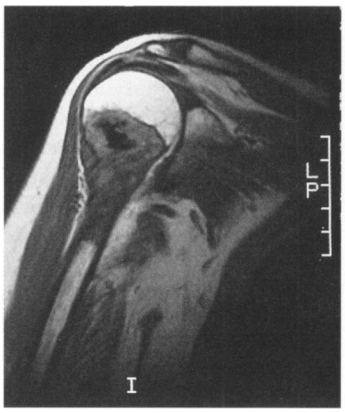
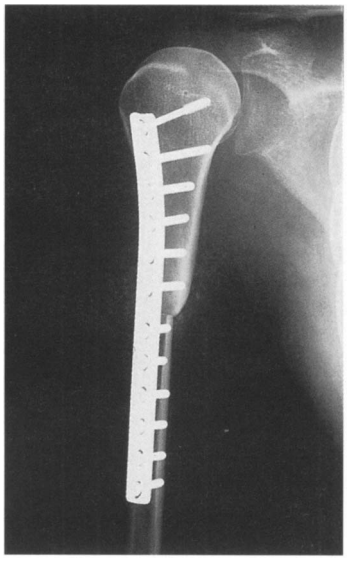


Figure 3. A. Osteosarcoma of proximal humeral metaphysis.



B. Osteoarticular allograft reconstruction.

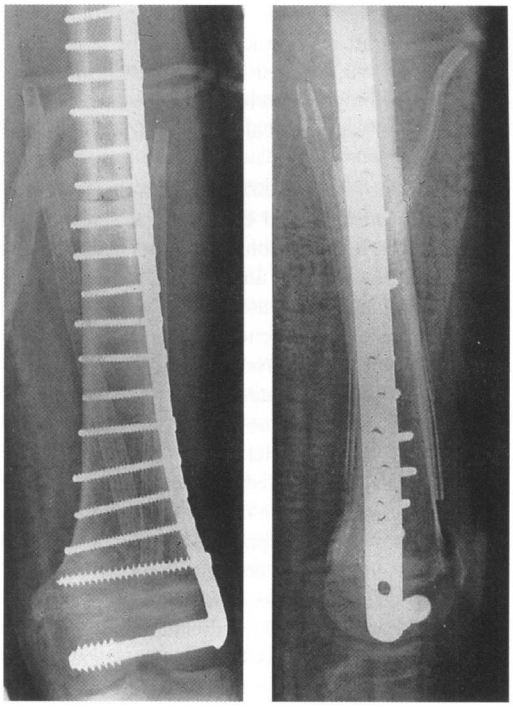
teoarticular allografts appear to be inferior to intercalary allografts and allograft prosthetic composites (Gitelis et al. 1987, Jensen et al. 1995, Mankin et al. 1996). Radial allografts perform better than distal femoral or proximal tibial allogafts and this may be a reflection of the greater forces applied about the knee. The longevity of osteoarticular allografts has been reported to be similar to that of allograft prosthetic composites with a 10 year survival of approximately 70% (Mankin et al. 1996).

III) Intercalary allografts. Intercalary allografts are suitable for replacing resected segments of metaphysis or diaphysis (Figure 4). Short or long allografts may be used and appear to have similar success rates.

Coaptation of the osteotomy sites are important for union at the host allograft junctions as well as to prevent late fracture. Internal fixation may include plate and screw fixation and if this is employed, it is recommended that the medullary canal is filled with cement to reinforce the allograft and to provide better purchase for the screws (Wunder et al. 1995). The use of antibiotic cement may also assist in reducing infection. An alternative fixation method is the use of an interlocking intramedullary rod which may allow early mobilisation with a lower risk of failure as compared to plate fixation. The most important point is that whatever fixation is employed, it must span the length of the allograft to avoid stress riser formation and fracture.

The advantages of intercalary allografts are its inherent stability and the problem of articular cartilage deterioration is avoided. Survival of intercalary re-

Figure 4. A. Diaphyseo-metaphyseal osteosarcoma.



B. Transepiphyseal resection and intercalary allograft reconstruction with condylar compression screw and plate.

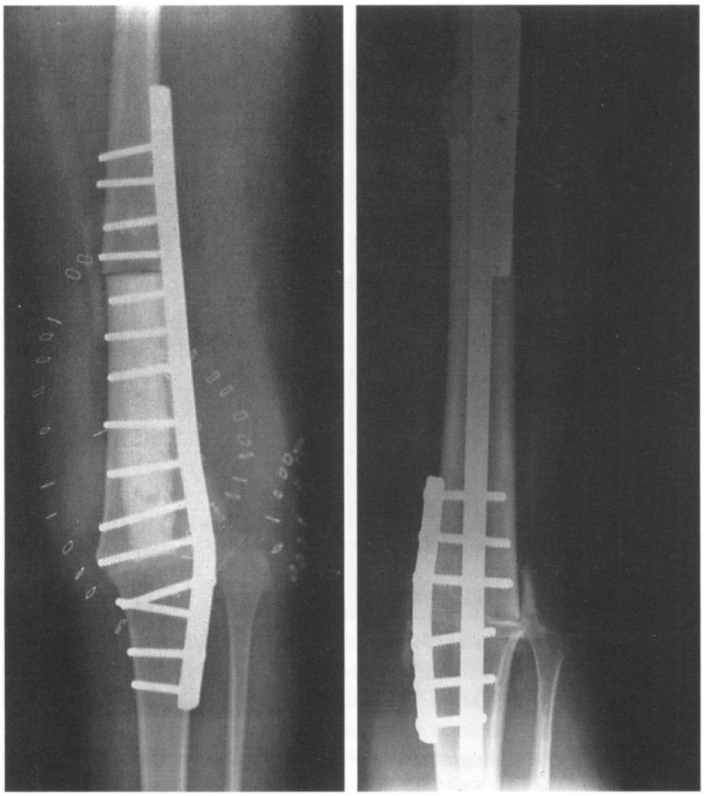


Figure 5. A. Allograft arthrodesis of the knee with plate fixation. Note intramedullary cement. B. Fixation with intramedullary rod and derotation plates.

constructions has been shown to be superior to other type of allograft reconstructions (Gitelis et al. 1987, Wang et al. 1993, Voggenreiter et al. 1995, Mankin et al. 1996) with 5 year survival of 100% (Gitelis et al. 1987) and 10 year survival close to 80% (Mankin et al. 1996).

IV) Allograft arthrodesis. Allograft arthrodesis is an excellent method after extraarticular resections of joint tumours. It is commonly used after extraarticular resection in the shoulder and around the knee. It may also be combined with vascularised bone grafts such as the fibular to supplement the arthrodesis.

The technique for arthrodesis is similar for intercalary allografts in that plate (Figure 5) or intramedullary (Figure 5) fixation are used for the knee, and in the shoulder, moulded plates supplemented with 6.5 cancellous screws are used. Because the majority of joints are surrounded by a thinner layer of soft tissue, it is imperative that adequate soft tissue coverage is achieved to avoid wound complications and infection. Rotation flaps around the knee using the gastrocnemius, or free vascularised rectus abdominus or latissimus dorsi myo-cutaneous flaps are excellent tissues for this purpose (Weiner et al. 1996). The diameter of the smallest bone is the limiting size for the intramedullary nail, and if a large descrepancy exists, interference fit may not be possible. To avoid rotational instability an nonunion derotation additional fixation is required in the form of small compression plates across the osteotomy site.

The advantages of arthrodesis are a stable and pain free joint once union occurs and the removal of joint problems such as instability and failure as seen with mobile reconstructions. The disadvantage of resection arthrodesis is loss of joint function and a high rate of nonunion (Gitelis et al. 1987, Weiner et al. 1996). Although nonunion was relatively frequent, supplemental autogenous bone grafting at a secondary procedure was usually successful in achieving union. Early bone grafting may prevent fatigue fracture of the nail. In the lower limb, arthrodesis of the knee should be preformed to include approximately 2–5 cm of shortening to allow clearance of the foot when walking.

Most authors report that if union occurs, a stable and pain free arthrodesis may be expected (Weiner et al. 1996). Interestingly, the largest series (n 873) published (Mankin et al. 1996) reported that allograft arthrodeses had the lowest 10 year survival rate (40%) as compared to osteoarticular (70%), intercalary (85%) and allograft prosthetic composites (70%).

V) Allograft prosthetic composites. Allograft prosthetic composites are an excellent way of reconstructing the joint using standard prosthetic devices (Figure 6). This technique combines the stability of an interclated allograft spacer with the movement of a joint replacement. It is commonly used about the hip, knee and shoulder.

For the majority, fixation of the prosthesis to the allograft is via antibiotic loaded cement. A stemmed prosthesis is recommended and this may be press-fit into the host bone or cemented. The osteotomy site may be step cut and held with circlage wires, or if no step-cut is used, then derotation plates should be employed. Fully cemented prostheses do not require step cuts. Soft tissue may then be reattached to the allograft bone if required.

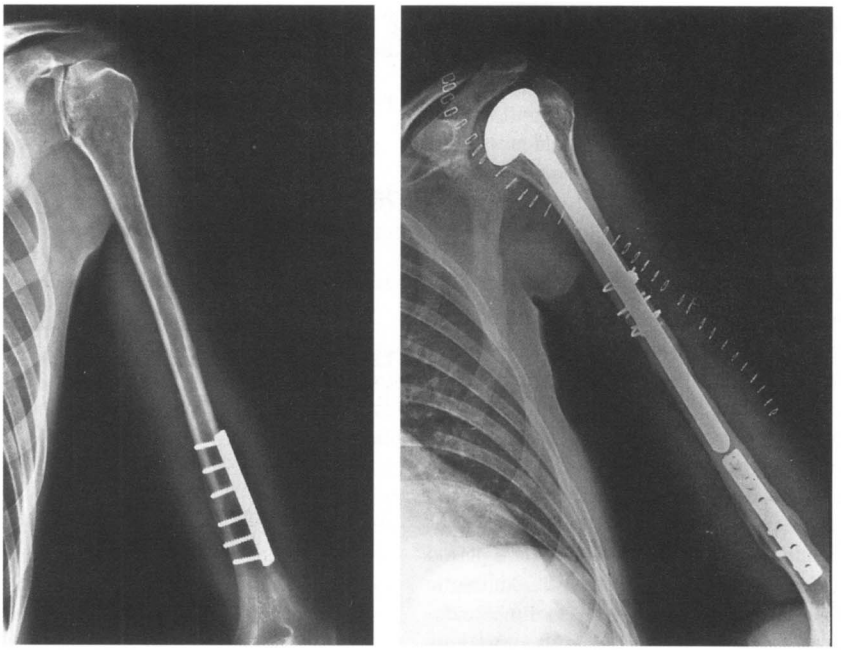


Figure 6. Allograft reconstruction of the proximal humerus after resection of a giant cell tumour. Collapse of the humeral head after 4 years. The allograft was resurfaced with a prosthesis.

The advantages of allograft prosthetic composites are that bone length is reconstituted and the allograft provides a firm foundation for the seating of a prosthesis. In the shoulder or the hip, a long stem prosthesis provides good protection for the allograft and graft disintegration is not usually a problem. Allograft prothesis composites are a good alternative to resection arthrodesis and a superior graft survival has been reported (Mankin et al. 1996). The function of allograft prosthetic composites are at least as good as megaprostheses in some series (Zehr et al. 1996).

The main disadvantage of this technique is the reattachment of ligamentous structures such as the abductors around the hip, the patella ligament at the knee and the rotator cuff at the shoulder. Not all allografts come with soft tissue cuffs, therefore different techniques to reattach host ligaments must be used. One in-vivo animal study (Markel et al. 1995) investigated the difference between bone–bone, tendon–tendon and tendon–bone attachments in allografts and noted that bone–bone attachments had the strongest tensile stiffness; the tendon–tendon strength increased significantly over 6 months while the tendon–bone attachment decreased in strength; the bone to bone attachment was associated with greater porosity, bone resorption and cortical thinning than the other methods. Reconstructions that potentially introduce significant blood supply to the allograft should be avoided to minimise graft resorption.

Complications

The use of allografts is tempered by the high complication rate reported (Rosenberg et al. 1994). The main complications include infection, fracture, nonunion and joint instability of which the former is the most devastating. Allograft complications are not surprising considering the massive resections performed, the quantity of devascularised tissue, the presence of foreign material in the wound, the use of preoperative chemotherapy and radiotherapy and the length of the operation.

Allograft complications are usually late. Infection is the cause for failure in about one third of patients, while fracture accounts for one quarter of failures. Nonunion occurs in about one fifth of cases while instability occurs in less than 10% of cases.

Reoperation with salvage of the original allograft is an option in all complications except infection. Graft fracture may be treated by bone grafting and internal fixation, graft replacement or resurfacing (Berry et al. 1990). The high rate of nonunion is thought to be related to chemotherapy which has been reported to have a deleterious effect on bone healing and fracture

union (Friedlaender et al. 1984, San et al. 1995). This is particularly evident for diaphyseal junctions (San et al. 1995). Nonunion may be treated with bone grafting or a supplemental vascularised bone graft such as the fibular. Instability may require techniques of reconstruction that include prosthetic ligaments or contrained devices.

Infection is a complication that requires prophylaxis as successful salvage of an infected allograft is unlikely. Approximately one half of organisms are gram positive (*staph. epidermidis* and *aureus*), 20% are gram negative (*proteus, pseudomonas, e. coli, bacteroides*) and the remainder are mixed infections (Lord et al. 1988). The main risk factors for infection include, nonunion, large allografts, wound complications and multiple operations.

Prophylactic antibiotics in the perioperative period including cephlasporins and vancomycin are recommended. Continuation of oral antibiotics for a period of 4 months may reduce late infections. Antibiotic loaded cement should be used in all cases where devices require cement. In cases of allograft arthrodesis or intercalated allografts where the allograft is exposed for long periods of time, wrapping the allograft in a layer of antibiotic loaded cement may help in reducing the rate of infection. Adequate attention to soft tissue coverage and wound closure will avoid early wound infections or dehiscence which may jeopardise allograft survival.

Conclusion

Allografts are a biological alternative in limb reconstruction. In contrast to prosthetic replacements, long term survival after the first 3 years appears to be stable with overall survival at 10 years exceeding 65% (Mankin et al. 1996). While the ease of availability and size matching make this technique attractive, the morbidity from recurrence, infection and fracture is high and accounts for over 85% of failures. This should be balanced against the benefits of its use. The applicability of allografts is not universal and each case should be considered on its merits.

References

Berry H, Lord CF, Gebhardt MC, Mankin HJ (1990). Fractures in allografts. J Bone Joint Surg 72(A): 825-33.

Friedlaender G, Tross RB, Doganis AC, et al. (1984). Effects of chemotherapeutic agents on bone. I. Short term methotrexate and doxorubicin treatment in a rat model. J Bone Joint Surg 66(A): 602-7.

Gitelis S, Heligman D, Quill G, Piaseki P (1987). The use of large allografts for tumour reconstruction and salvage of the failed total hip arthroplasty. Clin Orthop 231: 62-70.

Jensen KL, Johnston JO (1995). Proximal humeral reconstruction after excision of a primary sarcoma. Clin Orthop 311: 164-75.

Lexer E (1908). Die verwendung der freien knochenplastic nebst versuchen uber gelenkversteifung & gelenk-transplantation. Art Klin Chir 86: 939-54.

Lord CF, Gebhardt MC, Tomford WW, Mankin HJ (1988). The incidence, nature and treatment of allograft infections. J Bone Joint Surg 70(A): 369-76.

Mankin HJ, Gebhardt MC, Jennings LC, et al. (1996). Long-term results of allograft replacement in the management of bone tumors. Clin Orthop 1996;: .

Markel MD, Wood SA, Bogdanske JJ, et al. (1995). Comparison of healing of allograft/endoprosthetic composites with three types of gluteus medius attachment. J Orthop Res 13 (1): 105-14.

Rosenberg AG, Mankin HJ (1994). Complications of allograft surgery. In: Secondary Complications of allograft surgery (Ed. Epps CH). J.B. Lippincott. Philadelphia pp 1323-50.

San JAM, Leyes M, Mora G, Canadell J (1995). Consolidation of massive bone allografts in limb-preserving operations for bone tumours. Int Orthop 19 (6): 377-82.

Voggenreiter G, Klåes W, Assenmacher S, Schmit NK (1995). Massive intercalary bone allografts in the treatment of primary and secondary bone tumors. A report on 21 cases. Arch Orthop Trauma Surg 114 (6): 308-18.

Wang J, Shih C (1993). Allograft transplantation in aggressive or malignant bone tumours. Clin Orthop 297: 203-9.

Weiner SD, Scarborough M, Vander GR (1996). Resection arthrodesis of the knee with an intercalary allograft. J Bone Joint Surg Am 78 (2): 185-92.

Wunder JS, Davis AM, Hummel JS, et al. (1995). The effect of intramedullary cement on intercalary allograft reconstruction of bone defects after tumour resection: a pilot study. Can J Surg 38 (6): 521-7.

Zehr RJ, Enneking WF, Scarborough MT (1996). Allograft-prosthesis composite versus megaprosthesis in proximal femoral reconstruction. Clin Orthop.