Proximal humeral osteoarticular allografts: technique, pearls and pitfalls, outcomes

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Abstract Allograft transplantation is a biologic reconstruction option for massive bone defects after resection of bone sarcomas. This type of reconstruction not only restores bone stock but it also allows us to reconstruct the joint anatomically. These factors are a major concern, especially in a young and active population.

We are describing indications, surgical techniques, pearls and pitfalls, and outcomes of proximal humeral osteoarticular allografts, done at present time in our institution.

We found that allograft fractures and articular complications, as epiphyseal resorption and subchondral fracture, are the main complications observed in proximal humerus osteoarticular allograft reconstructions. Nevertheless, only fractures need a reconstruction revision. Joint complications may adversely affect the limb function, but for this reason, an allograft revision is rarely performed.

Keywords Humerus · Osteoarticular · Allograft

Introduction

In orthopedic oncology, increased emphasis has been placed in biologic reconstructive alternatives, because of concerns about the durability of prosthetic materials and because of the increasing survival of patients with sarcomas [1–4]. One biologic reconstruction option is massive bone allografts that include the possibility of supporting mechanical load and attaching host ligaments and muscles [1–4]. In addition, they are readily available from tissue banks and can be matched to the size of the resected bone [5]. Another potential advantage over synthetic materials is that they may be progressively incorporated by the host. However, possible disease transmission, host-donor junction complications, and negative effects on the strength and elastic modulus of the graft may affect their durability [2, 4].

The proximal humerus is one of the most common locations for tumors involving the appendicular skeleton [6]. Osteoarticular allograft reconstruction is a sound option after intra-articular proximal humerus resections. [7•, 8•].

The aim of this review was to describe present indications, surgical techniques, and final outcomes of osteoarticular allograft reconstructions performed at our institution for the proximal humerus.

Current indications:

- Reconstruction of osteoarticular defects of the proximal humerus in young patients (under 18 years old).
- Neurovascular bundle must be free of tumor.

Contraindications:

- Evidence of intra-articular tumor extension.
- Inadequate host soft-tissue to reconstruct the joint.
- Patients with osteoarthritis involving the glenoid.
- Patients who will receive radiotherapy.

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Surgical technique

All operations are performed in a clean-air enclosure with vertical airflow. After administration of adequate regional and/or general anesthesia, the patient is placed in the semi-upright “beach-chair position,” with the hips and knees flexed, and all osseous prominences are well padded. The head is secured in a neutral position, and the entire upper extremity is prepared and draped to the level of the mid-clavicle.

An extended deltopectoral approach is done that can be extended distally if more surgical exposure is needed. The cephalic vein is mobilized with the deltoid muscle and retracted laterally. The biopsy track is left in continuity with the specimen.

Usually, due to the compromise from the tumor, a biceps tenotomy is performed. The subscapularis tendon is released off of the lesser tuberosity, just medial to the long head of the biceps, in order to allow a dislocation of the humeral head with gentle external rotation and extension of the arm. It is preferable to dissect out the axillary nerve and protect it with a vessel loop to confirm its location and thereby diminish the risk of a nerve injury. The capsule is then released completely around the humeral neck. Then, the infraspinatus, supraspinatus, and teres minor tendons are released off of the greater tuberosity. The deltoid is then dissected free from the humeral shaft as well as the teres major, latissimus dorsi, and the major pectoralis tendons, if necessary. Humeral osteotomy is performed at the appropriate location as determined on the basis of the preoperative imaging studies. All remaining soft tissues at the level of the transection are cleared. The osteotomy is performed perpendicular to the long axis of the humerus. Following the osteotomy, the proximal humerus is then passed off the operative field.

Simultaneous with the tumor resection, the allograft specimen, previously selected from our virtual bone bank, is prepared in the back table. The graft is taken out of the plastic packaging and placed directly in a warm normal saline solution. After being thawed, the donor bone is cut to the proper length, and soft tissue structures are prepared for implantation. It is crucial during the joint reconstruction to have adequate soft tissue structures from the donor in order to repair them to correspondent host-tissues.

After resection of the tumor, the proximal humerus allograft is inspected to confirm that the size is appropriate and no degenerative changes are present. Then, the insertion of an allograft segment tailored to fit the bone defect is performed. Before the allograft bone is secured to the host shaft, the shoulder joint reconstruction is performed. First, we repair posterior capsule suturing autologous capsular tissues to the capsular tissues provided by the allograft with a number 1 non-absorbable suture. After the posterior capsular tissues are secured, the supraspinatus, infraspinatus, and teres minor tendons are repaired suturing autologous tendon tissues to the

tendon tissues provided by the allograft. Finally, the anterior capsule and the subscapularis tendon are repaired similarly as done with the posterior capsule and the rotator cuff. The rotator interval is repaired, and if the intra-articular biceps tendon was sectioned due to tumor compromise, the tendon can be tenodesed in the bicipital groove. Fitting the osteotomy between the host and donor in close apposition is a crucial step. When cortical bone is avascular, as in the allograft side, long-lasting stability is required, and under this situation, absolute stability offers the best conditions and chances for healing. The diaphyseal osteotomy is stabilized by internal fixation with two locking compression plates. The first plate is an anterior short plate that provides a primary stabilization and compression, and in order to minimize the risk of fracture, an additional lateral plate is placed to cover the entire length of the allograft. Two suction drains are inserted, and after lavage of the wound with saline solution, a meticulous suture repair of the intermuscular septum between the anterior deltoid and the pectoralis major muscles is done. A layered closure of the subcutaneous tissues and skin is then performed.

Postoperative management

A shoulder immobilizer is worn for 4 weeks while pendulum-type exercises are performed. After the first 4 weeks, a sling is used and supine active-assisted range-of-motion exercises are initiated. Active-assisted elevation can begin at 8 weeks, but resistive exercises are delayed until 12 weeks. The patient is encouraged to begin active forward flexion beginning at 8 weeks as comfort allows.

Pearls and pitfalls:

- To obtain a stable joint, the allograft must have adequate soft tissue structures from the donor in order to repair them to correspondent host-tissues.
- Reconstruction of the tendons, ligaments, and joint capsule must be meticulous and precise. The soft tissue reconstruction must begin from posterior to anterior.
- Compression of the osteotomy and rotational stability are better maintained with double plates and screws.
- We recommend reducing the host-donor osteotomy with an anterior short locking compression plate. Once the osteotomy is stabilized, the second plate is placed laterally to span as much as possible the length of the allograft.
- Locking compression plates are now used, for the majority of our patients, to obtain greater mechanical stability of the reconstruction.

Outcomes

From 1986 to 2010, in our institution, we performed 19 cases treated with an osteoarticular allograft of the proximal

Fig. 1 Graph shows Kaplan-Meier curve for survival of the proximal humerus osteoarticular allografts

humerus. The mean age was 22 years old and a mean follow-up of 91 months (min. 20–max. 240 months). One patient was excluded from this analysis because of lack of follow-up.

Considering an allograft to have failed when it was removed through either any type of revision procedure or an amputation, the allograft survival at 10 years was 55 % (CI 95 % 22–78 %) (Fig. 1).

We identified six patients with complications requiring a second surgery (33 %), including three fractures, two fragmentations of the epiphysis of the allograft with subchondral collapse (Fig. 2), and one local recurrence. In addition, we observed, in three cases, a massive proximal resorption where the affected patients had a significant loss of limb function, but

despite this, no patient will be operated for this complication. No patient of this series had an infection or a non-union. Of the six patients with failures requiring a second surgery, four of them were treated with an allograft prosthetic composite, one with a new osteoarticular allograft, and the remaining patient with a resection arthroplasty.

In patients who retained the allograft, the mean Musculoskeletal Tumor Society functional score (MSTS) [9] was 76 % (23 points). We observed that patients who had joint complications with massive proximal resorption had a significant loss of limb function.

There are few reports available to evaluate and compare outcomes of this biologic reconstruction [7•, 8•, 9, 10•,

Fig. 2 **a** Magnetic resonance image shows a 13-year-old patient with a Ewing sarcoma of the proximal humerus. **b** The postoperative anteroposterior (AP) radiograph shows how this patient was treated with an osteoarticular allograft stabilized with one locked compression plate. **c** An AP radiograph shows a 4-year control of the proximal

humerus osteoarticular allograft with incorporation of the graft. **d** An AP radiograph shows a 7-year control of the osteoarticular allograft with a fragmentation of the epiphysis associated with articular collapse. **e** An AP radiograph shows how this complication was resolved by placing an allograft prosthetic composite

11–15, 16•]. Most of them are retrospective studies with limited number of patients. According to the available literature, we could evaluate the following outcomes: allograft survival, complications, and MSTS functional scores.

In our series, the allograft survival rate was 55 % at 10 years. This survival rate is low in comparison with other implants [7•], but according to the literature, this survival rate is expected for this type of reconstruction [7•, 8•, 9, 10•, 11–15, 16•]. In articles available, allograft survival ranges from 78 to 50 % at 5 years of follow-up [7•, 8•, 9, 10•, 11–15, 16•]. Some authors do not recommend this type of reconstruction due to the low survival rate of the implant [14].

In our series, we had nine cases with major local complications. One was a local recurrence and the remaining eight were fractures and fragmentation of the epiphysis of the allograft with subchondral collapse. According to previous publications [7•, 8•, 9, 10•, 11–15, 16•], the frequency of these two complications is very high (up to 55 %). For that reason, DeGroot et al. [10•] performed an intra-medullar graft cementation to reduce the risk of fracture. Although this technique could lead to diminished fractures, it does not allow one to revise the allograft with a long-stemmed prosthesis unless one removes the remaining allograft or the intra-medullary cement. This is particularly important in cases of subchondral collapse.

Deep infections are also described with this reconstruction. According to previous publications, the rate of infection varies from 0 % [8•] to 15 % [11]. This complication may be related to multiple factors such as surgical time, nutritional status, diabetes, smoking status, and overall health of the patient. Due to the low number of patients included in the available literature, it is difficult to determine the risk factors for local infections.

Non-union is also described as a complication [7•, 8•, 9, 10•, 11–15, 16•] but is not a frequent complication in this location [1–3]. In addition, the allograft is rarely removed for this complication. The non-union generally responds well to revision surgery with autogenous bone graft with a new rigid fixation.

The mean MSTS functional score observed in our series was 76 % (23 points). This functional score is similarly observed in previous publications (range 50 to 78 %) [7•, 8•, 9, 10•, 12–15, 16•]. Comparing functional scores of proximal humerus osteoarticular allograft to other osteoarticular reconstructions like the distal radius [8•], this reconstruction has a lower score. We observed that joint complications may adversely affect the limb function.

Teunis T. et al. performed a systematic review study [7•] that compared the outcomes of proximal humerus osteoarticular allograft with endoprosthesis and allograft-prosthesis composite. They observed that functional scores in prosthesis studies ranged from 61 to 77 % (10 studies, 141 patients), from 50 to 78 % (eight studies, 84 patients) in

osteoarticular graft studies, and from 57 to 91 % (10 studies, 141 patients) in allograft-prosthesis composite studies. Implant survival ranged from 0.38 to 1.0 in the prosthesis group (341 patients), 0.33 to 1.0 in the osteoarticular allograft group (143 patients), and 0.33 to 1.0 in allograft-prosthesis group (132 patients). Overall complications per patient varied between 0.045 and 0.85 in the prosthesis group, 0 and 1.5 in the osteoarticular graft group, and 0.19 and 0.79 in the prosthesis-composite graft group. They observed a higher fracture rate for osteoarticular allografts, but other specific complication rates were similar. Therefore, they concluded that allograft-prosthesis composites and prostheses seem to have similar functional outcome and survival rates, and both seem to avoid fractures that are observed with osteoarticular allografts.

Conclusions

Osteoarticular allograft reconstruction is an alternative for massive bone defects of proximal humerus. Nevertheless, allograft fractures and articular complications, as epiphyseal resorption and subchondral fracture, are common complications observed in proximal humerus osteoarticular allograft reconstructions. Despite these complications, only fractures need a reconstruction revision. Joint complications may adversely affect the limb function, but for this reason, an allograft revision is rarely performed.

Compliance with ethical standards

Conflict of interest Dr. Aponte-Tinao has received consultant fees from Stryker Orthopedics. Dr. Farfalli, Dr. Ayerza, and Dr. Muscolo have nothing to disclose.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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