Clin Orthop Relat Res (2008) 466:205–209
DOI 10.1007/s11999-007-0011-8

ORIGINAL ARTICLE

Osteoarticular and Total Elbow Allograft Reconstruction With Severe Bone Loss

F. Daniel Kharrazi MD, Benjamin T. Busfield MS, MD, Daniel S. Khorshad, Francis J. Hornicek MD, PhD, Henry J. Mankin MD

Received: 21 May 2007 / Accepted: 2 October 2007

Abstract Osteoarticular allograft reconstruction is an option in patients with massive periarticular elbow bone loss secondary to tumor surgery or trauma. Our consecutive series consisted of 18 patients with tumors and one patient with trauma. Reconstruction consisted of 16 hemiarticular allografts and three total elbow osteoarticular allografts; patients had a minimum followup of 2 years (mean, 9.9 years; range, 2–12 years). For patients who had hemiarticular allografts, 14 of 16 were able to return to their preoperative level of occupational function, with one patient experiencing failure of the allograft from infection. For the three patients who had total elbow allograft reconstructions, all had degenerative changes develop after surgery and two of the allografts failed. Complications occurred in six of 19 patients. Hemiarticular elbow allograft reconstruction is useful for limb salvage with massive bone loss. Total elbow allograft reconstructions have a high failure rate in the mid-term.

Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

F. D. Kharrazi (✉), B. T. Busfield, D. S. Khorshad
Kerlan-Jobe Orthopaedic Clinic, 6801 Park Terrace Dr, Los Angeles, CA 90045, USA
e-mail: fdkharrazi@aol.com

F. J. Hornicek, H. J. Mankin
Department of Orthopedic Surgery, Orthopedic Oncology Unit, Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA

Introduction

After effective local control by wide surgical resection of a bone tumor, restoration of function of the limb is a primary goal of limb salvage surgery. Limb salvage after successful reconstruction frequently results in a more satisfactory outcome than amputation of the upper extremity. Massive allograft transplantation has become a potential reconstructive option in the management of large skeletal defects after wide resection of locally aggressive and malignant tumors of bone [2, 7, 9–11, 16, 17, 23–26, 28, 29]. To salvage the limb for function, allografts have been used for intercalary or osteoarticular reconstruction. As experience with allograft implantation has advanced during the past 25 years, it has become clear the results of allograft transplants depend on a multitude of factors [5, 7, 9, 14, 16, 22–26, 28, 29]. These factors include not only the type of allograft implanted (osteoarticular versus intercalary versus total joint transplantation) but also the particular joint reconstructed [6, 8, 14, 17, 20, 23–26].

Tumors affecting the distal humerus or proximal ulna, although rare, present a particularly challenging reconstructive dilemma. Because above-elbow amputation would be required in these cases, functional limb salvage reconstruction is an attractive approach. Reconstructive options include endoprosthetics, resection arthroplasty, interposition arthroplasty, arthrodesis, allograft reconstruction, or allograft-prosthesis composite arthroplasty [3, 11–13, 18, 21, 24, 27, 30–32]. Arthrodesis and endoprosthetic elbow reconstructions are made difficult by the

extent of the skeletal defects created by wide resection of these tumors. Patients with these tumors can be quite young and are not ideal candidates for elbow arthroplasty [8]. Arthrodesis, if possible, does not provide the same functional outcome as reconstruction [21]. For these reasons, osteoarticular allograft reconstruction of the elbow is an appealing alternative.

Although multiple case series of elbow allograft reconstructions used in the salvage for posttraumatic elbow injuries have been reported [2, 6, 10, 11, 17, 35, 36], a review of the literature failed to reveal a series specifically devoted to elbow osteoarticular allograft reconstruction after tumor resection. One series reported on two similar reconstructions of the distal humerus in 20 patients with nonunions of the distal humerus, whereas another reported on two series of complete elbow allograft reconstruction for salvage after failed total elbow arthroplasties [1, 15, 19]. These isolated reports with variable followups have not addressed the long-term outcomes in patients undergoing allograft elbow reconstruction after tumor resection.

We ascertained the functional results and complications of partial and complete osteoarticular allograft elbow reconstructions.

Materials and Methods

We retrospectively reviewed 19 patients who underwent osteoarticular allograft elbow reconstruction between 1976 and 1996. We included all patients who had osteoarticular allograft reconstruction of the elbow, including hemiarticular or total elbow. Eighteen patients had aggressive benign or malignant tumors about the elbow. The only patient included who did not have a tumor sustained a traumatic elbow injury with massive bone loss from an open fracture. Given the focus on functional outcome after elbow allograft reconstruction rather than tumor treatment, the patient was included in the study. Tumors included six giant cell bone tumors, five chondrosarcomas, a fibrosarcoma, a malignant myxoid epithelial tumor, a malignant fibrous histiocytoma of bone, a Ewing's sarcoma, a lymphoma, a chondromyxoid fibroma, and a metastatic renal cell carcinoma. Reconstruction consisted of 11 distal humerus only, five proximal ulna only, and three complete elbow osteoarticular allografts. Seven were left-sided and 12 were right-sided elbow surgeries. There were 10 female and nine male patients with an average age of 32 years (range, 14–66 years). Eight reconstructions were performed as the index procedure. Eleven reconstructions were performed as a salvage operation with an average of 1.5 previous surgeries (range, 1–4 procedures). Nine patients had a previous bone graft procedure performed. The minimum followup was 2 years (mean, 9.9 years; range, 2–12 years). One patient died at 24 months and another died at 36 months from their disease and were included in the review. Other than the patient who died 2 years after reconstruction, the minimum followup was 3 years.

The tumor operations included wide excision of the tumor involving the distal humerus, proximal ulna, or both. Patients with malignant tumors received adjuvant chemotherapy and radiation therapy based on protocols appropriate for the tumor diagnosis. The operative approach was dictated by the location and extent of the tumor, with the majority performed through a posterior approach with olecranon osteotomy as necessary. The reconstructions all were performed with frozen allografts obtained from the institution's bone bank using its harvest and processing protocols. All allografts were size-matched using orthogonal contralateral elbow radiographs. For hemiarticular allograft reconstruction, the native collateral ligaments were attached via bone tunnels to the allograft. If the patient's collateral ligaments were believed deficient intraoperatively, the collateral ligaments from the allograft were used for augmentation. For total elbow allograft reconstruction, the native ligaments on the allograft were left intact. All elbows were stable throughout a functional range of motion intraoperatively. Rigid internal fixation was used at the allograft-host junction using the standard AO technique. No total elbow or radial head arthroplasties were performed. Soft tissue coverage was adequate in each of our patients and no flaps were necessary.

Postoperatively, the patients received intravenous antibiotics while in the hospital and were discharged on a 2- to 3-month course of oral antibiotic prophylaxis. Immobilization was performed in a posterior splint for 4 to 6 weeks before beginning a supervised progressive range of motion exercise program wearing a custom-made hinged elbow brace.

All patients were followed closely with regular clinic visits and radiographs until union at the allograft-host junction. Thereafter, patients were followed with yearly clinic visits and radiographs. In a few cases in which the patients lived far away, followup was coordinated with a local orthopaedic surgeon to allow our review of the radiographs.

Functional outcome was evaluated by a system developed by Mankin et al. [26]. This system is based on a combination of factors, including survival, tumor recurrence, pain, and function. An excellent result indicates the patient is recurrence- and pain-free with normal function except for high-performance athletics. A good result indicates the patient is also recurrence- and pain-free with impairment in function that limits recreational but not occupational activities. A fair result indicates the need for aids or a brace as a result of pain or disability that may prevent return to work status. The result is considered a

failure if additional surgery is required for allograft resection, amputation, or the presence of or death from tumor recurrence. Thus, a good or excellent result by this classification indicates a return to preoperative occupational function.

Radiographic and functional outcomes were assessed by the senior author's (HJM) staff and were not blinded to the patients' procedures.

Results

Using the functional outcome criteria, 14 of 19 were able to return to their preoperative occupational function at the latest followup. For patients who had hemiarticular and total elbow allograft reconstructions, 14 of 16 and one of three returned to their preoperative occupational function. Average active range of elbow motion was flexion from 27° to 115°, pronation of 76°, and supination of 57°. Only one patient had severe limitation in his preoperative range of motion and had undergone a previous elbow contracture release. The likelihood of failure depended on the degree of allograft elbow reconstruction performed. Three patients from the entire series had failed reconstructions necessitating subsequent allograft resection. One failure occurred in a proximal ulnar hemiarticular allograft reconstruction resulting from a deep infection. All three patients who had a complete elbow allograft reconstruction had a Charcot-like joint develop 5 to 8 years after surgery. From this group, two of the three patients had unsuccessful reconstructions and ultimately required allograft excision with a residual flail elbow. The remaining patient in the complete elbow allograft reconstruction group had only a fair result. The three patients with unsuccessful reconstructions underwent allograft resection and managed the flail elbow with a brace. None elected to have an arthrodesis.

Complications occurred in six of 19 patients. Complications included two infections, a host-allograft junction nonunion, a postoperative dislocation, one unstable elbow, and two nerve palsies (one radial and one ulnar nerve). The patient with the superficial infection had the infection resolved with empirical antibiotics, as the organism was never identified. The only deep infection from Staphylococcus aureus ultimately necessitated resection of the allograft reconstruction after failed débridements and a course of antibiotics. No intraoperative cultures from the allografts were positive. The only host-allograft junction nonunion, defined as lack of bridging callus on radiographs at 6 months after surgery, occurred in a patient with metastatic renal cell carcinoma. He had two previously failed surgeries for intercalary allograft reconstruction. At his latest followup, he was pain-free with intact internal fixation. One patient underwent closed reduction for dislocation after a distal humerus allograft reconstruction after a fall 1 month after surgery. At his latest followup at 8.5 years, he has a stable and painless elbow without the need for bracing. The only patient with an unstable elbow had a fracture of her medial condyle 6 years after reconstruction. Because of instability to varus stress, she was managed with an elbow brace. One patient in this series had transient radial and ulnar nerve palsies. Although not correlated with function, degenerative changes on radiographs were common in patients followed for more than 2 years.

Discussion

In cases of elbow reconstruction after tumor resection, preservation and restoration of function are secondary goals to excision and local tumor control. Although multiple reconstruction options exist for elbow bone loss from tumor or trauma, we sought to determine the functional outcomes and likelihood of failure for hemiarticular and total elbow allograft reconstruction in 19 patients.

Our study has several limitations. The series was studied retrospectively and is a combination of partial and total elbow allograft reconstruction. The radiographic and functional outcomes were not determined by a blinded observer and the functional outcome criteria have not been formally validated as an outcome measure. However, given the rarity of this reconstructive surgery, this 19-patient series is relatively large compared with other series in the literature.

Numerous authors have reported on the techniques and results of arthroplasty of the elbow in cases with a large osseous defect by replacing the distal humerus [3, 4, 12, 13, 17, 20, 27, 31], the proximal ulna [18], or the entire elbow [2, 10, 11, 17, 36]. With less extensive bone loss, arthrodesis or resection arthroplasty may be an option [21, 31]. With massive bone loss in young patients, most surgical options are compromised and bulk allograft reconstruction becomes a viable alternative [36].

Reconstruction of the elbow with restoration of function can be challenging, particularly with large osseous defects created from tumor resection. In the largest series in the literature, results of custom endoprosthetic replacement of the humerus and elbow in 26 patients with destructive lesions of the distal humerus were reported at a mean followup of 4.5 years [31]. Three prostheses were removed for deep infection, whereas another three had aseptic loosening but were not revised. Despite these complications, endoprosthetic replacement was recommended as a limb salvage alternative. However, elbow prosthetic longevity in young patients and the postoperative restrictions are of particular concern [8].

Many authors have reported on the techniques, results, and complications of allograft reconstruction of other joints [5, 7, 14, 19, 22–26, 28, 29, 33, 34]. Regarding allograft elbow reconstruction, the literature is scarce, especially after tumor resection [1, 6, 35, 36]. With only four patients, a small series of hemiarticular posttraumatic defects treated by distal humerus allograft reconstruction were followed for an average of 5 years [6]. Despite complications occurring in half of our patients, including a deep infection and a nonunion, elbow allograft reconstruction was recommended as a surgical alternative for salvage of the posttraumatic elbow. Another small series reported on hemiarticular allograft reconstructions in two of 22 patients with distal humerus nonunions with inconclusive results [1]. In a series primarily consisting of posttraumatic patients undergoing complete allograft elbow reconstruction, nine patients had painless elbow motion but had degenerative joint changes seen on radiographs by 2 years [35]. Another series of total elbow allograft reconstruction reported a 70% complication rate in patients with six allograft resections and three patients who had conversion surgery to total elbow arthroplasty secondary to instability [10]. Instability occurred in five of six patients and three had revision to a constrained total elbow arthroplasty [11]. The allograft reconstruction was recommended as salvage only and in combination with total elbow arthroplasty, respectively [10, 11]. Despite concerns of instability in long-term followup of 5 to 7 years, only one patient in our series had instability secondary to trauma that was successfully managed with a brace.

Two small series with total elbow allograft reconstruction performed as a salvage procedure in patients with failed total elbow arthroplasty reported good initial functional results but long-term outcome is uncertain [15, 19]. In a small series of six patients treated with total elbow allograft reconstruction, radiograph degradation and lysis increased with time, although 83% had satisfactory outcomes [2]. Similarly, our radiographic findings at the latest followup confirm those of Urbaniak et al. [35, 36] in that joint function was consistently better than predicted based on radiographic appearance.

Although massive allograft reconstruction provides certain advantages, it carries with it serious potential complications [5, 22, 23, 34]. In several large series, complications included nonunion, infection, fracture, allograft resorption, and instability [5, 10, 11, 22–24, 34]. In our overall series, there were two infections (10%), one nonunion (5%), and one fracture with subsequent instability (5%). Our overall complication rates were relatively low compared with the rates in the literature, with the hemiarticular allograft reconstructions having a much lower failure rate than the total elbow allograft reconstructions. Only one allograft was removed for infection, and no amputations were performed. Despite rigid internal fixation, humeral allografts have higher nonunion rates than other sites [24, 26]. The only nonunion in our series occurred in a patient who had multiple operations for metastatic cancer. Despite the nonunion, he remained asymptomatic with good function.

Based on our study, a satisfactory functional outcome can be obtained with allograft elbow reconstruction, particularly with hemiarticular allografts. This trend was reported previously in a series with 100% (six of six) good and excellent results in hemiarticular versus one failure and one fair result in total elbow allografts [17]. The hemiarticular reconstruction subset of our series had 14 of 16 good and excellent results with one of 16 failing. The preservation of joint innervation and host bone load sharing may allow for better outcomes. All of the total elbow allograft reconstructions in our series showed radiographic degenerative changes. Our overall complication rate in approximately one third of our patients was less than that in similar reported series. Another series of posttraumatic total elbow allograft reconstructions followed for a minimum of 7 years had satisfactory outcomes in 83% of the patients [2]. Our small subset of complete elbow allograft reconstructions did not allow return to preoperative occupational function and two of three failed. Hemiarticular allograft elbow reconstruction appears superior to total elbow allograft reconstruction for functional outcome and failures. Although more failures occurred with the total elbow allograft reconstruction group, both allografts were resected 5 years after the reconstruction.

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