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ORIGINAL STUDY

Reconstruction of the proximal humerus for bone neoplasm using an anatomic prosthesis-bone graft composite

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This study assesses function after limb sparing bone tumour resections of the proximal humerus.
Twenty-seven patients had an intraarticular resection with reconstruction using an anatomic prosthesis-bone graft composite with average clinical follow-up of 6.3 years (range : 1.3-15.8 years).
Pain relief was achieved for 22 shoulders (81%) ; 19 of 25 patients responding (76%) were satisfied. Active elevation averaged 62°, external rotation 25°, and internal rotation to L-4. Complications included instability in 7, nonunion in 4, implant loosening in 3 of these and tumour recurrence in 1. There were 7 reoperations. Using the Neer rating, 19 primary operations (70%) were successful. The Musculoskeletal Tumor Society Score averaged 18.5 (62%), the American Shoulder and Elbow Surgeons functional score 18.4 (37%) with a total score of 51 (51%), and on the Simple Shoulder Test 5.4 of 12 questions were answered affirmatively.
This procedure is oncologically safe. There are structural complications, notably shoulder instability. Function ratings are one-third to one-half normal.

Keywords : proximal humerus ; bone neoplasm ; shoulder prosthesis-bone graft composite.

INTRODUCTION

Limb salvage procedures following resection of the proximal humerus for bone sarcomas, metastases, or aggressive benign neoplasms can be more frequently applied owing to improved diagnostic imaging, new classification systems, the development of refined surgical techniques, and expanding adjuvant chemotherapy and radiation treatment. Contemporary surgical options have included osteochondral allografts (*8,9,10,12,17*), large endoprotheses (*2,4,17,20,22*), or more standard proximal humeral prostheses plus an allograft (allograft-prosthesis composite or APC) (*1,3,10,16,17*).

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In the above reports attention is primarily focused on oncologic issues. When function was assessed the Musculoskeletal Tumor Society score was commonly applied (*3,5,9,16,17,22*). This score includes pain, emotional acceptance, hand positioning and dexterity, lifting ability, and a scale for function (*7*). The reverse shoulder prosthesis has been introduced as an alternative to the above reconstruction options with excellent functional results (*5,6*). However, the outcomes and complications remain to be defined. We felt it would be useful to more carefully define not only the oncologic outcome but also shoulder function using disease and joint specific assessments for this group of patients undergoing an intraarticular proximal humerus resection with preservation of the rotator cuff, the majority of the deltoid muscle, the neural innervation of these muscles, and reconstruction with an anatomic shoulder prosthesis as part of a bone graft-prosthesis composite – if the functional outcomes and prosthetic survival are reasonable, this treatment method can continue to be recommended for the younger and selected older adults with proximal humerus neoplasms.

PATIENTS AND METHODS

This study was approved by the Institutional Review Board of our Institution. Between the years 1988 and 2006, 30 patients with 30 affected shoulders had an intraarticular proximal humerus resection, limb sparing surgery, with reconstruction that included an anatomic prosthesis and a structural bone graft for the treatment of malignant bone tumours, aggressive benign neoplasms, or metastases to the proximal humerus. Three patients were followed less than one year (6 months, 8 months, and 10 months). They had no complications to that point but have been excluded from further evaluation. Of the remaining 27 patients, 14 were men and 13 were women. Their average age was 43.8 years (range : 15-74 years), 8 were 30 years of age or less, 14 were aged 31-60, and 5 were greater than 60 years of age.

The diagnoses included low grade chondrosarcoma in 11, osteogenic sarcoma in 4, Ewing's sarcoma in 3, giant cell tumour in 3, aneurysmal bone cyst in 1, and fibrosarcoma in 1. There were metastatic tumours in 3 ; these were of thyroid origin in 1, breast in 1, and renal in 1. One patient had a haematogenous malignancy (leukemia). Previous surgery included reconstruction of the proximal humerus with an osteoarticular allograft in 6. All had healed their allograft to native bone, but all had proximal graft fracturing with some collapse. One patient had a previous vascularized fibula – a reconstruction that resulted in a nonunion. Three had previous intramedullary nail placement for treatment of pathologic fracturing – complete in 2 and impending in 1. The one patient with an aneurysmal bone cyst had undergone previous curettage and bone grafting. Adjuvant therapy was not a part of the treatment regimen for patients with chondrosarcoma, giant cell tumour or the aneurysmal bone cyst. Four out of 4 with osteogenic sarcoma had chemotherapy. Three of 3 with Ewing's sarcoma had chemotherapy, and 1 had radiation therapy. Of those with metastatic tumours, 2 of 3 had radiation therapy and one had chemotherapy. The patient with a haematogenous malignancy had chemotherapy and radiation therapy.

Surgical Technique

All patients had a type I, intraarticular proximal humeral resection according to the Malawer classification (*10,11*). This was considered a wide "en bloc" excision of the proximal humerus and included varying lengths of the humeral shaft without surgical disruption of the glenoid side of the shoulder. The exposure was a long deltopectoral approach in 18, with extension distally into the arm as required. Nine had a more extensive anteromedial approach. The deltoid muscle was preserved except for muscle tissue surrounding the biopsy site that was excised in continuity with the proximal humerus. The average length of bony resection was 13 cm (range : 5 to 35 cm). Seven of the resections were proximal to the insertion of the deltoid, 4 were at the level of the deltoid insertion preserving some of the deltoid attachment and 16 were below the deltoid insertion with attempts made to maintain deltoid insertion-fascia continuity distally whenever possible (*19*). The bony division was transverse in 16 cases and step-cut in 11. There was a clear margin at the point of excision, as determined by histologic frozen section, in all patients.

The humeral implant was of standard length in 7 and of longer length in 20. The Neer design (Biomet, Warsaw, IN, USA) was used in 2 shoulders early in the series (1988, 1992). The Cofield design was used in 22 and was generally preferred due to the cylindrical shape of the stem that was available in multiple diameters and 4 lengths (Smith-Nephew, Memphis TN, USA). The Aequalis™ design was used in 2 (Tornier, Inc., Edina MN, USA) and the Global® design was used in 1 (DePuy, Warsaw IN, USA). In these 3 shoulders standard

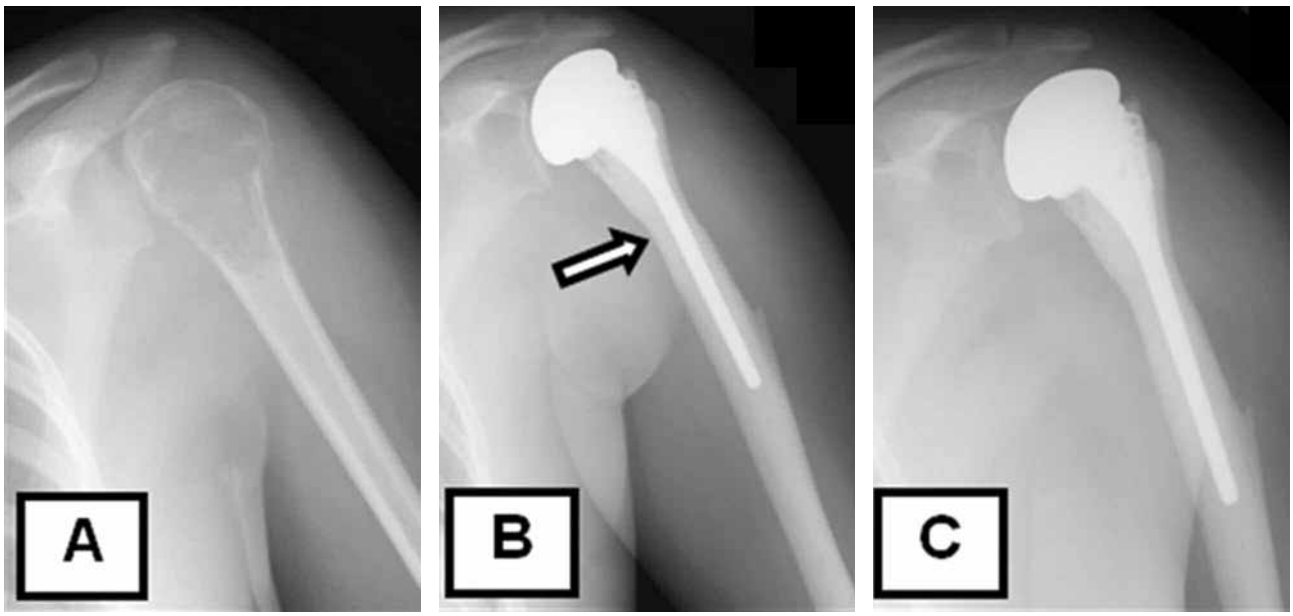

Fig. 1. — **A)** The radiograph shows a destructive lesion of the proximal humerus consistent with a giant cell tumour.
B) The proximal humerus was reconstructed by allograft-prosthetic composite reconstruction with cement used for fixation both proximally and distally. The arrow indicates the host-graft junction.
C) Radiograph obtained 7 years after surgery showing the allograft has healed to the native bone. There is no evidence of loosening and the shoulder is stable.

length implants were used not requiring the availability of different stem lengths so commonly needed in this type of surgery. In 26 shoulders a fresh frozen, non-irradiated bone allograft was used. These were obtained from our institutional bone bank in 8, and from 4 other banks in the remaining cases. In one shoulder with a resection of only 5 cm, extensive autograft material was obtained from the posterior iliac crest and secured around the metallic implant. After preparation of the bone, the humeral component was cemented proximally in the allograft in 23 shoulders and distally into native bone in 18 shoulders (Fig. 1). In 2 shoulders no bone cement was used. In addition, 7 patients had allograft struts applied and fixed with cables at the junction of the allograft with native bone, and cancellous allograft bone chips were placed at the junction in 7.

The rotator cuff and shoulder capsule were divided near their humeral attachments in all shoulders. The long head of the biceps was divided just distal to the transverse humeral ligament and freed from the bicipital groove. Following reduction of the allograft and prosthesis into the shoulder joint the native rotator cuff and shoulder capsule were sutured to the allograft rotator cuff and capsule, and stability was obtained in all cases. The long head of the biceps was tenodesed to local soft tissues. The deltoid insertion was, when necessary, sutured either to the surrounding fascial tissues or through drill holes into the humeral allograft. The axillary and suprascapular nerves were preserved in all cases.

Following surgery the shoulder was placed in a shoulder immobilizer or a pillow sling, protecting the arm for 6 to 8 weeks. A limited goals type of rehabilitation was outlined, limiting passive motion of the shoulder to below the horizontal and external rotation to no more than 20 degrees for the first 6 to 8 week period (*14,15*). At that point gentle active assisted motion exercises were started, and at three months isometric and elastic strap strengthening were allowed.

Clinical and Radiographic Assessment

A standard format was developed for assessment of shoulder function after arthroplasty (*21*). Pain was evaluated on a five-point scale. Patients were asked if they were satisfied or dissatisfied with their procedure. While the patient was seated, active elevation and active external rotation with the arm at the side were measured in degrees and internal rotation was measured as the highest spinal level that could be reached by the thumb.

The Neer result rating was applied using the limited goals rehabilitation rating because these patients had extensive loss of the rotator cuff muscle-tendon attachments and compromise of deltoid abductor power. The reconstruction was rated as successful if the shoulder was stable, comfortable, and the limb could be used for daily activities with the arm near the side. It was considered unsuccessful if these criteria were not met (*14,15*). The Musculoskeletal Tumor Society score (MSTS) developed for evaluating limb salvage procedures was applied as an end-result report (*7*). This score includes 6-point scales evaluations for pain, function, emotional acceptance, hand positioning, manual dexterity and lifting ability and expresses the result as a proportion of the expected normal function. The maximum possible score is 30.

Additional questionnaire response was possible for 12 patients, and outcome was also assessed by the American Shoulder and Elbow Surgeons method that evaluates pain on a 50 point scale and activities of daily living on a 50 point scale (*18*). Similarly, these patients were also evaluated by the Simple Shoulder Test, responding affirmatively or negatively to 12 direct questions (*13*).

Radiographs were assessed for glenohumeral subluxation, glenoid cartilage loss, allograft resorption, bone implant or bone cement lucent lines, shift in implant or allograft position and allograft to native bone healing.

RESULTS

There were 6 deaths in the 27 patients at an average of 41 months following surgery (15 to 69 months). Three of these deaths were cancer-related and associated with thyroid, breast and renal carcinomas metastatic to the shoulder. The other 3 deaths were unrelated to the shoulder lesions or to surgery. For the 27 shoulders the length of follow-up was between 1 and 2 years in 3 patients. One of the 3 died during that period, and 2 had reoperations. Follow-up was greater than 2 years in 24 patients. The overall follow-up length averaged 6.4 years (range : 1.3 to 15.8 years).

Evaluating pain on a 5 point scale, pain was reported as none in 11, slight in 6, occasionally moderate in 5, moderate in 4, and severe in 1. In 81% of shoulders there was no, slight or occasionally moderate pain postoperatively.

Average active elevation was 62 degrees with a considerable variation in range of motion. Twelve shoulders had less than 45 degrees of active elevation. Elevation was between 45 and 89 degrees in 7, between 90 and 120 degrees in 7, and greater than 120 degrees in 1. Overall, 30% of shoulders had 90 degrees of elevation or more. Active external rotation with the arm at the side averaged 25 degrees (range 0 to 60 degrees). Internal rotation behind the back had a median value to L4 (range S1 to T9).

In assessing patient satisfaction by questionnaire, 25 patients responded. Nineteen (76%) felt satisfied while 6 were dissatisfied. Association with dissatisfaction included poor motion (< 45 degrees) in 5, reoperation in 5, and moderate or severe pain in 4.

The Neer Limited Goals Result Rating was successful in 19 (70%) and unsuccessful in 8. Three additional types of functional ratings were obtained from newly sent questionnaires in 12 shoulders. These patients had an average MSTS score of 18.5 (62% of maximum). The American Shoulder and Elbow Surgeons functional score averaged 18.4 points (37% of maximum). The American Shoulder and Elbow Surgeons total score, including function and pain, averaged 51 points (51% of maximum). On the Simple Shoulder Test these patients averaged 5.4 affirmative answers (45% of maximum). The distribution of responses to the Simple Shoulder Test are depicted in Table I.

Radiographs were available for 21 shoulders at greater than one year of follow-up with a mean follow-up of 4.5 years (1.3 to 10.8 years). No shoulders had subluxation immediately after surgery. At final follow-up moderate or severe superior subluxation was present in 6, glenohumeral joint space narrowing in 6, one of which was painful, allograft resorption of varying degrees in 7, and lucent lines in 7 (Fig. 2). The lucent lines were 1 mm incomplete in 4 and 2 mm incomplete in 3. Nonunion between the allograft and native humeral bone developed in 4 patients, 2 of whom were on chemotherapy. Prosthetic tilt or subsidence developed in 3 shoulders, and these 3 shoulders were considered as being radiographically and clinically loose.

Concerning complications, a superficial infection developed in 1 shoulder. This was treated successfully with 4 debridements. Arthrofibrosis and

Table I. — Simple shoulder test (5) (12 patients)

Function	Number able to perform*
Arm comfortable at side	12
Sleep comfortably	10
Tuck in shirt	9
Throw underhand	9
Carry 20 lb	7
Do usual work	7
1 lb on shelf	5
Wash back of shoulder	4
Hand behind head	3
8 lb on shelf	2
Coin on shelf	2
Throw overhand	1

*Number of patients (out of 12 responders) who were able to perform the functions at final questionnaire contact. Displayed in order of number of yes responses. Questions of the simple shoulder test are shortened to highlight their functional goals (5).

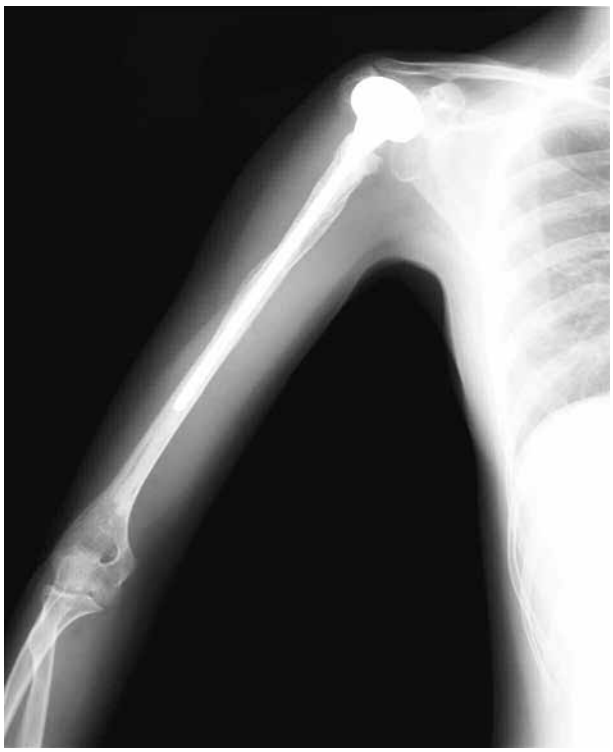

Fig. 2. — Three years following allograft-prosthesis reconstruction for osteosarcoma. The radiograph shows solid humeral fixation, proximal allograft resorption, and instability of the proximal humerus in the superior direction.

pain developed in 1 shoulder treated unsuccessfully with lysis of adhesions. Heterotopic ossification and pain developed in 1 shoulder treated successfully with removal of the heterotopic ossification. Clinically relevant instability developed in 7 shoulders, one of which underwent an unsuccessful soft tissue re-repair. Nonunion developed in 4 shoulders, two of which had a reoperation, and loosening developed in 3 shoulders, as mentioned above, and 2 of these patients with loosening and nonunion underwent revision surgery. There was a tumour recurrence in 1 patient with a chondrosarcoma. He had an unsuccessful local resection and went on to fore-quarter amputation. Overall, 7 shoulders had a reoperation to deal with the above complications.

Three factors were assessed that could potentially affect the clinical outcome. The type of implant used seemed to have little, if any, effect on outcome ; however, 22 of the 27 cases were of the Cofield design. In this design 15 of the 22 shoulders were successful (Neer limited goals rating), while in the other 5 cases having 3 types of implants, 4 were successful. Surprisingly, for the 11 shoulders with humeral resection above or through the deltoid insertion, the mean pain rating (1.6 vs 0.9), active elevation (65° vs 57°) or the functional scores (MSTS (19 vs 17), ASES (49 vs 50), SST (5 vs 5)) were not substantively different than those cases with resection distal to the deltoid insertion. However, the development of clinical instability did have negative effects. The mean pain score was 1.86 vs 0.95 in stable shoulders, and the three mean functional scores were lower with the MSTS score being 13 vs 19, the ASES score being 32 vs 56, and the SST score being 4 vs 5.

DISCUSSION

From an oncologic standpoint this operative method can be considered safe. There were no intraoperative complications, no problems with wound healing and only one infection which was superficial and treated effectively with debridements and antibiotics. Of the 27 shoulders there was

one local recurrence. This unfortunately led to amputation. That patient remains tumor-free. All these findings, a low early complication rate, only an occasional infection, and infrequent local recurrence, are similar to other reports (*1,3,17*). There were no deaths related to the shoulder lesion or to metastases from the shoulder lesion to elsewhere. Three of the deaths were associated with carcinomas that had been metastatic to the shoulder. All 3 of these patients maintained a comfortable shoulder and survived for more than a year following their shoulder procedure.

From a clinical perspective there are pluses and minuses relative to this procedure. Pain relief was reasonable but not perfect. There was no, slight, or occasionally moderate pain in 22 of the 27 shoulders. Similarly 19 of the patients were satisfied with their outcome. On the other hand, regaining active elevation was difficult with average active elevation being approximately one-third of normal and only 30% of patients achieving 90 degrees of active elevation or greater. This is similar to the average 56 degrees of active abduction reported by Abdeen *et al* (*1*). Rotational movements were better maintained but still limited.

A main direction of this study was to more carefully define the functional outcomes achieved by these patients in addition to their oncologic results. Neer suggested a limited goals type of rehabilitation for these patients with resection of the proximal humerus and total rotator cuff repair (*14,15*). Paralleling patient satisfaction and pain relief, a successful rating was achieved in 19 of the shoulders (70%). In these cases the shoulders were stable, and it was possible to use the arm with comfort when the arm was near the side. Functional outcomes were obtained at an average of 6.4 years, and some patients lost movement and strength over the postoperative period associated with glenohumeral subluxation, seemingly related to stretching of the rotator cuff and shoulder capsule repair. All the scores, the MSTS, the ASES Function Score, the ASES Total Score and the SST questions exhibited a value of between one-third and two-thirds normal centering around one-half what might be expected for normal upper extremity shoulder function. The MSTS score of all patients (average 62%) is less than that reported by Black *et al* (69%) (*3*) or Potter *et al* (79%) (*17*). It is much lower than the 90-96.7% reported for the reverse prosthesis by DeWilde *et al* (*5*). Only Black *et al* (*3*) reported a total ASES score (59) ; this is also slightly greater than the average 51 points obtained by the patients in this series. The number of patients and duration of follow-up is significantly less in the above studies than in this study. It could be that as time passes the cuff stretches and superior subluxation may develop as demonstrated in some of our patients. So, on one hand there is certainly great patient and surgeon satisfaction maintaining the extremity – being able to offer limb salvage – but on the other hand the functional recovery of the shoulder girdle complex is moderate. This can be most directly appreciated by reviewing the responses to the Simple Shoulder Test (Table I).

There was some degree of allograft resorption in 7 patients. This was proximal in 6 and in the diaphyseal region in 1. Proximal allograft resorption can be associated with humeral head subluxation as illustrated in Figure 2. Radiographically, humeral subluxation was present in 6 shoulders in the superior direction.

Instability in a superior direction with the humeral head contained under the coracoacromial arch was important relative to its association with some degree of anterior instability and that was clearly clinically significant. Fortunately, it was of such a magnitude to require reoperation in only one shoulder. This frequency of instability though does suggest considering the use of more constrained shoulder implants such as the reverse shoulder arthroplasty for treatment of these patients (*5,6*), particularly if they are older and the length of resection maintains the continuity of the deltoid insertion to native bone. This direction of thinking is reinforced by the reports identifying instability in one-quarter or more of patients treated with anatomic prosthesis-allograft reconstruction (*1,3,17*), such as was done in this study.

Mechanical implant and allograft problems were not too common, similar to other series, with 4 shoulders developing some issues related to nonunion at the allograft native bone junction or mechanical loosening (*1,3*). Of the 21 shoulders

analyzed (excluding the 6 who had previous osteoarticular allografts without an implant placed), 0 of 5 having had both a step-cut and bone cement proximally and distally experienced nonunion or loosening. This was true for 1 of 4 who had neither a step-cut or proximal or distal cement fixation, 2 of 5 with a step-cut without distal cement fixation, and 1 of 7 with cement distally and with a transverse cut. The numbers are too small to perform effective analysis of this issue, but it seems like there was a trend toward better fixation when using both the step-cut and proximal and distal bone-cement fixation (*23*).

CONCLUSIONS

Intraarticular humeral resection followed by reconstruction with an allograft prosthetic composite is oncologically safe and generally effective in treating proximal humerus lesions and avoiding more than an occasional local recurrence or metastases to other parts of the body. This form of treatment offers a reasonable opportunity for pain relief, patient satisfaction and successful outcome relative to limited functional goals. The prevention of clinically important instability has not been fully addressed by this type of procedure but problems with graft host bone union are not too common nor is allograft component loosening. Active elevation can occasionally be regained but not typically so. Functional outcomes are moderate.

Currently we would continue to offer this method of treatment for younger patients with these types of oncologic disease. It is important to firmly fix the implant and allograft to the adjacent normal bone. The frequency of instability may be lessened by truly applying limited goals rehabilitation methods, (ie. limb protection for approaching 3 months in duration). Whether that will, in fact, help improve the outcome of reconstruction is still to be proven.

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