Function following limb salvage for primary tumors of the shoulder girdle

10 patients followed 4 (1–11) years

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10 patients with primary neoplasms of the shoulder girdle underwent limb salvage procedures involving resection of the proximal humerus and parts of the scapula and clavicle. The function of the ipsilateral limb was assessed in all patients, in 9 at least one and a half years after surgery. Function was good in 3 of the 6 patients in whom an interposition bone graft was used and a successful shoulder arthrodesis was achieved. In the remaining 3, proximal arthrodesis was unsuccessful and the result was fair in 2 and a failure in 1. All 3 patients in whom the extended Tikhoff Linberg type of reconstruction was undertaken had good function although unsatisfactory cosmetic results. The 10th patient, who had a temporary cement and wire interposition, died of distant metastases 8 months after surgery and was considered a failure.

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Limb salvage, as opposed to ablation, is now well accepted for malignant neoplasms of the shoulder girdle. No difference in local recurrence, distant metastases, or survival has been demonstrated between these procedures (Craig and Thompson 1987). While previous reports (Francis and Worcester 1962, Enneking et al. 1980, Craig and Thompson 1987) focused on various reconstructive methods for limb salvage, reports on function of the resultant limb are sporadic and scanty (Francis and Worcester 1962, Markhede et al. 1985, Kurer et al. 1988). We report the function following shoulder reconstruction after major resection for sarcomas.

Patients and methods

Since 1979 10 patients with aggressive and malignant tumors of the shoulder girdle had major resection of the humerus and scapula (Table 1). There were 6 men and 4 women, mean age 34 (13–58) years. All patients were followed up by us, except 2 who lived overseas; their referring physicians kept us informed of the patient's status.

There were 2 soft tissue tumors. Case 9 was a fibrosarcoma that arose in the deltoid muscle and involved the glenohumeral joint (Figure 1). Case 10 was a synovial sarcoma that presented as a supraclavicular swelling and had infiltrated the clavicle and scapula with extension into the glenohumeral joint.

The remaining 8 cases were bone sarcomas which involved the proximal humerus, 4 osteosarcomas, 2 giant cell tumors, 1 malignant fibrous histicytoma, and 1 chondrosarcoma. They were all primary tumors, except Case 8 who had previously had a wide resection of the proximal two-thirds of the humerus for chondrosarcoma with an interposition vascularized fibula graft. She had excellent hand and elbow function with a fused shoulder. 19 months later she presented with recurrence involving the graft. The management of this recurrence is included in this series.

When first seen, all patients were evaluated with radiographs, bone scans, computed tomography, and some had arteriograms. An incisional biopsy was performed to establish the diagnosis. The surgical stage of the soft tissue tumors was IIB, and that of the bone tumors was 2 IB and 6 IIB (Enneking 1983).

The operative procedure was a wide resection of the proximal humerus, taking varying portions of the scapula, clavicle and the abductor mechanism (deltoid and rotator cuff muscles). The approach in all cases was through an extensile exposure via the deltopectoral groove. The site of the biopsy was excised en bloc with the resected specimen after the neurovascular bundle was isolated. Complete removal of the tumor was confirmed intraoperatively by frozen section

Table 1. Details of patients

Case	Age	Sex	Side	Diagnosis (Enneking stage)	Type of resection	Type of reconstruction
1	13	M	R	Malignant fibrous histiocytoma proximal humerus (IIB)	Proximal 2/3 humerus and glenoid. Deltoid and rotator cuff	VFG (15 cm)
2	21	F	R	Osteosarcoma proximal humerus (IIB)	*Ist stage: Proximal 2/3 humerus and glenoid. AO plate interposition. Deltoid and rotator cuff	VFG (14 cm)
3	18	M	L	Osteosarcoma proximal humerus (IIB)	Proximal 2/3 humerus and glenoid. Deltoid and rotator cuff	VFG (15 cm long) with vascularized lateral scapular border graft (9 cm)
4	46	M	R	Giant cell tumor proximal humerus (IB)	Outer 1/3 clavicle, glenoid coracoid and proximal 2/3 humerus. Deltoid and rotator cuff	VFG (13 cm)
5	44	F	R	Giant cell tumor proximal humerus (IB)	Proximal 1/2 humerus. Deltoid and rotator cuff	Vascularized lateral scapula border graft (9 cm)
6	58	F	R	Osteosarcoma proximal humerus (IIB)	Proximal 1/2 humerus. Deltoid and rotator cuff	Acromion (6 cm) osteotomized and plated to distal humerus
7	17	M	L	Osteosarcoma proximal (L) humerus (IIB)	Proximal 3/4 humerus and glenoid. Deltoid and rotator cuff	Cement and wire interposition[a]
8	40	F	R	Recurrent chondrosarcoma involving fibular graft (proximal) (IIB)	Distal 1/2 clavicle proximal 2/3 fibula & scapula (extended Tikhoff Linberg)	Remnant fibula to 4th rib. Reconstr. of thoracohumeral musculature to remnant biceps and triceps
9	49	M	R	Fibrosarcoma deltoid (IIB)	Distal 2/3 clavicle, proximal 1/2 humerus and scapula (extended Tikhoff Linberg)	Remnant humerus to 4th rib. Anastomosis of thoracohumeral musc. to remnant triceps and biceps
10	37	M	R	Synovial sarcoma supraclavicular fossa (IIB)	Distal 1/3 clavicle, scapula and proximal 1/2 humerus (extended Tikhoff Linberg)	Remnant humerus wired to clavicle. Reconstruction of thoracohumeral musc. to remnant biceps and triceps

VFG Vascularized fibular graft.[a]A temporary procedure.

examination of tissue from the residual margins.

In Cases 1–4, a vascularized fibula graft was harvested as previously described by Pho (1979) and used as an interposition graft to bridge the defect between the scapula remnant and the distal humerus. In 1 of these (Case 2) interposition of the fibula graft was a second stage procedure, the primary stage being an AO plate interposition after tumor resection. This temporary procedure was indicated as total removal of the tumor was not certain. In these 4 cases, proximal fixation of the fibula was achieved by wiring the fibula strut to the neck of the scapula and coracoid process. In Cases 2 and 3, the fibula was, in addition, telescoped through the neck of the scapula (Figure 1). The proximal fixation was not supplemented with a free cancellous bone graft. In Case 3, the proximal fixation was supplemented with a vascularized lateral scapular border bone graft, the pedicle being the teres major and minor muscles. This is a new technique developed by the senior author (RWHP) to enhance bone mass at the site of the shoulder arthrodesis to improve union rate. Distal fixation of the fibula graft was achieved by telescoping the fibula into the medullary cavity of the humerus and securing it with screws and plates.

The aim of the reconstruction in these 4 patients was to achieve a shoulder arthrodesis. The fibula restored adequate length, and the remnant distal humerus had sufficient flexors and extensors of the elbow to provide adequate function of that joint. The preservation of the neurovascular bundle ensured a satisfactory hand function in all 4 patients, with the exception of Case 4.

In Cases 5 and 6, the bridging of the defect was achieved by substantial shortening of the arm and interposition of a 9 cm vascularized lateral scapular border graft in Case 5 and a 6 cm vascularized acromion graft in the other. The former graft was obtained by an osteotomy of the lateral border of the scapula and by mobilizing it with the origin of the teres major and minor muscles. The acromion graft was mobilized

Table 1. Continued

Case	Complications	Stability of shoulder construct	F/U (mo)	Present status
1	Transient radial nerve palsy	+	37	Alive
2	Wound infection at Ist stage. Transient triple nerve palsy. AO plate removed. Healed with 2nd stage VFG	+	18	Died of metastases
3	Nil	+	24	Died of metastases
4	Infection and resorption of graft. Triple nerve palsy	–	126	Alive
5	Non-union at proximal end	–	37	Alive
6	Proximal non-union of acromion	–	42	Alive
7	Wound infection. Removal of cement and wire	–	8	Died of metastases
8	Nil	+	96	Alive
9	Transient edema	+	81	Alive
10	Nil	+	36	Metastases to lungs, wedge excision done. Alive

VFG Vascularized fibular graft. [a]A temporary procedure. F/U Follow-up

by an osteotomy at its base and included a part of the scapula spine. The muscle pedicle was the trapezius. Both grafts were reattached to the scapula by wiring them to the glenoid neck and coracoid process, and they were secured to the distal humerus by screws and plate. These reconstructions also aimed at an arthrodesis of the shoulder. Cosmetically, the shortening produced by using such short grafts may not be acceptable and the reason for this reconstruction was concern that the tumor was not removed by a wide margin in these 2 cases. Hence a more extensive procedure, like a vascularized fibula graft interposition, was not carried out at this stage.

In Case 7 bone cement reinforced with wires was used as a temporary spacer to be later replaced with a vascularized fibula graft. This was necessary as a life threatening blood loss occurred during resection of an osteosarcoma. This patient developed metastases to the lungs after 4 months and died.

For Cases 8–10 with an extended Tikhoff Linberg procedure, the biceps, the brachialis and triceps remnants from the distal humerus were approximated to the thoracohumeral musculature, namely the latissimus dorsi and trapezius posteriorly and pectoralis major and minor anteriorly. The distal humerus was, in addition, hitched to the 4th rib in Cases 8 and 9 and wired to the remnant clavicle in Case 10. This procedure was undertaken in view of the extensive nature of the tumors.

For the 6 patients where interposition bone grafts were used, the limb was immobilized in a shoulder spica with the arm in abduction for an average of 4 months. For the patient (Case 7) with the cement and wire interposition and the 3 with the extended Tikhoff Linberg reconstruction, the limb was immobilized in a sling for 6 weeks.

After discontinuation of immobilization, a supervised program of passive and then active exercises was begun. The 4 patients with osteosarcoma received adjuvant chemotherapy. Follow-up ranged from 8

Table 2. Function

Case	Shoulder		Elbow		Fingers		Touch pin pick	Function
	ROM[a]	Power	ROM[b]	Power	ROM	Power		
1	95	4	105	4	Full	4	Intact	Good
2	30	4	Full	4+	Full	4+	Intact	Good
3	60	4	Full	4	Full	5	Intact	Good
4	0	0	30	3+	3/4 normal	3+	Impaired	Poor
5	15	3	Full	4+	Full	5	Intact	Fair
6	20	3	Full	5	Full	5	Intact	Fair
7	Minimal	2	Minimal	2	Minimal	2	Intact	Poor
8	70	4	100	4	Full	4+	Intact	Good
9	45	3	Full	5	Full	5	Intact	Good
10	30	3+	Full	4+	Full	5	Intact	Good

ROM range of movement (°), [a]active flexion or abduction (whichever greater), [b] flexion/extension

months (patient died) to 10 years with an average of 4 years.

We objectively measured shoulder abduction and flexion and power, elbow extension and flexion and power, and finger flexion and hand grip strength. Power was graded 0–5, according to the Medical Research Council system (Table 2). We also assessed cosmetic outcome, as determined by limb length difference. Limb dominance preoperatively was compared to the postoperative state. All patients were right upper limb dominant preoperatively.

Function was evaluated by a system originally described by Mankin et al. (1982) for allograft reconstruction of the shoulder. We graded results as:

1. Excellent. Free of disease and pain and essentially normal function of the hand.

2. Good. Free of disease and pain. Able to return to occupational activities, but not sports.

3. Fair. Pain or disability requiring use of aids. Unable to return to work.

4. Failure. Pain, local recurrence or complication requiring amputation of limb. Death from local recurrence.

Results

Function (Table 2)

Function was good in Cases 1–3 where a successful shoulder arthrodesis was achieved. It was also good in Cases 8–10 who had the extended Tikhoff Linberg resection.

The function was, at best, fair in Cases 5 and 6 where interposition bone grafts failed to achieve a shoulder fusion. The outcome was a failure in Case 4 who had in effect a flail upper limb from triple nerve paresis and a failed shoulder arthrodesis. The result was also a failure in Case 7 who had a painful upper limb.

No patient was able to perform functions above the level of the shoulder. Case 1 was a student who returned to his studies after surgery. He was able to write with the operated dominant limb and was able to do his buttons. He was, however, unable to comb his hair, feed himself, wash his face or reach the perineal area for personal hygiene with his hand. The same was observed in Case 2, a factory worker. Both these patients transferred function to the non-dominant left hand. Case 3 also returned to his studies but continued his every-day activities with his non-operated dominant limb. Cases 5 and 6 had pseudoarthroses following an attempted fusion of the shoulder. Both were housewives. They returned to their household chores, but were able to use the operated dominant side only as an assisting limb. They were unable to feed themselves or perform any function with the operated limb. They complained of weakness of the limb and had difficulty even with doing up of buttons. This complication emphasizes the need for stability at the shoulder. All functions were transferred to the opposite limb, even though it was non-dominant.

Case 8 was a housewife who was able to do household chores. She was able to write with the operated dominant limb, button herself (Figure 2) and cut vegetables at the kitchen table. She was, however, unable to feed herself, brush her teeth, comb her hair or clean the perineal area with the operated limb. All these functions were transferred to the opposite limb. The same was observed in Case 9, a school teacher and Case 10, a factory supervisor. Both the latter had returned to their previous occupations. Case 9 was able to write on the blackboard with the non-operated non-dominant limb. He was able to transfer writing skills to this limb within 3 months after surgery. All

Figure 1. Case 9. 49-year-old man with fungating fibrosarcoma of deltoid muscle. Enneking stage IIB.

Postoperatively.

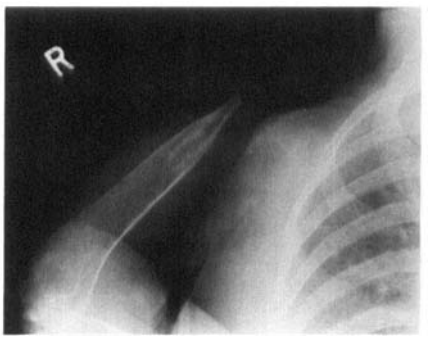
Fibula graft telescoped into fenestrum in glenoid neck and wired to glenoid and coracoid process.

Figure 2. Case 8. 40-year-old, right-handed woman who had an extended Tikhoff Linberg resection for recurrent chondrosarcoma

A. Primary tumor.

B. Local recurrence after resection and reconstruction with fibular graft.

D. The patient is able to button her blouse. Note abduction of shoulder, flexion of elbow and dexterous use of fingers. Her result was rated "good".



C. After extended Tikhoff Linberg resection.

patients were able to sleep on the operated side.

The shortening noted in the 4 patients with a vascularized fibula graft interposition was less than 3 cm. In Cases 5 and 6 with short segment vascular grafts from the scapula, shortening was 8 and 10 cm, respectively. The shortenings noted in the 3 extended Tikhoff Linberg procedures were 15, 16, and 20 cm, respectively.

No patient was unhappy with the surgery, although the women complained of the cosmetic appearance if the limb was short. None preferred amputation or a cosmetic upper limb prosthesis. Case 10 developed pulmonary metastases 16 months after surgery and had had resection of the involved segments. Now, 20 months after the last surgery, he remains well. Cases 2, 3 and 7 have died from pulmonary metastases. There was no local recurrence in any patient.

Discussion

Our study reaffirms previous reports (Kurer et al. 1988) that limb salvage for malignant neoplasms of the shoulder girdle is feasible and does not compromise the resection. This series also illustrates that a functional limb can be secured with appropriate surgery. However, the function regained is still far from optimal, even in instances where the results were graded good and patients often transferred function to the opposite limb, even when it was not dominant.

6 of our patients were categorized as good results. They had substantial active shoulder movements and also retained good elbow, forearm, and hand movements. Preservation of the distal third of the humerus appears to be adequate to provide sufficient surface area for origin of the elbow flexors and extensors as well as for the common flexors and extensors of the wrist and hand. Of these 6 patients, 3 had a successful shoulder arthrodesis using the interposition vascularized fibular graft and 3 had the extended Tikhoff Linberg procedure.

Patients with successful shoulder arthrodeses had marginally better function and cosmetically superior results when compared to patients with the Tikhoff Linberg reconstruction. The preservation of shoulder contour and length of the upper arm made the cases with successful arthrodeses cosmetically more acceptable. However, the lack of accessory shoulder muscles following these extensive resections and the less than optional length and positioning of the fibular graft resulted in function only marginally better than in the patients with the Tikhoff Linberg procedure. The latter procedure should, nevertheless, be restricted to those cases where shoulder arthrodesis is not possible, as when the scapula is completely or subtotally excised. Although proximal stabilization in these latter cases was less than optimal, satisfactory abduction/flexion was observed in our 3 cases. Fixation of the remnant humerus to the rib cage or to the remnant clavicle, as in Case 10, was sufficient to provide a stable pivot point for shoulder function.

Shoulder function was substantially impaired if arthrodesis was attempted but failed. This was especially true in Cases 5–7, where proximal pseudarthrosis resulted. Failure of arthrodesis disconnects the thoraco-scapular muscles from the limb and results in effect in a flail shoulder. To improve proximal fusion, rigid fixation with an AO plate bridging the scapula to the remnant humerus and spanning the interposition graft, as proposed by Enneking et al. (1980), may seem more appropriate. The use of cancellous bone graft proximally to enhance union should also be adopted. The vascularized acromion and lateral scapular border grafts were probably poor choices as interposition graft materials by themselves. They may, however, be used as supplementary vascularized grafts at the proximal fusion site to enhance union, as seen in Case 3.

Because of the small cross-section of the fibula increased contact area between the scapula and fibula may be achieved by telescoping the proximal fibula into the neck of the scapula, as shown in Cases 2 and 3 where this technique proved adequate, even without rigid fixation. Distal fixation by telescoping the fibula into the medullary canal of the humerus and securing it with plate and screws was effective in all our cases.

Besides difficulties with achieving a successful arthrodesis, this surgery was often associated with complications. Wound infection, probably related to extensive dissection and prolonged surgery, has to be meticulously avoided. In our subsequent cases, a two-team approach helped considerably in reducing operation time. Nerve palsy was fortunately transient in our cases, except for Case 4; the complete resorption of the fibula graft combined with the maintenance of the normal length of the limb, we feel may have contributed to the traction triple nerve palsy seen in this patient. Some shortening in these reconstructions may be useful in preventing traction on the neurovascular bundle.

As confidence is gained in our ability to achieve wide resection of bone and soft tissue tumors without compromising resection margins, emphasis must be placed on reconstructing the shoulder, not only to achieve a functionally acceptable limb, but also one that is cosmetically desirable to the patient. To this end our attempts to restore limb length by use of the vascularized fibula graft seem to have paid off. Clearly, improved techniques to achieve proximal arthrodesis of the shoulder are required. Telescoping the fibula through the scapula neck and supplementing this with

a vascularized bone graft from the scapula appeared to be effective. Additional cancellous bone graft from the iliac crest may also be added. The extended Tikhoff Linberg resection also left an effective elbow, forearm, and hand and is indicated when major resections involving large segments of the scapula are performed. However, the cosmetic result is compromised.

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