Reconstruction and limb salvage after resection for malignant bone tumour of the proximal humerus

A SLING PROCEDURE USING A FREE VASCULARISED FIBULAR GRAFT

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We assessed the intermediate functional results of eight patients after wide resection of the proximal humerus for malignant bone tumour. We used a free vascularised fibular graft as a functional spacer and a sling procedure to preserve passive scapulohumeral movement. Scapulohumeral arthrodesis was not carried out. Five patients had osteosarcoma, two chondrosarcoma and one a malignant fibrous histiocytoma of the bone. The mean duration of follow-up was 70 months (median, 76) for the seven patients who were still alive at the time of the latest follow-up. One patient died from the disease 12 months after surgery. There were no local recurrences.

The functional results were described and graded quantitatively according to the rating system of the Musculoskeletal Tumour Society. Our results were satisfactory with regard to pain, emotional acceptance and manual dexterity. Function and lifting ability were unsatisfactory in two patients. One patient had delayed union between host and graft, but this united after six months without further surgery. Radiographs of the shoulder showed absorption or collapse of the head of the fibula in four of the eight patients and a fracture in another. No functional problems related to absorption or fracture of the head of the fibula were noted. There was no infection or subluxation of the head. We conclude that this is a reasonably effective technique of limb salvage after resection of the proximal humerus.

In patients who have a malignant bone tumour of the proximal humerus, it is often possible to carry out curative resection which spares the limb. Reconstruction, however, remains a problem because none of the prostheses which are currently available adequately compensates for the functional loss after amputation.

There are two main groups of reconstructive procedures for the proximal humerus. One involves arthrodesis and includes autogenous grafts,\(^1,2\) allografts\(^3\) and composite allografts.\(^1,4\) The other aims to preserve glenohumeral movement using functional pacers,\(^4,5\) prostheses for replacement of the proximal humerus\(^6,7\) or osteoarticular allografts.\(^8\) The advantages and disadvantages have been widely discussed.

After resection of a malignant bone tumour of the proximal humerus, we used a free vascularised fibular graft as a functional spacer, and a sling procedure to preserve scapulohumeral passive movement.\(^2,9\) We reviewed a consecutive series of eight patients who had this reconstructive procedure, assessing function at a mean of 63 months after surgery.

**Patients and Methods**

Between 1988 and 1995 five women and three men of mean age 27 years (10 to 47) underwent this procedure (Table I). All had a primary malignant tumour of the proximal humerus. Excluded from the study were patients with soft-tissue sarcomas or tumours of the clavicle, scapula or proximal part of the humeral diaphysis which did not involve the humeral head. Patients were selected only if preoperative imaging had shown that a satisfactory surgical margin could be achieved and, if metastatic disease was present, that this was also amenable to resection. Preoperative studies included plane radiography of the shoulder, MRI or CT of the region around the tumour, full body technetium bone scanning and CT of the chest. None of the patients had distant metastasis at the time of operation. There were five osteosarcomas, two chondrosarcomas and one malignant fibrous histiocytoma (MFH) of the bone. The surgical stage was Ib for one patient with chondrosarcoma and Ib for the remaining seven. All patients presented with pain and a palpable mass, and two had pathological fractures.
We classified the extent of each resection according to the scheme proposed by Malawer, Meller and Dunham. The functional results were described and graded quantitatively according to the most recent rating system of the Musculoskeletal Tumour Society (Table II).

The mean length of follow-up was 63 months. One patient died from lung metastases 12 months after surgery. The mean length of follow-up for the seven surviving patients was 70 months (median, 76; range 32 to 91).

All five patients with osteosarcoma and the one with MFH of the bone had systemic chemotherapy, both pre- and postoperatively. Neither of the two patients with chondrosarcoma had chemotherapy.

**Oncological and reconstructive procedure.** A wide surgical margin was achieved in all eight patients. We carried out either an intra-articular resection of the proximal humerus with the abductor mechanism intact (type IA) or an extra-articular humeral and glenoid resection with the abductor mechanism disrupted (type VB).

A free vascularised fibular graft was inserted as a functional spacer, using a sling procedure in six patients who had primary resection, in one in whom a replacement proximal humeral prosthesis had failed, and in one who had resection without reconstruction. The mean duration of the operation was 7.4 hours (5.5 to 11) and the mean blood loss was 1131 ml (635 to 1634). The mean length of the graft was 20.4 cm (15 to 26).

**Sling procedure.** An appropriate length of free vascularised fibula, including the head, was harvested from the ipsilateral or contralateral leg. The distal end of the fibula was fixed to the proximal stump of the humerus with a 3.5 mm dynamic compression plate. The tendons of biceps femoris and palmaris longus together with a transient

### Table I.
Details of the eight patients who had a sling procedure for sarcoma of the proximal humerus

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (yr)</th>
<th>Gender</th>
<th>Pathological diagnosis</th>
<th>Surgical staging</th>
<th>Type of resection*</th>
<th>Time of reconstruction</th>
<th>Graft length (cm)</th>
<th>Lattissimus dorsi rotation</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43</td>
<td>M</td>
<td>Chondrosarcoma</td>
<td>Ib</td>
<td>IA</td>
<td>Primary</td>
<td>22</td>
<td>-</td>
<td>Delayed union</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>M</td>
<td>Osteosarcoma</td>
<td>Ib</td>
<td>VB</td>
<td>Secondary†</td>
<td>26</td>
<td>-</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>F</td>
<td>Osteosarcoma</td>
<td>Ib</td>
<td>VB</td>
<td>Primary</td>
<td>15</td>
<td>-</td>
<td>Absorption of the fibular head</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
<td>F</td>
<td>Osteosarcoma</td>
<td>Ib</td>
<td>VB</td>
<td>Primary</td>
<td>20</td>
<td>-</td>
<td>Absorption of the fibular head</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>M</td>
<td>Osteosarcoma</td>
<td>Ib</td>
<td>VB</td>
<td>Secondary‡</td>
<td>25</td>
<td>-</td>
<td>None</td>
</tr>
<tr>
<td>6</td>
<td>34</td>
<td>F</td>
<td>MFH</td>
<td>Ib</td>
<td>IA</td>
<td>Primary</td>
<td>17</td>
<td>-</td>
<td>Absorption of the fibular head</td>
</tr>
<tr>
<td>7</td>
<td>14</td>
<td>F</td>
<td>Osteosarcoma</td>
<td>Ib</td>
<td>VB</td>
<td>Primary</td>
<td>15</td>
<td>Primary</td>
<td>Absorption of the fibular head</td>
</tr>
<tr>
<td>8</td>
<td>47</td>
<td>F</td>
<td>Chondrosarcoma</td>
<td>Ib</td>
<td>VB</td>
<td>Primary</td>
<td>23</td>
<td>Secondary</td>
<td>Fracture, absorption of the fibular head</td>
</tr>
</tbody>
</table>

* see text
† wide resection only was carried out at initial operation
‡ reconstruction after failed prosthetic implant

### Table II.
Functional rating system of the Musculoskeletal Tumour Society for the upper limb

<table>
<thead>
<tr>
<th>Rating</th>
<th>Pain</th>
<th>Function</th>
<th>Emotional acceptance</th>
<th>Positioning of the hand</th>
<th>Manual dexterity</th>
<th>Lifting ability</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>None</td>
<td>No restrictions</td>
<td>Enthusiastic</td>
<td>Unlimited</td>
<td>No limitation</td>
<td>Normal load</td>
</tr>
<tr>
<td>3</td>
<td>Modest/non-disabling</td>
<td>Recreational restrictions</td>
<td>Satisfied</td>
<td>Not above shoulder or no pronation or supination</td>
<td>Loss of fine movements</td>
<td>Limited</td>
</tr>
<tr>
<td>1</td>
<td>Moderate/intermediately disabling</td>
<td>Partial occupational restriction</td>
<td>Accepted</td>
<td>Not above waist</td>
<td>Cannot pinch</td>
<td>Helping only</td>
</tr>
<tr>
<td>0</td>
<td>Severe/continuously disabling</td>
<td>Total occupational restriction</td>
<td>Dislikes</td>
<td>None</td>
<td>Cannot grasp</td>
<td>Cannot help</td>
</tr>
</tbody>
</table>

Diagram of the operative procedure, reproduced with permission of Medical View Inc.
stainless-steel wire were used to suspend the head of the fibula from the remaining part of the scapula, usually the acromion. The peroneal artery was anastomosed to the circumflex humeral or deep brachial artery (Figs 1 and 2). A latissimus dorsi flap was rotated in two patients (cases 7 and 8) to create adequate muscle coverage around the shoulder (Fig. 3).

**Results**

**Graft union and hypertrophy.** The graft united in under four months in seven of the eight patients. In the other (case 1), union took six months. None of the patients needed a second operation to achieve union.

Hypertrophy did not develop in any of the eight grafts.
No longitudinal growth of the fibular graft occurred in either of the two patients (cases 3 and 7) with open epiphyses at the time of surgery.

**Oncological evaluation.** Six patients remained free from disease at a mean of 74 months (median, 73) after surgery. One patient (case 2) with osteosarcoma died from the disease 12 months after operation. A patient with chondrosarcoma (case 8) developed a lung metastasis and was successfully treated by thoracotomy. There were no local recurrences.

**Reconstruction.** Functional data were available for all eight patients (Table III). The mean overall functional rating was 79% (67 to 83). With regard to pain, emotional acceptance and manual dexterity, the results were rated as satisfactory with a score of 3.0 points or more in all patients. In two (cases 2 and 8), they were unsatisfactory with a score of less than 3.0 points as regards function and lifting ability. In one patient (case 2) the sling procedure was carried out 18 months after wide resection of the tumour. Marked preoperative elbow contracture could not be relieved. In another (case 8) the short head of biceps could not be preserved because of involvement of the tumour leading to poor function and lifting ability.

**Complications.** Radiographs of the shoulder showed absorption or collapse of the head of the fibula in five of the eight patients (Fig. 2c) and one had a fracture of the head. There was no superficial or deep infection. Subluxation or dislocation of the head was not seen. No problems were encountered at the donor site.

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**Table III.** Functional and oncological results for the eight patients after the sling procedure for sarcoma of the proximal humerus

<table>
<thead>
<tr>
<th>Case</th>
<th>Length of follow-up (mth)</th>
<th>Pain</th>
<th>Function</th>
<th>Emotional acceptance</th>
<th>Positioning of hand</th>
<th>Manual dexterity</th>
<th>Lifting ability</th>
<th>Overall (%)</th>
<th>Prognosis*</th>
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<tbody>
<tr>
<td>1</td>
<td>90</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>83</td>
<td>CDF</td>
</tr>
<tr>
<td>2</td>
<td>12 (30)†</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>70</td>
<td>DOD</td>
</tr>
<tr>
<td>3</td>
<td>91</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>83</td>
<td>CDF</td>
</tr>
<tr>
<td>4</td>
<td>90</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>83</td>
<td>CDF</td>
</tr>
<tr>
<td>5</td>
<td>76 (191)†</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>77</td>
<td>CDF</td>
</tr>
<tr>
<td>6</td>
<td>64</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>77</td>
<td>CDF</td>
</tr>
<tr>
<td>7</td>
<td>49</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>83</td>
<td>CDF</td>
</tr>
<tr>
<td>8</td>
<td>32</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>67</td>
<td>NED</td>
</tr>
</tbody>
</table>

* CDF, continuous disease-free; NED, no evidence of disease; DOD, died of disease
† indicates follow-up period after wide resection of the tumour.
Discussion

Resection of the proximal humerus, the glenoid fossa and abductor mechanism (type VB) presents a challenge. Reconstruction with a spacer or proximal humeral prosthesis offers immediate distal fixation and makes it possible to administer chemotherapy and/or radiotherapy in the early postoperative period. It is generally the least time-consuming of the available options. Although it restores minimal function to the shoulder, the implant provides a stable fulcrum for elbow and hand function and prevents pain arising from traction on the neurovascular bundle. Complications may arise, however, due to subluxation, bone loss arising from stress-shielding, and deep infection. Using an intramedullary nail as a spacer, Courpied et al reported functional results which were fair in two patients and poor in three. In three patients it was necessary later to remove the nail because of loosening and pain in the surrounding soft tissue. Ross et al noted that 19 of 25 patients with proximal humeral implants developed subluxation or dislocation of the head.

Gehhardt et al, reviewing 20 patients who received osteoarticular allografts to replace the proximal end of humerus after wide resection of bone tumours, found the procedure to be unsuitable for those with high-grade extra-compartmental neoplasm requiring resection of the abductor mechanism. The high rate of infection caused concern.

O’Connor et al reported that after type-VB resection arthrodesis gave better results than reconstruction with a proximal humeral prosthesis or a spacer. The functional results of glenohumeral arthrodesis, undertaken for conditions not related to tumours, do not deteriorate with time. It may, however, take a long time to achieve bony union, even when a vascularised bone graft is used since it is difficult to fix the reconstructed humerus to the vestigial scapula. The necessary prolonged immobilisation in a shoulder spica causes difficulties for patients who need postoperative chemotherapy. The concomitant use of a conventional fibular graft can contribute to stable fixation.

Deep infection after arthrodesis remains a problem. There is a high risk of fracture with an arthrodesis. O’Connor et al reported this in four of their ten patients. Cofield and Briggs described fracture of the humerus in eight of 71 patients who had glenohumeral arthrodesis for treatment of conditions other than tumours. Similarly, Richards and Kostuik noted fractures in two of their 53 patients.

We used a free vascularised fibular graft as a functional spacer, preserving passive scapulohumeral movement. Positioning of the hand and lifting ability were not as good as those obtained with arthrodesis, but were better than those reported by previous authors who used proximal humeral prostheses or spacers. An autogenous bone graft facilitates the healing of soft tissue and results in better function of the preserved biceps and triceps. We also stabilised the reconstructed humerus by attaching tendon to the bone. This may be why none of our patients developed subluxation or dislocation of the head of the fibula.

The sling procedure is easier than an arthrodesis, there is no need for postoperative immobilisation and the rate of fracture is low. One complication of the use of a free vascularised fibular graft is bony protrusion of the acromion under the skin, which may cause pain and be unsightly. This can be prevented by a primary rotation of the latissimus dorsi. Absorption or collapse of the head of the fibula may occur which may have caused the fracture of the head in one of our patients. This complication is probably due to a deficient blood supply to the head through the peroneal artery. Theoretically, concomitant anastomosis of a lateral inferior genicular artery or a branch of the anterior tibial artery could improve the blood supply, but we did not attempt this. Alternatively, the use of the anterior tibial artery as a pedicle may provide better blood supply to the graft. None of our patients with absorption of the head of the fibula developed symptoms.

Conventional or non-vascularised fibular autografts have been used as passive spacers for many years. Non-vascularised fibular autografts longer than 12 cm tend to fracture, and the fractures do not always unite. Although no graft hypertrophy was noted, we believe that the use of vascularised fibula reduces the risk of fracture.

The extent of resection and the needs of the patient should dictate the choice of the procedure used for reconstruction. Despite the minor complications, we believe that the functional results of the sling procedure are comparable to, or better than, those obtained by other methods. According to Springfield, a flail shoulder is often the best alternative for the patient who does not need to use the hand in space. The procedure which we describe is a useful limb-salvaging technique after resection of the proximal humerus, particularly for patients who do light work.

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References


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