Tikhoff-Linberg Procedure for Bone and Soft Tissue Tumors of the Shoulder Girdle

Gregor Voggenreiter, MD; Stefan Assenmacher, MD; Klaus-Peter Schmit-Neuerburg, MD

Objective: To evaluate complications and the oncological and intermediate-term functional results in patients with bone and soft tissue tumors of the shoulder girdle who were managed with interscapulothoracic resection (Tikhoff-Linberg procedure).

Design: Case series of 19 consecutive patients during a 10-year period at a mean follow-up of 6.3 years (range, 1-11 years).

Setting: University hospital; referral center for musculoskeletal tumor surgery.

Patients: The initial diagnosis in this consecutive series of patients with shoulder girdle tumors requiring the Tikhoff-Linberg procedure was chondrosarcoma in 7 patients, Ewing sarcoma in 3 patients, malignant fibrous histiocytoma in 3 patients, solitary metastasis of thyroid carcinoma in 2 patients, osteosarcoma, synovial sarcoma, angiosarcoma, and neurofibrosarcoma in 1 patient each. According to the Musculoskeletal Tumor Society staging system, there were 6 in surgical stage IB, 10 in stage IIB, and 3 in stage III. Nine tumors involved the proximal humerus, 8 were located in the scapula or surrounding soft tissues, 1 in the lateral clavicle, and 1 in the acromioclavicular joint.

Interventions: For reconstruction of the proximal humerus after en bloc tumor resection an isoelastic cemented shoulder tumor prosthesis was inserted in every patient to restore arm length.

Main Outcome Measures: Complications, and oncological and intermediate-term functional results.

Results: Twelve patients were alive with no evidence of disease. One of these patients died of nontumorous disease 2 years after surgery. One patient is alive with pulmonary metastases after 12 months. Six patients died of metastases at a mean (SD) interval of 18 months (range, 3-35 months) postoperatively. Two of these patients had additional local recurrence. A deep infection necessitated the explantation of the prosthesis in 1 patient. The mean functional score and SD according to the rating system of the Musculoskeletal Tumor Society was 72% ± 14% (range, 33%-87%) for the 12 surviving patients evaluated. Major complications (1 infection and 2 local recurrences) that may be attributed to the procedure occurred in 3 of the 19 patients.

Conclusion: Despite an overall complication rate of 74% the Tikhoff-Linberg procedure proved to be a valuable surgical procedure for extended tumors of the shoulder girdle for functional and oncological outcome and is superior to forequarter amputation.

Arch Surg. 1999;134:252-257

THE TREATMENT of many musculoskeletal neoplasms has changed from radical ablative surgery toward limb salvage. Tumors of the shoulder girdle are challenging the surgeon to preserve function and cosmesis without compromising local tumor control. The reconstruction of skeletal defects created by resection of the proximal humerus includes arthrodesis, prosthetic replacement, osteoarticular allografts, and autogenous grafts. The en bloc upper humeral interscapulothoracic resection, known as the Tikhoff-Linberg procedure, is, in properly selected cases of tumors of the shoulder girdle, an alternative treatment to forequarter amputation. The Tikhoff-Linberg procedure is indicated in tumors of the scapula, proximal humerus, lateral clavicle, or of the periscapular soft tissue where tumor invasion of the subchondral bone, the joint capsule, synovial membrane, or the entire joint is evident on preoperative studies. Prerequisites for the procedure are that the tumor does not extend to the axillary neurovascular bundle, to the chest wall, or the lymph nodes. Additional indications are palliation of malignant lesions where amputation is not justified because of chest wall involve-
PATIENTS AND METHODS

Between 1986 and 1996 nineteen interscapulothoracic resections were performed (approximately 2 patients per year). There were 15 male and 4 female patients, whose mean age at operation was 49.0 years (age range, 12-83 years). The follow-up period of patients surviving free of disease ranged from 1 to 11 years (mean, 6.3 years). Eleven lesions were primary malignant bone tumors, 6 were malignant soft tissue tumors, and 2 were solitary metastases. According to the Musculoskeletal Tumor Society (MSTS) staging system there were 6 in surgical stage IB, 10 in stage IIB, and 3 in stage III (Table). Nine tumors involved the proximal humerus, 8 were located in the scapula or surrounding soft tissues, 1 in the lateral clavicle, and 1 in the acromioclavicular joint. Eight patients were operated on for tumor recurrence after local resections before they were referred to our unit. Imaging studies include plain radiograms, bone scanning, computed tomographic scan of the chest and shoulder girdle, and magnetic resonance imaging. An incisional biopsy was performed to establish the diagnosis.

After the initial staging and diagnosis the patients with Ewing sarcoma (n = 3), osteosarcoma (n = 1), and synovial sarcoma (n = 1) received preoperative and postoperative chemotherapy. Three patients with malignant fibrous histiocytoma received postoperative radiotherapy and 2 patients with solitary metastases of thyroid carcinoma preoperative and postoperative radioactive iodine 131 treatment. After a patient had been managed with neoadjuvant chemotherapy, the tumor was restaged using a computed tomographic scan of the chest and local magnetic resonance imaging of the shoulder girdle. In 1 patient (case 9) pulmonary metastases were detected on the computed tomographic scan before initiating preoperative chemotherapy. After chemotherapy he was free of pulmonary disease on computed tomographic scan and he was referred for operation. The patients who had chondrosarcoma were managed without adjuvant therapy. The operative technique of the classic Tikhoff-Linberg procedure and of modifications has been described in detail in several publications.

According to the classification system for shoulder girdle resections of Malawer et al,11 11 were type V resections (modified Tikhoff-Linberg resection with osteotomy of the neck of the scapula) and 8 were type VI resections (classic Tikhoff-Linberg resection). After considering the size of the tumor and its anatomic location, the resection of bone and soft tissue was adapted to each patient to achieve the widest margins of resection and greatest preservation of tissue. One patient with infection of a solitary metastasis of a thyroid carcinoma underwent a 2-step procedure. In the first step the tumor was resected and polymethyl methacrylate chains were implanted. Four weeks later after healing of the infection the prostheses was inserted (Figure 1) (second step).

A complication was defined as any condition that led to additional treatment after the initial reconstruction. It was related to the operative procedure, the reconstruction, or tumor recurrence.

In 12 surviving patients function was assessed according to the MSTS functional evaluation system.12 This system is based on the analysis of the following 6 factors: pain, functional activities, emotional acceptance, position of the hand, manual dexterity, and lifting ability. For each of the 6 factors values of 0 to 5 are assigned. The result is expressed as the proportion of expected normal function for the patient. The patients’ occupation and whether the patient was collecting a disability pension was recorded.

RESULTS

ONCOLOGICAL OUTCOME

Histological margins were free of disease in all patients. Of 19 patients who underwent the Tikhoff-Linberg procedure, 12 were alive with no evidence of disease at a mean follow-up of 6.3 years (range, 1-11 years).1,11 One patient (case 15) died of nontumorous disease 2 years after surgery. One patient (case 5) is alive with pulmonary metastases and local recurrence after 12 months. The remaining 6 patients died of pulmonary (n = 5) or intracerebral (n = 1) metastases postoperatively at a mean interval of 18 months (range, 3-35 months). All patients with oncological complications had high-grade malignant extracompartmental lesions (6 in stage IIB and 1 in stage III). Two of these patients developed additional local recurrence 5 (case 13) and 11 months (case 5), respectively, after surgery. Four of 8 patients with tumor complications had interscapulothoracic resection for tumor recurrence after previous surgery was performed at another institution. The overall disease free survival rate in stage IB was 6 of 6 patients and 4 of 10 patients in stage IIB.

Local resection performed at another institution had no adverse effects on outcome. Five of 10 patients...
with stage IIB tumors had local resection prior to the Tikhoff-Linberg procedure; 5 had not. In each group pulmonary metastases developed in 3 patients. The 2 patients with local recurrence had not undergone a previous operation.

FUNCTIONAL OUTCOME

The functional range of motion of the hand was unaffected in all but 1 (case 14, patient with palsy of brachial plexus) of 12 surviving patients although strength was slightly diminished. Shoulder abduction was absent in 1 patient (case 14) requiring explantation of the prosthesis for deep infection. In the remaining patients abduction ranged from 30° to 45°.

According to the MSTS evaluation system the mean rating was 72% ± 14% (range, 33%-87%) of normal function (Figure 2). There was nothing to suggest that the scores deteriorated with time. The patient with neurologic deficit due to plexus brachialis lesion (case 14) was the only one reporting intermittent pain. The rating for function determined by restriction of activities was 2.9 ± 0.8 points (range, 2 to 4 points) indicating recreational restriction, although one patient continued playing tennis after the operation (case 4). The emotional acceptance of the Tikhoff-Linberg procedure was excellent (3.9 ± 0.8 point; range, 3-5 points). The rating for hand positioning revealed 3.1 ± 1.2 points (range, 1-5 points) reflecting almost unaffected dexterity and sensibility. The patient's ability to actively lift objects and place them unaffected was possible for minor loads (2.9 ± 1.0 points; range, 0-4 points). Ten of 11 patients who remained free of disease were able to return to their previous employment. Only one patient (case 8) collected a disability pension. The patient (case 14) with the lowest score (33%) was able to return to his job as a lawyer.

### Clinical Data on 19 Patients

<table>
<thead>
<tr>
<th>Patient No./Sex/Age at Diagnosis, y</th>
<th>Type of Tumor</th>
<th>Stage*</th>
<th>Treatment Elsewhere</th>
<th>Type of Resection†</th>
<th>Secondary Procedure/Complication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/M/60 Solitary metastasis of thyroid carcinoma</td>
<td>III</td>
<td>None</td>
<td>V</td>
<td>Resection of infected tumor and implantation of polymethyl methacrylate chains, implantation of prosthesis at 4 wk; and 2 revisions for seroma at 4 y</td>
<td></td>
</tr>
<tr>
<td>2/M/27 Chondrosarcoma</td>
<td>IIB</td>
<td>None</td>
<td>V</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>3/M/27 Chondrosarcoma</td>
<td>IB</td>
<td>None</td>
<td>V</td>
<td>Internal plate fixation and corticocancellous allograft for humeral shaft fracture at 5 y; revision for seroma at 9 y</td>
<td></td>
</tr>
<tr>
<td>4/M/12 Angiosarcoma</td>
<td>IIB</td>
<td>None</td>
<td>VI</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>5/M/42 Chondrosarcoma</td>
<td>IIB</td>
<td>None</td>
<td>V</td>
<td>2 Revisions for lymphoid fistula at 4 and 10 wk</td>
<td></td>
</tr>
<tr>
<td>6/F/16 Ewing sarcoma</td>
<td>IIB</td>
<td>Local resection with local recurrence</td>
<td>VI</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>7/M/28 Chondrosarcoma</td>
<td>IB</td>
<td>None</td>
<td>V</td>
<td>Transient palsy of median nerve</td>
<td></td>
</tr>
<tr>
<td>8/F/52 Chondrosarcoma</td>
<td>IB</td>
<td>None</td>
<td>V</td>
<td>Fracture of prosthesis at 9 y and exchange of prosthesis</td>
<td></td>
</tr>
<tr>
<td>9/M/19 Ewing sarcoma</td>
<td>III</td>
<td>None, complete regression of pulmonary metastases with preoperative chemotherapy</td>
<td>VI</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>10/M/20 Synovial sarcoma</td>
<td>IIB</td>
<td>None</td>
<td>VI</td>
<td>Rupture of Trevira tape at 4 mo</td>
<td></td>
</tr>
<tr>
<td>11/M/60 Chondrosarcoma</td>
<td>IB</td>
<td>None</td>
<td>V</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>12/M/43 Ewing sarcoma</td>
<td>IIB</td>
<td>Local resection with local recurrence</td>
<td>V</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>13/M/35 Osteosarcoma</td>
<td>IIB</td>
<td>None</td>
<td>V</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>14/M/49 Neurofibrosarcoma</td>
<td>IB</td>
<td>2 Local resections with recurrence</td>
<td>VI</td>
<td>Palsy of brachial plexus; revision for seroma at 2 wk, and explantation of prosthesis at 4 wk due to deep infection</td>
<td></td>
</tr>
<tr>
<td>15/M/77 Malignant fibrous histiocytoma</td>
<td>IIB</td>
<td>9 Local resections with recurrence</td>
<td>VI</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>16/M/83 Malignant fibrous histiocytoma</td>
<td>IB</td>
<td>2 Local resections with recurrence</td>
<td>VI</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>17/F/66 Malignant fibrous histiocytoma</td>
<td>IIB</td>
<td>Local resection with recurrence</td>
<td>VI</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>18/M/69 Solitary metastasis of thyroid carcinoma</td>
<td>III</td>
<td>Local resection with recurrence</td>
<td>V</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>19/F/38 Chondrosarcoma</td>
<td>IB</td>
<td>None</td>
<td>V</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

* According to the Musculoskeletal Tumor Society staging system.11
† According to the staging system for shoulder girdle resections.6
‡ NED indicates no evidence of disease.
§ NA indicates not available for death of patient.
NONTUMOROUS COMPLICATIONS

Postoperative nontumorous complications due to the operation occurred in 9 of 19 patients. Four of these patients required more than one surgical revision after initial surgery (cases 1, 3, 5, and 14). Early postoperative seroma requiring operative revision developed in 3 patients (cases 1, 3, and 5). One patient (case 3) underwent internal plate fixation for a fracture of the humeral shaft distal of the tip of the prosthesis and alloplastic corticocancellous bone grafting 5 years after surgery. In another patient (case 8) the prosthesis fractured at its tip 9 years after surgery requiring exchange of the prosthesis. In 2 patients (cases 1 and 10) the Trevira tape securing the prosthesis to the scapula and clavicle ruptured. Neurologic complications developed in 2 patients (cases 7 and 14). The same patient (case 14) required the removal of the prosthesis due to a deep infection 4 weeks after surgery. The infection healed after a second surgical revision. No patients had vascular problems or necrosis of skin flaps.

Most sarcomas of the shoulder girdle involving the proximal humerus can be managed with reconstruction of the created defect under preservation of the shoulder joint.1,2 The interscapulothoracic resection is suitable in extra-compartmental high-grade malignant neoplasms of the proximal humerus or scapula involving the shoulder joint. In the series of Malawer et al6 3 patients and in the case series of Capanna et al2 5 patients undergoing the Tikhoff-Linberg procedure had stage IB tumors. This indicates that resection of the shoulder joint may be necessary in cases of low-grade malignant neoplasms with extensive local disease. Six patients with stage IB tumors were included in our case series. All 5 patients with chondrosarcoma had tumor invasion of the joint capsule and extensive infiltration of the deltoide muscle. Another patient (case 14) had 2 local recurrences of neurofibrosarcoma of the scapula after previous resections elsewhere. If the tumor is located in the proximal humerus and does not involve the glenoid a modified technique with resection of the glenoid lateral to the coracoid provides better functional and aesthetic results.2

Jensen and Johnston1 reported a case series of 19 proximal humeral resections with prosthetic reconstruction. In their case series all 8 patients with stage IIB tumors had resection with preservation of the glenoid (type I resection). Two of these patients had local recurrence. Meller et al9 had 1 local recurrence of 10 after Tikhoff-Linberg resection and conclude that type I resections in stage IIB tumors might be too dangerous for local tumor control. We observed local recurrence in 2 of 10 patients with stage IIB disease after modified (type V) Tikhoff-Linberg resections. The 2 patients developing local recurrence had extensive local disease preoperatively with tumor diameters of more than 10 cm. A local recurrence rate of 10% compares favorably with other reports of limb salvage when the MSTS staging of the patients is compared.1,2

The results of our small case series confirm the observations of Ueda et al13 that local recurrence after inadequate surgery does not adversely affect outcome. Five of 10 patients with stage IIB tumors had local resection prior to the Tikhoff-Linberg procedure; 5 had not. In each group pulmonary metastases developed in 3 patients. In contrast local recurrence after the Tikhoff-Linberg procedure was associated with pulmonary metastases in 2 cases. In the series of Capanna et al2 1 of 24 patients had local recurrence with concomitant pulmonary metastases and 14 of 24 were free of disease after a mean follow-up of 22.5 months.

In our study, the most severe and frequent complications were metastases and local recurrence. Although the stage IIB tumors were managed with adjuvant therapy (with the exception of chondrosarcoma), this rate of metastatic disease (6 of 10 patients) at the time of intermediate-term follow-up evaluation is troubling but reflects the biology of the disease more than the operative approach. Despite a careful selection of patients for interscapulothoracic resection the postoperative nontumorous complication rate in our series was high (9 of 19) but comparable to other studies.2,7,8 Capanna et al2 observed deep
Figure 1. A, Magnetic resonance image showing solitary metastasis of a thyroid carcinoma with tumor invasion and inflammation of surrounding soft tissue. B, Type V resection, dissection of the neurovascular bundle and temporary insertion of gentamycin sulfate–coated polymethyl methacrylate chains. C, Implantation of an isoelastic tumor prosthesis 4 weeks later.

Figure 2. A, Computed tomographic scan showing chondrosarcoma of the left humeral head with extensive invasion of the shoulder joint and of muscles of the rotator cuff. Implantation of an isoelastic humeral tumor prosthesis after en bloc tumor resection. Functional outcome (active range of motion) with Musculoskeletal Tumor Society staging system score of 73%. B, Notice shortening of the extremity that allows better soft tissue covering.
infection with removal of the prostheses in 3 of 24 patients.

The limiting factor in functional outcome is the resection of the abductor mechanism to ensure wide margins of resection. Abduction is dependent on contraction of trapezius muscle and sliding of the remaining scapula over the dorsal chest wall. The overall functional result based on the analysis of factors pertinent to the patient as a whole and factors specific to the upper limb revealed a mean rating of 72% of normal function. During the field trail conducted by the MSTS, 87 patients were evaluated after various resections for tumors of the upper limb. The mean rating in their series was 68%. These results are comparable to the findings of Meller et al9 who reported a rating of 72% after 10 Tikhoff-Linberg resections. The functional results after Tikhoff-Linberg resections are also comparable to the functional outcome reported by Gibbons et al9 after subtotal scapulectomy (mean MSTS score of 71.6). All but one patient were able to return to their previous employment. We are convinced that the functional results after Tikhoff-Linberg procedures based on activity, pain, and subjective psychological factors are clearly superior to amputation. Application of the functional rating system to patients after a forequarter amputation would give uniformly low scores, as a score of 0 would have been given for 3 of 6 items that were directly attributed to function of the hand (position of the hand, manual dexterity, and lifting ability). Even the patient with the worst score in our series (33%) had a score that was probably better than it would have been if a forequarter amputation had been performed. He stated that he accepts the procedure and would do it again.

The importance of reconstruction of the proximal humerus and preservation of major nerves is demonstrated for poor function in one patient in our series requiring early explantation of the prosthesis for deep infection. No abduction or elevation of the arm is possible. Unfortunately a lesion of the brachial plexus occurred in the same patient revealing major sensory and dexterity loss.

The Tikhoff-Linberg procedure proved to be a valuable operation for extended tumors of the shoulder girdle for functional and oncological outcome for local recurrence. However patients must be informed that there are substantial complications. The functional result in consideration of the patient as a whole is almost comparable to less extensive surgery for tumors of the proximal humerus treated by prosthetic replacement and preservation of the shoulder joint.

The Tikhoff-Linberg procedure is associated with substantial complications but is clearly superior to forequarter amputation. Under consideration of the indications of the Tikhoff-Linberg procedure, forequarter amputation should no longer be regarded as an alternative treatment. Forequarter amputation should have a role only in tumors invading the axillary neurovascular bundle. It is imperative that patients with malignant tumors of the shoulder girdle should be referred to specialized institutions.

**REFERENCES**


**Announcement**

The Archives of Surgery will give priority review and early publication to seminal works. This policy will include basic science advancements in surgery and critically performed clinical research.