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Function after Resection of Humeral Metastases

Analysis of 59 Consecutive Patients

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Metastatic bone disease of the humerus may require surgery for treatment of an impending or existing pathologic fracture or for alleviating disabling pain. Prompt restoration of function is a main goal of surgery, although published results do not reveal if that goal is being met. We retrospectively reviewed range of motion and function of 59 patients operated on from 1986–2003 for those indications. After resection, tumors around the humeral head and condyles (n = 20) were reconstructed with a prosthesis, and tumors at the humeral diaphysis (n = 39) were reconstructed with cemented nailing. Each patient's range of motion was recorded, and functional outcome was evaluated according to the American Musculoskeletal Tumor Society system. Patients who had cemented nailing had better shoulder motion, hand positioning, lifting ability, and emotional acceptance than patients who had endoprosthetic reconstruction. Pain alleviation and dexterity were comparable in both groups. All patients had a stable extremity, and the overall function of 56 patients (95%) was greater than 68% of normal upper extremity function. An aggressive surgical approach in patients with humeral metastases who met the criteria for surgical intervention was associated with good function.

Level of Evidence: Therapeutic study, Level IV (case series—no, or historical control group). See the Guidelines for Authors for a complete description of levels of evidence.

Patients with metastatic bone disease are considered as having an extremely poor prognosis. The majority of metastatic bone lesions are treated effectively by nonoperative procedures such as radiotherapy, chemotherapy, intravenous bisphosphonates, and bone-seeking isotopes.[8,12,13,16,18,23,25] Surgery may be required for patients with an existing or impending pathologic fracture or intractable pain.[7,10,14,15,17,18,24,26,28] Surgical intervention for metastatic disease of the humerus is a palliative procedure. Its primary goal is to achieve local tumor control and structural stability of the surgically treated extremity, and to restore normal function as quickly as possible. Failure to achieve one of these goals usually necessitates a second surgical intervention and additional impairment of an already compromised quality of life. The different surgical techniques used for treatment of bone metastases reflected medical patients' helplessness and anticipated death, and resulted in unsatisfactory results.[27,28] One study of 166 patients who had surgery for treatment of a pathologic fracture of the humerus and femur documented a 33% implant failure at 60 months.[28] Common reasons for failure were poor initial fixation, improper implant selection, and progression of disease in the operative field.

Advances in adjuvant treatments and palliative care resulted in increased survival of patients with metastatic bone disease.[2,9,11,12,15,18,28] Those observations have motivated cancer surgeons to practice more aggressive treatments to provide lasting palliation and have led to the application of surgical techniques used for the treatment of primary sarcomas of bone.[1,4,5] Reports on large series of patients who had resections of humeral metastases are rare.[1,4,5,10,15] Although function is a key parameter, to the best of the authors' knowledge, detailed functional outcome of such patients has not been reported.

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Each author certifies that his or her institution has approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research, and that informed consent was obtained.
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TABLE 1. Histologic Diagnoses of 59 Patients with Metastatic Disease of the Humerus

Histologic Diagnosis	Number of Patients
Breast carcinoma	22
Renal cell carcinoma	13
Multiple myeloma	9
Malignant melanoma	5
Adenocarcinoma of lung	4
Adenocarcinoma of colon	1
Nasopharyngeal carcinoma	1
Endometrial carcinoma	1
Adenocarcinoma of unknown origin	3
Total	59

We therefore wondered whether these operations relieved pain and restored range of motion (ROM) and function (including lifting ability, hand positioning, and dexterity).

MATERIALS AND METHODS

We retrospectively reviewed the reports of 207 consecutive patients with bone metastases treated from 1986 to 2003; 59 were located at the humerus. Indications for surgery included: pathologic fracture (n = 42), impending pathologic fracture (n = 11), and intractable pain associated with locally progressive disease that showed inadequate response to narcotics and preoperative radiation therapy (n = 6) (Table 1). Impending pathologic fractures were defined as humeral lesions that caused destruction of greater than 50% of the cortical diameter.[3] Seven patients who had an impeding pathologic fracture received preoperative radiotherapy. Patients who had humeral metastases that did not cause an impending or pathologic fracture, or that were not associated with intractable pain, did not require surgery and were excluded from the study. Patients who had humeral metastases with extensive bone destruction and soft tissue involvement and required amputation also were excluded from the study. Forty-two patients had evidence of additional bone metastases, none of which required surgery, and 25 patients had metastatic lung disease. All 59 patients were expected to survive for at least 3 months postoperatively.

Eighteen patients had endoprosthetic replacements of the proximal humerus, 39 patients had cemented nailing of the humeral diaphysis, and two patients had endoprosthetic replacement of the distal humerus. Deltoid and pectoralis major muscles insertions were preserved in all patients who had cemented nailing. It was possible to preserve the deltoid insertion in four of 18 patients who had endoprosthetic replacement of the proximal humerus, but pectoralis major insertion was sacrificed in all 18 patients. The axillary nerve was spared in surgery and remained functional in all 59 patients.

Fig 1. Type I humeral metastasis involving the humeral head is evident in this radiograph.

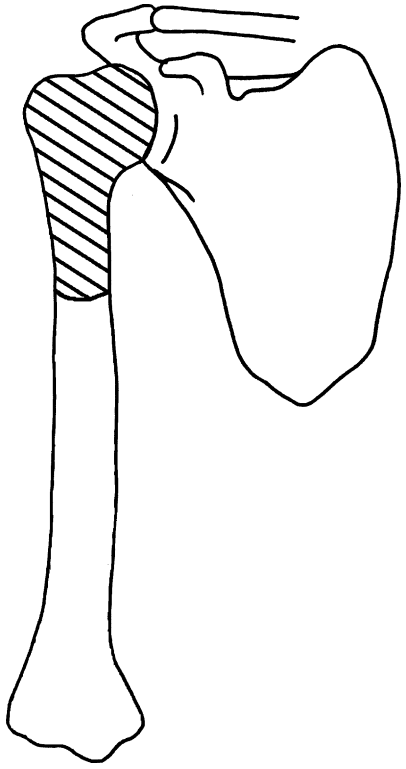

Fig 2. This drawing shows a Type I metastasis.

Fig 3. Type II humeral metastasis involving the humeral diaphysis can be seen on this radiograph.

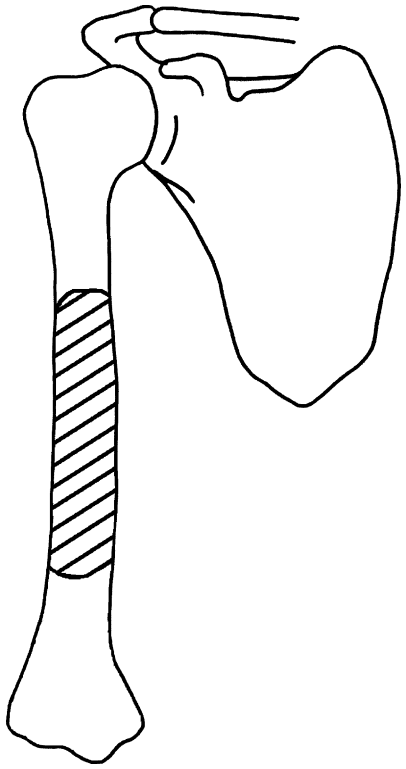

Fig 4. This drawing shows Type II metastasis where the humeral head and condyles are spared.

Complete preoperative staging studies were completed for all patients. Imaging studies included plain radiography and computed tomography (CT) of the entire shoulder, arm, and elbow. Particular attention was given to distinguishing the extent of tumor involvement and cortical breakthrough, the magnitude of soft tissue extension, and to its relation to the axillary and brachial vessels. Bone scintigraphy was used to detect other skeletal metastases. Selective arterial embolization of the metastatic lesion was done during the day before surgery in all patients with metastatic renal cell carcinoma to diminish intraoperative blood loss.[21] Eighteen metastases extended to the humeral head and across the anatomic neck (Type I), 39 metastases involved the humeral diaphysis between the anatomic neck and the supracondylar ridges of the humerus (Type II), and two metastases extended to the humeral condyles below the supracondylar ridges (Type III) (Figs 1–6). We treated Types I and III metastases with endoprosthetic reconstruction, and Type II metastases with resection and cemented nailing.

Surgery of humeral metastases was done in two stages: tumor resection and reconstruction. The patient was placed in a semilateral position and an anterior utilitarian shoulder girdle incision was used. It began at the junction of the inner and middle ⅓ of the clavicle and continued over the coracoid process, along the deltopectoral groove, and down the arm over the medial border of the biceps muscle. Exposure of the distal humerus was by an anteromedial incision along the distal ⅔ of the arm. First, the site of metastasis was exposed and tumor resection was done. Types I and III metastases were removed by intraarticular resection of the humeral ends, and Type II metastases were removed with curettage and high-speed burr drilling of the tumor cavity.

Cryoablation was done as an adjuvant in patients with Type II metastases (16 patients) in which the cortices remaining after tumor removal allowed containment of liquid nitrogen.[19,22] It involved freezing the tumor cavity by direct pouring of liquid nitrogen followed by slow thawing. Endoprosthetic hemiarthroplasties of the proximal humerus and constrained elbow prostheses were used for reconstruction after intraarticular resections of Types I and III metastases, respectively. An antegrade, noninterlocked intramedullary rod and a side plate were used for reconstruction following resection of Type II metastases (Figs 7–9). All prosthetic devices and intramedullary rods were cemented into the remaining humeral shaft using gentamicin containing polymethylmethacrylate (PMMA). Proximal humeral prostheses were matched to fit the size of the resected humeral head. The rotator cuff was advanced and secured tightly to the prosthetic head with a 3-mm Dacron tape (Deknatel, Falls River, MA).

Routine perioperative antibiotic therapy with a second-generation cephalosporin was administered intravenously on the day of surgery and on the following day. Postoperatively, the shoulder was immobilized in a sling for 3 weeks or until soft tissue healing was established. During that time, the rehabilita-

Fig 5. Type III humeral metastasis involving the humeral condyles is seen on this radiograph.

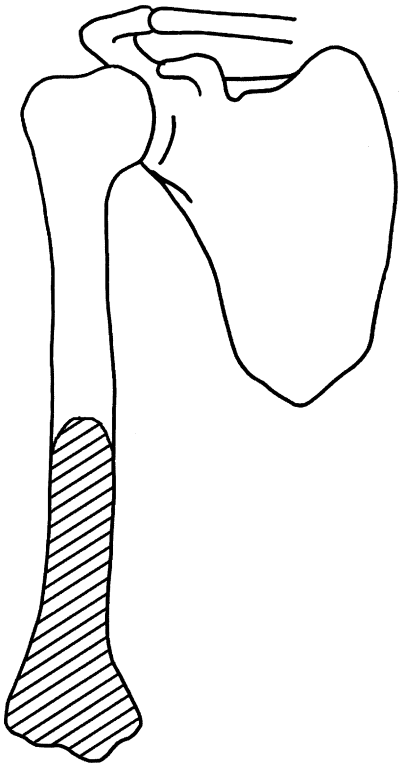

Fig 6. The drawing shows a Type III metastasis.

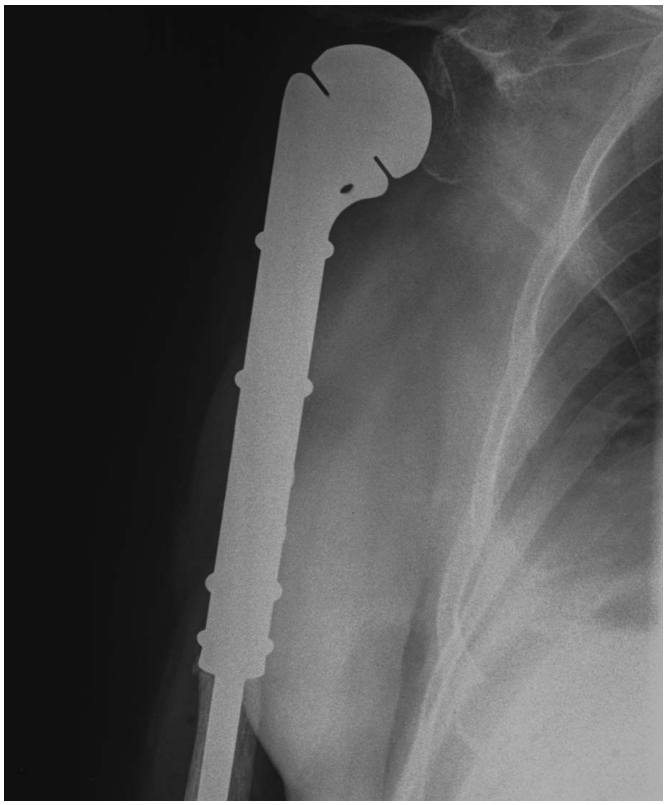

Fig 7. The reconstruction of a Type I metastasis with a proximal humeral endoprosthesis can be seen on this radiograph.

tion program emphasized ROM of the elbow, wrist, and fingers with gravity assistance. Gradual passive and active ROM of the shoulder, with emphasis on forward flexion, abduction, and shrugging then was started.

Postoperatively, 31 patients were treated with radiation therapy, 35 patients were treated with chemotherapy, and 14 patients were treated with immunotherapy. Postoperative radiotherapy using 3000–3500 Gy external beam radiation was given to patients who had intralesional tumor removal without cryoablation. Patients who had tumor resection with endoprosthetic reconstruction did not receive radiotherapy. Adjuvant chemotherapy and immunotherapy were given based on the specific tumor type and treatment protocol practiced at that time.

All patients were followed up for 13–73 months (median, 1.7 years) and evaluated every 3 months. A physical examination, plain radiographs, and chest CT scans were obtained at each visit. An orthopaedic oncologist analyzed the clinical records, imaging studies, and operative reports. Data on the histologic diagnoses, surgical techniques of tumor resection and reconstruction, complications, function, ROM around the operated extremity, and rates of local tumor recurrence and surgical revisions were retrieved and recorded. The function of all 59 study patients was evaluated and determined by the operating surgeon using the American Musculoskeletal Tumor Society system.[6] This system assigns numerical values (range, 0–5) based on

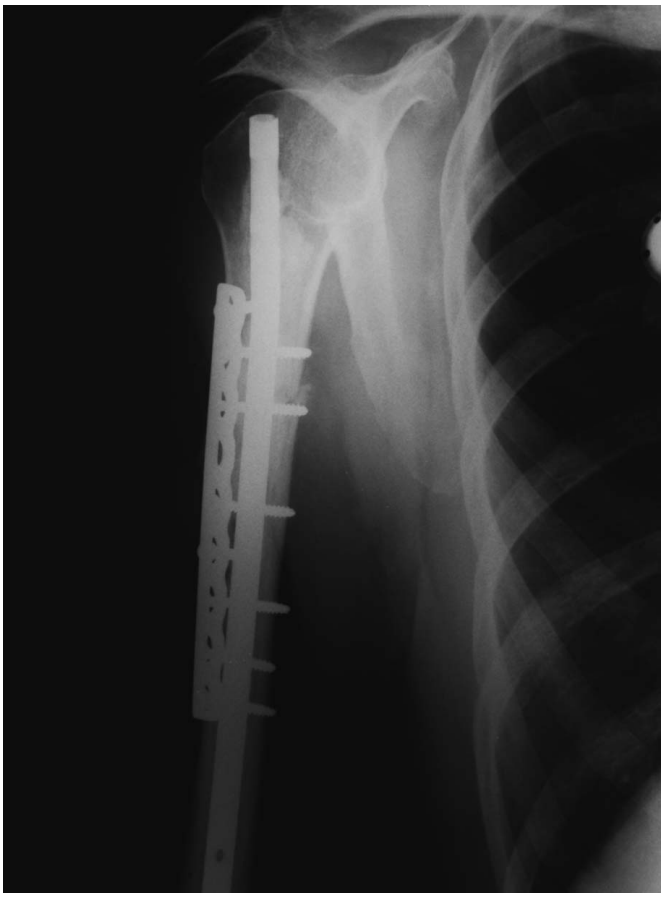

Fig 8. Reconstruction of a Type II metastasis with cemented nailing is seen on this radiograph.

established criteria for six categories: pain, function, emotional acceptance, hand positioning, dexterity, and lifting ability.[6] Results of total function are expressed as the proportion of full function in all six categories and are based on the patient's most recent followup.

Statistical analysis included log rank and Breslow tests, which were used independently to compare cumulative survival data and determine statistical significances. Tests were considered statistically significant if the probability value was less than 5%.

RESULTS

Postoperatively, all patients reported immediate pain relief. No patients had flap necrosis, delayed wound healing, nerve palsy, or thromboembolic complications. Three patients had deep wound infections that resolved after surgical débridement and a 12-week course of antibiotics. Only one of these deep infections occurred in a patient who had preoperative radiotherapy.

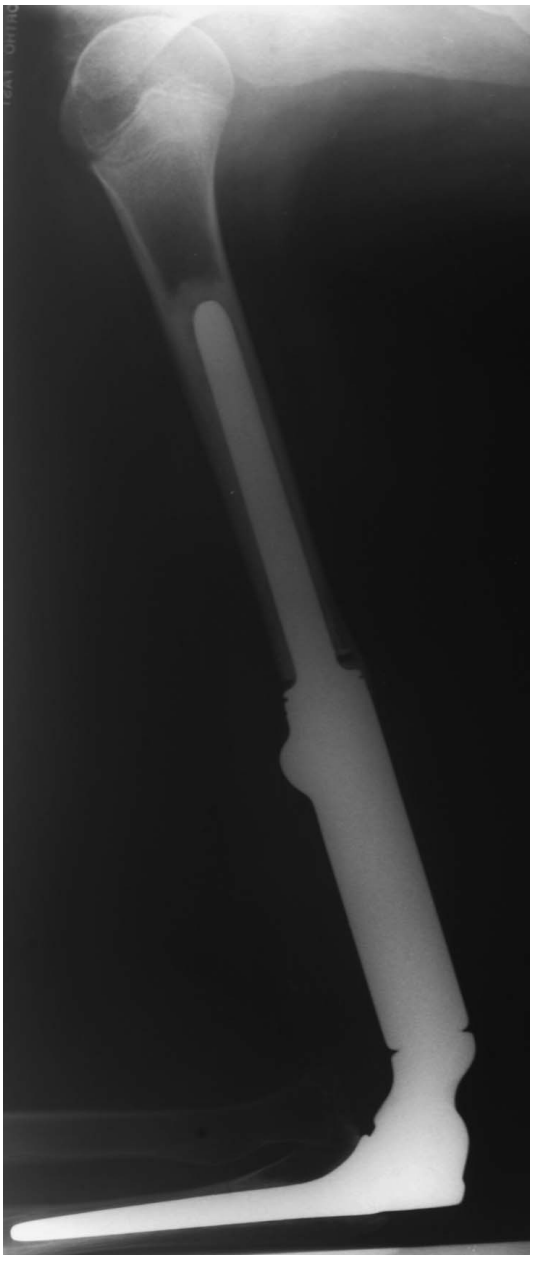

Fig 9. Reconstruction of a Type III metastasis with a distal humeral endoprosthesis is shown on this radiograph.

Range of motion around the surgically treated extremity was documented satisfactorily for 31 patients who had cemented nailing, for 15 patients who had proximal humeral endoprostheses, and for two patients who had distal humeral endoprostheses. Patients who had cemented nailing had better ($p < 0.03$) forward flexion, abduction, external rotation, and internal rotation than patients who had endoprosthetic reconstruction (Figs 10–13). Patients who had distal humeral prostheses had −30° extension, 45° flexion, and normal pronation and supination.

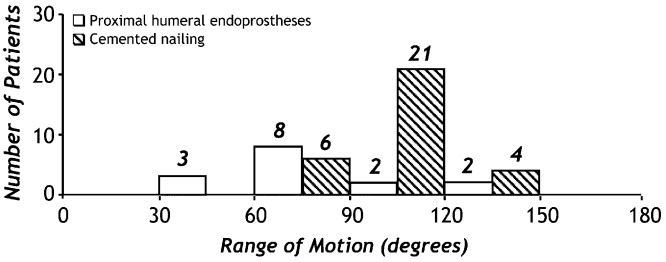

Fig 10. The ranges of forward flexion were better in patients who had cemented nailing compared with patients who had endoprosthetic reconstruction.

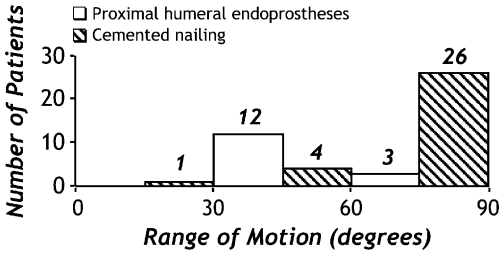

Fig 12. The ranges of external rotation were better in patients who had cemented nailing compared with patients who had endoprosthetic reconstruction.

Patients who had cemented nailing had better overall function, lifting ability, hand dexterity, and emotional acceptance than patients who had endoprosthetic reconstruction (Fig 14). Pain was alleviated satisfactorily, and hand dexterity was preserved similarly in both groups (Fig 14). Patients who had deep infection had a similar functional outcome as those who did not. Overall, total function in 56 patients (95%) was greater than 68% of full normal upper extremity function, which is the mean rating of the functional outcome after reconstruction of the upper extremity (Fig 15).[6] Patients who had cemented nailing had better ($p < 0.025$) total function than patients who had endoprosthetic reconstruction (Fig 15).

Local tumor recurrence was diagnosed in two patients (3.3%) as a palpable and painful mass around the site of surgery, and evidence of a destructive bone lesion at the bone-cement interface with soft tissue extension was seen on plain radiographs and CT scans. One of these patients was treated with wide local excision and adjuvant radiotherapy, and the other patient had an amputation because of extensive tumor invasion into the surrounding soft tissues and around the neurovascular bundle. Fifty-two (88%) patients survived more than 1 year, 24 (41%) patients survived more than 2 years, and 13 (22%) patients survived more than 3 years postoperatively. All reconstructions remained stable at the most recent followups.

DISCUSSION

Function is a key factor in assessing the efficacy of surgery in patients who had resection of humeral metastasis. However, functional outcome has been poorly evaluated and reported. Our study was designed to evaluate the functional outcome of patients who had resection of humeral metastases. It is a relatively small and uncontrolled series with partially missing data, but the detailed functional evaluation allows overall assessment of this unique study group.

Considering the short life expectancy of patients with metastatic disease, surgery must provide good and immediate local tumor control and function and be associated with the least possible degree of morbidity. The surgical procedures used in these patients follow the principles used for long bone metastases at other skeletal locations (ie, the tumor is resected first and the remaining bone defect is reconstructed). Structural stability was achieved by using cemented nailing, not by allografts or allograft-prosthetic composites which rely on bone healing.[7,10,14,15,17] Experience with endoprosthetic reconstruction after resection of primary sarcomas of bone around the shoulder girdle, and experience with cryosurgery of benign-aggressive bone tumors, have allowed successful use in patients with metastatic bone disease.[1,4,5,15] Poly-

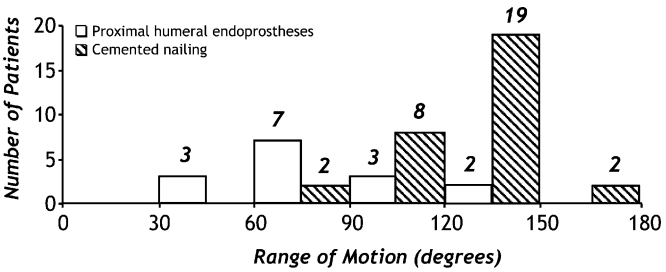

Fig 11. The ranges of abduction were better in patients who had cemented nailing compared with patients who had endoprosthetic reconstruction.

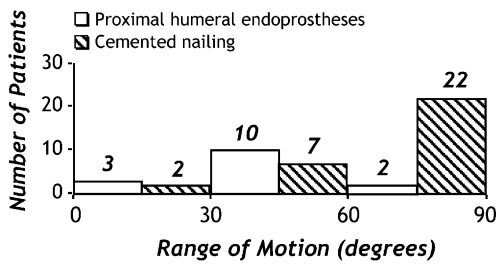

Fig 13. The ranges of internal rotation were better in patients who had cemented nailing compared with patients who had endoprosthetic reconstruction.

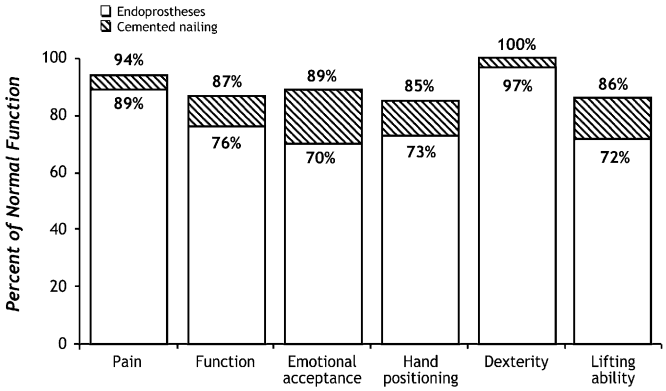

Fig 14. Most of the functional criteria (American Musculoskeletal Tumor Society system[6]) for the 59 study patients were satisfactory.

methylmethacrylate is used routinely to reinforce the fixation devices implanted during surgery. It augments structural stability and enables the patient to withstand the stress of immediate motion and function.[1,10,14,15,17] Polymethylmethacrylate in the operative field does not impair tissue response to radiotherapy, and was not shown to be associated with patient morbidity.[10] Rotational stability of cemented nailing was achieved with a side plate rather than static interlocking screws because a plate allowed the use of multiple screws. Diaphyseal Type II metastases also could be treated using intercalary prostheses.[4] Experience with these implants was limited. They were recommended for lesions in the middle ⅓ of the humeral diaphysis, and implant failure was not uncommon.[4]

Marcove and Miller were the first to use cryoablation in conjunction with the treatment of metastatic bone tumors in a 48-year-old man with painful metastatic lung carcinoma to the proximal humerus that was resistant to radiotherapy.[20] Their technique included wide incision, thorough curettage of the tumor cavity, and repetitive exposure of the curetted area to temperatures less than −20°C by instillation of liquid nitrogen.[20] They advocated this method as a physical adjuvant to decrease the high rates of local recurrence after curettage, and to avoid the need for extensive resection and reconstruction. The patient experienced complete pain relief after the treatment.[20]

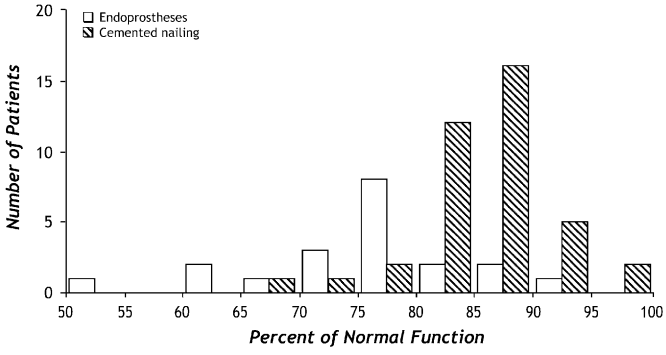

Fig 15. Patients with cemented nailing tended to have better extremity function (American Musculoskeletal Tumor Society system[6]) than patients with endoprostheses.

Unlike primary sarcomas of bone, bone metastases usually do not have a substantial amount of soft tissue extension. This allows resection of these tumors and preservation of the surrounding cuff of muscles in the majority of these patients. As a result, most of our study patients had a level of function greater than 68% of full function, which is the mean rating for upper extremity reconstruction according to the American Musculoskeletal Tumor Society system.[6] Resection of the humeral head or condyles requires sacrifice of numerous muscle and ligamentous attachments. Although soft tissue reconstruction is done, joint function inevitably is impaired. This explains why patients who had endoprosthetic reconstructions had relatively inferior ROM and function compared with patients who had surgery around the humeral diaphysis and reconstruction with cemented nailing.

The objectives of surgery for patients with humeral metastases were to restore function and achieve local tumor control. Because patient survival was determined by the metastatic load, local tumor control and function were the most appropriate criteria for evaluating the efficacy of this type of surgery. Resections of humeral metastases were shown to be safe and reliable. An aggressive surgical approach in patients who had humeral metastases and who met the criteria for surgical intervention was rewarding. Pain was alleviated satisfactorily alleviated, tumor progression was well controlled, and good function and ROM associated with durable reconstructions were achieved in the majority of patients.

Acknowledgment

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