The humerus is a common site of metastatic bone disease requiring surgery. A metastasis at that site, especially when it involves the dominant extremity, has an immediate and profound impact on the affected individual’s ability to perform activities of daily living. The quality of surgery, therefore, is an important factor in restoring vital function.

A detailed preoperative clinical and imaging evaluation is mandatory for defining the morphologic characteristics of the lesion and, in turn, establishing the indications for surgical intervention, as well as distinguishing between lesions that can be managed with curettage and cemented fixation and those that require resection with endoprosthetic reconstruction.

Unlike primary sarcomas of the humerus, metastatic tumors usually have a small soft tissue component, even in the presence of extensive bone destruction. This characteristic allows resection of bony elements only, permitting sparing of the extracortical structures, such as the joint capsule, overlying muscles, and muscle attachments, and affords the opportunity to use them to reconstruct and preserve function. To this end, exposure of the proximal humerus is done by splitting the deltoid muscle rather using the deltopectoral interval, as is done in the case of a primary sarcoma of bone, which necessitates en bloc resection of the deltoid muscle with the tumor. Moreover, a few centimeters of upper limb shortening following resection of bone segment has minimal impact on function, because a slight difference in positioning of that extremity in space can easily compensate for such limb-length discrepancy.

In contrast, a similar discrepancy in the lower extremities, which require almost equal length for normal gait, would result in an inevitable limp, the extent of which would be proportional to the shortening of the operated extremity.

Because of different anatomic and surgical considerations, surgeries around the proximal humerus (type I), humeral diaphysis (type II), and distal humerus (type III) are discussed separately.

### ANATOMY

#### Proximal Humerus: Type I Metastasis
- The proximal humerus is covered anteriorly and laterally by the deltoid muscle.
- The joint capsule encircles the humeral head and attaches to the base of the anatomic neck.
- The proximal humerus is the attachment site for the rotator cuff muscles. The long head of the biceps muscle crosses the anterior aspect within the bicipital groove.

#### Humeral Diaphysis: Type II Metastasis
- The upper half is occupied by muscle insertions:
  - Medial aspect: teres major, latissimus dorsi, coracobrachialis
  - Lateral aspect: pectoralis major, deltoid
- The radial nerve curves at the back from medial to lateral at the mid-arm level.
- The lower half is occupied by muscle origins:
  - Medial aspect: Brachialis
  - Lateral aspect: Brachioradialis
  - Neurovascular bundle along its medial aspect

#### Distal Humerus: Type III Metastasis
- The neurovascular bundle lies along its medial aspect between the biceps and brachialis muscles.
- The radial nerve lies along its lateral aspect between the brachialis and brachioradialis muscles.

### INDICATIONS
- Pathological fracture
- Impending pathological fracture
- Intractable pain associated with locally progressive disease that has shown inadequate response to narcotics and preoperative radiation therapy
- Solitary bone metastasis in selected patients

### IMAGING AND OTHER STAGING STUDIES
- Plain radiographs of the entire humerus are mandatory to rule out synchronous metastases that may change the extent and technique of surgery. A CT scan of the lesion will clearly define the extents of bone destruction and soft tissue component. Total body bone scintigraphy is done to detect synchronous metastases elsewhere in the skeleton. At the conclusion of imaging, the surgeon should be able to answer the following questions:
  - Are there additional humeral metastases and, if there are, can they be managed by nonoperative techniques or do they require surgery?
  - Are there additional skeletal metastases and, if there are, can they be managed by nonoperative techniques or do they require surgery?
  - What is the appropriate surgery? As a rule, the tumor curettage and cemented fixation approach is used for lesions in which the remaining cortices allow containment of the fixation device; otherwise, surgery involves resection of the affected bone segment with prosthetic reconstruction.
Primary bone sarcomas usually have considerable extension into the soft tissues. Resection of such tumors at the proximal humerus would require en bloc removal of the overlying deltoid muscle, rotator cuff tendons, and the joint capsule. Bone metastases, however, usually present with less soft tissue involvement, and their resection involves removal of bony elements with only a thin layer of surrounding soft tissues.

FIG 1 • A. Type I humeral metastasis extending across the anatomic neck to the humeral head. B. Type II humeral metastasis involving the humeral diaphysis between the anatomic neck and the supracondylar ridges of the humerus. C. Type III humeral metastasis extending to the humeral condyles below the supracondylar ridges. (From Bickels J, Kollender Y, Wittig JC, et al. Function after resection of numeral metastases. Analysis of 59 consecutive patients. Clin Orthop Relat Res 2005;437:201–208, with permission.)
TYPE I AND II METASTASES

Position and Incision
- The patient is placed in a semilateral position, and an anterior utilitarian shoulder girdle incision is made. It begins at the junction of the inner and middle thirds of the clavicle and continues over the coracoid process, along the deltopectoral groove, and down the arm over the medial border of the biceps muscle (TECH FIG 1A,B).

Exposure
- The deltoid muscle is divided longitudinally to expose the humeral head and the proximal third of the humeral diaphysis. Exposure of the remaining diaphysis is achieved by similarly dividing the brachialis muscle. Electrocautery and rasps are used to detach and reflect the periosteum and muscle attachments from the underlying cortex (TECH FIG 1C,D).

Tumor Removal
- Type I metastasis
  - Using electrocautery, the rotator cuff tendons are detached from the humerus, the long head of the biceps is cut at its insertion site around the glenoid, and the joint capsule is opened. Osteotomy is carried out at the required level below the surgical neck, 1 to 2 cm below the distal margin of the tumor, and the proximal humerus can now be removed (TECH FIG 2).

TECH FIG 1 • A,B. The utilitarian shoulder incision is used for exposure of type I and II metastases. It begins at the junction of the inner and middle thirds of the clavicle and continues over the coracoid process, along the deltopectoral groove, and down the arm over the medial border of the biceps muscle up to the distal arm, if required. C,D. The deltoid and brachialis muscles are divided longitudinally to expose the humeral head and humeral diaphysis. The periosteum is divided similarly and reflected with muscle to expose the underlying cortex.
Type II metastasis
- A longitudinal cortical window with oval edges is made just above the lesion (TECH FIG 3A). Gross tumor is removed with hand curettes (TECH FIG 3B, C). Curettage should be meticulous and leave only microscopic disease in the tumor cavity. It is followed by high-speed burr drilling of walls of the tumor cavity (TECH FIG 3D–F). Occasionally, the cortices of the involved segment are completely destroyed, leaving no option but an intercalary resection of the affected segment. This is achieved by an osteotomy 1 to 2 cm above and below the segment (TECH FIG 3G–I).

Mechanical Reconstruction
- Type I metastasis
  - A cemented prosthesis is used for reconstruction (TECH FIG 4). The prosthetic design should allow the reattachment of rotator cuff tendons.
- Type II metastasis
  - An intramedullary nail is introduced. After proper position and length are verified, the nail is partially pulled back, and the entire tumor cavity is filled with cement (TECH FIG 5A,B). The nail is then pushed back into the medullary canal and fixed with interlocking screws. Alternatively, a side plate can be used for reinforcement (TECH FIG 5C,D). If an intercalary resection has been done, the remaining bone defect is filled with cement (TECH FIG 5E–G).

Soft Tissue Reconstruction and Wound Closure
- Type I metastasis
  - The rotator cuff tendons are attached to the prosthetic head using 3-mm Dacron tapes (Deknatel, Falls River, MA) or no. 5 Ethibond sutures (Ethicon, Somerville, NJ; TECH FIG 6). The pectoralis major, teres major, latissimus dorsi, and coracobrachialis muscles are similarly attached. Using the same technique, the prosthetic head also is secured to the drill holes within the bony elements around the shoulder joint, acromion, clavicle, and glenoid. The second, overlying muscular layer includes the deltoid and brachialis muscles, which are sutured to cover the implant.
- Type II metastasis
  - The deltoid and brachialis muscles are sutured to cover the humeral diaphysis.

TYPE III METASTASES
- Type III metastases extend to the humeral condyles below the supracondylyar ridges. In most of these cases, the extent of bone destruction allows tumor curettage and reconstruction with cemented hardware (the technique is described in the following section). Rarely will extensive destruction of the distal humerus necessitate formal resection with endoprosthetic reconstruction.
TECH FIG 3 • **A.** A longitudinal cortical window with oval edges is made just above the lesion. **B,C.** Gross tumor is removed with hand curettes. Curettage should be meticulous and should leave only microscopic disease in the tumor cavity. **D,E.** Curettage is followed by high-speed burr drilling of walls of the tumor cavity. **F.** Tumor cavity following curettage and burr drilling. **G.** Plain radiograph of type II thyroid carcinoma metastases. The extent of cortical destruction may does not allow curettage and burr drilling and so intercalary resection of the affected segment is indicated. **H-J.** Intercalary resection is achieved by proximal and distal osteotomies 1 to 2 cm above and below the tumor margin.
Position and Exposure

- The patient is placed supine on the operating table with the ipsilateral arm lying across the chest. A slightly curved incision is made on the lateral aspect of the arm over the supracondylar ridge of the elbow (TECH FIG 7A).
- The distal humerus is exposed using the plane between the brachioradialis and triceps muscles. The brachioradialis is reflected anteriorly and the triceps posteriorly. Further posterior reflection of the anconeus muscle combined with detachment and anterior reflection of the common extensor origin exposes the radial head (TECH FIG 7B).

Tumor Removal and Mechanical Reconstruction

- A longitudinal cortical window with oval edges is made just above the lesion. Gross tumor is removed with hand curettes (TECH FIG 8A), and this is followed by high-speed burr drilling (TECH FIG 8B).
- An intramedullary rod is introduced through the tumor cavity, which is then filled with cement. A reconstruction plate along the lateral supracondylar ridge is used to reinforce the reconstruction (TECH FIG 8C).
TECH FIG 5 • (continued) (D) showing side plate reinforcement of a cemented intramedullary humeral nail. Plain radiograph (E) and intraoperative photographs (F,G) showing side plate reinforcement of a cemented intramedullary humeral nail following intercalary resection of a type II metastasis. The remaining bone defect is filled with cement.

TECH FIG 6 • 3-mm Dacron tapes (A) or no. 5 Ethibond sutures (B) are used for securing the prosthetic head to the neighboring acromion, clavicle, and glenoid and for reattachment of the rotator cuff tendons. C. Rotator cuff tendons are sutured to the prosthetic head.
TECH FIG 7 • A. To expose a lesion at the distal humerus, the patient is placed supine on the operating table with the ipsilateral arm lying across the chest. A slightly curved incision is made on the lateral aspect of the arm over the supracondylar ridge of the elbow. B. The distal humerus and radial head are exposed using the plane between the brachioradialis and triceps muscles.

TECH FIG 8 • A. Gross tumor is removed with hand curettes. B. Curettage is followed by high-speed burr drilling. C. A cemented intramedullary rod that is reinforced by a reconstruction plate along the supracondylar ridge is used for reconstruction.
POSTOPERATIVE CARE

Type I and II Metastases
- Continuous suction is required for 3 to 5 days, and perioperative intravenous antibiotics are continued until the drainage tubes are removed. If endoprosthetic reconstruction was done, the shoulder is immobilized in a sling for 3 weeks. During that time, the rehabilitation program emphasizes range of motion (ROM) of the elbow, wrist, and fingers with gravity assistance.
- If tumor curettage has been carried out, ROM exercises should be practiced without delay. Once the wound has healed, usually 3 to 4 weeks after surgery, patients are referred to adjuvant radiation therapy. Radiation therapy usually is not required in patients who have undergone proximal humerus resection with endoprosthetic reconstruction.

Type III Metastases
- The wound is closed over suction drains. Continuous suction is required for 3 to 5 days, and perioperative intravenous antibiotics are continued until the drainage tubes are removed.
- Passive and active ROM exercises of the elbow joint are initiated when the suction drains are removed.
- Once the wound has healed, usually 3 to 4 weeks after surgery, the patient is referred to adjuvant radiation therapy. Radiation therapy usually is not required, however, for patients who have undergone distal humerus resection with endoprosthetic reconstruction.

OUTCOMES
- Most patients who undergo resection of a humeral metastasis experience immediate relief of their metastasis-related pain. Patients who had a type II metastasis and who have undergone either curettage or intercalary resection have better ROMs and superior functional outcome than those who underwent proximal or distal humeral resection with endoprosthetic reconstruction.
- Bickels et al.² reported that overall total function in their 56 patients (95%) who had undergone resection of a humeral metastasis was over 68% of full normal upper extremity function, which is the mean functional outcome score after reconstruction of the upper extremity.⁴

COMPLICATIONS
- Thromboembolic complications, deep wound infections, and prosthetic loosening (rare)
- Proximal humeral prosthetic dislocation, from poor securing to the adjacent bones and inadequate soft tissue coverage
- Decreased ROM around the shoulder, due to poor attachment of the rotator cuff tendons to the prosthesis
- Decreased elbow ROM after surgery around distal humerus lesions
- Local tumor recurrence of less than 5% if adjuvant tumor removal was done adequately and adjuvant radiation therapy was administered.

REFERENCES