BACKGROUND

The upper extremity is involved by bone and soft tissue neoplasms only one third as often as the lower extremity. The scapula and proximal humerus are common sites of primary sarcoma, including osteosarcoma and Ewing sarcoma in children and chondrosarcoma in adults. Metastatic tumors, especially hypernephroma, also have a propensity for the proximal humerus. When soft tissue tumors occur in the upper extremity, they tend to favor the shoulder girdle and may secondarily involve the scapula, proximal humerus, or clavicle. The axilla is another site around the shoulder girdle where primary soft tissue tumors may develop or where metastases can spread to and replace the local lymph nodes. The axilla is a relatively “silent” area, where tumors may grow to large sizes before they become symptomatic and are detected.

The shoulder girdle consists of the proximal humerus, the scapula, and the distal third of the clavicle, as well as the surrounding soft tissues. Each bone may be involved by a primary malignant bone tumor or metastases, with or without soft tissue extension. The bones of the shoulder girdle also may be secondarily involved by a soft tissue sarcoma, which requires resection and reconstruction techniques similar to those of a primary bone tumor (FIG 1).

Until the mid-20th century, forequarter amputation was the treatment for malignant tumors of the shoulder girdle. Today, about 95% of patients with sarcomas of the shoulder girdle can be treated safely by limb-sparing resection such as the Tikhoff–Linberg resection and its modifications. The relation of the neurovascular bundle to the tumor and other structures of the shoulder girdle is the most significant anatomic factor in determining resectability, removal of the tumor, and reconstruction.

The resection and reconstruction of tumors of the shoulder girdle consists of three components: (1) surgical resection of the tumor following oncologic principles; (2) reconstruction of the skeletal defect (ie, endoprosthetic replacement); and (3) soft tissue reconstruction using multiple muscle transfers to cover the skeletal reconstruction and provide a functional extremity. The goals of all shoulder girdle reconstructions are to provide a stable shoulder and to preserve normal elbow and hand function. The extent of tumor resection and remaining motor groups available for reconstruction dictate the degree of shoulder motion and function that are retained.

Historical Background

Some of the earliest discussions concerning limb-sparing surgery focused on techniques for resection of tumors about the scapula. Initial reports of shoulder girdle resections were confined to the individual bones or portions of the scapula. The first reported scapular resection was a partial scapulectomy performed by Liston in 1819 for an ossified aneurysmal tumor. Between this time and the mid-1960s, several other authors discussed limb-sparing resections about the shoulder girdle. In 1965, Papioannou and Francis reported 26 scapulectomies and discussed the indications and limitations of the procedure.

The Tikhoff–Linberg interscapulothoracic resection or triple-bone resection was described in the Russian literature by Baumann in 1914. He referred to a 1908 report by Pranishkov that described the removal of the scapula, the head of the humerus, the outer one third of the clavicle, and the surrounding soft tissue for a sarcoma of the scapula. The shoulder was suspended from the remaining clavicle by metal sutures. Tikhoff and Baumann performed three such operations between 1908 and 1913, and Tikhoff was named as the originator of the procedure. The technique became established in the Western surgical community only after Linberg’s English publication in 1926.

Classically, most shoulder girdle resections were done for low-grade tumors of the scapula and for periscapular soft tissue sarcomas. Before 1970, most patients with high-grade spindle cell sarcomas (eg, osteosarcoma, chondrosarcoma) involving the shoulder girdle were treated with a forequarter amputation. In 1977, Marcove et al were the first to report limb-sparing surgery for high-grade sarcomas arising from the proximal humerus. These authors reported performing an en bloc extra-articular resection that included the proximal humerus, glenoid, overlying rotator cuff, lateral two thirds of the clavicle, deltoid, coracobrachialis, and proximal biceps. Local tumor control and survival rates were similar to those achieved with a forequarter amputation. Resection, however, preserved a functional hand and elbow. These early results were confirmed by other surgeons. After the 1980s, osteosarcoma, chondrosarcoma, and Ewing sarcoma of the proximal humerus became the tumors most commonly treated with a Tikhoff–Linberg resection. A variety of new techniques and modifications of shoulder girdle resections have been developed. Most have been reported as “Tikhoff–Linberg” or “modified Tikhoff–Linberg” resections. These eponyms are not accurate descriptions, however, because the Tikhoff–Linberg procedure was not intended to refer to sarcomas of the humerus.

As the popularity of limb-sparing surgery for shoulder girdle sarcomas grew, the extent of resection necessary for various tumors, particularly indications for an extra-articular resection, remained a matter of debate. The best method for reconstruction also came under considerable discussion. In response, Malawer et al developed a surgical classification system based on tumor location, extent, grade, and pathologic type. This system was intended to provide guidelines regarding the extent of resection necessary for primary bone sarcomas and soft tissue sarcomas that secondarily involve the bones of the shoulder girdle.

SURGICAL CLASSIFICATION SYSTEM

The current surgical classification system was described by Malawer and associates in 1991 (FIG 2). It is based on the...
indications are described briefly in the following section. The

All six of these types of shoulder girdle resections and their

■ of resection performed for high-grade spindle cell sarcomas.

■ extracompartmental resections and are the most common type

■ Type B resections, in which the abductors are resected, are

rare situation, however. This type of resection also is recom-

■ opposed mechanism (the deltoid muscle and rotator cuff):

Each type is subdivided according to the status of the abduc-

tor mechanism (the deltoid muscle and rotator cuff);  

■ Abductors intact

■ Abductors partially or completely resected

■ Type A resections, in which the abductors are preserved, usually are recommended for high-grade spindle cell bone sar-

comas that are entirely intracompartamental (ie, contained within either the proximal humerus or scapula bone). This is a rare situation, however. This type of resection also is recom-

■ recommended for low grade-bone sarcomas, selected metastatic car-

cinomas, and, often, round cell sarcomas.

■ Type B resections, in which the abductors are resected, are extracompartamental resections and are the most common type of resection performed for high-grade spindle cell sarcomas.

■ All six of these types of shoulder girdle resections and their indications are described briefly in the following section. The

surgical techniques for each resection and reconstruction are described in ON-8, 10, and 11–13.

GUIDELINES FOR SHOULDER GIRDLE RESCTION

Local Growth and Transarticulation Involvement by Shoulder Girdle Tumors

■ The shoulder joint appears to be more prone than other joints to intra-articular or pericapsular (ligamentous) involve-

ment by high-grade bone sarcomas.

■ Four basic mechanisms underlie tumor spread across the

shoulder joint: direct capsular extension; tumor extension along the long head of the biceps tendon; fracture hematoma from a pathologic fracture; and poorly planned biopsy (FIG 3).

■ These mechanisms place patients undergoing intra-articular resections for high-grade sarcomas at greater risk for local recurrence than those undergoing extra-articular resections. Therefore, it often is necessary to perform an extra-articular resection for high-grade bone sarcomas of the proximal humerus or scapula.

■ Most tumors arise from the metaphyseal portion of the

proximal humerus. They extend beyond the cortices and spread underneath the deltoid muscle, subscapularis muscle, and remaining rotator cuff muscles. As the tumor grows, the extraosseous component spreads along the long head of the biceps tendon, along the glenohumeral ligaments, and under-

neath the rotator cuff, heading toward the glenoid or directly crossing the glenohumeral joint. The deltoid, subscapularis muscle, and remaining rotator cuff muscles are compressed into a pseudocapsular layer. These muscles form compart-

mental boundaries around the tumor. The axillary nerve and circumflex vessels enter this compartment. The major neu-

rovascular bundle is displaced by the tumor; however, in most instances the fascia overlying the subscapularis muscle as well as the axillary sheath that contains the blood vessels and nerves protect the major neurovascular bundle from tumor involvement or encasement.

■ Similarly, most scapular sarcomas originate from the

metaphyseal portion of the scapula or the scapula neck, and grow centripetally into the soft tissues. They form a soft tis-

sue mass that extends outward and usually is contained by the subscapularis and other rotator cuff muscles. These tu-

mors follow the path of least resistance and are directed to-

ward the glenohumeral joint and proximal humerus. Eventually, the tumor contaminates these structures. The subscapularis muscle and its investing fascia function as a barrier and protect the axillary vessels and brachial plexus from tumor invasion. These neurovascular structures usually are displaced by the adjacent tumor that lies deep to the sub-

scapularis muscle.

Functional Anatomic Compartment of the Shoulder Girdle

■ Sarcomas grow locally in a centripetal manner and com-

press surrounding tissues (muscles) into a pseudocapsular layer. The pseudocapsular layer contains microscopic finger-

like projections of tumor, which are referred to as satellite nodules.

■ Sarcomas spread locally along the path of least resistance. Surrounding fascial layers resist tumor penetration and,
therefore, provide boundaries to local sarcoma growth. These boundaries form a compartment around the tumor (FIG 4).

- A sarcoma will grow to fill the compartment in which it arises, and only rarely will an extremely large sarcoma extend beyond its compartmental borders. In discussing bony sarcomas that extend beyond the cortices into the surrounding soft tissues, the term functional anatomic compartment refers to the investing muscles that are compressed into a pseudocapsular layer (Fig 4).

- These muscles provide the fascial borders of the compartment, a fact that has important surgical implications. A wide resection of a bone sarcoma removes the entire tumor and pseudocapsular layer and must, therefore, encompass the investing muscle layers (compartmental resection).

- The functional compartment surrounding the proximal humerus consists of the deltoid, subscapularis and remaining rotator cuff, latissimus dorsi (more distally), brachialis, and portions of the triceps muscles. The glenoid and scapular neck also reside within the functional compartment of the proximal humerus, because they are contained by the rotator cuff and capsule and the subscapularis muscle. Sarcomas that arise from the proximal humerus and extend beyond the cortices compress these muscles into a pseudocapsular layer.

- The fascial layers surrounding these muscles resist tumor penetration. The only neurovascular structures that enter this compartment are the axillary nerve and humeral circumflex vessels.

- The main neurovascular bundle (ie, brachial plexus and axillary vessels) to the upper extremity passes anterior to the subscapularis and latissimus dorsi muscles. These muscles and their...
investing fascial layers are particularly important, therefore, for protecting the neurovascular bundle from tumor involvement. They also protect the pectoralis major muscle, which must be preserved during surgical resection for soft tissue coverage.

- High-grade sarcomas that extend beyond the bony cortices of the proximal humerus expand the investing muscles that form the compartmental borders and pseudocapsular layer.
- These sarcomas grow along the path of least resistance and, therefore, are directed toward the glenoid and scapular neck by the rotator cuff and glenohumeral joint capsule.
- Anteriorly, the tumor is covered by the subscapularis, which bulges into and displaces the neurovascular bundle. Only rarely does a very large proximal humerus sarcoma extend beyond the compartmental borders.
- In these instances the tumor usually protrudes through the rotator interval. A wide (compartmental) resection for a high-grade sarcoma must, therefore, include the surrounding muscles that form the pseudocapsular layer (ie, deltoid, lateral portions of the rotator cuff, the axillary nerve, humeral circumflex vessels, and the glenoid). (extra-articular resection of the proximal humerus).
- Most high-grade scapular sarcomas arise from the region of the scapular neck. The compartmental borders surrounding the scapular neck consist of the rotator cuff muscles and portions of the teres major and latissimus dorsi muscles. The compartment consists of all of the muscles that originate on the anterior and posterior surfaces of the scapula: the subscapularis, infraspinatus, and teres muscles. The deltoid, although it is not typically considered one of the compartmental borders, since it attaches to a narrow region of the scapular spine and acromion, may be involved secondarily by a large soft tissue extension. In most instances the deltoid is protected by the rotator cuff muscles because the anatomic origin of most tumors is from the neck and body region. Similar to the proximal humerus, the rotator cuff muscles are compressed into a pseudocapsular layer by sarcomas that arise from the scapula. The subscapularis also protects the neurovascular bundle from tumor involvement. The head of the proximal humerus is contained within the compartment surrounding the scapula by the rotator cuff muscles. Wide resection of a high-grade scapular sarcoma must, therefore, include the rotator cuff and, in most instances, the humeral head.
- The axillary nerve is not contained within the compartment and therefore can be spared from resection. Additionally, because the deltoid is not compressed into a pseudocapsular layer, it usually can be preserved.

INDICATIONS
Indications for Limb-Sparing Surgery
- High-grade and some low-grade bone sarcomas
- Soft tissue sarcomas arising from the shoulder girdle
Metastatic carcinomas: isolated metastasis or metastatic lesions that have caused significant bony destruction
Occasionally, benign-aggressive tumors also may require these treatment techniques.
Selection of patients for limb-sparing surgery is based on the anatomic location of the tumor and a thorough understanding of the natural history of sarcomas and other malignancies.

Contraindications for Limb-Sparing Surgery
Absolute contraindications for limb-sparing procedures include tumor involvement of the neurovascular bundle, or a patient’s inability or unwillingness to tolerate a limb-sparing operation.
Relative contraindications may include chest wall extension, pathologic fracture, previous infection, lymph node involvement, or a complicated, inappropriately placed biopsy that has resulted in extensive hematoma, which has resulted in tissue contamination.

Biopsy Site
One of the most common causes for forequarter amputation is an inappropriately placed biopsy site that has resulted in contamination of the pectoralis muscles, neurovascular structures, and chest wall. Extreme care must be taken with biopsy placement and technique (see Fig 3).

Vascular Involvement
Fortunately, most tumors of the proximal humerus are separated from the anterior vessels by the subscapularis, latissimus dorsi, and coracobrachialis muscles. It is rare for the axillary or brachial artery to be involved with tumor, although a large soft tissue component may cause displacement and compression.
In general, if the vessels appear to be involved with tumor, the adjacent brachial plexus also is involved, and a limb-sparing procedure may be contraindicated.

Nerve Involvement
The three major cords of the brachial plexus follow the artery and vein and rarely are involved with tumor. The axillary nerve may be involved by neoplasm as it passes from anterior to posterior along the inferior glenohumeral joint capsule. Resection of the axillary nerve usually is required for stage IIB tumors of the proximal humerus.
The musculocutaneous and radial nerves rarely are involved. The deficit created by resecting the radial nerve is greater than that for the musculocutaneous nerve, but this should not be an indication for amputation.
If resection will lead to a major functional loss and a close margin (increasing the risk of local recurrence), amputation should be considered. Direct tumor extension into or encasement of the brachial plexus necessitates a forequarter amputation.

Lymph Nodes
Bone sarcomas rarely involve adjacent lymph nodes; nevertheless, axillary nodes should be evaluated and may require biopsy. In the rare incidence of lymph node involvement documented by biopsy, a forequarter amputation may be the best method for removing all gross disease.
Alternatively, a lymph node dissection in conjunction with a limb-sparing procedure may be considered. Malawer has found, based on two cases, that local control and long-term survival can be obtained by this method (unpublished data).

Chest Wall Involvement
Tumors of the shoulder girdle with large extraosseous components occasionally may involve the chest wall, ribs, and intercostal muscles.
Chest wall involvement should be evaluated preoperatively with physical examination and imaging studies; however, such involvement often is not determined until the time of surgery. It is not an absolute indication for forequarter amputation; a limb-sparing procedure combined with a chest wall resection may be performed, depending on the involvement of adjacent soft tissues and neurovascular structures.

Previous Resection
The local recurrence rate is increased in cases in which a wide resection is attempted (1) following a previous inadequate resection around the shoulder girdle or (2) when a tumor already has recurred locally. This possibility must be a consideration especially with tumors of the scapula and clavicle and of soft tissue tumors that involve the proximal humerus.

Infection
In patients with high-grade sarcomas, limb-sparing procedures performed in an area of infection are extremely risky, because these patients must receive postoperative adjuvant chemotherapy. If an infection cannot be eradicated with the primary resection, amputation is advisable.

SURGICAL MANAGEMENT
Preoperative Planning
Physical Examination
The physical examination is important for assessing tumor resectability and for estimating the extent of resection that may be required. Physical examination is important in determining tumor extension into the glenohumeral joint, neurovascular involvement, or tumor invasion of the chest wall. If tumor has invaded the joint, shoulder range of motion usually is reduced, and the patient may complain about discomfort and pain.
Neurovascular involvement or compression may be suggested by an abnormal neurovascular examination or by decreased or absent pulses.
Tumors that move freely with respect to the chest wall usually are separated from it by at least a thin tissue plane through which it is safe to dissect.

Determining Tumor Resectability
High-grade tumors arising from the shoulder girdle region often are large and encroach on the neurovascular bundle. Tumors that encase or invade the brachial plexus are considered unresectable. In many cases it is difficult to determine, both clinically and radiologically, which tumors involve or encase the neurovascular structures directly as opposed to merely displacing these structures. Although most tumors that displace the neurovascular structures are resectable, some are unresectable, and it can be difficult to determine clinically which are in this category.
We have found the clinical triad of intractable pain, motor deficit, and a venogram showing obliteration of the axillary vein to be very reliable in predicting brachial plexus invasion. No single imaging study is available that accurately visualizes the brachial plexus. MRI and CT scans typically show a large tumor juxtaposed to the neurovascular bundle (FIG 5).

Venography, however, is extremely accurate in predicting brachial plexus invasion. The axillary vein, axillary artery, and brachial plexus travel in intimate association within a single fascial sheath, the axillary sheath.

The major nerves and cords travel along the periphery of the sheath; therefore only complete obliteration—not just compression—of the brachial or axillary vein denotes direct tumor extension in and around the nerves and also indicates secondary involvement of the venous wall. This progression also explains the clinical triad of pain, motor loss, and venous obstruction.

Tumors that invade or encase the brachial plexus obliterate the axillary vein because of that vein’s thin walls and low intraluminal pressure. In these instances arteriography demonstrates displacement of the axillary artery; however, the axillary artery remains patent because of its thick walls and high intraluminal pressures.

The final decision regarding the need for a forequarter amputation should be reserved until surgical exploration of the brachial plexus has been performed.

Prosthetic Reconstruction

When endoprosthetic reconstruction was developed in the 1940s, attention initially was focused on reconstruction of skeletal defects of the lower extremity. Use of the technique was broadened gradually to include defects of the upper extremity and shoulder girdle.

The MRS shoulder prosthesis has undergone several design changes and improvements since that time. The current components for proximal humerus and scapular replacement show in Chapters ON-10 and 8, respectively. The MRS is used in conjunction with both intra- and extra-articular resections, and results are highly predictable and successful.

Reported rates of fracture, infection, nonunion, reoperation, and tumor recurrence are lower, and length of immobilization is shorter with extremity endoprosthetic reconstruction than with allograft, composite reconstruction, or arthrodesis.

Survival of the MRS proximal humeral prosthesis is reported to be 95% to 100% at 10 years.

FIG 5 • Imaging studies of the shoulder girdle and axillary space demonstrating bony and soft tissue findings. A. CT scan showing a tumor arising from the glenoid and involving the glenohumeral joint. CT scans are the best modality for observing bony detail. B. Coronal MRI scan showing direct tumor extension. C,D. A large soft tissue axillary tumor protruding anteriorly through the pectoralis major and the skin. This is a high-grade fungating soft tissue sarcoma. MRI is the best scan for evaluation of soft tissue masses in relation to other soft tissue structures. E. MRI scan of the axillary space (coronal view) showing a secondary skipped lesion along the axillary vein, coming from a high-grade soft tissue sarcoma lower in the axilla. Metastatic lesions of the axilla and lymph nodes are a common source of large axillary masses and are best evaluated by MRI scans. F. Angiography and embolization of metastatic renal cell carcinoma (hypernephroma) to the distal clavicle. Following embolization, there is no evidence of a tumor blush. Embolization often is performed for large high-grade soft tissue sarcomas prior to a resection. G. On this axillary venogram, the axillary vein is occluded by thrombosis, and there is a small backward filling from the innominate vein. This is the most pathognomonic finding of brachial plexus involvement seen during the time of surgery. Brachial plexus involvement often correlates with the clinical findings of neurologic deficits, numbness, or muscle weakness of the affected extremity.
SKELETAL RECONSTRUCTION FOLLOWING HUMERUS AND SCAPULA RESECTIONS

- Special prosthetic replacements are recommended for skeletal reconstruction following proximal humerus and total scapula resections, although the utilitarian approach may be used with any method of reconstruction (TECH FIG 1).
- Soft tissue reconstruction is accomplished using a dual suspension technique that employs static and dynamic methods of prosthetic stabilization and soft tissue and motor reconstruction.
- Static methods of stabilization include the use of heavy nonabsorbable sutures, Dacron tapes, or Gore-Tex grafts, depending on the site of tumor resection and the prosthesis that is being used. This method offers secure fixation and stabilization of the prosthesis until the soft tissues heal and scar to each other.
- Dynamic methods of stabilization and reconstruction include multiple muscle rotation flaps and muscle transfers that eventually heal, scar to each other and the prosthesis, and provide the necessary motor units for a functional extremity.
- Soft tissue reconstruction follows skeletal reconstruction and static stabilization. The short head of the biceps is attached with a tenodesis proximally to the coracoid (intra-articular proximal humerus reconstruction), or to the clavicle (extra-articular proximal humerus reconstruction) or pectoralis major (total scapula reconstruction). The pectoralis minor also is tenodesed back to its origin, when possible, or to the scapula to protect the neurovascular structures. The pectoralis major is repaired to its humeral insertion or, in cases requiring extra-articular proximal humerus reconstruction, transferred to cover the prosthesis with soft tissues. The latissimus dorsi may be transferred laterally to function as an external rotator following extra-articular proximal humerus resection.
- In total scapula reconstruction, the periscapular muscles are tenodesed to the prosthesis with heavy nonabsorbable sutures or tapes in a manner that covers the entire prosthesis with muscle. Following isolated axillary tumor resection, the distal (humeral) transected edge of the latissimus dorsi muscle is rotated into the defect and sutured to the superficial surface of the subscapularis muscle to fill the dead space. Large-bore closed suction drains are routinely placed prior to skin closure.

TECH FIG 1 • A. Utilitarian incision. This incision has been developed based on the extensive experience of surgeons performing resections around the shoulder girdle. It consists of three components. Dashed line A indicates the anterior approach, an extended deltopectoral incision coming from the midclavicle through the deltopectoral interval and distally over the medial aspect of the arm, curving in a posterior direction. Dashed line B is a posterior incision that is somewhat curved in nature, to allow development of a large posterior fasciocutaneous flap for exposure of the entire scapula and rhomboid region. Dashed line C is an incision that connects A and B through the axillary folds. This permits resection of large axillary tumors or performance of forequarter amputations. (continued)
B. The initial steps of the anterior approach of the utilitarian shoulder girdle incision. The key to this approach is the release of the pectoralis major from its insertion on the humerus (1–2 cm away). With the pectoralis major now reflected onto the chest wall, the entire axillary space can be exposed. This is termed the first layer of musculature of the axillary space. The second muscular layer of the axillary space is then visualized. With the pectoralis major layer retracted, the axillary space is completely covered by fascia, similar to the peritoneum. This covers two muscles, the short head of the biceps and the pectoralis minor, which attach to the coracoid process, which must be released. With these two muscles released, the axillary space and infraclavicular component of the brachial plexus (ie, the axillary vein and artery through its entire length) can be explored completely. If necessary, a portion of the clavicle can be resected to exposed the subclavian artery and vein. (Courtesy of Martin M. Malawer.)

**TECH FIG 1 • (continued)** B. The initial steps of the anterior approach of the utilitarian shoulder girdle incision. The key to this approach is the release of the pectoralis major from its insertion on the humerus (1–2 cm away). With the pectoralis major now reflected onto the chest wall, the entire axillary space can be exposed. This is termed the first layer of musculature of the axillary space. The second muscular layer of the axillary space is then visualized. With the pectoralis major layer retracted, the axillary space is completely covered by fascia, similar to the peritoneum. This covers two muscles, the short head of the biceps and the pectoralis minor, which attach to the coracoid process, which must be released. With these two muscles released, the axillary space and infraclavicular component of the brachial plexus (ie, the axillary vein and artery through its entire length) can be explored completely. If necessary, a portion of the clavicle can be resected to exposed the subclavian artery and vein. (Courtesy of Martin M. Malawer.)

**PEARLS AND PITFALLS**

**Preoperative evaluation**
- Physical examination and radiologic imaging modalities are useful for predicting whether a tumor is resectable. The scapula and proximal humerus should move freely from the chest wall. Chronic swelling in the distal extremity, intractable pain, motor loss, and a venogram that demonstrates obliteration of the axillary vein strongly suggest that the tumor is unresectable. The final determination regarding the need for a forequarter amputation is made intraoperatively, after anterior exposure and exploration of the brachial plexus and neurovascular structures.

**Neurovascular exploration and mobilization**
- The key to a safe and adequate resection of all types of neoplasms around the shoulder girdle lies in adequate visualization, exposure, dissection, mobilization and preservation of all vital neurovascular structures. Full exposure is facilitated by releasing the pectoralis major muscle from its humeral insertion and the strap muscles from the coracoid process.

**Type of resection**
- High-grade sarcomas that arise from the proximal humerus or scapula are likely to contaminate or cross the glenohumeral joint, either grossly or microscopically. An extra-articular type of resection is used for most high-grade sarcomas arising from the scapula or proximal humerus. Clavicular tumors, although less common, require a slightly different surgical approach (FIG 6).

**Soft tissue reconstruction**
- Soft tissue reconstruction is just as important as skeletal reconstruction during limb-sparing surgery if a functional extremity is to be provided. Static and dynamic methods of soft tissue reconstruction and stabilization are used. Static methods rely on heavy nonabsorbable sutures, Dacron tapes, and Gore-Tex grafts. Dynamic methods rely on multiple muscle transfers and rotational muscle flaps.
OUTCOMES

- The types of tumors, anatomic locations, and types of shoulder girdle resections performed in 143 patients treated at the authors’ institutions from 1980 to 1998 are shown in FIGURE 7A. Experience in these patients with endoprosthetic reconstruction of the proximal humerus and scapula demonstrates that this is a reliable and durable technique of reconstruction (FIG 7B–E). Survival rates based on Kaplan–Meier analysis demonstrate a 9-year survival rate of 98% to 99% for proximal humeral replacements.
- No mechanical failures or dislocations occurred. Other groups have reported a significant incidence of dislocation following endoprosthetic reconstruction of the shoulder girdle, but this has not been our experience.
- The results shown in Figure 7 reflect the use of “dual suspension” (ie, both static and dynamic) or capsular reconstruction techniques and meticulous attention to soft tissue reconstruction.

FIG 6 • Example of a safe exposure of a clavicular tumor. The tumor arising from the distal clavicle is a solitary metastasis. The trapezius has been mobilized. The pectoralis major has been detached from the clavicle, and the deltoid has been detached from the acromion.

FIG 7 • A. Results of 134 shoulder girdle resections classified as type of resection versus function as measured by the Musculoskeletal Tumor Society (MSTS) scale. B. Composite photograph demonstrating head, body, and stem components for humeral resections. C. Proximal humerus modular replacement system options from Stryker Orthopedics. D. Proximal humerus and scapular prosthesis system. E. Plain radiograph following reconstruction using a constrained total scapula replacement.
REFERENCES