Chapter 8

Total Scapular Resections with Endoprosthetic Reconstruction

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BACKGROUND

- Tumors arising from the scapula may become very large before diagnosis. Initially, they are often contained by muscle, which protects other tissues within the shoulder girdle. Patients with scapular tumors often present with pain, a mass, or both.
- Chondrosarcomas are the most common primary malignancy of the scapula in adults; in children the most common primary malignancy of the scapula is the round cell tumor Ewing sarcoma.
- Soft tissue tumors may involve the periscapular musculature and secondarily invade the scapula.
- The majority of shoulder girdle malignancies can be treated safely with limb-sparing surgeries in lieu of forequarter amputation. Indications for limb-sparing surgeries at this location include most high-grade bone sarcomas and some soft tissue sarcomas, depending on the tumor extension.
- Scapular tumors, like tumors of the proximal humerus, require careful preoperative staging, appropriate imaging studies, and a thorough knowledge of local anatomy. Selection of patients whose tumor does not involve the neurovascular bundle, thoracic outlet, or adjacent chest wall is required.
- It is rare when forequarter amputation is indicated. It is mainly reserved for patients with large, fungating tumors or infected tumors; those in whom limb-sparing resection has failed; and those with tumors invading the major nerves and vessels or the chest wall.
- Before 1970, most patients with high-grade sarcomas arising from the scapula were treated with a forequarter amputation.[2,3,4,7] The first limb-sparing surgeries for high-grade sarcomas arising from the shoulder girdle were reported by Marcove et al in 1977.[6] They reported that the Tikhoff-Linberg resection (**FIG 1A**) achieved local tumor control and survival similar to that achieved with a forequarter amputation. Most importantly, a functional hand and elbow were preserved. Limb-sparing surgery for patients with high-grade sarcomas in this location soon became standard treatment. Today, the majority of malignancies arising from or involving the scapula can be treated safely with limb-sparing surgery in lieu of a forequarter amputation.
- Shoulder motion and strength are nearly normal after a partial scapular resection (type II). However, there is significant loss of shoulder motion, predominantly shoulder abduction, after a total scapular resection (type III), alone or in conjunction with an extra-articular resection of the shoulder joint and proximal humerus (types IV and VI). Suspension of the proximal humerus and meticulous soft tissue reconstruction are the keys to providing shoulder stability and a functional extremity. If significant periscapular muscles remain after tumor resection (especially the trapezius and deltoid muscles), a total shoulder–scapula prosthesis may be the optimal reconstructive option (**FIG 1B–F**).

ANATOMY

- The local anatomy of a scapular tumor determines the type of scapular resection and subsequent reconstruction. Because these tumors become quite large before diagnosis, the surgeon should thoroughly inspect the chest wall, axillary vessels, proximal humerus and rotator cuff, and periscapsular tissue to ensure that an appropriate procedure is planned.
- Sarcomas involving the glenoid, scapular neck, or supraspinatus musculature usually involve the glenohumeral joint and adjacent capsule. Therefore, an extra-articular resection through a combined anterior and posterior approach should be performed for tumors in this location.
- Large sarcomas of the scapula with soft tissue extension can involve the axillary vessels and the brachial plexus. Likewise, lymph nodes in the surrounding region should be evaluated to determine resectability.
- Suprascapular tumors are difficult to palpate on physical examination. Even sophisticated imaging modalities may incorrectly estimate the extent of these tumors. Tumors in this location can extend into the anterior and posterior triangles of the neck, making resection impossible except in the cases of palliation.

Key Anatomic Structures of the Scapular Region

Neurovascular Bundle

- The subclavian artery and vein join the cords of the brachial plexus as they pass underneath the clavicle. Beyond this point the nerves and vessels are surrounded by a fibrous sheath and can be considered one structure (ie, the neurovascular bundle).
- The suprascapular, dorsal scapular, and circumflex scapular vessels form an extensive vascular network around the posterior scapula. Each of these vessels must be ligated and transected to resect the scapula.

Axillary Vessels

- The axillary blood vessels are a continuation of the subclavian vessels as they pass underneath the middle third of the clavicle and are called the brachial vessels once they pass the inferior border of the latissimus dorsi muscle. The axillary vessels pass medial and inferior to the coracoid process en route to the proximal humerus. They are surrounded by the brachial plexus throughout their entire course.
- The artery yields several branches during its course. The first branch arises as the artery passes over the first rib and is called the supreme thoracic artery. While the artery is deep to the pectoralis minor muscle, the thoracoacromial artery arises followed by the lateral thoracic artery and then the subscapular artery. The thoracoacromial artery gives rise to four branches, one of which supplies the area around the acromion.
- The subscapular artery divides into the thoracodorsal artery and the circumflex scapular artery that wraps around the lateral border of the scapula and tethers the axillary vessels to the scapula.

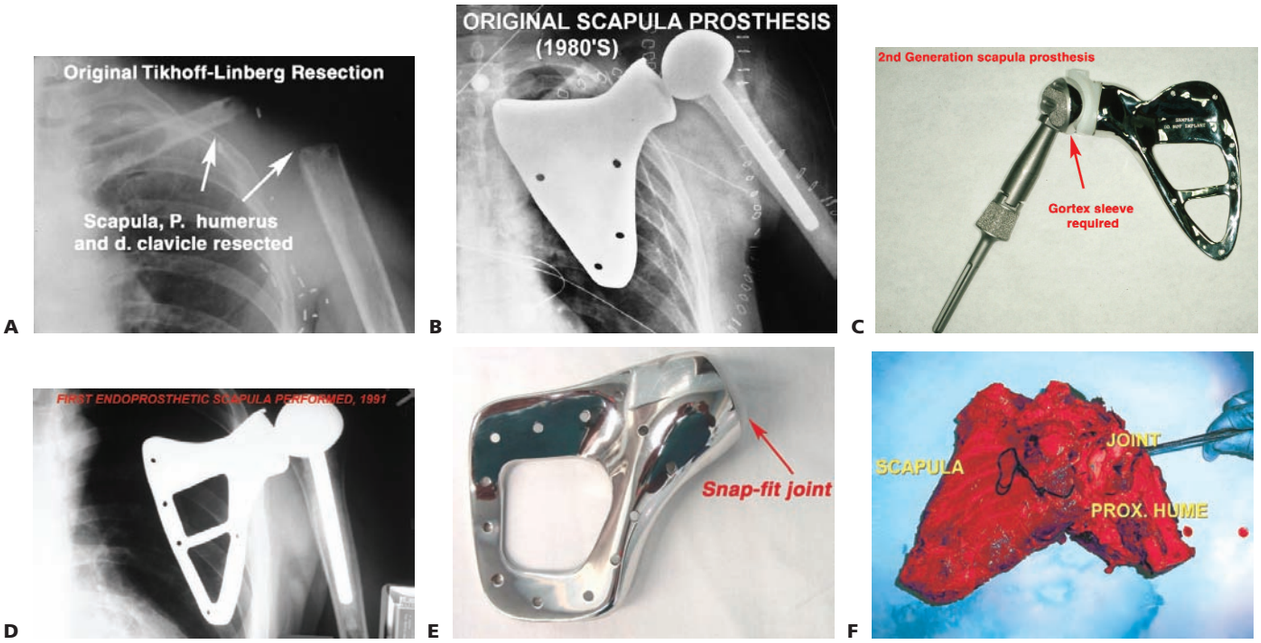

FIG 1 • A. Plain radiograph showing the traditional resection of the shoulder girdle after a Tikhoff-Linberg resection. The Tikhoff-Linberg resection includes the entire scapula and the proximal humerus en bloc extra-articularly. **B.** The original scapular prosthesis designed by Howmedica, Inc. (Rutherford, NJ, 1991). This prosthesis is quite solid and large and contains fenestrated holes for reattachment. The humeral head articulated with a polyethylene glenoid but was held in place only by muscle transfers and/or the use of a Gore-Tex sleeve. **C.** The second-generation of the scapula that was used in the late 1990s. This prosthesis offered fenestrations within the body of the scapula to allow the adjacent muscles to tenodese to give the recreated shoulder a new and more stable attachment. The proximal humeral component could, at this point, be mated with the Modular Replacement System for resections of the proximal humerus. This greatly increased the surgeon's ability to reconstruct the proximal humerus and shoulder girdle. **D.** Plain radiograph showing a 13-year follow-up of this prosthesis in a patient with hemangiosarcoma of the scapula. **E.** The third-generation scapular prosthesis that was developed by Howmedica, Inc. (now Stryker Orthopedics, Mahwah, NJ). This prosthesis is the first articulating scapular prosthesis. The bipolar proximal humeral head fits into the glenoid with a polyethylene retaining rim. **F.** Gross specimen after an extended Tikhoff-Linberg resection (type IV) that included the entire scapula, an extra-articular resection of the glenohumeral joint, and a portion of the proximal humerus with all of the muscles attached.

- The anterior and posterior humeral circumflex arteries are the final branches of the axillary artery. They arise at the level of the inferior border of the subscapularis muscle and wrap circumferentially around the humeral neck. The axillary nerve runs with the posterior humeral circumflex vessels. The humeral circumflex vessels tether the neurovascular structures down to the proximal humerus and hence to any neoplasm that arises from this site. Early ligation of the circumflex vessels is a key maneuver in resection of scapular sarcomas because it permits mobilization of the axillary and brachial vessels and brachial plexus away from the tumor mass.
- Likewise, ligation of the subscapular artery, or circumflex scapular artery if possible, allows mobilization of the neurovascular structures away from the scapula. Occasionally, there is anatomic variability in the location of the branches of the axillary artery that leads to difficulty in identification and exploration if not previously recognized. A preoperative angiogram can help determine vascular displacement by neoplasm and anatomic variability.

Suprascapular Nerve

- The suprascapular nerve arises from the superior trunk of the brachial plexus as it passes over the first rib. It travels posterior through the scapular notch deep to the transverse scapular ligament and supplies the supraspinatus and infraspinatus muscles.

Musculocutaneous and Axillary Nerves

- These two nerves are often in close proximity to or in contact with tumors around the scapula. The musculocutaneous nerve is the first nerve to arise from the brachial plexus. It arises from the lateral cord just distal to the coracoid process, passes through the coracobrachialis, and runs between the brachialis and biceps. It should be preserved, if possible, to maintain elbow flexion.
- The path of this nerve may vary extensively. It usually passes 2 to 7 cm inferior to the coracoid process. Tumors that arise from the scapula often displace this nerve anteriorly so that it occupies a position only 1 to 2 mm deep to the fascia. Care should be taken when opening the fascia overlying this nerve in the interval between the coracobrachialis and pectoralis minor muscles. The nerve should be identified and protected before releasing any muscles from the coracoid process because it can be easily injured during the resection.
- The axillary nerve arises from the posterior cord of the brachial plexus and courses, along with the posterior humeral circumflex vessels, inferior to the distal border of the sub-

scapularis. It then passes between the teres major and minor muscles to innervate the deltoid muscle posteriorly. Tumors of the scapula usually displace and stretch the axillary nerve. The nerve is usually protected from the tumor by the subscapularis muscle.

Radial Nerve

- The radial nerve arises from the posterior cord of the brachial plexus. It passes anterior to the latissimus dorsi—teres major insertion on the humerus. Just distal to the latissimus dorsi insertion, the nerve courses into the posterior aspect of the arm, just lateral to the long head of the triceps, to run in the spiral groove between the medial and lateral heads of the triceps. The radial nerve must be isolated and protected before resection.

Upper and Lower Subscapular Nerves and Thoracodorsal Nerve

- The upper and lower subscapular nerves and the thoracodorsal nerve arise from the posterior cord of the brachial plexus near where the subscapular artery and humeral circumflex vessels arise from the axillary artery. The upper and lower subscapular nerves descend and enter directly into the substance of the subscapularis muscle. These nerves are routinely ligated during a scapulectomy. The thoracodorsal nerve passes with the thoracodorsal artery distally, directly anterior to the subscapularis muscle, to supply the latissimus dorsi muscle. The thoracodorsal nerve can usually be spared during most scapular resections.

INDICATIONS

- Limb-sparing surgery is indicated for most sarcomas of the scapula (**FIG 2**).
- Soft tissue sarcomas that extend into the scapula can usually be resected with a limb-sparing surgery.
- Tumors that extend into the axilla with vessel involvement or invasion of the brachial plexus or those that have extensive involvement with the chest wall typically cannot be safely resection using limb-sparing techniques.
- Metastatic carcinoma, myeloma, or lymphoma that has completely destroyed the scapula and has either failed to respond radiation therapy or chemotherapy or may be treated by limb-sparing surgery.
- Certain key muscles, along with the axillary nerve, must be capable of being preserved if the shoulder girdle is to be reconstructed with a total scapula prosthesis: the trapezius, deltoid, rhomboids, serratus anterior, and latissimus dorsi. These muscles provide the soft tissue coverage necessary to suspend the prosthesis and allow it to function. If these muscles cannot be preserved, the humerus is suspended from the clavicle. Static and dynamic methods of soft tissue reconstruction are used to stabilize the humerus. This involves the use of 3-mm Dacron tapes, heavy nonabsorbable sutures, and multiple muscle rotations and transfers.

Contraindications for Limb-Sparing Surgery for Scapula Tumors

- Tumor invasion or encasement of the brachial plexus and axillary vessels. Involvement of a single nerve is not an absolute contraindication.
- Extensive chest wall involvement
- Relative contraindications include:
  - An inappropriately placed biopsy that has resulted in extensive contamination of the surrounding soft tissues
  - An active or previous infection

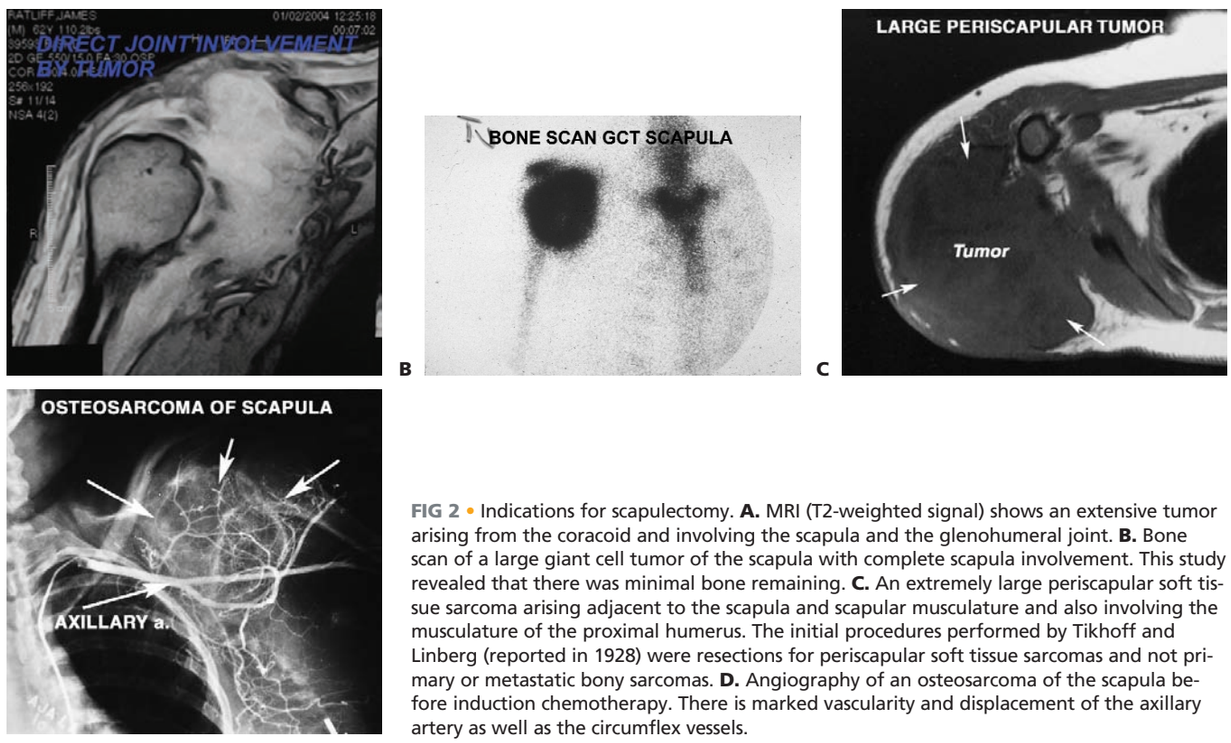

FIG 2 • Indications for scapulectomy. **A.** MRI (T2-weighted signal) shows an extensive tumor arising from the coracoid and involving the scapula and the glenohumeral joint. **B.** Bone scan of a large giant cell tumor of the scapula with complete scapula involvement. This study revealed that there was minimal bone remaining. **C.** An extremely large periscapular soft tissue sarcoma arising adjacent to the scapula and scapular musculature and also involving the musculature of the proximal humerus. The initial procedures performed by Tikhoff and Linberg (reported in 1928) were resections for periscapular soft tissue sarcomas and not primary or metastatic bony sarcomas. **D.** Angiography of an osteosarcoma of the scapula before induction chemotherapy. There is marked vascularity and displacement of the axillary artery as well as the circumflex vessels.

- A recurrent sarcoma that cannot be adequately resected without performing a forequarter amputation
- Presence of a displaced pathological fracture secondary to a sarcoma, which does not heal after preoperative chemotherapy

IMAGING AND OTHER STAGING STUDIES

Plain Radiography

- Plain radiography is often the first imaging modality in the diagnosis of tumors of the scapula. This will reveal most bony and some soft tissue involvement. The scapula can sometimes be difficult to visualize on plain radiographs because it is often obscured by the rib cage. Mineralization shown on plain radiographs may help categorize a bone sarcoma as either an osteosarcoma or chondrosarcoma.

Computed Tomography and Magnetic Resonance Imaging

- CT and MRI are the most valuable means of determining the size and extent of extraosseous disease and its relationship to the axillary vessels, glenohumeral joint, and chest wall (see Fig 1C–E).
- CT is extremely important for evaluating the rib cage. Subtle erosion of the rib cage by an adjacent scapula tumor is better visualized on a CT scan than an MRI. It is the best test for detecting subtle mineralization within tumors as well as for detecting subtle areas of scapular involvement by adjacent soft tissue sarcomas. Contrast-enhanced CT is particularly helpful for determining the proximity of the tumor to the axillary and brachial vessels and brachial plexus.
- MRI is most accurate for determining intraosseous and extraosseous tumor extent as well as for detecting skip metastases. An appreciation of the intraosseous extent is necessary for determining the length of bone resection. The proximal humerus is usually transected approximately 2 to 3 cm distal to the intramedullary extent of the neoplasm as visualized on a T1-weighted MRI image. The proximity of the extraosseous component to the axillary and brachial vessels and brachial plexus can also be evaluated.

Bone Scan

- A bone scan is helpful in identifying bony involvement of the proximal humerus or ribs in the regional area, and metastatic disease in the entire bony skeleton. Since the scapula is very thin throughout the major part of its body, the bone scan may not be as accurate as when evaluating the long bones for tumor extent.
- The bone scan should be correlated with an MRI.
- It is also used to detect bony metastases.
- The bone scan can also be beneficial when evaluating the chest wall and proximal humerus for local extension.

Angiography and Other Studies

- Angiography can determine vascular involvement and reveal any anomalies of the vascular anatomy. Displacement of the axillary vessels is indicative of anterior tumor extension into the axilla.
- Axillary venography is performed if there is any clinical suspicion of brachial plexus involvement, such as nerve pain or distal edema, the hallmarks of invasion of the brachial plexus. Occluded axillary veins seen on venography correlate with brachial plexus infiltration.

Biopsy

- We recommend fine-needle or core biopsies be performed under CT or fluoroscopic guidance in an attempt to protect the neurovascular bundle.
- One puncture site is required. The needle is then reintroduced through that site at various angles to obtain cores from several different regions of the tumor.
- The biopsy site should be placed along the intended incision site of the resection (**FIG 3**).
- A posterior needle biopsy is recommended for tumors arising within the body of the scapula; the anterior approach should be avoided to minimize the risk of soft tissue contamination by tumor.

Scapular Biopsies

- Biopsies of the scapular body are more difficult to perform than biopsies of the proximal humerus. They should be performed along the lateral or axillary aspect of the scapula and not along the vertebral (medial) border or directly posterior through any potential skin flaps.
- The biopsy site should be along the intended incision site of the resection. A posterior needle biopsy is recommended for tumors arising within the body of the scapula; the anterior approach should be avoided.

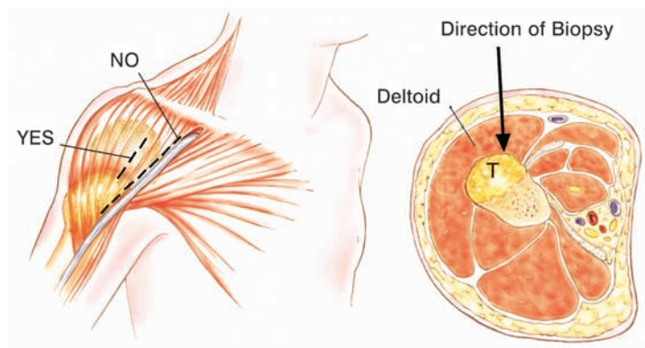

FIG 3 • Proper biopsy technique for tumors in the shoulder compartment. (Reprinted with permission from Bickels J, Jelinek JS, Shmookler BM. Biopsy of musculoskeletal tumors. Current concepts. Clin Orthop Relat Res 1999;368:212–219.)

- Biopsies of tumors in the lateral aspect of the scapula or glenoid region should be performed along the lateral or axillary aspect of the posterior scapula directly through the infraspinatus or teres minor muscles.

SURGICAL MANAGEMENT

Preoperative Planning

- All imaging studies, particularly CT, MRI, and angiography or venography, are reviewed before surgery to determine surgical resection type and feasibility.
- The patient is examined for distal edema and motor loss, which may indicate brachial plexus infiltration, an unresectable situation. The scapula should also move free from the chest wall, indicating that gross chest wall invasion is unlikely.
- Distal pulses are checked before surgery to ensure adequacy.
- The MRI and CT are reviewed to determine the proximity of the neoplasm to the brachial plexus and axillary vessels as well as to the chest wall. The soft tissue extent of the lesion is determined and a judgment is made about preservation of important periscapular muscles, essential for prosthetic reconstruction of the scapula. The arteriogram and venogram are also reviewed. Final determination of resectability and the use of a total scapula prosthesis, if the tumor is deemed resectable, is made intraoperatively.

Positioning

- The patient is placed in a lateral or semilateral position that permits access to the posterior aspect of the shoulder girdle all the way to the spinous processes. The affected extremity is prepared and draped free (**FIG 4A**).

Approach

- Most tumors of the scapula or periscapular soft tissues that require a total scapula resection are resected through a combined anterior and posterior approach. Most of these tumors have a large anterior soft tissue component that is juxtaposed to or that displaces the axillary vessels and brachial plexus.
- The anterior approach is crucial in these instances to explore and mobilize these structures away from the neoplasm so that a safe and adequate resection can be performed. The procedure uses both incision A (anterior extended deltopectoral incision) and incision B (posterior incision) of the utilitarian shoulder girdle incision (**FIG 4B**).
- Occasionally, a total scapula resection can be performed solely through a posterior approach for neoplasms that do not have an anterior soft tissue component. The surgeon must have a thorough knowledge of the course of axillary vessels, brachial plexus, and all of its branches to perform this procedure safely entirely through a posterior approach. If there are any uncertainties, then the procedure is most safely performed through a combined anterior and posterior approach.
- The axillary vessels and plexus are explored and mobilized anteriorly. This requires the pectoralis major to be detached and reflected for adequate exposure.
- The posterior incision permits the release of all muscles attaching to the scapula.
- The glenohumeral joint is removed extra-articularly. The osteotomy is performed below the level of the joint capsule.
- A scapular prosthesis is used if sufficient musculature remains; specifically, the deltoid, trapezius, rhomboids, and latissimus dorsi muscles are required for a prosthetic replacement.
- If there is not sufficient musculature after the resection, the remaining humerus is supported from the clavicle with Dacron tape (static suspension) and the conjoin tendon (dynamic suspension) and a pectoralis major rotational flap is also performed.

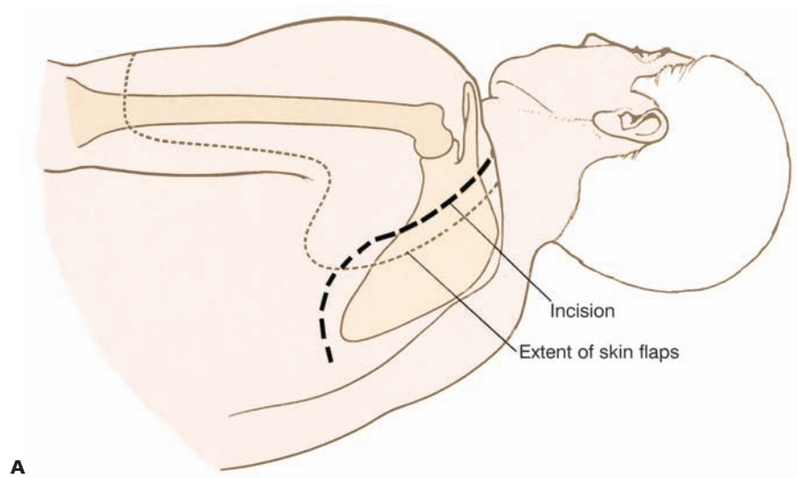

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FIG 4 • **A.** Patient positioning. *(continued)*

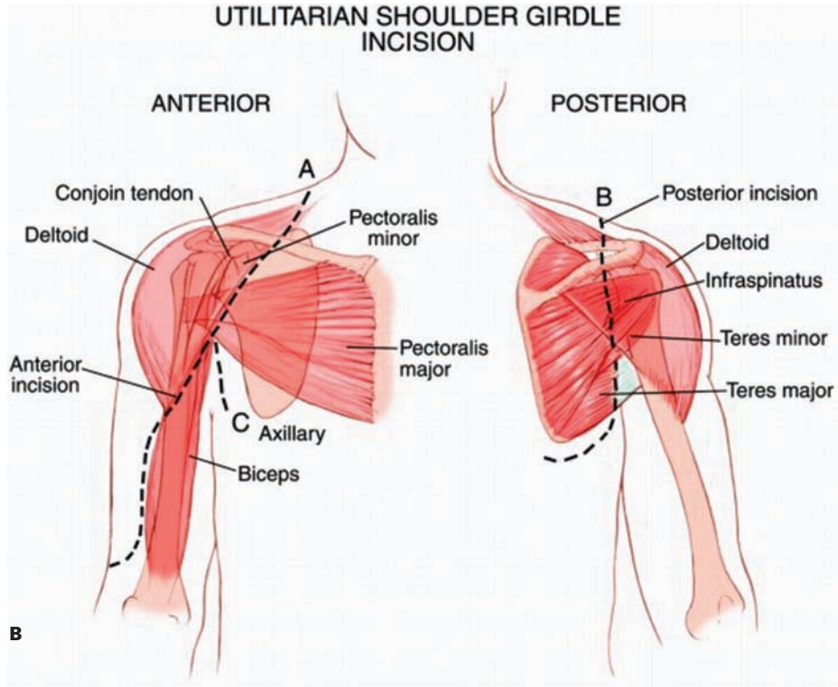
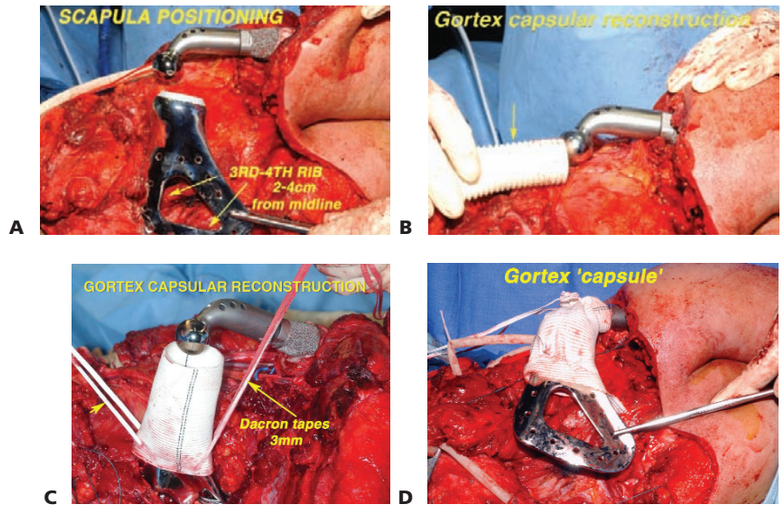


FIG 4 *(continued)* • **B.** Utilitarian incision of the shoulder girdle. Occasionally a scapula resection can be performed completely through the posterior incision; however, if there is a large anterior tumor extension with displacement of the axillary vessels or an extraosseous soft tissue component, it is much safer to proceed with an anterior approach similar to the proximal humeral resections.

TECHNIQUES

EXTRA-ARTICULAR TOTAL SCAPULA AND HUMERAL HEAD RESECTION (TYPE IV): THE TIKHOFF-LINBERG PROCEDURE[5]

- This procedure is an extra-articular en bloc resection of the scapula, glenohumeral joint and humeral head, and distal clavicle.
- Incision: A utilitarian anteroposterior approach is used.
- A large posterior fasciocutaneous flap is developed.
- The rhomboids and trapezius muscles are released from the vertebral border of the scapula and the latissimus dorsi muscle is mobilized but not transected.
- If the tumor does not involve the deltoid or the trapezius, the muscles are preserved and are reflected off the scapular spine and acromion. The classic Tikhoff-Linberg resection does not preserve the deltoid or trapezius muscles.
- An osteotomy below the humeral head (ie, a scapulectomy and extra-articular resection of the glenohumeral joint in conjunction with the scapula) is performed.
- Prosthetic reconstruction: If there are significant remaining muscles after a type IV shoulder girdle resection, then a scapula prosthesis is used[9] (**TECH FIG 1A**).
- The scapula prosthesis is fenestrated to permit the muscles to tenodese to themselves. It has holes drilled along the axillary and vertebral borders for fixation with Dacron tapes.
- The scapula prosthesis is sutured first to the rhomboid muscles with Dacron tape, and then the latissimus dorsi is rotated over the body of the scapula prosthesis and sutured along the vertebral border.
- The humeral component is then inserted into the osteotomized proximal humerus. A Gore-Tex graft is used to reconstruct the capsular mechanism (**TECH FIG 1B**).
- The Gore-Tex is sutured to the proximal humerus prosthesis and the glenoid neck on the scapula prosthesis with 3-mm Dacron tape (**TECH FIG 1C,D**).
- The muscle closure consists of tenodesis of the deltoid to the trapezius and the latissimus over the rhomboids and to the serratus anterior muscles. The scapula prosthesis fits between the serratus anterior and the latissimus dorsi and rhomboid muscles.
- The deltoid and trapezius muscles have been preserved and are tenodesed together. The latissimus dorsi is rotated up to the lower border of the deltoid and to the rhomboid muscles.
- The latissimus is sutured to the holes in the axillary border of the scapula prosthesis and the adjacent musculature using Dacron tape and Ethibond sutures, respectively.

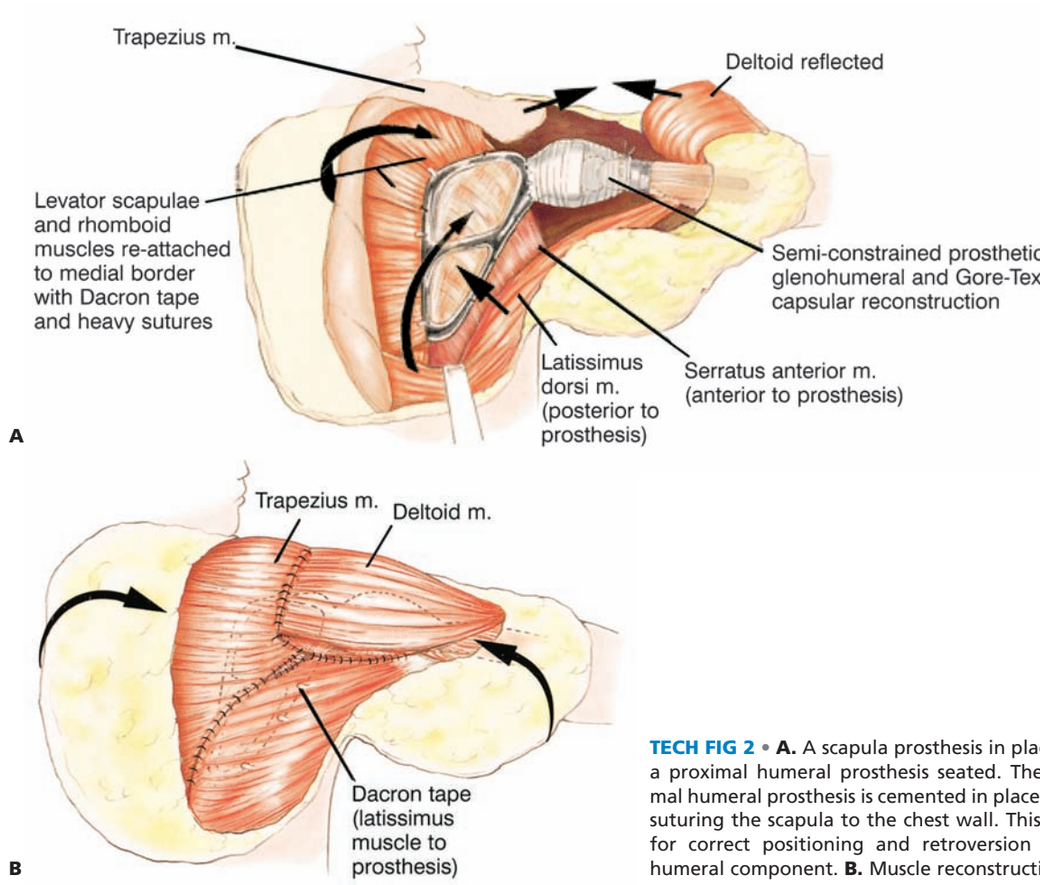


TECH FIG 1 • **A–D.** A scapula prosthesis in place with a proximal humeral prosthesis seated. The proximal humeral prosthesis is cemented in place before suturing the scapula to the chest wall. Technique of Gore-Tex capsule reconstruction. Reconstruction of an artificial capsule is essential for appropriate function and stability. Even though the third-generation scapular prosthesis offers a "snap-fit," it can dislocate due to the continuous traction forces caused by the weight of the arm. Muscle reconstruction is completed by rotating the latissimus dorsi over to the rhomboids and the trapezius to the deltoid. All of these muscles are then tenodesed to themselves.

INTRA-ARTICULAR SCAPULAR RESECTION (TYPE III)

- This resection is an intra-articular total scapulectomy. It is most commonly performed for soft tissue sarcomas that secondarily invade the scapula.
- A posterior and anterior incision is used, respectively.
- The posterior deltoid is released from the acromion and scapular spine. The trapezius muscle is released and retracted.
- The rhomboid muscles are released starting at the inferior angle of the scapula.
- The tip is then elevated and the scapula is retracted away from the chest wall as muscle release continues medially, laterally, and then superiorly to permit visualization of the axilla and chest wall.
- The inferior tip of the scapula is rotated, and traction is applied with the arm abducted. The axillary contents are gently retracted.
- The neurovascular structures are approached from the back, unless the tumor has an anterior extraosseous component.
- The neurovascular structures are visualized as the scapula is retracted away from the chest wall.
- The infraspinatus and supraspinatus muscles are transected and the joint is entered.
- The anterior capsule and the subscapularis tendon are transected.
- The long head of the biceps is identified, tagged with suture, and divided.
- The acromioclavicular joint is entered and released or the distal portion of the clavicle is resected with the specimen.
- As the scapula is gently elevated, the short head of the biceps and the coracobrachialis and pectoralis minor muscles are released from the coracoid.
- The musculocutaneous nerve must be protected as it passes near the coracoid.
- The dual suspension technique using Dacron tape to suspend the proximal humerus from the clavicle can be used.
- Dacron tape (3-mm) is used to suspend the remaining humerus from the distal clavicle. The biceps, coracobrachialis, and triceps are reattached through drill holes in the distal clavicle.
- If the deltoid muscle has been preserved, it is tenodesed anteriorly to the pectoralis major and trapezius muscles to further reconstruct the anterior aspect of the shoulder girdle.
- If adequate musculature remains, a total scapular prosthesis (see Tikhoff-Linberg Techniques) can be used to reconstruct the defect (**TECH FIG 2**).
- There are two major pairs of muscles that must be reconstructed: the trapezius muscle to the remaining portion of the deltoid (this is tenodesed over the superior third of the prosthesis and glenohumeral joint) and then the rhomboid muscles to the prosthesis (covered by the transfer of the latissimus dorsi from its origin). This forms a nice pocket for the prosthesis to sit in between the latissimus dorsi and rhomboids and against the serratus anterior and chest wall.

TECHNIQUES



TECH FIG 2 • **A.** A scapula prosthesis in place with a proximal humeral prosthesis seated. The proximal humeral prosthesis is cemented in place before suturing the scapula to the chest wall. This allows for correct positioning and retroversion of the humeral component. **B.** Muscle reconstruction.

PEARLS AND PITFALLS

Preoperative evaluation	■ MRI and CT are important for evaluating the proximity of the tumor to the neurovascular structures, chest wall invasion, and involvement of other key muscles around the scapula.
Resection	■ Most total scapula resections (extra-articular and intra-articular) are performed through an anterior and posterior approach. This is the safest method when a large anterior soft tissue component exists.
Exposure of neurovascular structures	■ The axillary vessels and brachial plexus are best exposed through an anterior approach (extended deltopectoral incision) that involves releasing the pectoralis major muscle from its humeral insertion and the coracobrachialis muscle and the short head of biceps and pectoralis minor muscle from their coracoid attachments.
Posterior exposure and exploration	■ During the posterior portion of the resection it is important to preserve the periscapular muscles, which are crucial for prosthetic reconstruction, if possible. These muscles include the rhomboids, trapezius, deltoid, serratus anterior, and latissimus dorsi muscles. The axillary nerve must also be preserved.
Prosthetic reconstruction	■ A small scapular component is used if it will facilitate better soft tissue coverage. The humeral component is chosen to allow for up to 2 cm of shortening of the extremity, which also facilitates soft tissue closure. A constrained total scapula is preferred. A Gore-Tex aortic graft is used to reconstruct the glenohumeral joint capsule. The scapula prosthesis is positioned as medial as possible (1 to 2 cm away from the spine) in a pocket between the rhomboids and serratus anterior muscles. The deltoid and trapezius muscles are retensioned as they are sutured to each other and to the prosthesis. The latissimus provides final coverage of the prosthesis. At the conclusion of the procedure, the entire prosthesis must be thoroughly covered with muscle.
Postoperative care	■ The patient is kept in a brace for 6 weeks with the arm abducted 45 to 60 degrees and the elbow flexed 45 degrees.

POSTOPERATIVE CARE

- Epineural catheters are routinely used with a continuous bupivacaine (4 to 8 mL of 0.25% bupivacaine) infusion for 3 to 5 days.
- A special brace is recommended for 6 weeks postoperatively that will hold the arm in 45 to 60 degrees of abduction and the elbow flexed 45 degrees.
- Postoperatively, a sling is required for 4 to 6 weeks.
- In the immediate postoperative period the patient is instructed on motion exercises for the wrist and hand, and elbow flexion is encouraged within the confines of the sling.
- Neck motion and shoulder elevation exercises are instituted within 1 to 2 days after surgery.
- Once the incision has healed and the sutures are removed, at 2 to 4 weeks after surgery, pendulum exercises and gentle shoulder motion (flexion, extension, internal and external rotation) are done with the help of a family member or physical therapist.
- Elbow flexion, extension, supination, and pronation are also performed.
- Gentle strengthening is instituted once motion has returned, with the use of active motion and isometric exercises and light weights (2 to 10 pounds). At 12 weeks postoperatively, strengthening is initiated with Thera-Bands and other resistance exercises up to a 10-pound weight limit. Ultimately the patient is restricted to a 15- to 20-pound weight limit.
- Long-term weightlifting restrictions of less than 20 pounds are generally recommended.

OUTCOMES

- Prosthetic reconstruction of the scapula is a very reliable method of reconstruction after an intra-articular or extra-articular resection of the scapula.
- All patients have a painless, stable shoulder girdle and functional use of the hand and elbow. Rotation below the shoulder is preserved and ranges from −10 degrees of external rotation to T6 for internal rotation.[1,8] Internal rotation, adduction, and extension strength are virtually normal.
- Active forward elevation and abduction (combined glenohumeral and scapulothoracic motion) range from 25 to 45 degrees and are grade 3 to 4 in terms of motor strength.
- Scapular protraction, retraction, and elevation are restored. These muscles participate in stabilizing the upper extremity when lifting objects. Patients can lift and carry objects up to 20 pounds. Most patients can perform push-ups. Upper extremity strength is better than when the shoulder is left flail or the remaining humerus is suspended from the clavicle. The Musculoskeletal Tumor Society Score for Upper Extremity Function ranges from 24 to 27 out of 30 points (80% to 90%) (**FIG 5**).
- Elbow, wrist, and grip strength are normal in all patients.
- All patients can reach the tops of their heads, opposite shoulder and armpit, and perineal area with their hand. There are no limitations in activities of daily living, including feeding, dressing, and personal hygiene. Lifting ability is normal with the arm at the side of the body. Cosmesis is acceptable.
- The major limitations have been with recreational activities and other activities that require the arm to be lifted above the shoulder level.

COMPLICATIONS

- Complications from a prior biopsy with extensive contamination of tissues may make a limb-sparing scapular resection inadvisable; therefore, an appropriately placed and performed biopsy must occur.

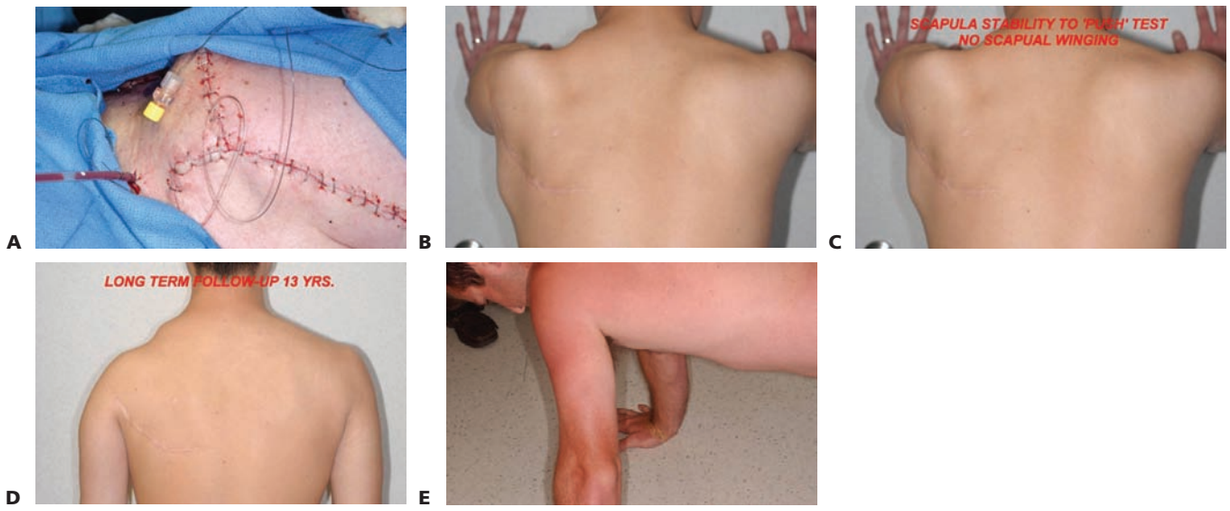


FIG 5 • **A.** Wound closure with good approximation and no tension. The perineural catheter is placed into the brachial plexus sheath before wound closure. This provides excellent postoperative anesthesia with minimal sensory deficit when 0.25% bupivacaine is used. **B.** Posterior view of a scapular prosthesis 13 years after reconstruction. Quite impressive symmetry has been attained when comparing the operative and contralateral sides. **C.** Push test, which is designed to test the rhomboids, serratus anterior, and latissimus dorsi. There is minimal winging of the scapula. In addition, the cosmetic effect of retaining the trapezius and the deltoid is impressive and evident. **D,E.** Patient performing a push-up. Great strength and stability of the shoulder girdle is seen here. This stability permits the patient to place the hand in three dimensions in space, the anatomic function of the normal shoulder girdle. Hand and elbow function is normal after these resections. It is extremely rare to have to resect any chords of the brachial plexus, which would result in loss of function of the distal portion of the arm.

- If the deltoid muscle cannot be preserved, a scapular prosthesis may not be used.
- Loss of function of activities above the level of the shoulder girdle should be anticipated: the goal of this surgery is to permit good use of the hand and elbow.
- Skin necrosis occurs rarely. Dislocation of the reconstructed scapular mechanism is rare. In less than 5% of patients, glenohumeral dissociation occurs; it can usually be treated conservatively.

REFERENCES

1. Bickels J, Wittig JC, Kollender Y, et al. Limb-sparing resections of the shoulder girdle: a long-term follow-up study. J Am Coll Surg. 2002; 194:422–435.
2. De Nancrede CBG. The end results after total excision of the scapula for sarcoma. Ann Surg 1909;50:1.
3. Linberg BE. Interscapulo-thoracic resection for malignant tumors of the shoulder girdle region. J Bone Joint Surg 1928;10:344.
4. Liston R. Ossified aneurysmal tumor of the subscapular artery. Edinb Med J 1820;16:66–70.
5. Malawer MM. Tumors of the shoulder girdle: technique of resection and description of a surgical classification. Orthop Clin North Am 1991;22:7–35.
6. Marcove RC, Lewis MM, Huvos AG. En bloc upper humeral interscapulo-thoracic resection. Clin Orthop Relat Res 1977;124:219–228.
7. Syme J. Excision of the Scapula. Edinburgh: Edmonston & Douglas, 1864.
8. Ward B, McGarvey C, Loetz M. Excellent shoulder function is attainable after partial or total scapulectomy. Arch Surg 1990;125:537–542.
9. Wittig JC, Bickels J, Wodajo F, et al. Constrained total scapula reconstruction after resection of a high-grade sarcoma. Clin Orthop Relat Res 2002;397:143–155.