Chapter 13

Axillary Space Exploration and Resections

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BACKGROUND

- The axilla is a common site for primary soft tissue sarcomas as well as for metastatic disease that involves the axillary lymph nodes, such as advanced breast cancer or melanoma.
- Sarcomas typically arise from the muscles defining the axillary space (FIG 1). Occasionally, however, they may arise directly from the brachial plexus or axillary vessels (eg, malignant peripheral nerve sheath tumors, neurosarcoma, leiomyosarcoma). Several types of malignant tumors may involve the axillary space and may require surgical resection. Primary sarcomas occur within the muscles (ie, the pectoralis major, latissimus dorsi, teres major, and subscapularis muscles) that make up the borders of the axillary space. Rarely do they develop within the axillary fat itself. More commonly, large metastatic deposits to the regional lymph nodes create large, matted masses that may require resection. The most common of these are metastatic melanoma and recurrent breast carcinoma. In addition, there are primary tumors that arise from the brachial plexus, either the nerves or the vessels. These include leiomyosarcomas of the axillary vein and neurofibrosarcomas of the adjacent nerves.
- Small masses may be clinically silent, but large masses inevitably will result in significant pain or loss of function due to involvement of the brachial plexus.
- Venous occlusion may be seen in neglected, massive tumors and is a harbinger of loss of limb and possibly even of life due to gangrene.
- Historically, surgical management of tumors in this location consisted of forequarter amputation; advances in radiographic imaging, adjuvant therapies, and surgical techniques have greatly improved our ability to perform limb-sparing resections in this location. The key to adequate and safe surgical resection of axillary tumors is the complete visualization and mobilization of the infraclavicular portion of the brachial plexus and the axillary artery and vein and the cords that surround them. In general, imaging studies of the axillary space are not reliable for determining vascular or nerve sheath involvement. Multiple imaging studies are required, but the ultimate decision to proceed with a limb-sparing surgery is based on the intraoperative findings at the time of exploration.
- Axillary tumors extending along the chest wall often can be elevated off the underlying ribs; however, tumor extension into the intercostal spaces may require thoracotomy and rib resection to ensure adequate margins.

ANATOMY

- The axilla is a pyramid-shaped space between the chest wall and the arm defined by its surrounding muscles; it appears triangular when seen from either the coronal or axial views.
- The superior apex of the pyramid is formed by the junction of the clavicle and the first rib, approximately 1 to 2 cm medial to the coracoid process.
- The muscular boundaries of the axilla consist of the pectoralis major muscle anteriorly; the subscapularis, teres major, and latissimus dorsi muscles posteriorly; and the coracobrachialis, short head of the biceps, and triceps muscles laterally.
- Vital structures in the axilla include the major branches of the infraclavicular portion of the brachial plexus and the axillary vessels. Any surgery in this region requires detailed knowledge of and familiarity with these structures.
- Infracavicular brachial plexus
  - The lateral, posterior, and medial cords of the infraclavicular brachial plexus are found at the level of the pectoralis minor muscle, where they then give rise to five major branches: the median, ulnar, radial, musculocutaneous, and axillary nerves. The cords and branches run along the axillary vascular sheath as it passes through the axilla.
  - The lateral cord gives rise to the musculocutaneous nerve, which travels along the medial aspect of the conjoint tendon, where it innervates the coracobrachialis and short head of the biceps. This nerve is the first to be identified during the exploration, because it is located in the superficial axillary fat inferior to the coracoid process. The largest portion of the lateral cord combines with the medial cord to create the median nerve.
  - The posterior cord gives rise to the axillary nerve, which travels deep in the space and passes inferior to the glenohumeral joint and subscapularis muscle, where it innervates the deltoid muscle. The main portion of the posterior cord becomes the radial nerve, which travels posterior to the sheath and exits the axillary space along with the axillary sheath.
  - The medial cord gives rise to the ulnar nerve, which travels along the most medial aspect of the sheath and exits distally along with the sheath. Because of its medial position along the sheath, the ulnar nerve is the nerve most commonly involved by tumors arising inferior to the brachial plexus, which can present with symptoms of either weakness or neuropathic pain. The median nerve, formed by a combination of the lateral and medial cords, is found on the lateral aspect of the sheath and exits the inferior aspect of the axillary space along the sheath.
- Axillary vessels
  - The axillary artery and vein are the continuation of the subclavian vessels, changing name as they enter the apex of the axilla below the clavicle and first rib. These vessels run in a single sheath, surrounded by the cords of the brachial plexus. The vessels pass through the axillary space medial to the coracoid to the medial aspect along the humeral shaft. Distal to the teres major, the vessels are renamed the brachial vessels. Major vascular branches in the axillary space include the thoracocromial artery (with its pectoral, deltoid, clavicular and acromial branches), the lateral thoracic artery, the subscapular artery, and the anterior and posterior humeral circumflex vessels.
Lymphatics
- A substantial amount of fat surrounds the vascular sheath as it runs through the axilla along with the lymphatics and lymph nodes. Major clusters of lymph nodes are found along the brachial and axillary vessels, the lateral thoracic vessels (anterior axillary nodes), and the subscapular vessels (posterior axillary nodes). Axillary tumors may arise from lymph node metastases anywhere along the axillary vessels; the most common sites are nodes along the distal portion of the axillary vessels.

INDICATIONS
- Any mass in the axillary space should be considered for biopsy or resection given the propensity for malignant tumors to develop in the axilla and the predictability of neurogenic pain arising from continued tumor growth.
- Palpate radial and ulnar pulses and inspect for venous congestion or swelling. Consider venography to evaluate loss of venous drainage indicative of tumor involving the brachial plexus.
- Diminution of arterial flow is a late sign indicative of potential loss of limb—consider forequarter amputation.
- Test sensation and strength of the axillary, radial, median, and ulnar nerves. Loss of nerve function typically is a very late finding indicative of major tumor involvement of the brachial plexus—consider forequarter amputation.

IMAGING AND OTHER STAGING STUDIES
- Three-dimensional imaging of the axillary space is important for accurate anatomic tumor localization and surgical planning. CT, MRI, angiography, and three-phase bone scans are used in the same manner as in other anatomic sites. In addition, we have found that venography (of the axillary and brachial veins) is essential to the evaluation of tumors of the axilla and brachial plexus.

Plain Radiography
- Careful inspection of posterior—anterior chest, anterior shoulder, and axillary view radiographs may reveal the presence of increased soft tissue density corresponding to an axillary mass.
- Bone involvement and the presence of calcifications in the soft tissues should be noted.

Computed Tomography and Magnetic Resonance Imaging
- Multiplanar MRI is extremely helpful in visualizing the anatomic contents of the axillary space and defining the anatomic extent of the tumor (FIG 2A–C).
- Axial CT imaging, with administration of IV contrast, demonstrates the major vascular structures, outlines the major muscle planes, and can detect subtle matrix formation within the tumor. CT is most useful in evaluating the bony walls of the axilla, specifically the humerus, glenohumeral joint, and scapula (FIG 2D).
- Certain tumors, such as lipomas or hemangiomas, may have characteristic findings on T1- and T2-weighted MRI sequences suggestive of the proper histologic diagnosis. The presence or absence of lymphatic involvement should be noted, particularly in patients with a history of metastatic carcinoma.
- Although the brachial plexus may be very difficult to visualize, particularly when tumors distort or compress the surrounding fatty planes, the anatomic relationship of the nerve sheath to the vessels helps pinpoint their location.
- Although CT imaging of the lungs is routinely performed as part of patient staging, the chest wall should always be inspected carefully to rule out tumor involvement of the rib cage and pleural cavity.

Nuclear Imaging
- Positron emission tomography (PET) imaging, particularly when fused with MRI or CT imaging data, may significantly improve the ability to detect lymphatic spread of tumor in and around the axilla. Standardized uptake values (SUV) correlate
with tumor metabolism and may help to distinguish between benign and malignant lesions.

**Angiography and Other Studies**

- Angiography remains a valuable method of imaging the axilla, particularly for preoperative planning, because tumors may significantly distort the regional vascular anatomy through mass effect as well as through angiogenesis (ie, formation of abnormal vessels feeding the tumor; **FIG 3**). Venography, either alone or in conjunction with angiography, can demonstrate venous compression from surrounding tumors. The axillary arterial wall is thick and rarely shows signs of occlusion, whereas the axillary vein is a thin-walled structure that is easily compressed and infiltrated by tumor. Therefore, occlusion is almost synonymous with involvement of the vascular sheath and brachial plexus. Venous occlusion, visualized as absent filling of the axillary vein, is characteristic of significant tumor involvement of the brachial plexus and warrants careful thought as to whether a limb-sparing procedure is possible. The triad of axillary venous occlusion, distal motor weakness, and neuropathic pain is a very reliable predictor of tumor infiltration of the brachial plexus sheath.

- Infraclavicular brachial plexus and vascular exploration is mandatory before resection is attempted. Tumor involvement of these structures usually indicates that a forequarter amputation is required.

**Biopsy**

- Core needle biopsy is the preferred method of diagnosis, because it minimizes risk of injury and contamination of the axillary contents. If a metastatic lesion is suspected, fine needle aspiration is the most appropriate means to identify carcinoma cells.

- Large or superficial palpable masses are amenable to needle biopsy in the clinic, whereas deep lesions are best approached with radiographic guidance using CT or ultrasound.

- The biopsy tract should be positioned after consultation with the treating surgeon to ensure proper location along the path of planned resection. The biopsy should be performed through the base of the axillary space, not through the pectoralis major muscle or near the vascular sheath. It can easily be performed under CT guidance. Deep-seated lesions near the chest wall also can be approached in this manner. Anterior lesions, on occasion, can be approached through

**FIG 2** Imaging studies of the axillary space. **A.** T2-weighted MRI scan showing a large mass (arrow) occupying the axillary space. **B.** Coronal T2-weighted MRI scan showing a large tumor below the pectoralis major that fills the entire axillary space, from the clavicle to the lower end of the base of the pyramid that forms the axillary space. **C.** Axial MRI scan of a large fungating tumor from the axillary space. There are no muscle or skin components adjacent to the tumor, which protrudes anteriorly. **D.** CT scan of a primary bony sarcoma with a large extraosseous component that extends into the axilla. This finding is an excellent indication for the use of the anterior portion of the utilitarian incision for resections of large tumors of the proximal humerus. It demonstrates that the axillary space must be completely visualized and that the vessels must be mobilized.

**FIG 3** Schematic representation of an axillary tumor with its relationship to the axillary sheath. **A.** The tumor does not involve the sheath but it displaces the artery, vein, and accompanying nerves. **B.** The tumor has invaded the axillary sheath, occluding the axillary vein. This is a significant finding on venography that almost always indicates vascular infiltration. **C.** Axillary venogram performed and shows complete occlusion of the axillary vein (red line). Collateral filling is seen around the mass. Obliteration of the vein almost always indicates infiltration of the infraclavicular plexus. **D.** Gross specimen following forequarter amputation showing tumor infiltration around the nerves and cords of the brachial plexus and surrounding the axillary artery and vein.
the lower portion of the pectoralis major muscle. The biopsy site must be removed in its entirety during resection of the tumor.

- Open biopsy should be reserved for those patients in whom core needle biopsy was nondiagnostic or in those cases when additional samples of tumor are necessary for research purposes. Great care must be taken to avoid contamination of critical structures and otherwise uninvolved tissue planes. A small laterally placed incision, avoiding the pectoralis major muscle and the axillary sheath, is recommended.

- Although small tumors are amenable to excisional biopsy, care must be taken to remove the entire pseudocapsule in the event that the tumor is found to be a sarcoma.

**SURGICAL MANAGEMENT**

- Although many patients can safely undergo limb-sparing resections of the axillary space, extremely large or neglected tumors may present with significant involvement of the axillary vessels and brachial plexus.

- Evidence of vascular involvement and, therefore, nerve sheath invasion should raise the question as to whether the patient is suitable for a limb-sparing resection; forequarter amputation may be necessary.

- Proper placement of the biopsy tract is critical in limiting potential injury or contamination of the axillary space; large, poorly planned open biopsy tracts may necessitate forequarter amputation.

- Adjuvant radiation to the axilla carries an increased risk of significant lymphedema, which can be functionally disabling, as well as potential wound problems.

**Preoperative Planning**

- Careful review of preoperative imaging studies is necessary to formulate a surgical plan.

- Extent of resection is determined by tumor size and stage and whether a palliative or curative option exists.

- Consideration should be given to preoperative angiography or venography when vascular involvement is suspected on the basis of CT or MRI scans.

- A double-lumen endotracheal tube should be used whenever preoperative imaging suggests significant rib involvement. Deflation of the underlying lung protects the lung during the rib resection.

**Positioning**

- Positioning of the patient for axillary resection is determined by the size and anatomic extent of the tumor to be removed.

- Most axillary tumors are best approached via an extensile anterior incision with the patient in the supine position. The patient is brought to the edge of the table, and a large padded bump is placed under the medial portion of the scapula to facilitate exposure. After prepping and draping the arm, axilla, and anterior shoulder girdle, the arm is placed over a padded Mayo stand, and the surgeon stands inside the axilla for the procedure. The surgical assistant is best placed superior to the arm to facilitate retraction.

- Less commonly, the posterior or inferior portion of the axilla is involved, requiring access to the back of the axilla and shoulder girdle. When this is the case, the patient should be placed in the lateral decubitus position so that the entire shoulder girdle may be easily accessed. The arm is elevated over the patient’s head and supported by an assistant to permit access to the axilla. The surgeon should stand anterior to the patient, closest to the brachial plexus.

**Approach**

- Anterior/medial utilitarian approach. The most commonly used approach for axillary resections is the common extensile approach to the shoulder girdle and arm, running along the deltopectoral groove. As the pectoralis major comprises the anterior anatomic boundary of the axilla, release of its broad tendon insertion into the humerus is vital to proper exposure of the axillary contents (FIG 4).
The traditional incision along the inferior boundary of the axilla offers a very limited view of the axillary contents and makes identification of the brachial plexus difficult. This incision is best used only for patients with tumor limited to the chest wall (inferior axillary resection) or posterior (latissimus) axilla.

A combination of the traditional axillary incision with the anterior extensile incision may be performed by extending the skin incision across the pectoralis muscle, meeting the anterior incision near the coracoid process (FIG 5). This is useful in the salvage of patients having attempted resections or open biopsies through the inferior axilla.

**FIG 5** • Surgical technique of exposure and resection of axillary tumors. **A.** The anterior portion of the utilitarian shoulder girdle incision is used. This is an extended deltopectoral incision, which may be curved in a posterior direction toward the axilla. The pectoralis major is then released 1 cm from its insertion onto the humerus. This is the first layer of axillary space musculature. **B.** Operative photograph showing the second muscle layer. The short head of the biceps and the pectoralis minor attach to the coracoid. The axillary contents with the vessels and nerves are not seen, because they are enclosed within the axillary fat and fascia. **C.** The musculocutaneous nerve is found 1 to 2 cm distal to the coracoid, below the insertion of the pectoralis minor and adjacent to the short head of the biceps. This nerve must be identified before the second layer of muscles is released. **D,E.** Resection bed following removal of the tumor of the axillary space. It is necessary to begin at the level of the clavicle and ligate all branches that pass distal and inferior to the tumor mass. Most tumors arise inferior to the neurovascular bundle.

**Axillary Exploration Through Anterior Approach**

- Identify landmarks.
  - Palpate and mark the bony landmarks: coracoid process, acromion, acromioclavicular joint.
  - Palpate the groove between the deltoid and pectoralis muscles.
- Incision
  - The skin incision should extend along the deltopectoral groove to the coracoid process and may curve into the axilla as needed. Open this interval, sparing or ligating the cephalic vein as necessary.
  - Detachment of pectoralis major (TECH FIG 1)
    - Identify the pectoralis major insertion into the humeral shaft and release using the electrocautery approximately 1 cm from the bone to preserve enough insertion for later repair. After the pectoralis major is fully released from the humerus, retract the muscle medially over the anterior chest wall, preserving its vascular pedicles and exposing the serratus anterior.
- Development of anterior axillary fascial plane
  - Develop the surgical plane along the clavipectoral fascia, which is a thick, well-defined layer that contains the axillary space and structures.
- Release of conjoint tendon and pectoralis minor
  - Palpate the conjoint tendon insertion at the coracoid process and release. Protect the musculocutaneous nerve inserting into the muscle belly just distal to the tendon from the underlying brachial plexus by limiting distal retraction. Release of these muscles is key to exposing the vascular sheath and brachial plexus.
**Neurologic exploration**
- Identify the sheath of the brachial plexus and axillary vessels underneath the detached conjoint tendon. The musculocutaneous nerve comes around the lower border of the coracoid under the pectoralis minor muscle. The axillary nerve comes off deeper from the posterior cord and travels toward the shoulder joint. Both must be identified at this stage.

**Vascular exploration**
- Completely exposure and control the axillary vessels and brachial plexus proximally by opening the pedicle sheath and placing loops around the major structures; careful dissection is then used to mobilize these structures distally into the arm. Mobilization often is necessary to facilitate adequate exposure prior to tumor resection.

**Resection of tumor**
- All of the feeding branches entering into the mass are serially ligated and transected. Axillary fat is left around the tumor mass as the only true margin. The tumor is removed, tagged for orientation, and sent to pathology for margins and histologic evaluation.

**Lymphatic involvement**, frequently seen in patients with breast cancer extending into the axilla, requires meticulous dissection of the axillary and subclavian vessels proximally; sampling of lymph nodes is crucial in patient with carcinomas or melanoma.

**Resection of Posterior Axillary Tumors**
- Further exposure of the axilla is achieved by extending the vascular and neurologic exploration further down the arm, widening the area to reach posterior or distal tumors (TECH FIG 2).
- Identify the latissimus insertion into the humerus, which defines the posterior aspect of the axilla distal and posterior to the pectoralis insertion.
- Before performing tendon release, identify and protect the axillary nerve proximal to and the radial nerve distal to the tendon; both nerves serve to tether the brachial plexus and reduce the ability to retract the plexus.
- Tumor involvement of the latissimus may require sacrifice of one or both of these nerves.
- The latissimus muscle may be elevated off the chest wall as necessary for tumor resection.
- Chest wall involvement may require thoracotomy and resection of contiguous ribs; deflate the lung before opening the chest cavity to protect the underlying lung.
- Intrathoracic extent of tumor may be determined by palpation of the pleural surface following thoracotomy. Osteotomy of the ribs using a rib cutter under direct visualization permits en bloc removal of the involved chest wall.

**Reconstruction Following Tumor Resection**
- Repair and reconstruction of the axilla is necessary following tumor resection.
- Insertion of an epineural catheter into the sheath of the brachial plexus permits postoperative administration of local anesthetics such as bupivacaine (Marcaine) to minimize postoperative pain.

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**TECH FIG 1**
- **A.** Schematic diagram of the muscles of the anterior aspect of the axillary space being released to expose a large underlying axillary tumor. Two layers of muscles are encountered: the pectoralis major muscle and the pectoralis minor with the short head of the biceps. Both layers attach to the coracoid. The musculocutaneous nerve must be mobilized before the second layer of muscle is detached. **B.** Operative photograph taken following removal of a large axillary tumor shows all of the muscles of the axillary space, the axillary sheath, and corresponding cords of the brachial plexus.
Reattachment of the conjoint tendon and pectoralis minor to the coracoid with the use of mattress, nonabsorbable sutures covers the brachial plexus and axillary vessels.

Defects of the chest wall can be covered with local rotation flaps using the latissimus dorsi or pectoralis major muscle, which may be tenodesed to the subscapularis tendon as needed.

Careful wound closure over closed suction drains and placement of absorbent padding in the axilla reduce the risk of skin maceration and wound infection. Use of a sling or shoulder immobilizer permits early mobilization of the patient.

Functional deficits resulting from resection of portions of the brachial plexus may require delayed reconstruction after completion of adjuvant treatment.

**PEARLS AND PITFALLS**

<table>
<thead>
<tr>
<th>Preoperative angiogram and venogram</th>
<th>In addition to mapping out the course of the vessels, loss of flow through the brachial or axillary vein is a worrisome sign that tumor involves the brachial sheath. This often is the first sign of an unresectable tumor (FIG 6) for which forequarter amputation should be considered</th>
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<tr>
<td>Axillary incision</td>
<td>The axillary incision is not easily extended and severely restricts the ability to dissect out the neurovascular bundle. This incision is rarely indicated.</td>
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<tr>
<td>Pectoralis major</td>
<td>Detachment of the humeral insertion is key to opening up the entire axilla and permits exploration of all important structures. It is not necessary to reattach the pectoralis to its insertion; rotation of this muscle is valuable for reconstruction of defects around the shoulder.</td>
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<tr>
<td>Musculocutaneous nerve</td>
<td>Injury due to over-retraction of the conjoint tendon may occur, leading to loss of elbow flexion and resulting disability. This may be unavoidable for tumors involving the conjoint tendon.</td>
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**FIG 6** • Unresectable sarcoma of the axilla. A. Multiple recurrences with a large soft tissue mass. B. Operative view through the anterior incision showing a large tumor surrounding the axillary sheath.
POSTOPERATIVE CARE
- Postoperatively, a sling or shoulder immobilizer is applied to support the arm. Closed suction drains are removed after output slows.
- Patients are mobilized on postoperative day 1, from bed to chair. Ambulation is begun as tolerated to improve pulmonary function.
- A sling is used until the skin wound is sufficiently healed.
- Early shoulder motion with assistance is started as soon as the wound permits.
- Aggressive wrapping of the arm and use of custom-fitted compression gloves is started if there is evidence of lymphedema.

OUTCOMES
- Functional outcome is determined by the amount of muscle resection and loss of particular nerves.
- Loss of shoulder motion results in mild disability, which is easily compensated for by use of the other arm for overhead activities.

COMPLICATIONS
- Although uncommon, the complication most often seen following axillary resection is the accumulation of third-space fluid with secondary wound problems. Previous radiation therapy increases this probability. Use of suction drains and compressive dressings helps mitigate this complication.
- Chronic pain may occur following nerve resection, especially after radiation. Use of nerve sheath catheters with postoperative infusion of local anesthetics may reduce the incidence of neuropathic pain.
- Lymphedema may result in significant disability and chronic pain; early aggressive treatment may lessen the severity or duration of swelling. The risk is greatest following surgery and radiation therapy.
- Infections and flap necrosis following axillary tumor resections rarely occur, because of the substantial network of subcutaneous blood vessels perfusing the shoulder girdle.

REFERENCES