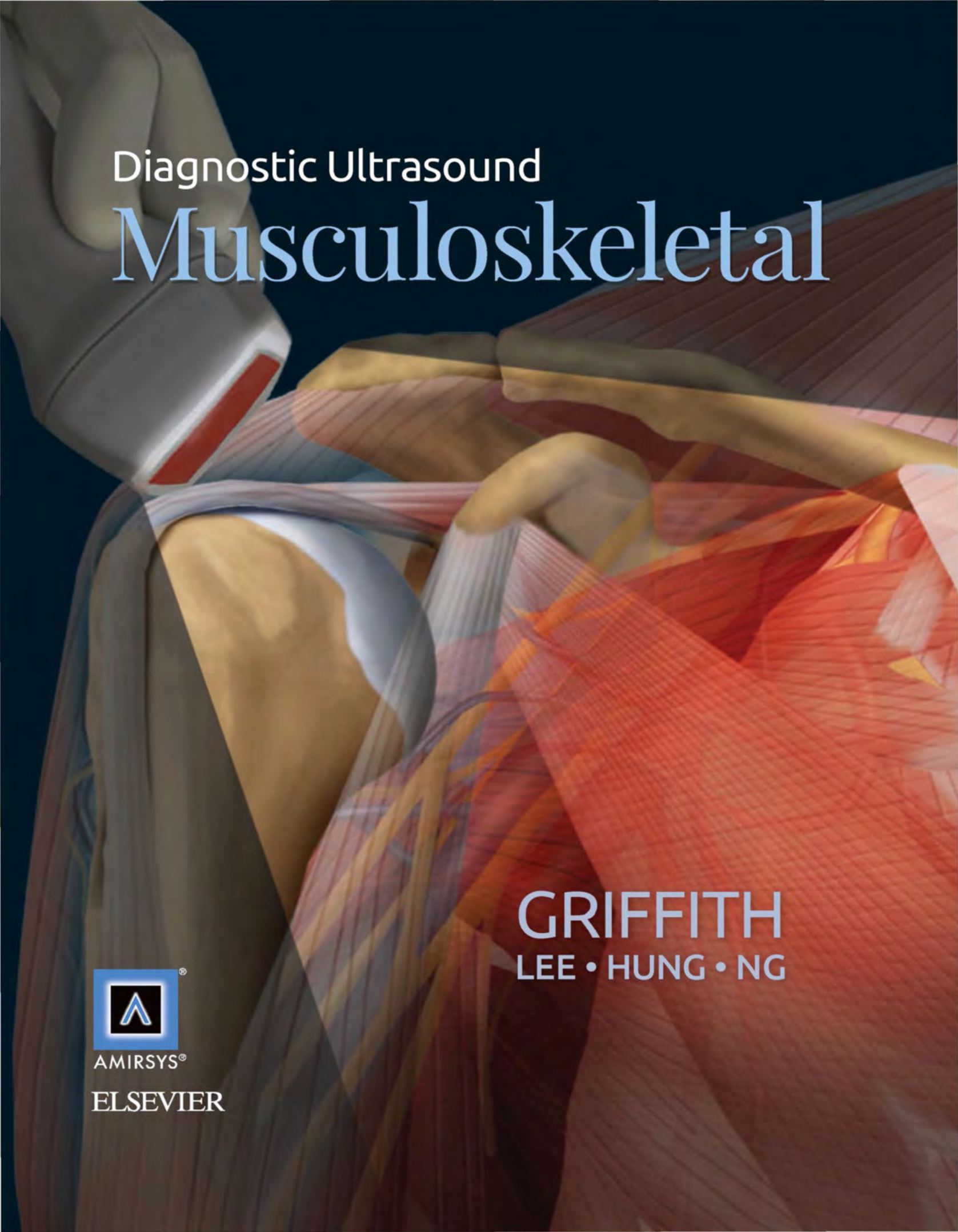
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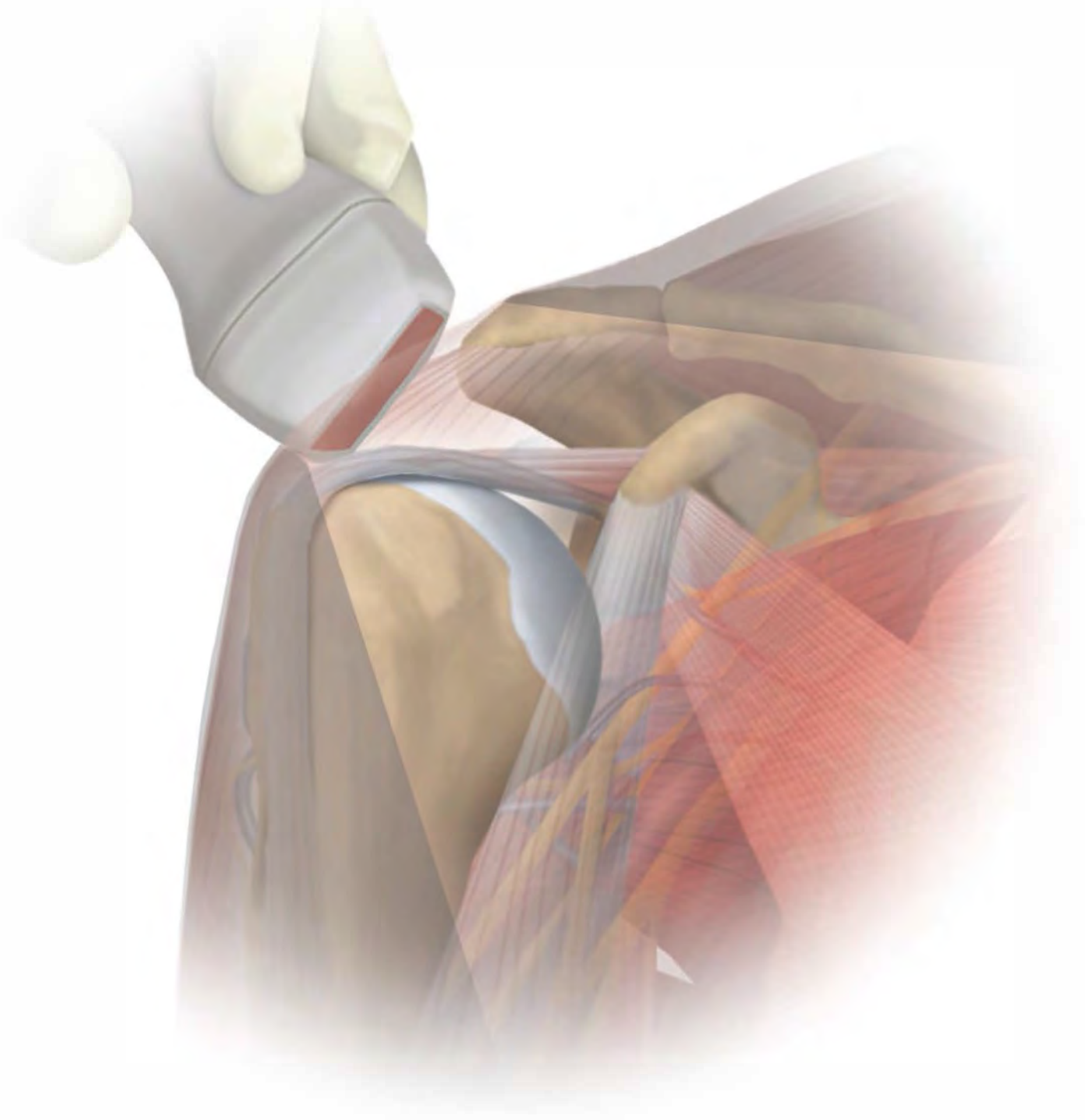

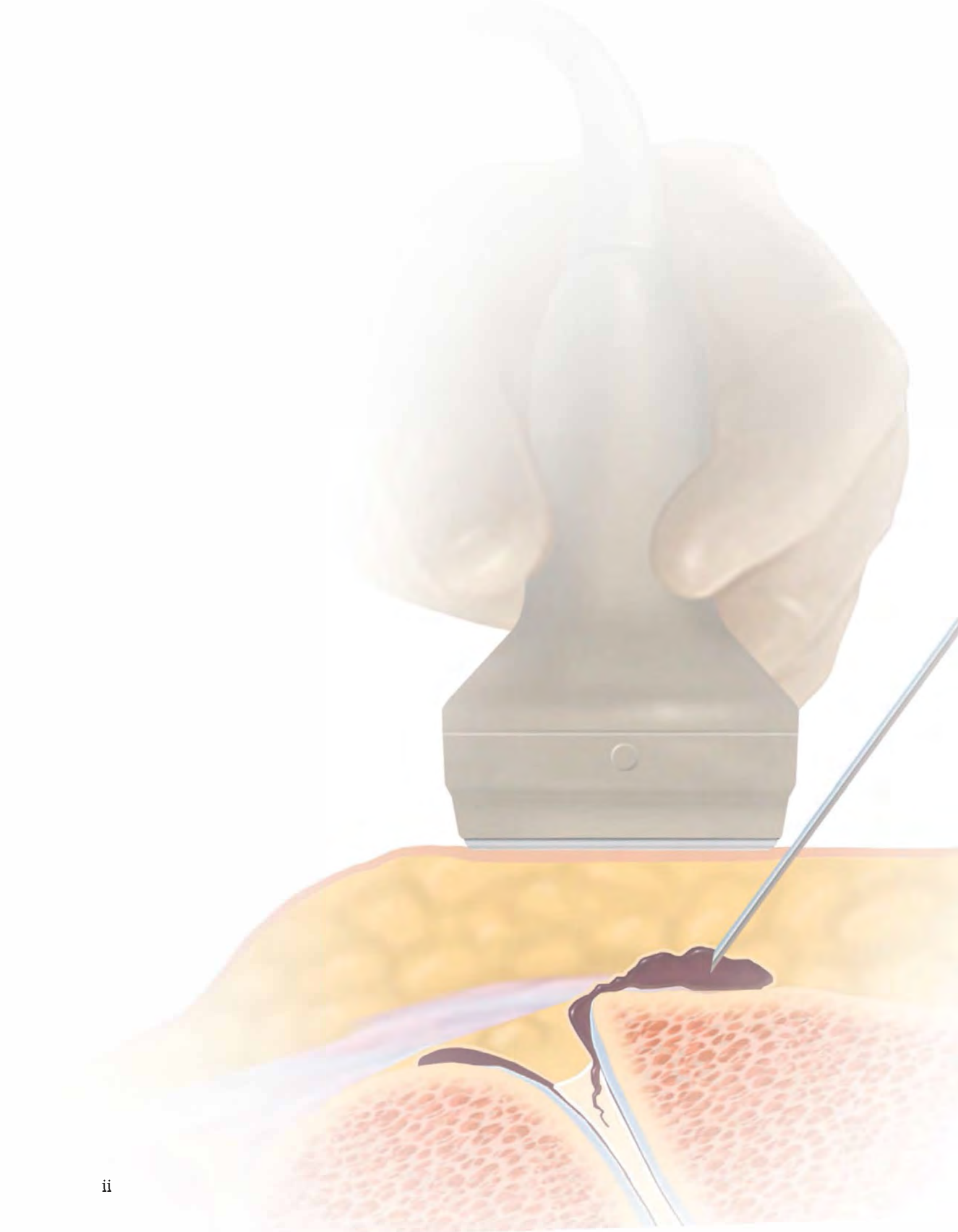

Diagnostic Ultrasound

Musculoskeletal

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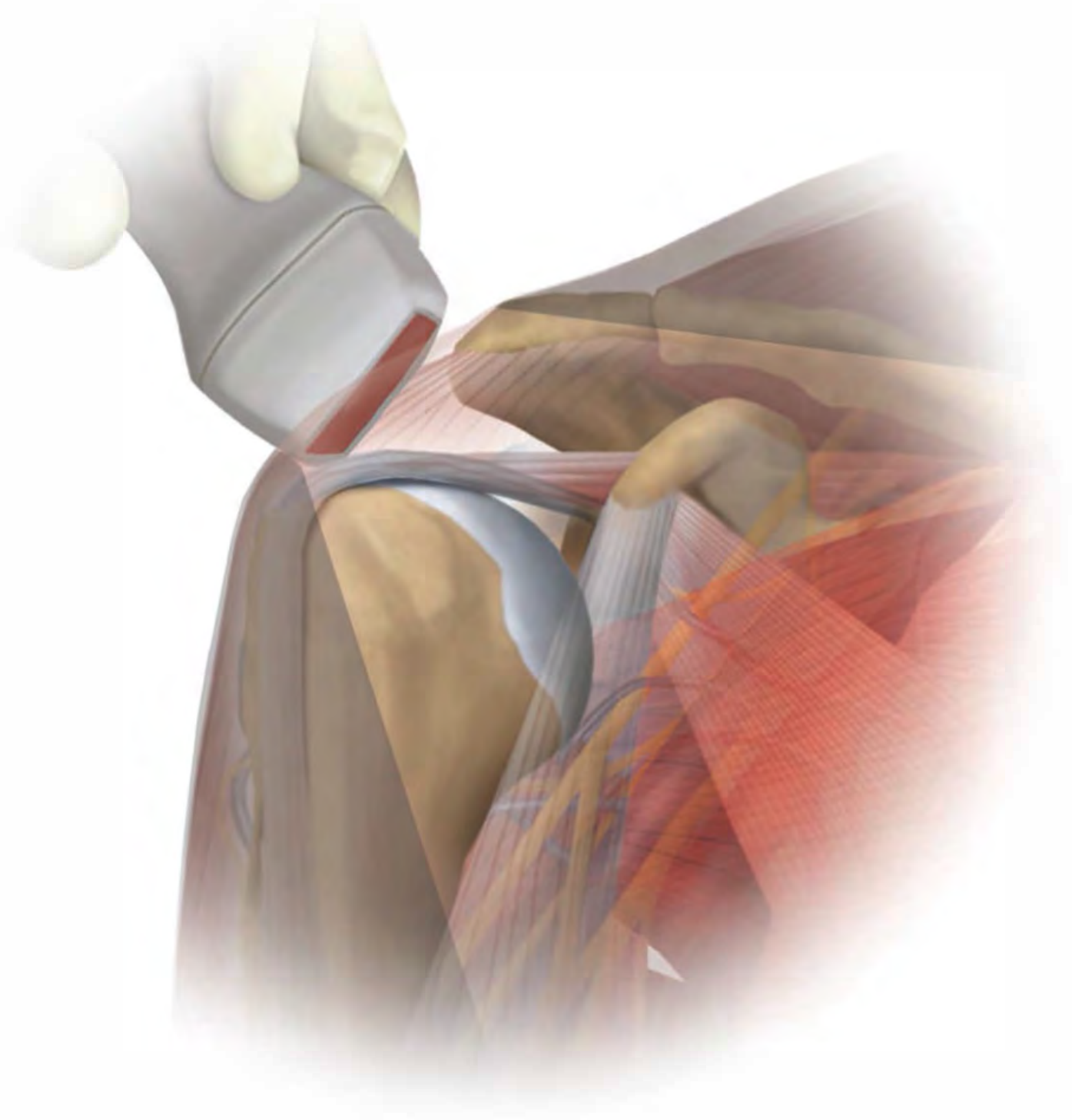
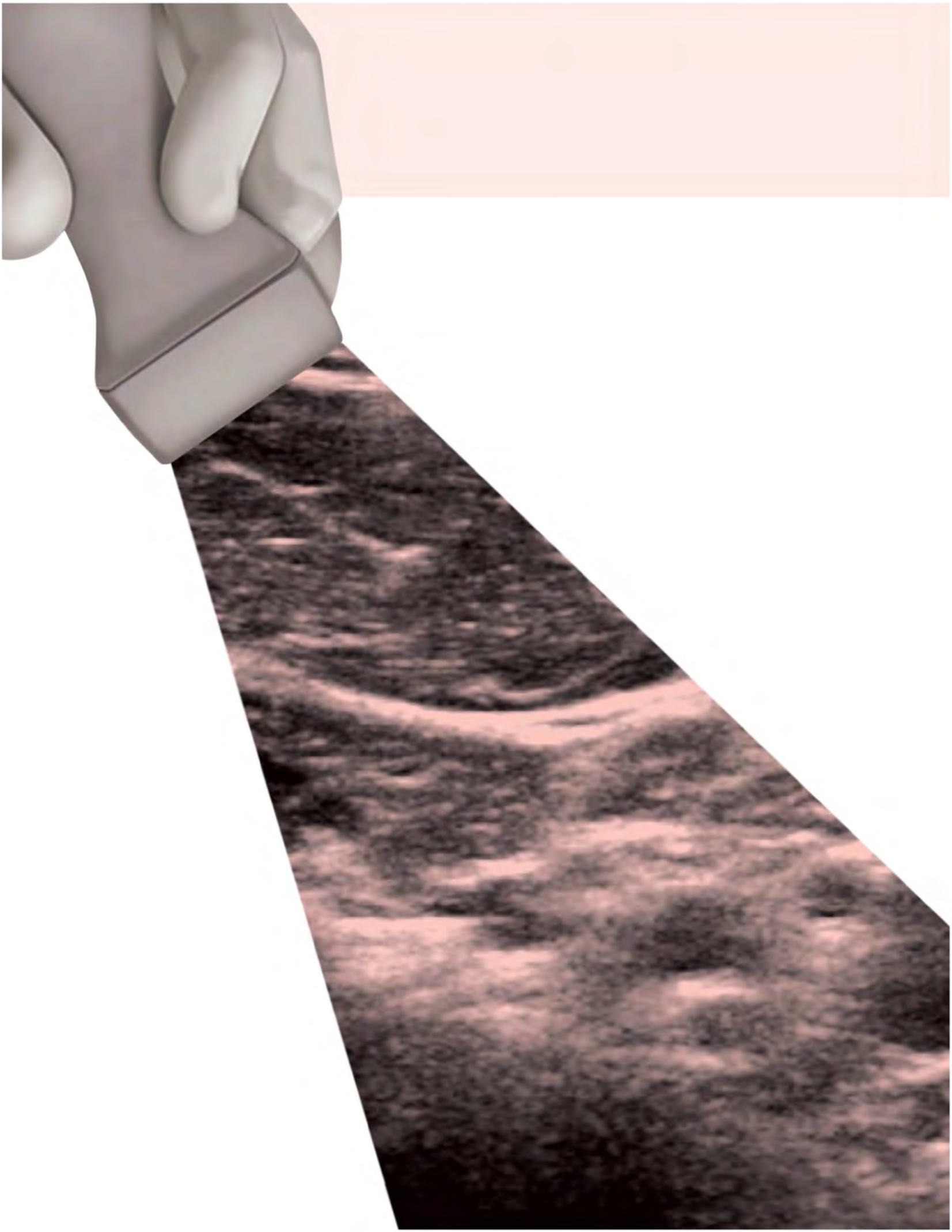
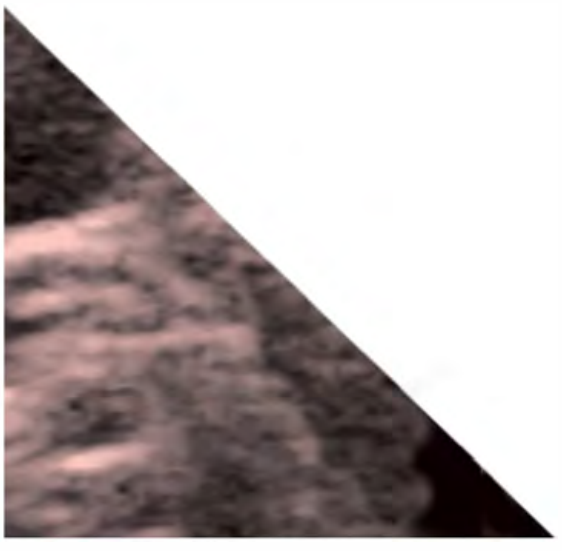




SECTION 1

Upper Limb



STERNOCLAVICULAR AND ACROMIOCLAVICULAR JOINTS

TERMINOLOGY

Abbreviations

- Sternoclavicular (SC) joint
- Acromioclavicular (AC) joint

GROSS ANATOMY

Sternoclavicular Joint

- Between medial end of clavicle and manubrium
  - Synovial sellar-type (saddle) joint
  - Medial end of clavicle = large and bulbous
  - Much larger than manubrial concavity
  - < 1/2 of medial clavicle articulates with manubrium
    - Stability through capsuloligamentous structures
- Intraarticular disc
  - Attached to joint capsule anteriorly and posteriorly
  - Complete or incomplete ± perforations
  - Thickest posterosuperiorly (3 mm)
- Ligaments of sternoclavicular joint
  - Capsular ligaments
    - Cover anterosuperior and posterior aspects of sternoclavicular joint
    - Prevent upward displacement of medial clavicle, which may be caused by downward force on shoulder
    - Anterior stronger than posterior portion
  - Interclavicular ligament
    - Connects superomedial aspect of clavicle to capsular ligaments and upper manubrium
    - Covers anterosuperior and posterior aspects of joint
    - Prevents excessive upward motion of clavicle
  - Costoclavicular ligaments
    - Unite inferior surface medial end clavicle to upper surface of 1st rib
    - Anterior fibers arise from anteromedial surface of 1st rib and resist upward motion
    - Posterior fibers arise lateral to anterior fibers and resist downward motion
- Muscle attachments to medial clavicle and sternum
  - Pectoralis major from anterior aspect medial 2/3 clavicle (clavicular head)
  - Sternocleidomastoid from posterior surface medial 1/3 of clavicle (clavicular head)
  - Sternohyoid and sternothyroid muscles separate great vessels from sternoclavicular joint

Acromioclavicular Joint

- Synovial joint between lateral end of clavicle and medial end of acromion
  - Articular surface of clavicle oriented posterolaterally whereas articular surface of acromion oriented anteromedially
    - Angle of inclination between opposing articular surfaces varies with clavicle overriding acromion (50%), vertical orientation between acromion and clavicle (25%), clavicle underriding acromion (5%), and mixed pattern (20%)
    - Maximum width of normal joint on ultrasound = 5 mm if < 35 years and < 4.4 mm if > 35 years
    - Maximum thickness of capsule from bony surface = 2.7 mm if < 35 years and < 3.6 mm if > 35 years
- Intraarticular disc
  - Undergoes rapid degeneration beginning in 2nd decade → marked degeneration of disc by 4th decade
- Ligaments of AC joint
  - Superior AC ligament
    - Stronger and thicker (2.0-5.5 mm) than thin or absent inferior AC ligament
    - Inserts along lateral clavicle (8 mm) and medial acromion (10 mm)
  - Coracoclavicular ligaments
    - Conoid and trapezoid ligaments
    - Vary significantly in length and width
    - Conoid ligament located posteromedially
    - Inserts to conoid tubercle which is located where middle 1/3 of clavicle curves into lateral 1/3 of clavicle
    - Mainly prevents upward movement of clavicle
    - Trapezoid ligament located anterolaterally
    - Inserts to trapezoid ridge, which runs along inferior surface, of lateral 1/3 of clavicle
    - Mainly prevents lateral compression of clavicle against acromion
  - Muscle attachments to lateral clavicle
    - Deltoid attached to anterior surface lateral 1/3 of clavicle
    - Trapezius attached to posterior surface lateral 1/3 of clavicle

ANATOMY IMAGING ISSUES

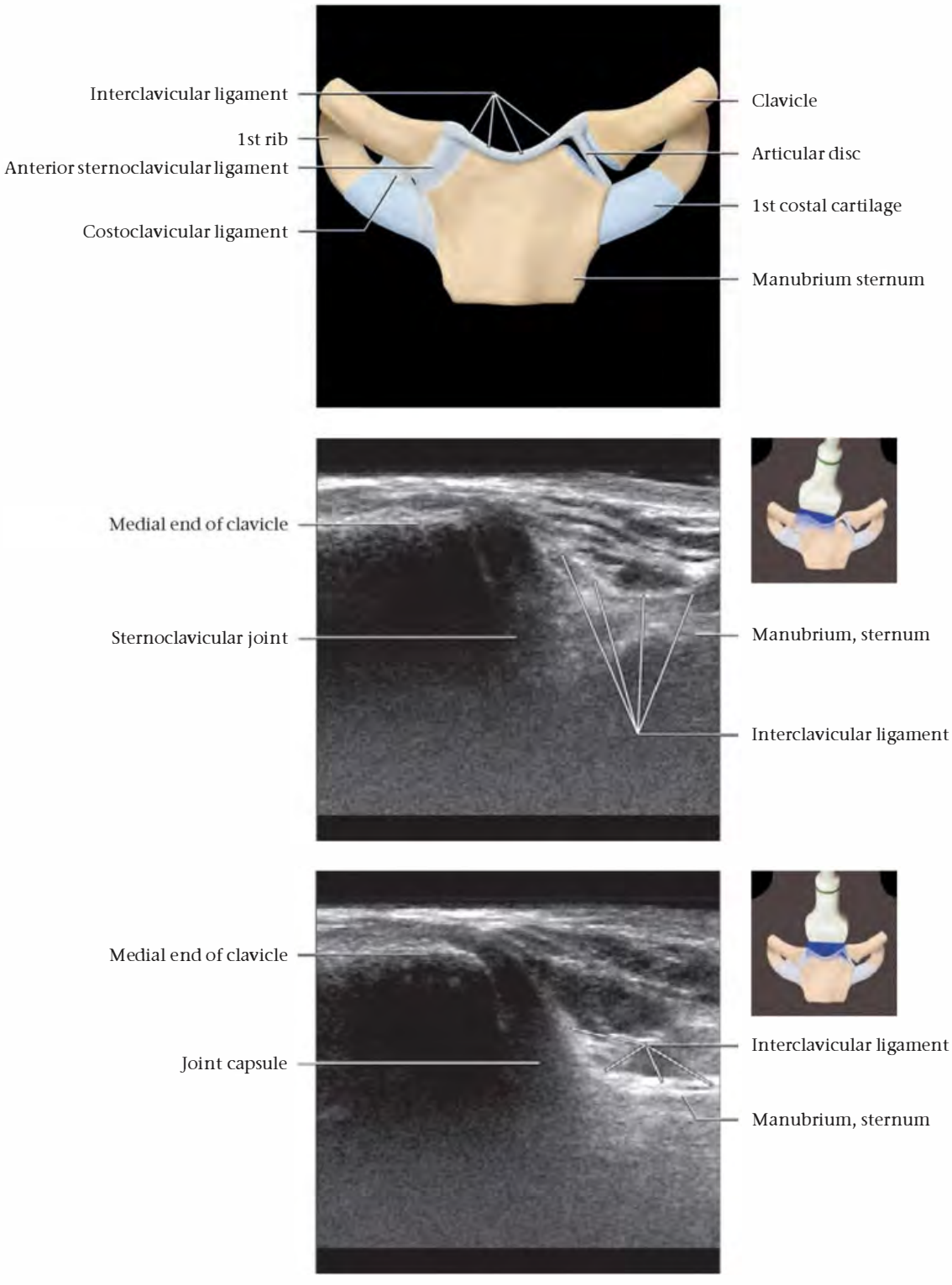
Imaging Recommendations

- High-resolution linear transducer
- Align transducer transversely along SC or AC joints
- AC joint laxity can be assessed by pulling down on arm while observing change in joint width on ultrasound
  - Compare with contralateral side
- Main clinical presentation of SC joint is painless lump
  - Mild degrees of capsular thickening readily apparent clinically since joint just beneath skin surface
    - Clinical swelling often due to relative forward positioning of apparently swollen SC joint due to axial rotation of upper trunk
    - Occasionally due to mild capsular swelling ± mild subluxation secondary to SC osteoarthritis
  - Main clinical presentation of AC joint is pain due to osteoarthritis, AC joint impingement, inflammatory arthropathy, and subluxation/dislocation

Imaging Pitfalls

- SC or AC joints
  - Normally a step-off between medial clavicle and manubrium and, to lesser degree, between lateral clavicle and acromion
  - Should not be interpreted as subluxation
  - Acromion normally elevates from rest position during arm adduction
  - AC joint index = AC joint width of uninjured side/AC joint width of injured side = 1.0 normally
  - Determine whether
    - AC joint not subluxed (similar to opposite side) : Grade 1
    - AC joint partially subluxed (clavicle subluxed < 50% depth of AC joint) : Grade 2
    - AC joint severely subluxed or dislocated (clavicle subluxed > 50% depth of AC joint) : Grade 3

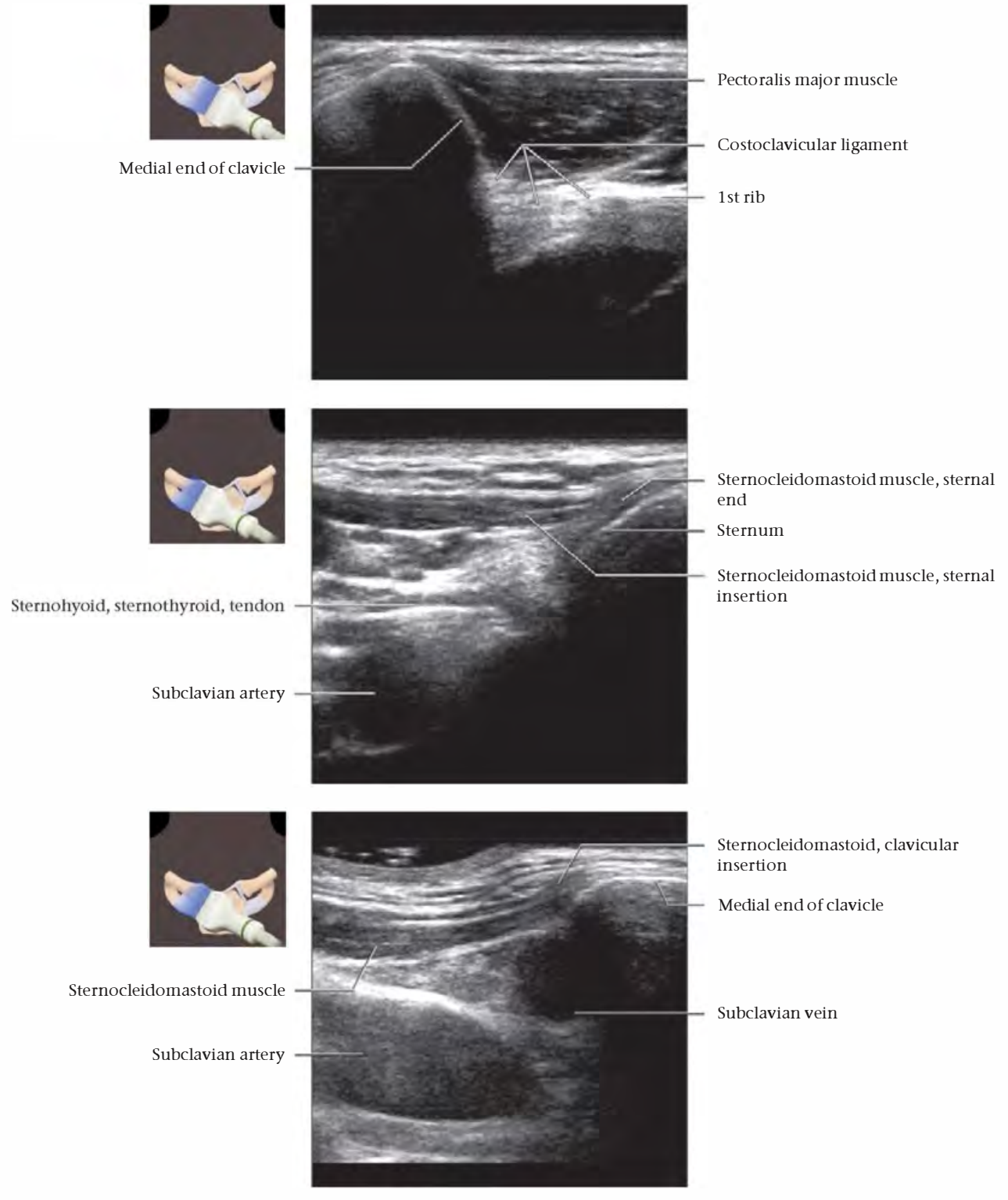
TRANSVERSE US, STERNOCLAVICULAR JOINT



(Top) *Graphic shows the anterior aspect of the sternoclavicular joint. Note the joint capsule, articular disc, and interclavicular ligament.* ***(Middle)*** *Transverse grayscale ultrasound shows the anterosuperior aspect of the sternoclavicular joint. The medial clavicle is much larger than the articulating surface of the manubrium. The thin interclavicular ligament is closely applied to the superior aspect of manubrium, and its connection with the medial ends of both clavicles is depicted.* ***(Bottom)*** *Transverse grayscale ultrasound shows the superior aspect of the sternoclavicular joint. The costoclavicular ligament prevents upward movement of the medial clavicle when the lateral clavicle or shoulder is depressed.*

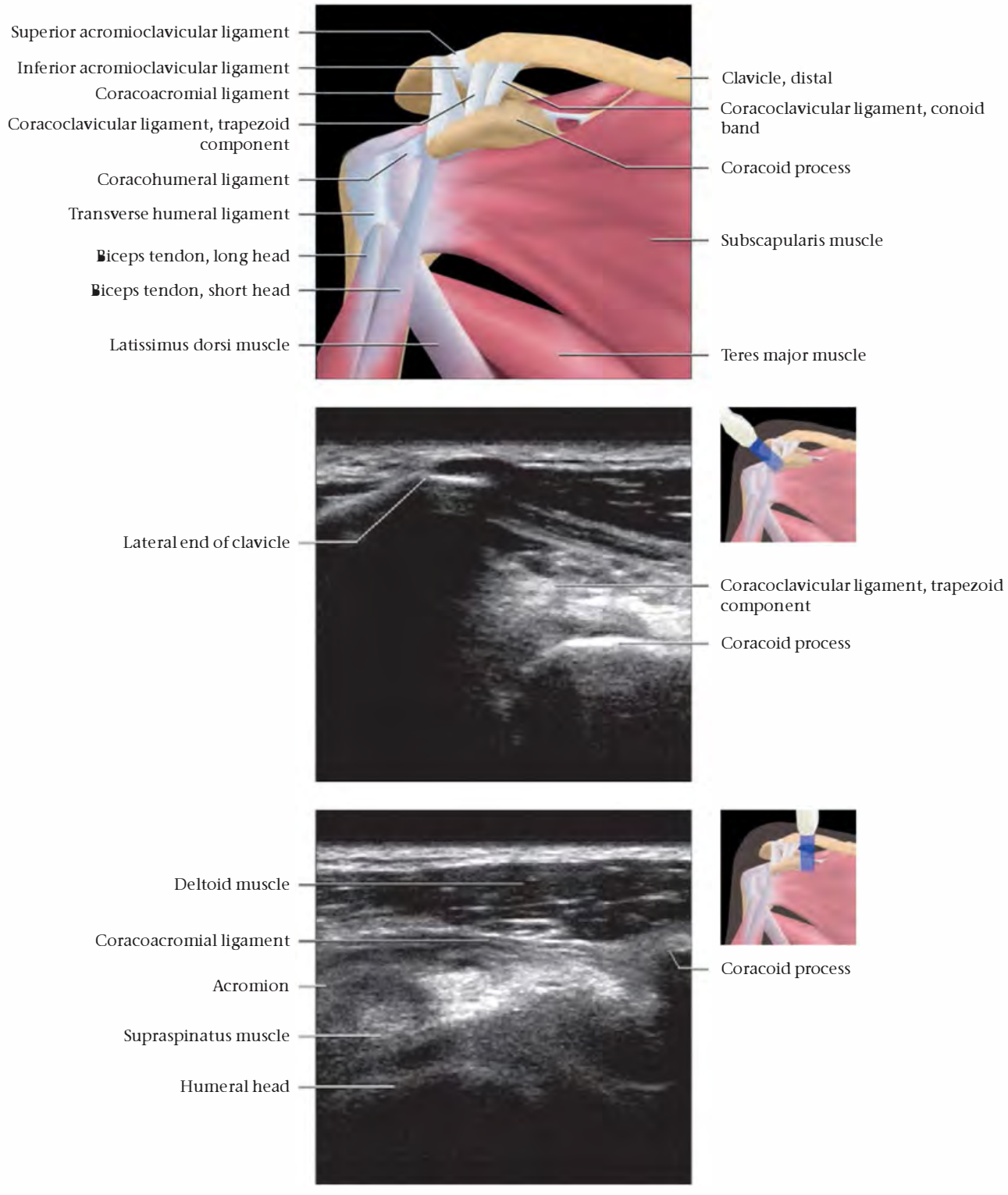
STERNOCLAVICULAR AND ACROMIOCLAVICULAR JOINTS

LONGITUDINAL US, STERNOCLAVICULAR JOINT



(Top) *Longitudinal grayscale US shows sternoclavicular joint. Costoclavicular ligament prevents upward movement of the medial clavicle when shoulder is depressed. Pectoralis major muscle arises from the medial 1/2 of the anterior surface of the clavicle as well as from the sternum, upper costal cartilages, and upper part of external oblique aponeurosis.* ***(Middle)*** *Longitudinal grayscale US shows sternoclavicular joint region. Sternocleidomastoid is attached to the upper surface of the medial end of the clavicle as well as the upper anterior surface of the manubrium. Sternohyoid and sternothyroid are attached to the posterior aspect of the sternum as well as the clavicle and 1st costal cartilage.* ***(Bottom)*** *Longitudinal grayscale US shows sternoclavicular joint. Great vessels lie posterior to sternoclavicular joint and may get injured in posterior dislocation. All tendinous attachments should be assessed if dislocation is present as they may also be injured.*

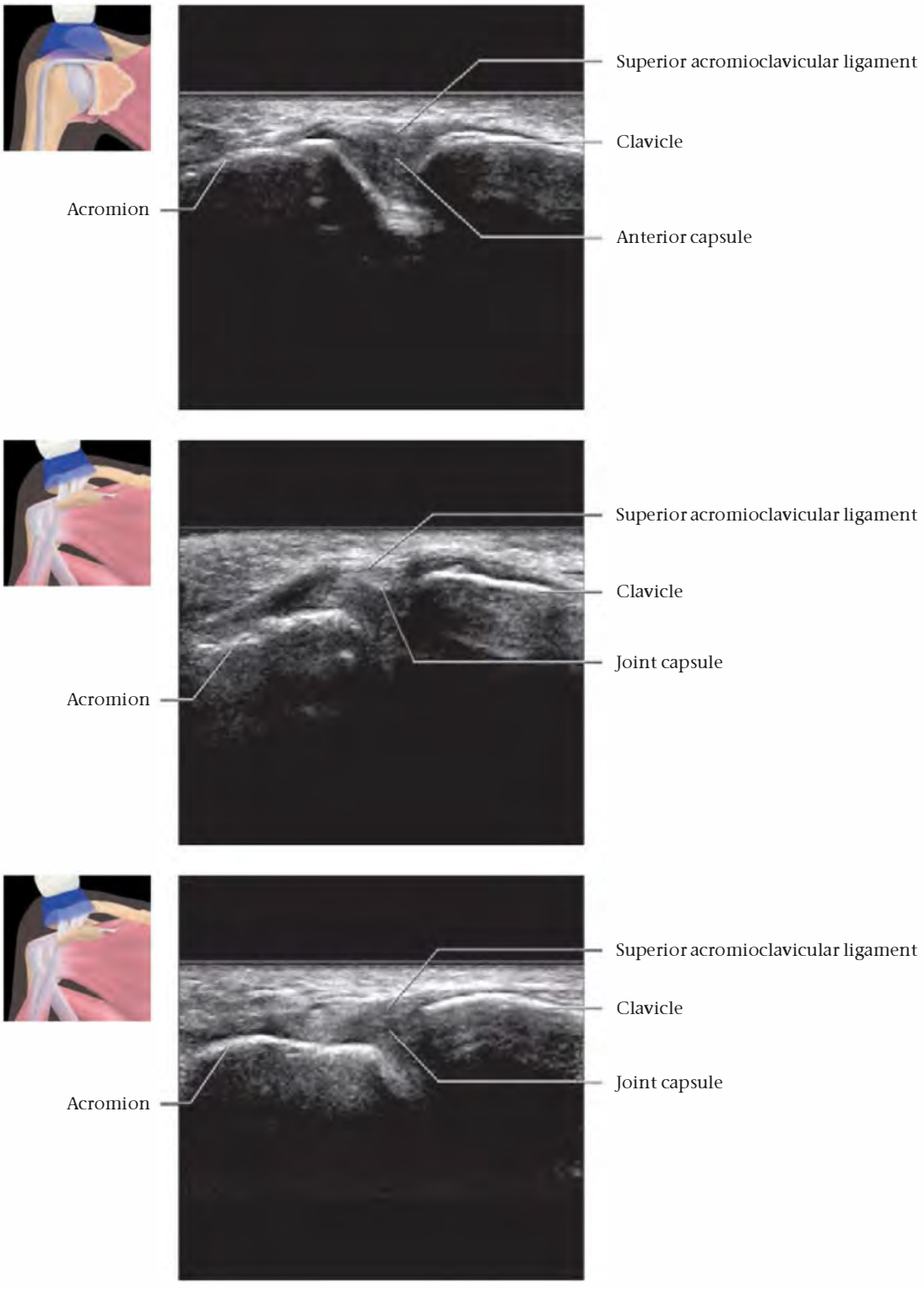
US, ACROMIOCLAVICULAR JOINT



(Top) *Anterior graphic shows the shoulder in superficial dissection.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the acromioclavicular joint region. The coracoclavicular ligament is demonstrated but is not as clearly depicted on US as it is on MR exam. These ligaments prevent upward and lateral movement of the clavicle.* ***(Bottom)*** *Transverse grayscale ultrasound of the acromioclavicular joint region shows the coracoacromial ligament. The supraspinatus tendon and intervening bursa can impinge against the coracoacromial ligament during arm abduction.*

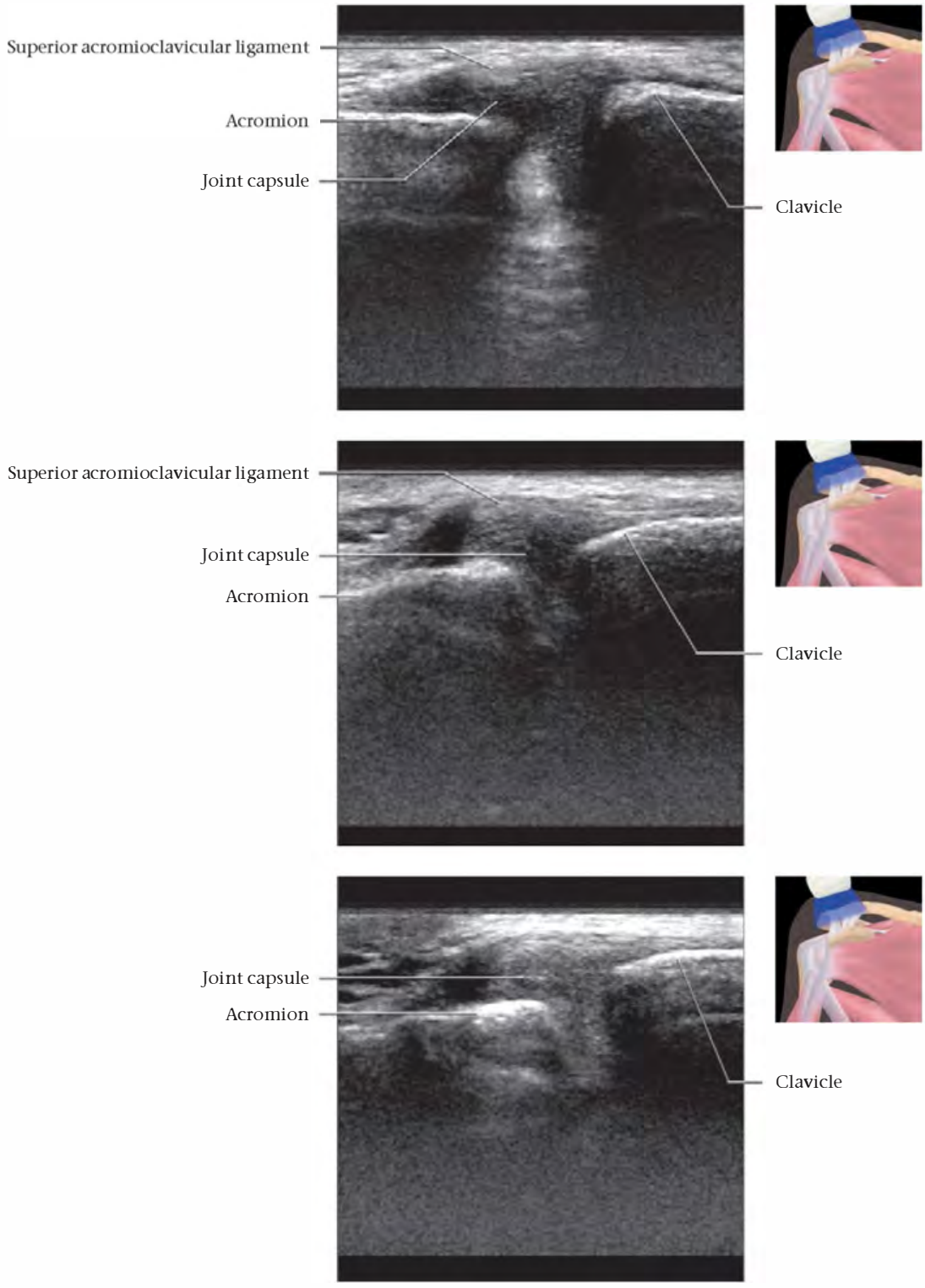
STERNOCLAVICULAR AND ACROMIOCLAVICULAR JOINTS

TRANSVERSE US, ACROMIOCLAVICULAR JOINT



(Top) *Transverse grayscale ultrasound shows the anterior aspect of the acromioclavicular joint. The joint capsule of the acromioclavicular joint is thin with a strong supporting superior acromioclavicular ligament.* ***(Middle)*** *Transverse grayscale ultrasound shows the anterosuperior acromioclavicular joint. Separation of the clavicle and acromion can be readily appreciated. Note how opposing bone margins are not vertically aligned.* ***(Bottom)*** *Transverse grayscale ultrasound shows the superior aspect of the acromioclavicular joint. In this image, the clavicle slightly overrides the acromion. This is a normal configuration.*

TRANSVERSE US, ACROMIOCLAVICULAR JOINT



(Top) *Transverse grayscale ultrasound shows the anterosuperior aspect of the acromioclavicular joint with the arm positioned by the side of the body. Note that the clavicle slightly overrides the acromion.* ***(Middle)*** *Transverse grayscale ultrasound shows the acromioclavicular joint with the arm in abducted position. The acromion is now level with the lateral aspect of the clavicle. Note how the joint capsule bulges superiorly and the opposing bones are approximated with the arm abducted.* ***(Bottom)*** *Transverse grayscale ultrasound shows the acromioclavicular joint with the arm in an adducted position. The acromion is now depressed relative to this lateral end of the clavicle.*

SHOULDER

IMAGING ANATOMY

Overview

- **Rotator cuff**
  - Consists of supraspinatus, infraspinatus, teres minor, subscapularis muscles, and tendons
  - Cuff tendons blend with shoulder joint capsule
  - Supraspinatus and infraspinatus tendons are inseparable at insertion
  - Anterior 2.25 cm of tendon comprises supraspinatus tendon insertional area
- **Supraspinatus muscle**
  - Origin: Supraspinatus fossa of scapula
  - Insertion: Superior facet (horizontal orientation) and anterior portion of middle facet of greater tuberosity
    - Broad insertional area
  - Nerve supply: Suprascapular nerve
  - Blood supply: Suprascapular artery and circumflex scapular branches of subscapular artery
  - Action: Abduction of humerus
  - Muscle consists of 2 distinct portions
    - Anterior portion is larger, fusiform in shape, has dominant tendon, and is more likely to tear
    - Posterior portion is flat and has terminal tendon
  - Most commonly injured rotator cuff tendon
- **Infraspinatus muscle**
  - Origin: Infraspinatus fossa of scapula
  - Insertion: Mid to posterior aspects of middle facet of greater tuberosity
    - Centrally positioned within tendon
  - Nerve supply: Suprascapular nerve, distal fibers
  - Blood supply: Suprascapular artery and circumflex scapular branches of subscapular artery
  - Action: External rotation of humerus and resists posterior subluxation
- **Teres minor muscle**
  - Origin: Lateral scapular border, middle 1/2
  - Insertion: Inferior facet (vertical orientation) of greater tuberosity
  - Nerve supply: Axillary nerve
  - Blood supply: Posterior circumflex humeral artery & circumflex scapular branches of subscapular artery
  - Action: External rotation of humerus
  - Least commonly injured rotator cuff tendon
- **Subscapularis muscle**
  - Origin: Subscapular fossa of scapula
  - Insertion: Lesser tuberosity and up to 40% may insert at surgical neck
  - Also some fibers cross over to lateral lip of bicipital groove reinforcing and blending with fibers of transverse ligament
  - Nerve supply: Subscapular nerve, upper and lower
  - Blood supply: Subscapularis artery
  - Action: Internal rotation of humerus, also adduction, extension, depression, and flexion
  - 4-6 tendon slips converge into main tendon; multipennate morphology increases strength
- **Rotator cuff tendon blood supply**
  - Derived from adjacent muscle, bone, and bursae
  - Normal hypovascular regions in tendons
    - Termed "critical zone" ~ 1 cm proximal to insertion
    - This area is vulnerable to degeneration and calcific deposition
    - However, insertional area is more prone to tearing than critical zone
- **Biceps tendon, long head**
  - Origin: Superior glenoid labrum (biceps anchor)
    - Portions may attach to supraglenoid tubercle, anterosuperior labrum, posterosuperior labrum, and coracoid base
  - Runs along superior aspect shoulder to bicipital groove
  - Action: Stabilizes and depresses humeral head
  - Anatomic variants: Anomalous intra- & extraarticular origins from rotator cuff and joint capsule
  - Tendon sheath communicates with glenohumeral joint and normally contains small amount of fluid
- **Subacromial-subdeltoid fat plane**
  - Subacromial and subdeltoid portions
    - ± subcoracoid extension in some patients
  - Fat plane is superficial to bursa
  - May be interrupted or absent in normal patients
  - Attached along free border of coracoacromial ligament and adjacent deep surface of deltoid muscle, and humeral neck region
- **Rotator cuff interval**
  - Space between supraspinatus and subscapularis tendon through which biceps tendon passes
  - **Borders of rotator cuff interval**
    - Triangular-shaped space
    - Reflections of glenohumeral ligament and coracohumeral ligament form biceps reflection pulley
    - Biceps reflection pulley stabilizes biceps tendon within rotator cuff interval
    - Superior border: Leading edge of supraspinatus
    - Inferior border: Superior aspect subscapularis tendon
    - Lateral border: Long head of biceps tendon and bicipital groove
    - Medial border: Base of coracoid process
  - **Contents of rotator interval**
    - Long head of biceps tendon
    - Biceps reflection pulley
- **Coracoacromial ligament**
  - Forms coracoacromial arch along with acromion and coracoid process
    - Reinforces inferior aspect of acromioclavicular joint
  - Extends from distal coracoid to subacromial area
  - Broad insertion to undersurface acromion
    - Ligament is thicker at acromion (normal thickness < 2.5 mm) and may be associated with spurs
- **Glenoid labrum**
  - Triangular-shaped rim of fibrocartilage, which extends around periphery of glenoid

ANATOMY IMAGING ISSUES

Imaging Approaches

- Tendons best seen when on stretch
  - High-resolution linear transducer
  - Long-axis (longitudinal) and transverse view of each tendon
  - Each part of tendon needs to be examined; anisotropy prevents all parts of curved rotator cuff tendons being seen at same time
  - Need to realign ("toggle") probe to see different parts of tendons

- Supraspinatus tendon
  - Arm extended and internally rotated behind lumbar region (Crass position)
    - Or, if too painful, hand in posterior hip region ("back pocket") with elbow close to body (modified Crass position)
- Infraspinatus and teres minor tendons
  - Arm flexed and internally rotated with hand placed on contralateral shoulder
  - Teres minor tendon located posteroinferior to infraspinatus tendon
- Subscapularis tendon
  - Arm neutral and externally rotated
- Long head of biceps tendon
  - Arm neutral and externally rotated
  - Vary degree of external rotation for optimal view of biceps tendon
  - Check for tendon subluxation
- Subacromial-subdeltoid bursa
  - Stretching tendons may squeeze fluid from area of bursa under inspection
  - Examine in all positions and also in neutral position
  - Fluid collects preferentially just lateral to acromion, lateral to proximal humerus, and near coracoacromial ligament
- Coracoid process and coracoacromial ligament
  - Neutral position
- Acromioclavicular joint
  - Neutral position
  - Can pull down on arm when examining acromioclavicular joint to assess joint laxity
- Glenohumeral joint
  - Neutral position
  - Best seen from posterior aspect of joint
  - Passive movement of arm during scanning can help in identifying posterior glenoid labrum
- Spinoglenoid notch
  - Neutral position just medial to glenohumeral joint
- Supraspinatus and infraspinatus muscles
  - Neutral position with hands resting on thigh
  - Examine thickest part of muscles from behind (in coronal and sagittal planes)
  - ↓ muscle bulk, ↑ muscle echogenicity and reduced visibility of central tendon are signs of muscle atrophy with fatty replacement
    - Compare muscle echogenicity to that of trapezius or deltoid muscle

Imaging Sweet Spots

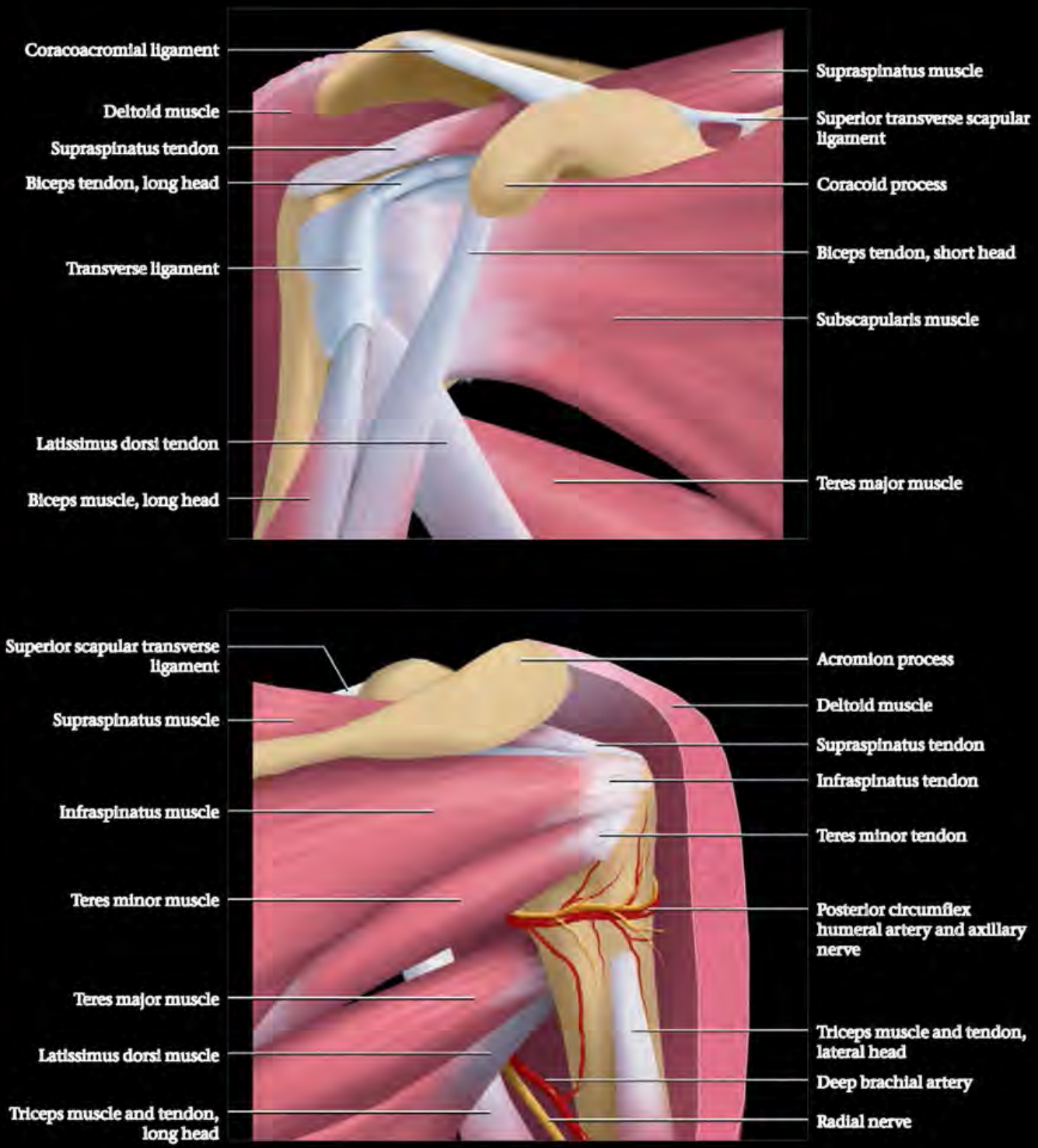
- Look for tears particularly at anterior leading edge of supraspinatus tendon
  - Unexplained bursal fluid is a good secondary sign of rotator cuff tear
- Bursal fluid is often best seen with arm in neutral position or ↓ internal rotation (hand in back pocket)

Imaging Pitfalls

- **Anisotropy**
  - Echoes are optimally reflected when transducer is parallel to tendon fibers
  - Rotator cuff tendons are prone to anisotropy due to curved course
  - If transducer is not at right angles to tendon, it will appear either isoechoic or hypoechoic to muscle
    - May simulate tendinosis or partial tear
- **Tendon edges**
  - Interfaces of tendons with adjacent structures may simulate tears
  - All tears and other tendon pathology should be confirmed in 2 planes
- **Rotator cuff cable**
  - Thick band of fibers running perpendicular to supraspinatus tendon
  - Located on deeper aspect of tendon just proximal to insertional area
  - May reinforce 'critical zone' supraspinatus fibers
  - Cable thicker in young subjects but more easily seen in elderly subjects due to supraspinatus tendinosis
  - Can simulate tendinosis or partial thickness tear
- **Tendinous interspace at rotator cuff interval**
  - Interspace between leading edge (anterior edge) of supraspinatus and long head of biceps tendon may simulate tear
  - Overcome by recognizing ovoid or rounded shape of biceps tendon
  - Rotator cuff interval best seen with arm in external rotation
- **Focal thinning at supraspinatus-infraspinatus junction**
  - Mild diffuse thinning of supraspinatus and infraspinatus tendon junction is normal finding
  - Should not be mistaken for tendon attenuation or partial thickness tear
- **Musculotendinous junction**
  - Supraspinatus tendon
    - Hypoechoic muscle extending along superficial aspect of tendon may simulate subacromial-subdeltoid bursal distension
    - Interdigitating tendons of anterior and posterior portions may simulate tendinosis or tear
  - Infraspinatus tendon
    - Muscle fibers surrounding centrally positioned tendon may be confused with tear
  - Subscapularis tendon
    - 4-6 tendon slips converging into main tendon may simulate tendinosis
- **Fibrocartilaginous insertion**
  - Thin layer of fibrocartilage exists between tendon and bone at insertional area
  - The steeper the tendon insertion, the thicker the fibrocartilaginous layer
  - This thin hypoechoic layer of fibrocartilage may simulate avulsive tear
- **Subacromial-subdeltoid fat plane**
  - Fat plane lies mainly superficial to bursa and deep to deltoid muscle
  - Normal bursa is very thin
  - Thickness of echogenic fat plane is variable among patients though usually similar from side to side
  - May be wrongly interpreted as bursal fluid
    - Look for intrabursal fluid ± hyperemia (latter is a feature of inflammatory arthropathy)
- **Fluid in biceps tendon sheath**
  - Communicates with glenohumeral joint
  - Small amount of fluid is normal
    - Do not misinterpret as long head of biceps tenosynovitis
  - ↑ fluid in biceps tendon sheath usually reflects ↑ fluid in glenohumeral joint

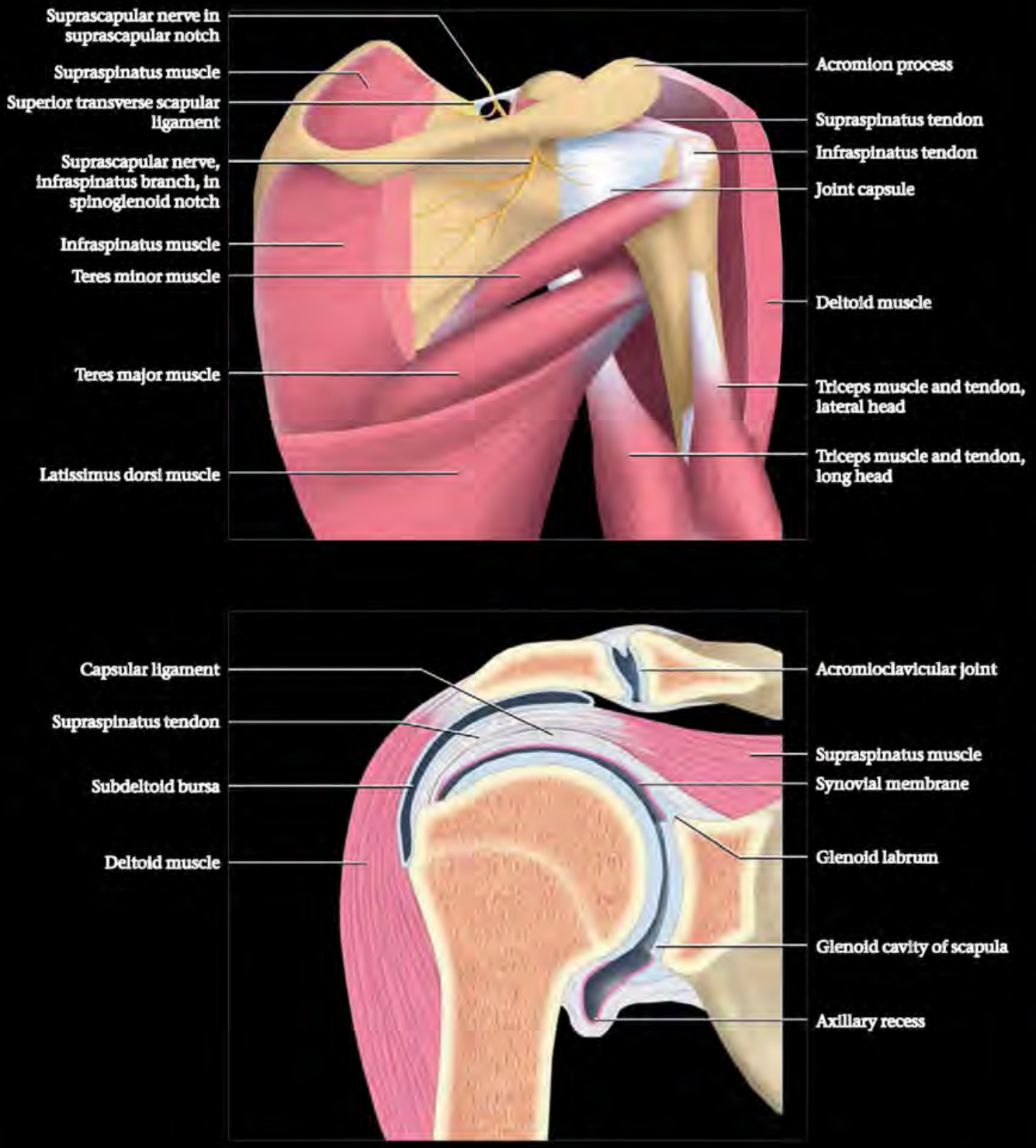
SHOULDER

GRAPHICS, MUSCLES AND LIGAMENTS



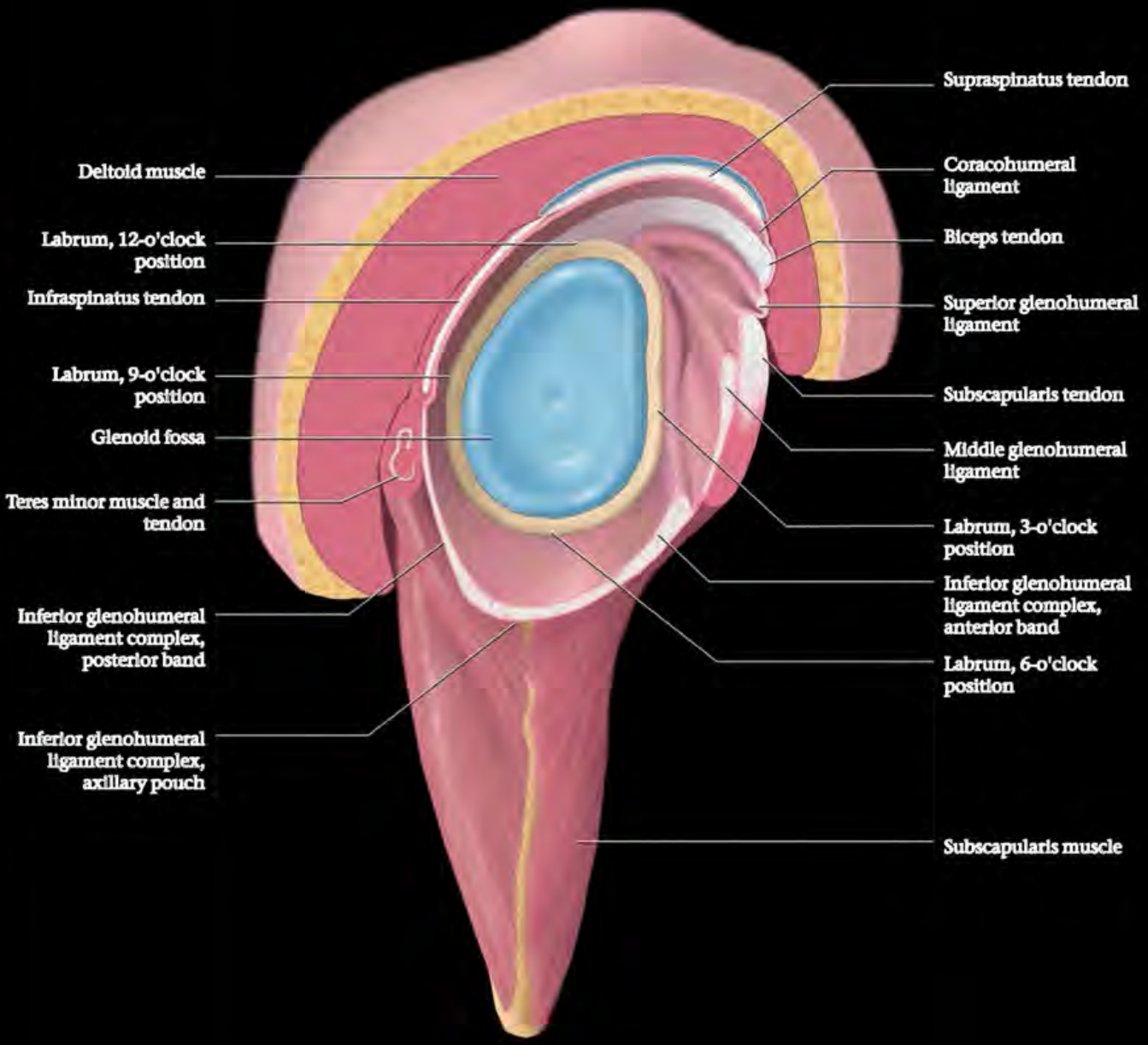
***(Top)** Anterior graphic of the shoulder illustrates the rotator cuff and adjacent structures. The rotator cuff consists of supraspinatus, infraspinatus, teres minor, and subscapularis muscles and tendons. The biceps tendon courses the rotator cuff interval between the supraspinatus and subscapularis tendons, then descends along the bicipital groove, which is covered by the transverse ligament. **(Bottom)** Posterior graphic of the shoulder illustrates the rotator cuff and adjacent structures. The infraspinatus and teres muscles and tendons form the posterior wall of the rotator cuff. Inferior to the teres minor muscle and superior to the teres major, is the axillary nerve and posterior circumflex humeral vessels running through a space named the quadrilateral space.*

GRAPHICS, DEEP STRUCTURES



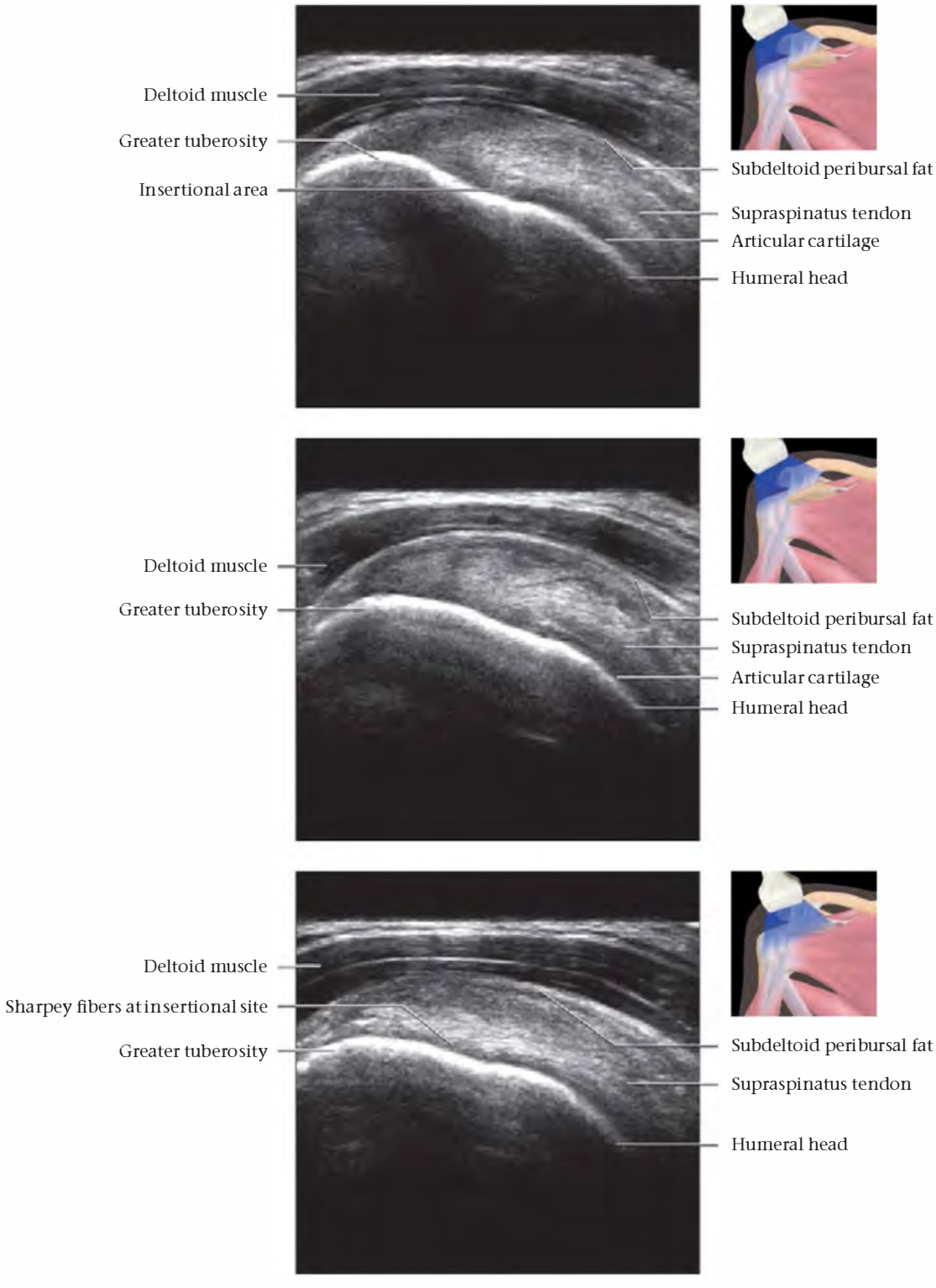
***(Top)** Deep scapulohumeral dissection shows the course of the suprascapular nerve. The nerve enters the supraspinous fossa through the suprascapular notch, below the superior transverse scapular ligament. The nerve then passes beneath the supraspinatus, and curves around the lateral border of the spine of the scapula to enter the infraspinous fossa. **(Bottom)** Graphic shows the coronal section through the midportion of the shoulder joint. Note the subacromial-subdeltoid bursa is situated in the space between the deltoid, acromion, acromioclavicular joint, distal clavicle superiorly, and the supraspinatus tendon and muscle inferiorly. There is no direct communication between the bursa and glenohumeral joint unless there is full thickness tear of the supraspinatus tendon. The bursa is the main pain-producing structure around the shoulder. The wide expanse of the subacromial-subdeltoid bursa enables one to understand why shoulder symptoms are poorly localized. Patients often complain of generalized shoulder pain.*

SAGITTAL GRAPHIC, NORMAL LABRUM



Sagittal graphic shows the glenoid fossa. The labrum lines the edge of the glenoid, increasing the circumference and depth of the shoulder joint. The labrum plays an important role in stabilization of the shoulder joint. At the inferior aspect of the glenoid, the labrum is barely discernible. The superior, middle, and inferior glenohumeral ligaments are distinctive thickenings of the anterior shoulder capsule and cannot be seen as separate structures on ultrasound examination.

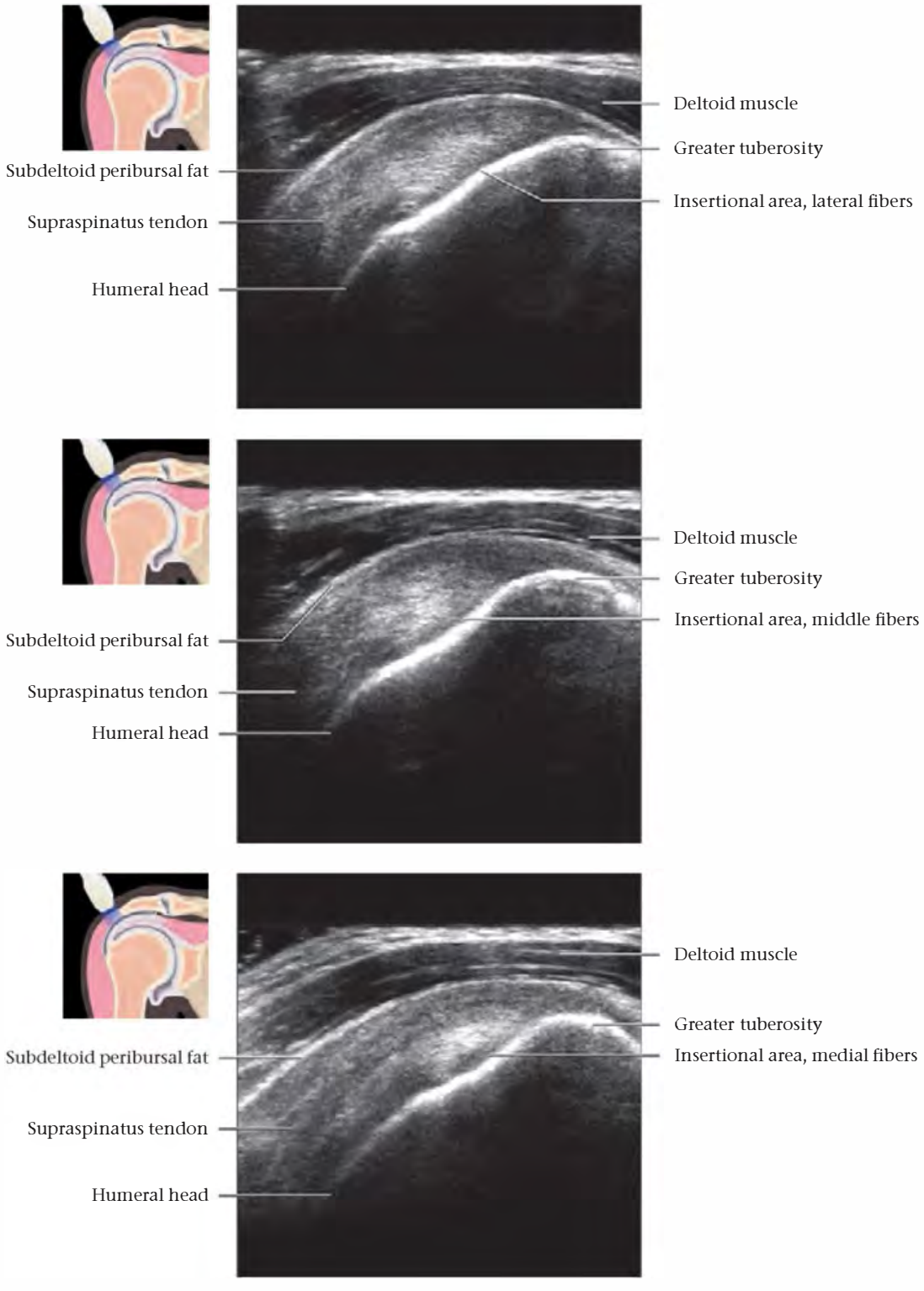
LONGITUDINAL US, SUPRASPINATUS INSERTIONAL AREA



(Top) *Longitudinal grayscale ultrasound shows the anterior fibers of the supraspinatus tendon insertional area. The supraspinatus tendon inserts over a wide area (footprint) on the anterior aspect of the greater tuberosity. Many tears of the supraspinatus tendon involve avulsion of the tendon from its insertional site.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the supraspinatus tendon midfibers. There is often a thin hypoechoic line at the insertional area. This represents Sharpey fibers and fibrocartilage.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the supraspinatus tendon posterior fibers. The anterior, middle, and posterior fibers should be evaluated in turn.*

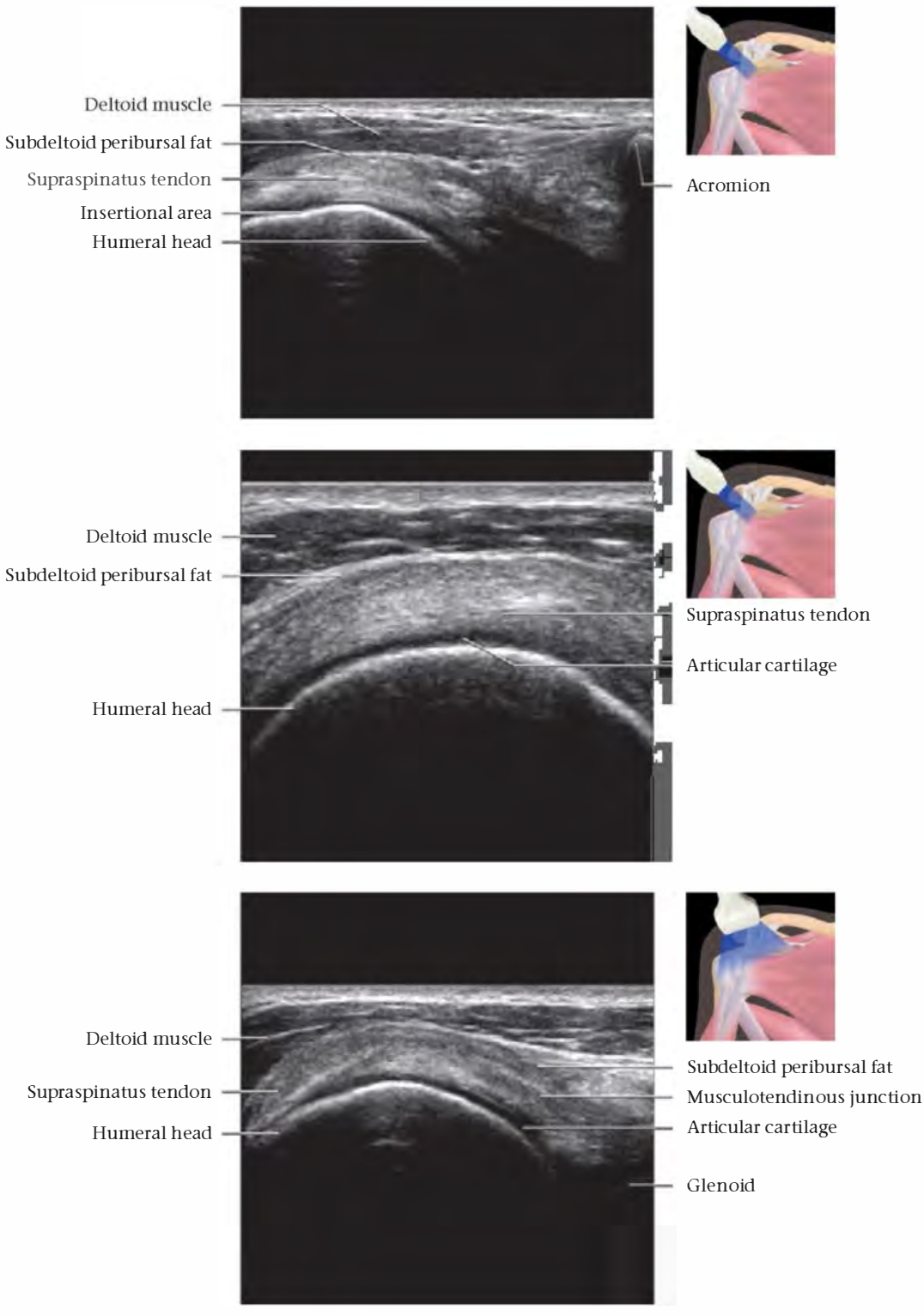
SHOULDER

TRANSVERSE US, SUPRASPINATUS INSERTIONAL AREA



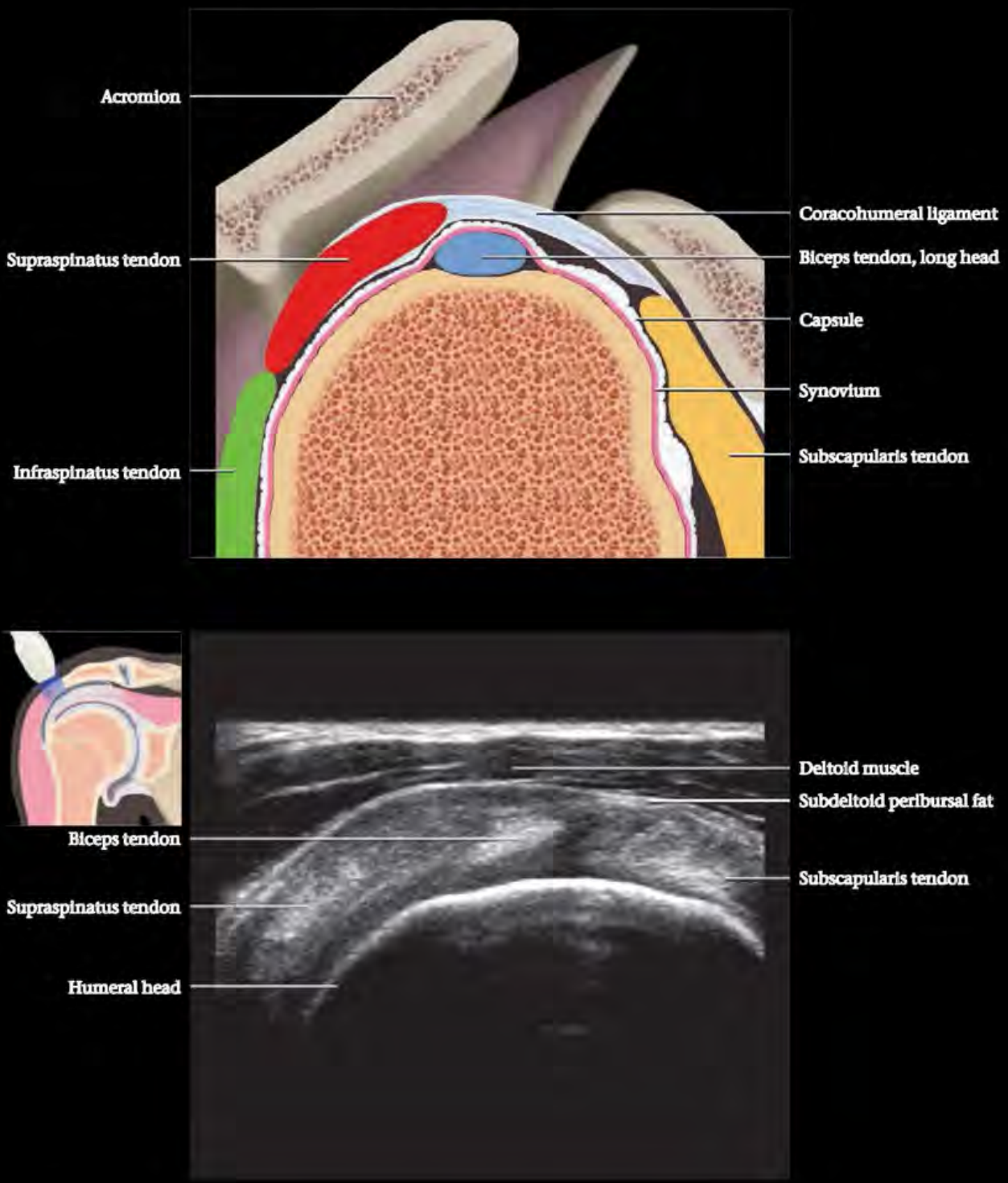
(Top) *Transverse grayscale ultrasound shows the supraspinatus tendon insertional area. Angulation and slight movement of the transducer will allow visualization of the lateral, middle, and medial fibers, respectively. The leading anterior edge of the supraspinatus is a common site of tear (rim rent tear).* ***(Middle)*** *Transverse grayscale ultrasound shows the supraspinatus tendon at the insertional area of midfibers. The fibrillar echotexture of the supraspinatus tendon can be seen but is prone to anisotropy.* ***(Bottom)*** *Transverse grayscale ultrasound shows the supraspinatus midfibers insertional area. Subdeltoid peribursal fat is variable in depth. The normal bursa cannot be depicted. It is seen only when distended with fluid or thickened due to synovitis.*

TRANSVERSE AND LONGITUDINAL US, SUPRASPINATUS



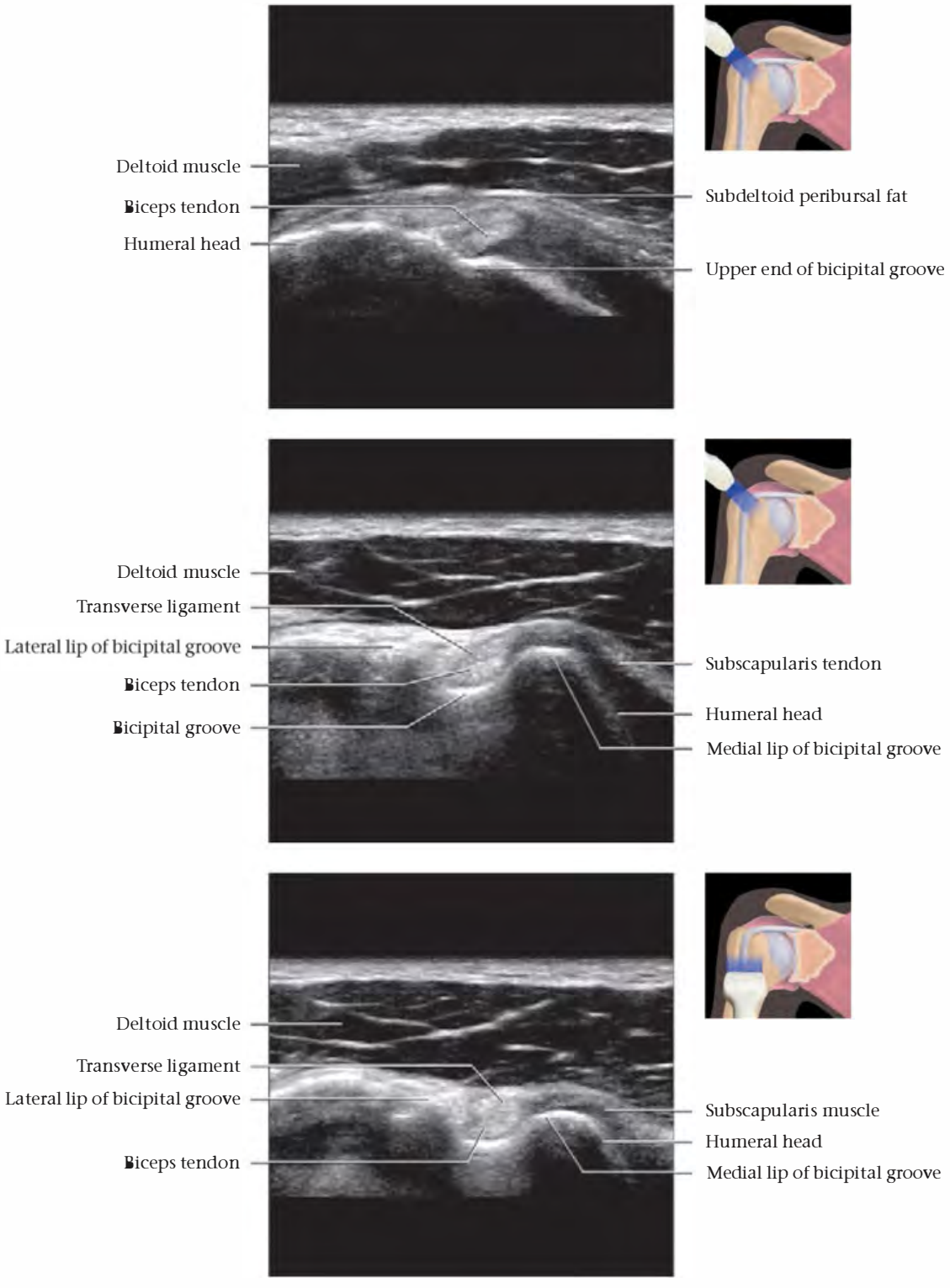
(Top) *Transverse grayscale ultrasound shows the supraspinatus tendon just medial to the insertional area. The critical zone is located just medial to the insertional area. This is a relatively hypovascular area. It is prone to calciific tendinosis and tears, though most tears tend to occur at the insertional site.* ***(Middle)*** *Transverse grayscale ultrasound shows the supraspinatus medial to the insertional area. The fibrillar pattern of the supraspinatus tendon is prone to anisotropy. With tendinosis, the fibrillar pattern is disrupted. The tendon becomes more hypoechoic and thickened.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the supraspinatus tendon at a slightly more medial aspect. Tears of the musculotendinous junction are relatively uncommon.*

GRAPHIC AND TRANSVERSE US, ROTATOR CUFF INTERVAL



***(Top)** Graphic shows the relationship of the coracohumeral ligament to the rotator cuff tendons. The coracohumeral ligament is not a true ligament but a folded portion of the glenohumeral capsule that extends from the coracoid process to the humerus. The undersurface is lined by synovium. Portions of the coracohumeral ligament pass superficial and deep to the supraspinatus tendon. The coracohumeral ligament attaches to the superior border of the subscapularis tendon as well as to the greater tuberosity. **(Bottom)** Transverse grayscale ultrasound shows the shoulder at the rotator cuff interval. The rotator cuff interval represents the space between the leading anterior edge of the supraspinatus tendon and the adjacent superior edge of the subscapularis. It contains the biceps tendon. This should not be mistaken for a tear of the anterior aspect of the supraspinatus tendon. Patients with adhesive capsulitis may show increased hypoechogenicity and hyperemia of the rotator cuff interval as a result of inflammatory fibrovascular soft tissue overgrowth.*

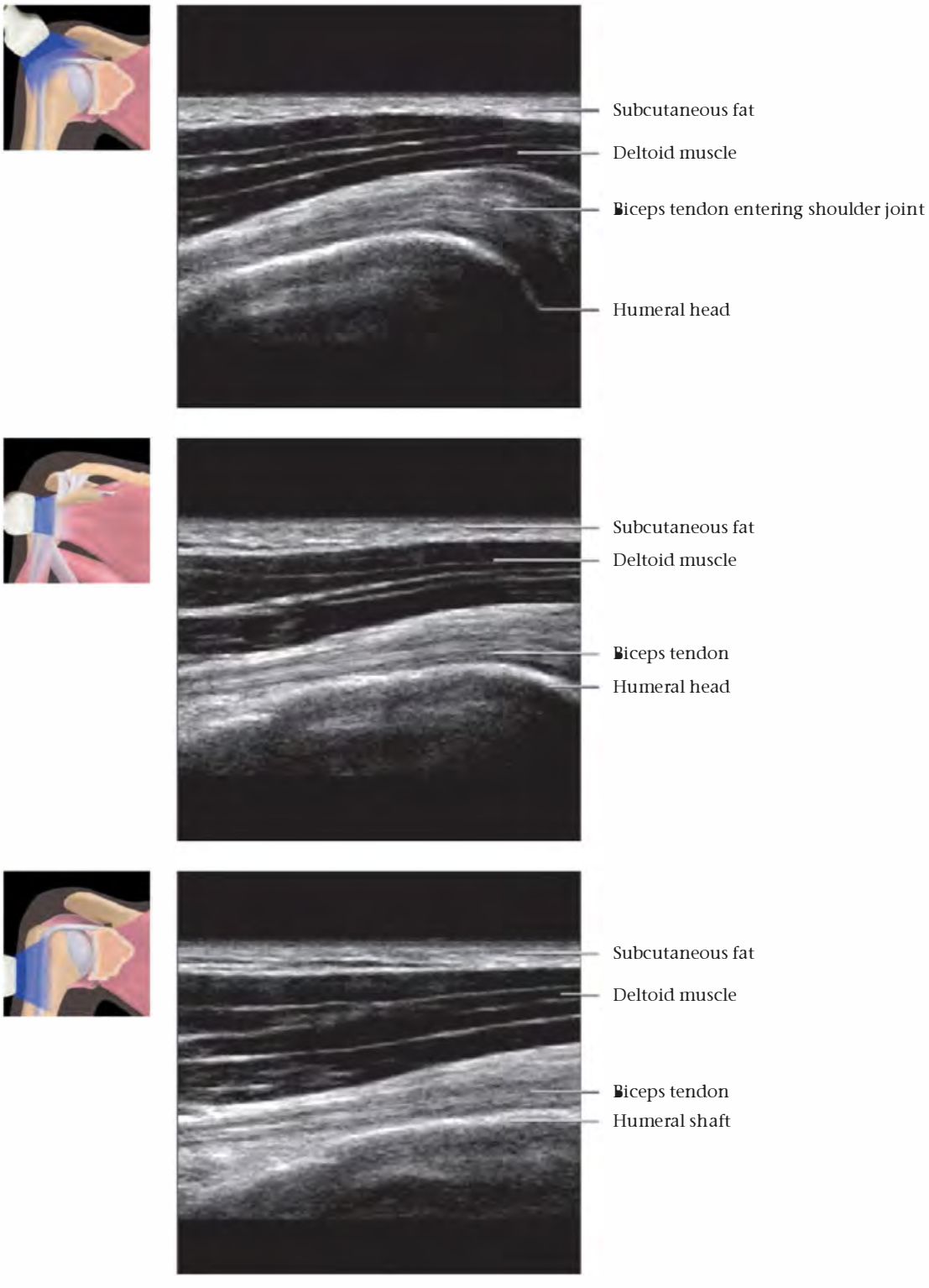
TRANSVERSE US, BICEPS TENDON



(Top) *Transverse grayscale ultrasound at the proximal aspect of the biceps tendon: The bicipital groove forms a fibroosseous tunnel for the biceps tendon. The normal biceps tendon has an ovoid configuration. With tendinosis, the tendon becomes larger and more rounded in appearance.* ***(Middle)*** *Transverse grayscale US shows the biceps tendon. The biceps tendon is held in position by the transverse ligament. The subscapularis tendon inserts into the lesser tuberosity, which forms the medial lip of the bicipital groove. The biceps tendon may sublux medially from the groove and may be associated with subscapularis tendon injury.* ***(Bottom)*** *Transverse grayscale US shows relations of the biceps tendon. The transverse ligament is not a distinct entity but consists of a fibrous expansion of both the pectoralis major tendon and subscapularis tendon inserting into the lateral lip of the bicipital groove.*

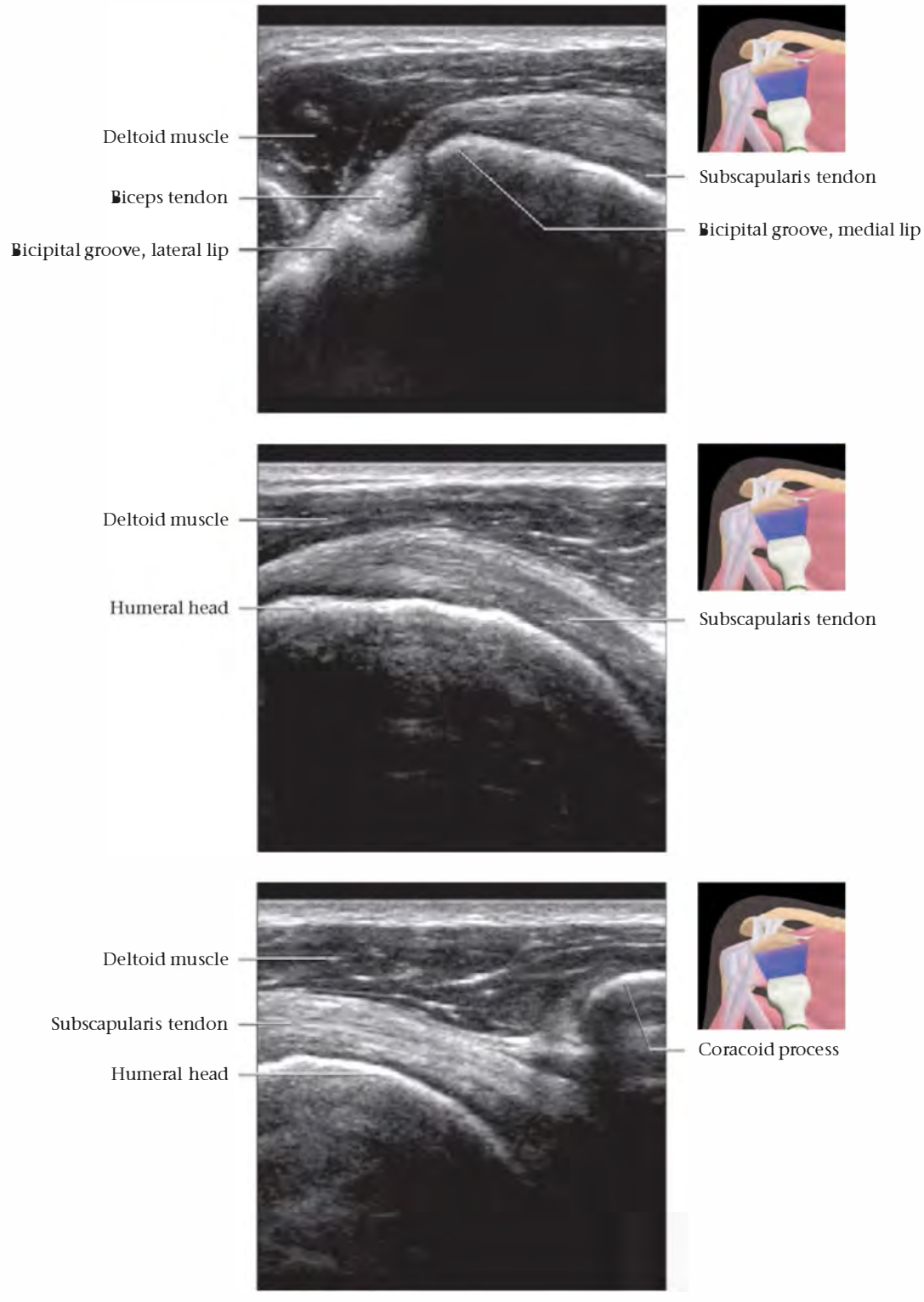
SHOULDER

LONGITUDINAL US, BICEPS TENDON



(Top) *Longitudinal grayscale ultrasound shows the uppermost section of the biceps tendon. The intraarticular portion of the biceps long head tendon cannot be fully depicted on longitudinal imaging. On longitudinal section, the biceps tendon seems to expand at its upper end as it becomes more ovoid in contour. This location is also the most common site of biceps tendinosis, which also manifests as enlargement of the biceps tendon.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the upper section of the biceps tendon. A small amount of fluid in the biceps tendon sheath, which is continuous with the glenohumeral joint, is normal and should not be mistaken for tenosynovitis. No fluid is depicted in this image.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the lower aspect of the biceps tendon. Most incomplete tears of the biceps tendons are longitudinal in orientation and are best depicted on transverse imaging.*

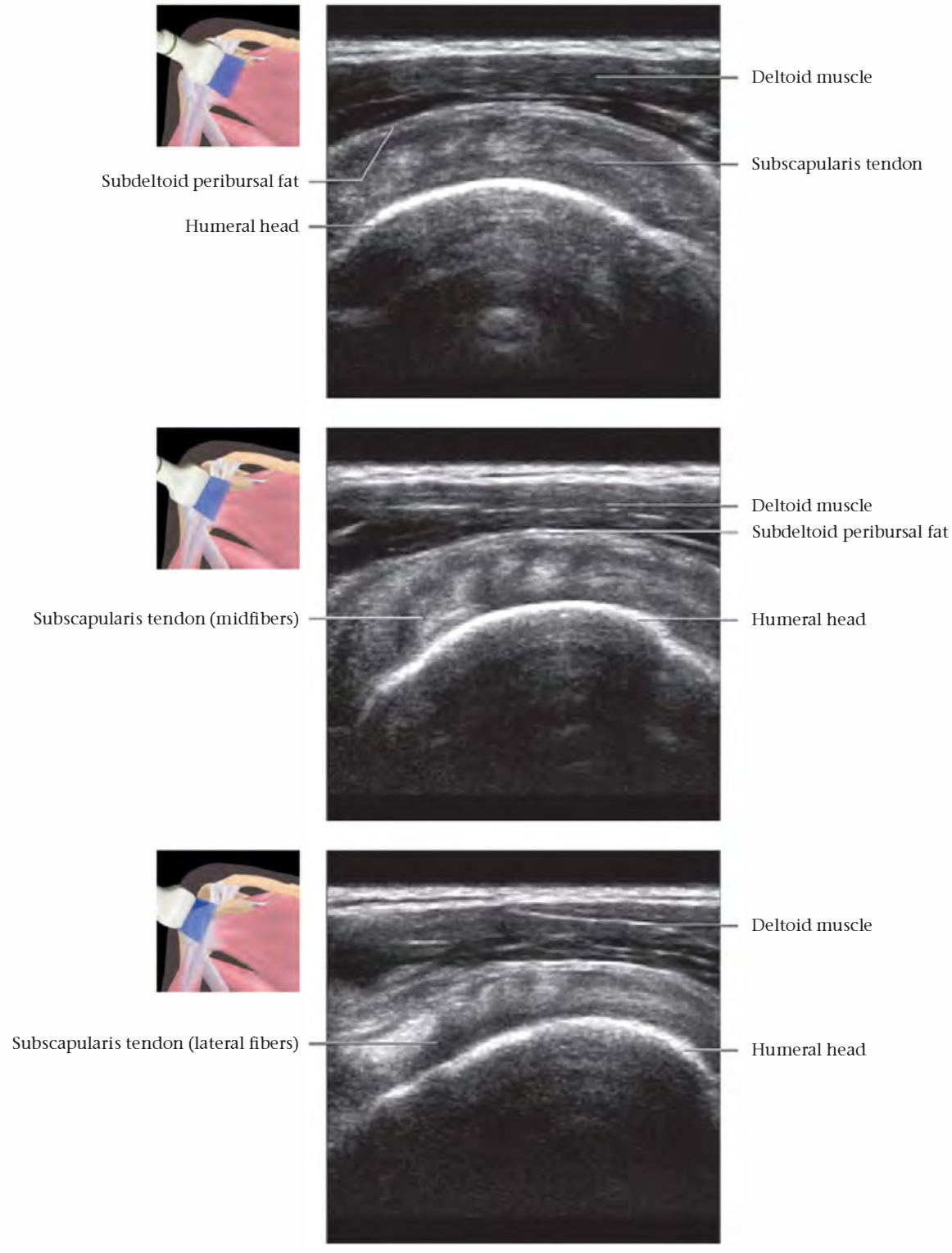
LONGITUDINAL, SUBSCAPULARIS



(Top) *Longitudinal grayscale ultrasound shows the subscapularis insertion. The subscapularis inserts into the medial lip of the bicipital groove but has a fibrous expansion traversing the biceps tendon, through which it also gains attachment to the lateral lip of the bicipital groove.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the subscapularis insertional area. Complete tears of the subscapularis are uncommon and usually follow a severe traumatic event. Partial tears are more common and usually involve the superior edge of the tendon.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the subscapularis tendon. The subscapularis moves beneath the coracoid process during internal-external rotation. Impingement may potentially occur at this location (subcoracoid impingement).*

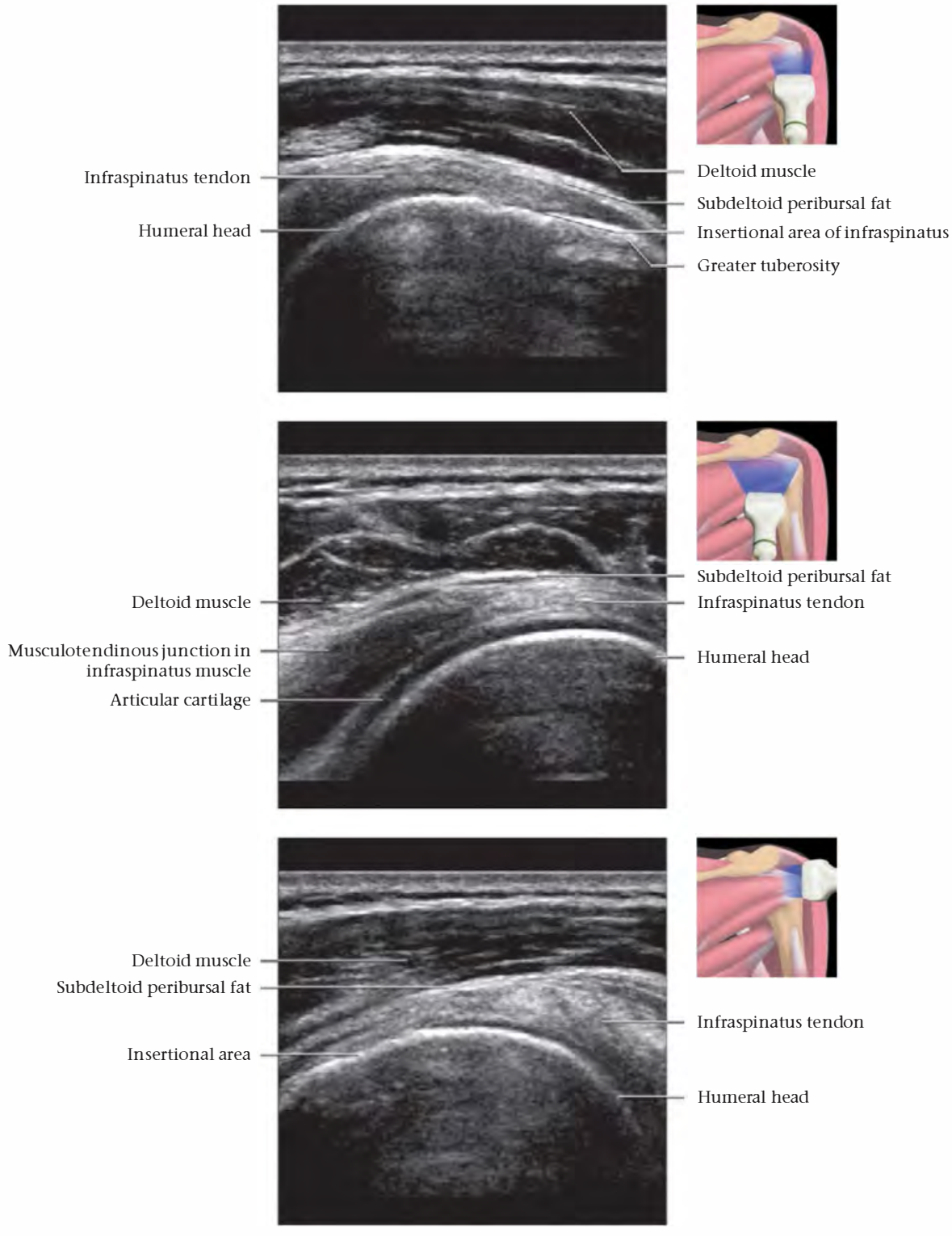
SHOULDER

TRANSVERSE US, SUBSCAPULARIS TENDON



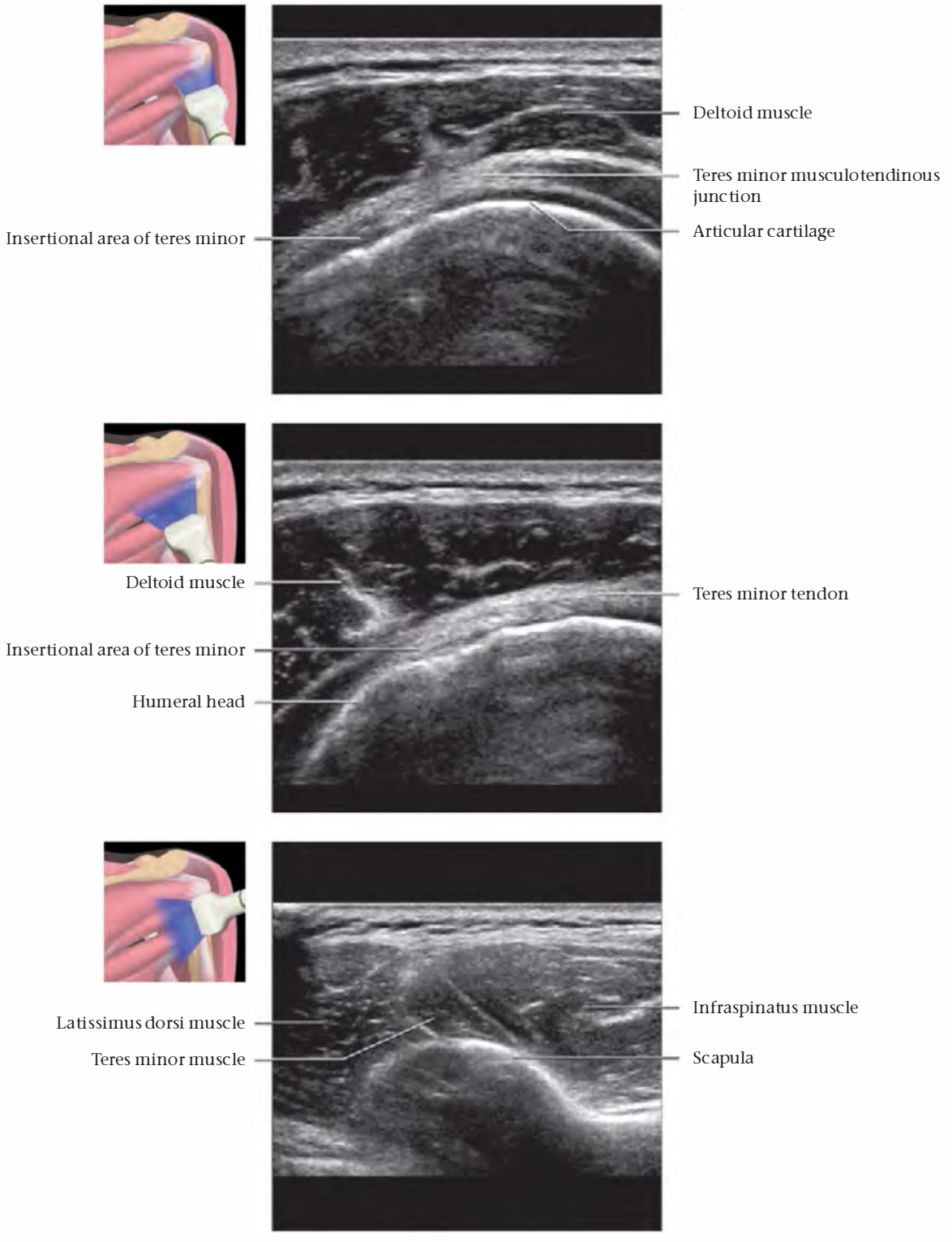
(Top) *Transverse grayscale ultrasound shows the subscapularis tendon midfibers. As they converge toward the insertion, fiber bundles of the multipennate subscapularis tendon give the tendon a mixed echogenic appearance. This is normal and should not be mistaken for tendinosis.* ***(Middle)*** *Transverse grayscale ultrasound shows the subscapularis at the level of midfibers.* ***(Bottom)*** *Transverse grayscale ultrasound shows the subscapularis tendon. Tears of the subscapularis tendon usually occur just proximal to the insertional area. These tears may involve the fascial covering of the biceps tendon, facilitating biceps tendon dislocation.*

LONGITUDINAL AND TRANSVERSE US, INFRASPINATUS



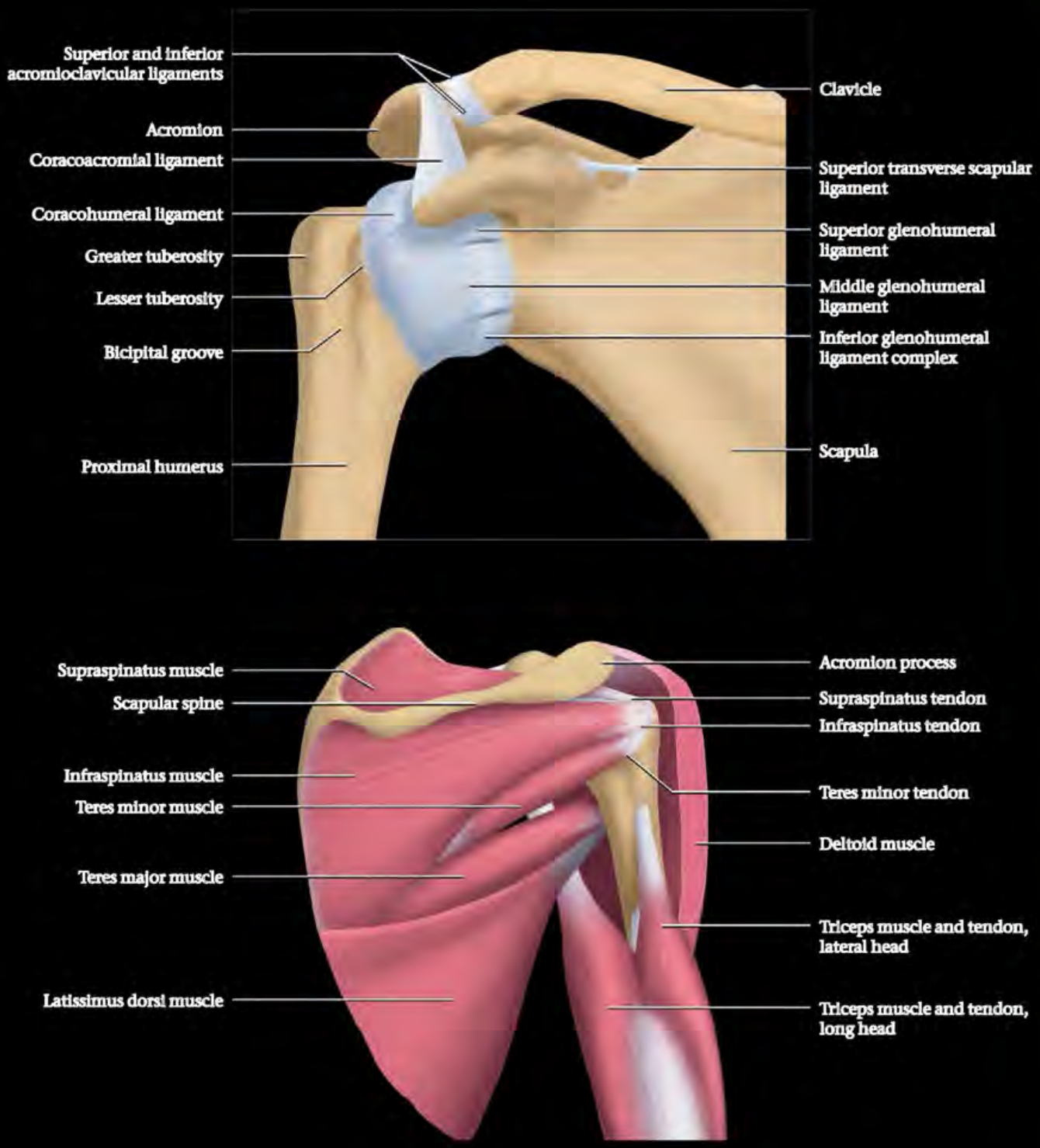
(Top) *Longitudinal grayscale ultrasound shows the infraspinatus tendon insertional area. The infraspinatus tendon is less commonly torn than the supraspinatus tendon. Most tears are avulsive-type tears involving the insertional area.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the infraspinatus musculotendinous junction. The muscle fibers interdigitate with the tendon at the musculotendinous junction and should not be mistaken for tears/tendinosis.* ***(Bottom)*** *Transverse grayscale ultrasound shows the infraspinatus insertional area. All tears of the rotator cuff tendons should be confirmed in both planes (transverse and longitudinal).*

LONGITUDINAL AND TRANSVERSE US, TERES MINOR



(Top) *Longitudinal grayscale ultrasound shows the teres minor muscle insertional area. The teres minor muscle is usually not torn in isolation, but it may be torn in massive rotator cuff tears. It is a small muscle and tendon seen at the posteroinferior edge of the infraspinatus tendon.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the teres minor insertional area.* ***(Bottom)*** *Transverse grayscale ultrasound shows the teres minor. The teres minor muscle is best depicted on longitudinal imaging at the inferior aspect of the infraspinatus tendon. Isolated atrophy of the teres minor muscle can occur in quadrilateral space syndrome due to compression of the axillary nerve (part of the deltoid muscle may also be affected).*

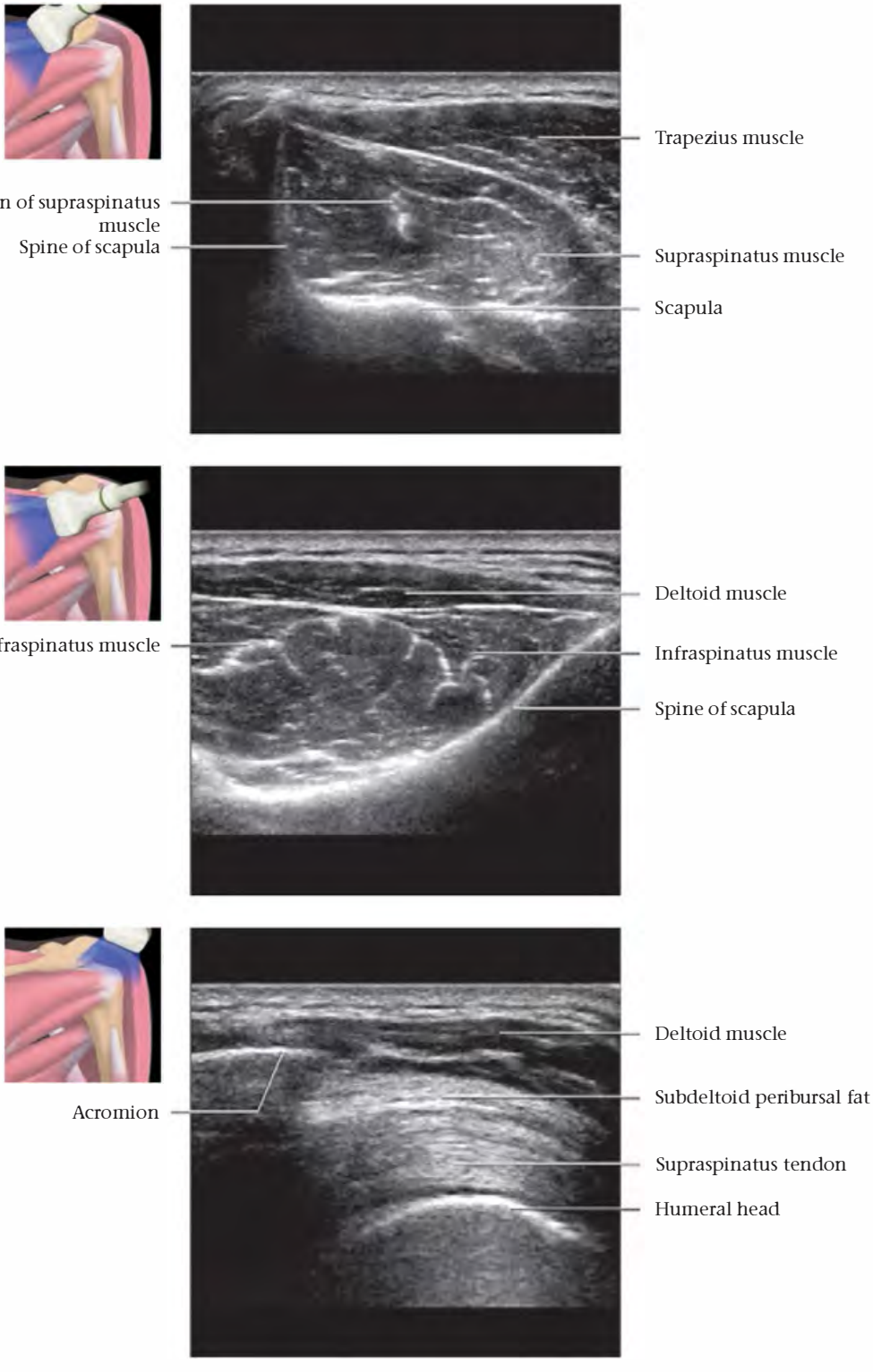
GRAPHICS, SHOULDER JOINT AND POSTERIOR ASPECT



***(Top)** Anterior graphic illustrates the right shoulder in deep dissection. The muscles have been removed. **(Bottom)** Posterior graphic illustrates the shoulder. Superficial scapulohumeral dissection demonstrates the musculature.*

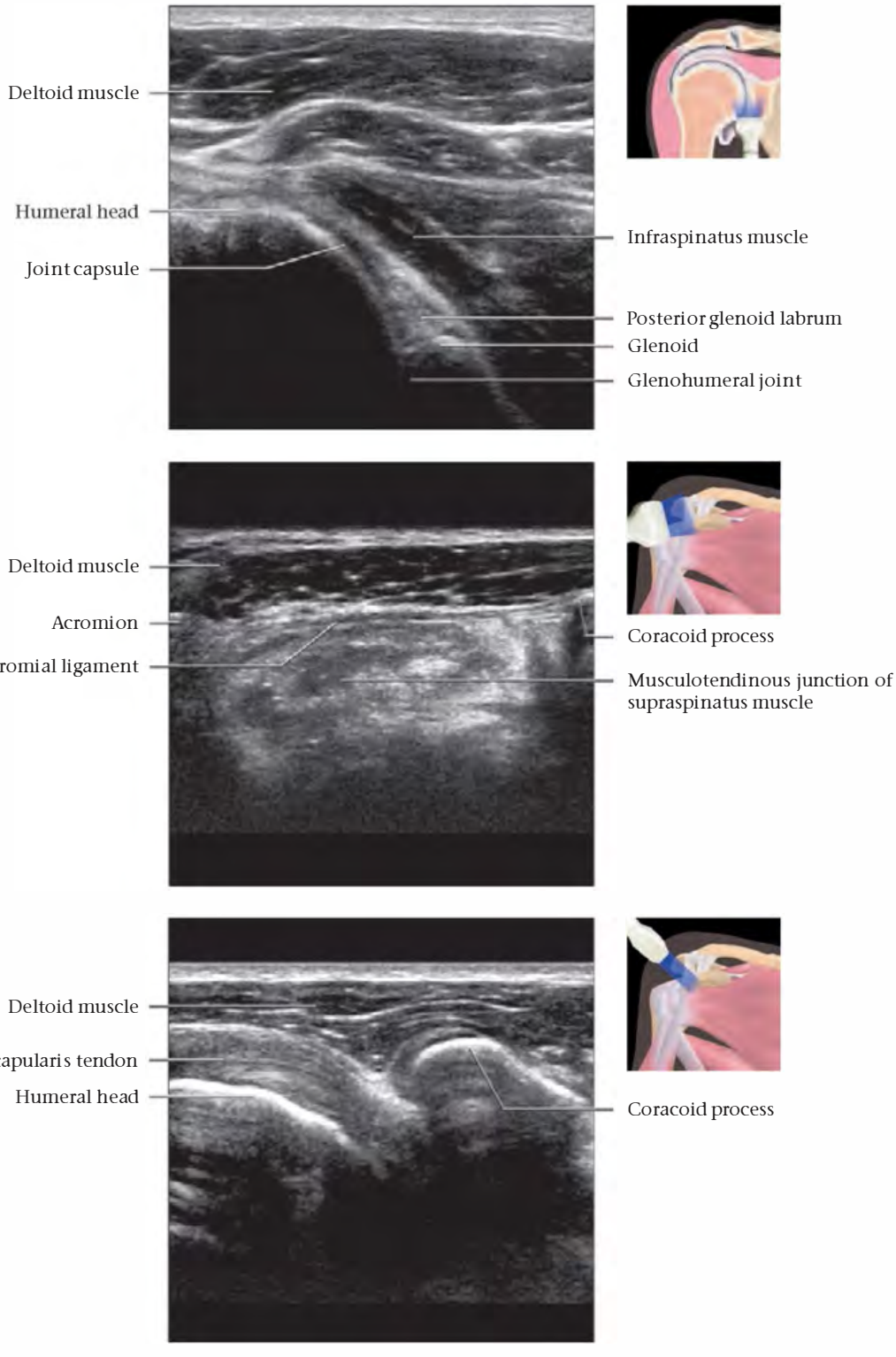
SHOULDER

LONGITUDINAL US, POSTERIOR ASPECT



(Top) *Longitudinal grayscale US shows the posterior shoulder at the supraspinatus muscle. Muscle atrophy is common in rotator cuff pathology. US is almost as sensitive as MR in depiction of muscle atrophy. Atrophy is seen as reduction in muscle bulk with increase in muscle echogenicity. As a result, the central tendon is less readily seen.* ***(Middle)*** *Longitudinal grayscale US shows the shoulder on posterior view. Infraspinatus muscle atrophy usually accompanies supraspinatus muscle atrophy to a lesser or greater degree. Similar to the supraspinatus muscle, muscle bulk is reduced and becomes more echogenic with the central tendon becoming less easy to see.* ***(Bottom)*** *Longitudinal grayscale US shows the supraspinatus tendon. The supraspinatus tendon slides below the acromion during abduction. This relationship may be seen from either the anterior or posterior aspect of the shoulder. Dynamic imaging may reveal impingement of the supraspinatus against the acromion during abduction.*

LONGITUDINAL AND TRANSVERSE US, POSTERIOR GLENOID LABRUM AND GLENOHUMERAL JOINT



(Top) *Longitudinal grayscale ultrasound shows the posterior shoulder. The glenohumeral joint is most easily seen from the posterior aspect. This is a good site for ultrasound-guided joint injection. Joint effusions are also best seen in this area.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the coracoacromial ligament. The coracoacromial ligament extends from the coracoid process to the anteroinferior margin of the acromion. Impingement of the supraspinatus tendon and the overlying subacromial-subdeltoid bursa may occur during shoulder abduction.* ***(Bottom)*** *Transverse grayscale ultrasound shows the coracoid process. The coracoid process is close to the humeral head and intervening subscapularis. Occasionally, the coracohumeral distance is reduced, and subcoracoid impingement may potentially occur.*

AXILLA

TERMINOLOGY

Definitions

- Fat-filled space between upper limb and thoracic wall

IMAGING ANATOMY

Extent

- Axilla is shaped like a pyramid with top layers shaved off
- Consists of apex, base, and 4 walls
  - Apex
    - Bounded by scapula, 1st rib, and mid 1/3 of clavicle
    - Arm communicates with posterior triangle of neck via apex of axilla
  - Anterior wall
    - Composed of pectoralis major and minor muscles
  - Posterior wall
    - Composed of teres major, latissimus dorsi, and subscapularis muscles
  - Medial wall
    - Composed of serratus anterior, upper ribs, and intercostal spaces
  - Lateral wall
    - Medial and lateral lips of bicipital groove into which anterior and posterior walls are inserted
  - Base
    - Composed of axillary fascia, subcutaneous fat, and skin
- Contents of axilla
  - Axillary artery and vein
  - Cords and branches of brachial plexus
  - Coracobrachialis and biceps muscles
  - Lymph nodes and vessels
  - Fat
- Axillary artery
  - Continuation of subclavian artery
  - Lies on posterior wall of axilla
  - Surrounded by cords and branches of brachial plexus
  - Vein lies medial to artery
  - Arterial branches
    - Superior thoracic artery
    - Acromiothoracic artery
    - Lateral thoracic artery
    - Subscapular artery
    - Anterior and posterior circumflex humeral arteries
- Axillary vein
  - Continuation of brachial vein
    - Tributaries correspond to branches of axillary artery and also cephalic vein
- Brachial plexus
  - Cord and terminal branches of brachial plexus pass through axilla
  - 3 cords: Lateral, medial, and posterior
  - Lateral cord gives rise to
    - Lateral pectoral nerve
    - Musculocutaneous nerve: Pierces coracobrachialis to descend down arm between biceps and brachialis muscles
    - Contributes to median nerve
  - Medial cord gives rise to
    - Medial pectoral nerve
    - Ulnar nerve
    - Contributes to median nerve
    - Medial cutaneous nerves of arm and forearm
  - Posterior cord gives rise to
    - Subscapular nerve
    - Thoracodorsal nerve
    - Axillary nerve, which passes through quadrilateral space posteriorly around surgical neck of humerus, accompanied by posterior circumflex humeral artery
    - Radial nerve

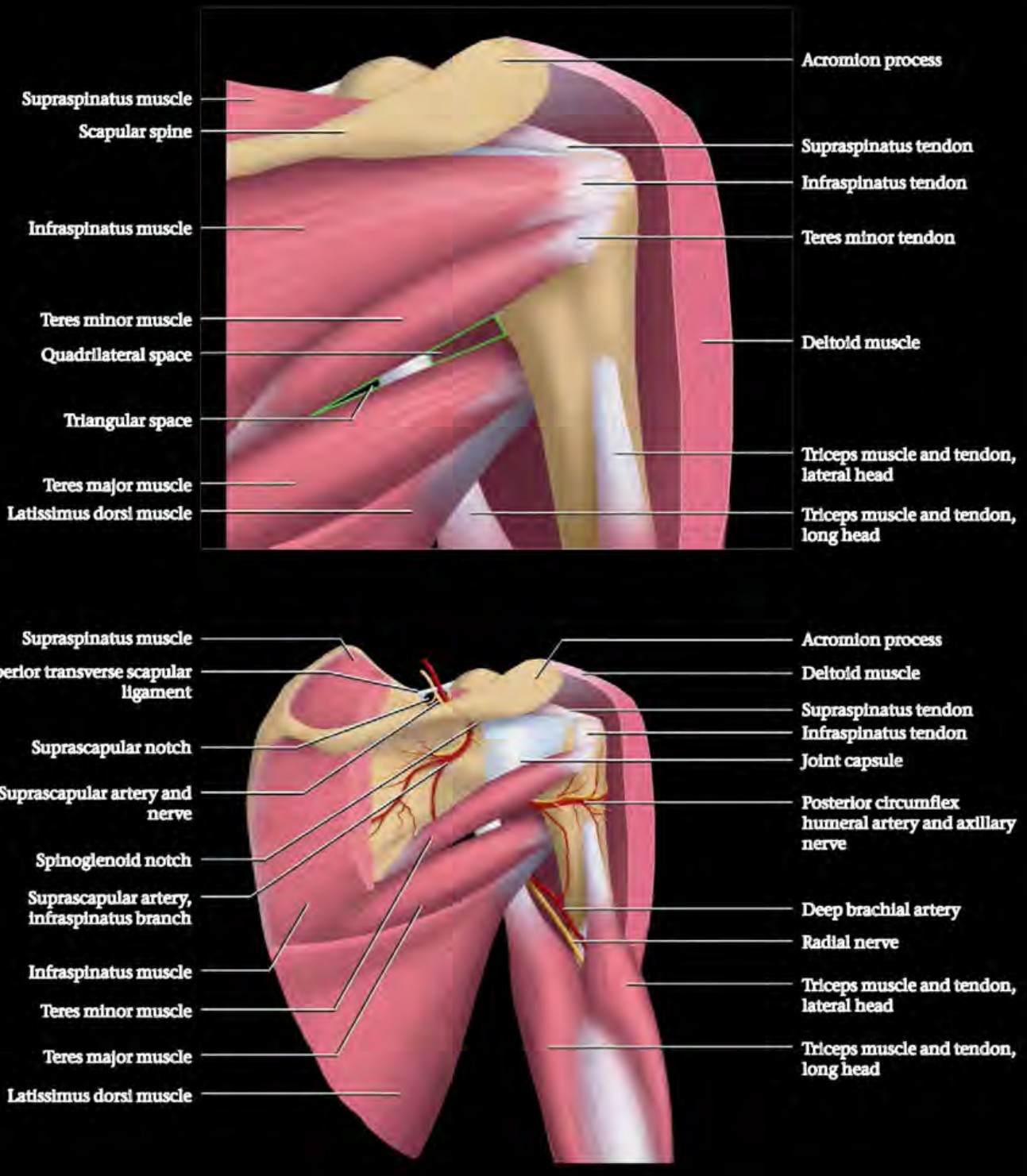
Anatomy Relationships

- **Quadrilateral space**
  - Superior border: Teres minor muscle
  - Inferior border: Teres major muscle
  - Lateral border: Surgical neck of humerus
  - Medial border: Long head of triceps muscle
  - Contents: Axillary nerve and posterior circumflex humeral artery
    - Axillary nerve supplies teres minor muscle, deltoid muscle, posterolateral cutaneous region of shoulder and upper arm
- **Triangular space**
  - Located medial to quadrilateral space
  - Superior border: Teres minor muscle
  - Inferior border: Teres major muscle
  - Lateral border: Long head of triceps muscle
  - Contents: Circumflex scapular artery
    - Branch of subscapular artery supplying infraspinatus fossa

ANATOMY IMAGING ISSUES

Questions

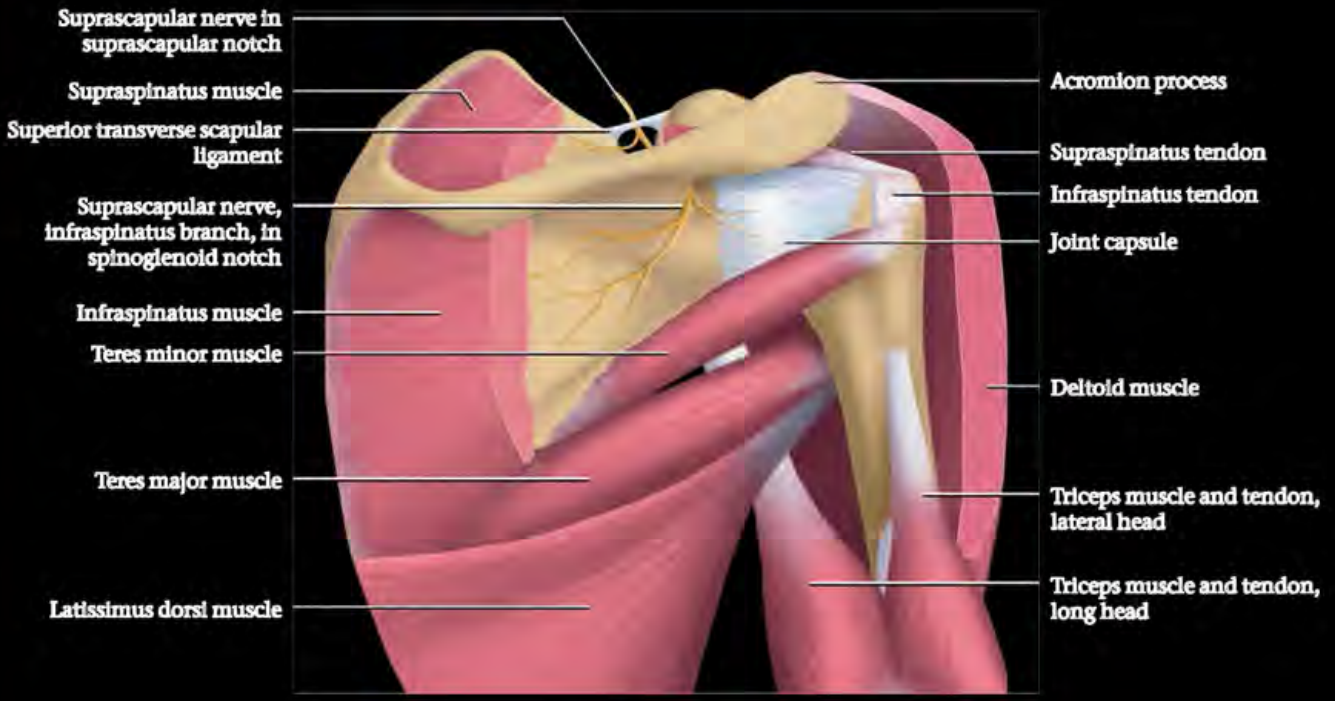
- Quadrilateral space syndrome = neurovascular compression syndrome due to compression of axillary nerve or posterior humeral circumflex artery in quadrilateral space
  - Can have complications that are purely neurologic, purely vascular, or both
  - Effects
    - Point tenderness of quadrilateral space
    - Poorly localized shoulder pain ± paresthesia radiating top lateral arm
    - Symptoms aggravated by abduction and external rotation of arm
    - Teres minor ± deltoid atrophy
    - Intermittent ischemic-type pain
  - Due to
    - Humeral fracture
    - Fibrous bands secondary to trauma
    - Muscle hypertrophy ± fibrotic bands seen in throwing athletes, tennis players, or volleyball players
    - Paralabral cysts: Most common cause of mass in this region, high associations with labral tears
    - Glenohumeral joint dislocation
    - Extreme or prolonged abduction of arm during sleep

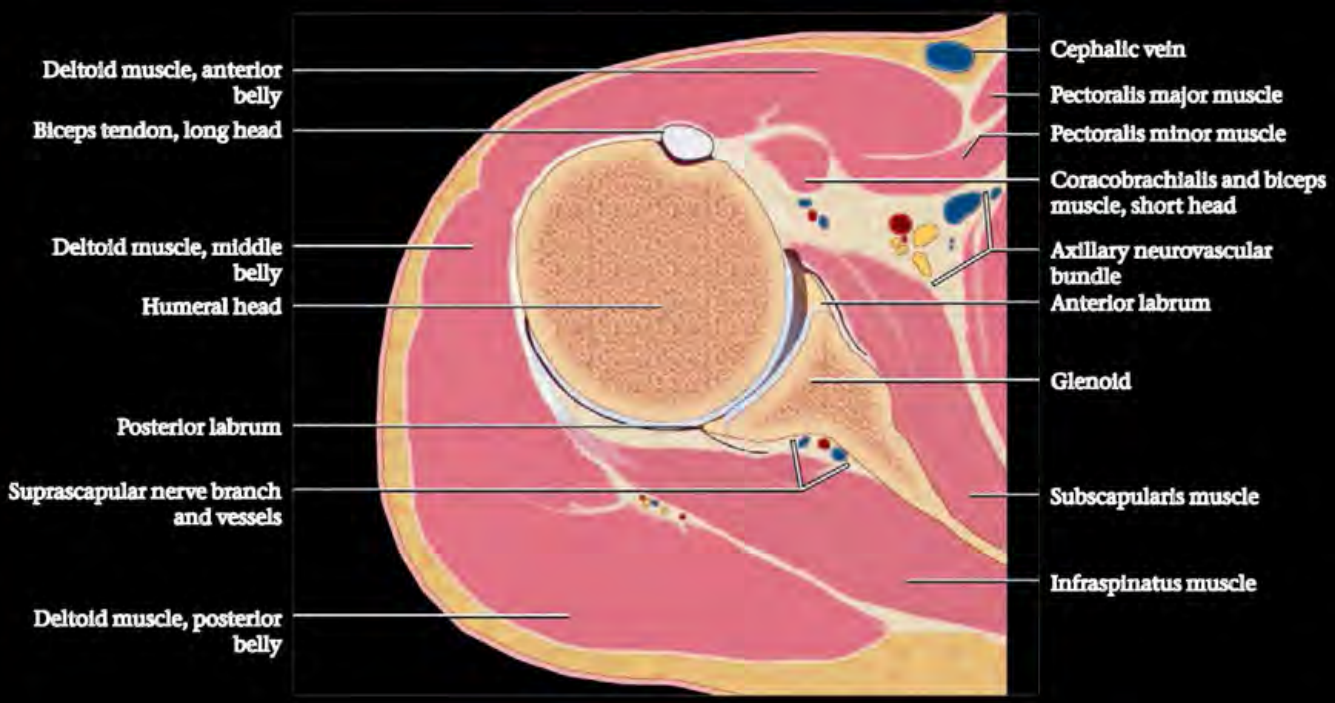


***(Top)** Posterior graphic shows the shoulder. Superficial scapulohumeral dissection shows the location of the quadrilateral space and triangular space (each outlined in green). The quadrilateral space transmits the axillary nerve and the posterior circumflex humeral artery while the much less important triangular space transmits the scapular circumflex vessels. **(Bottom)** Graphic of the deep scapulohumeral dissection shows the major neurovascular structures, including those in the quadrilateral space.*

AXILLA

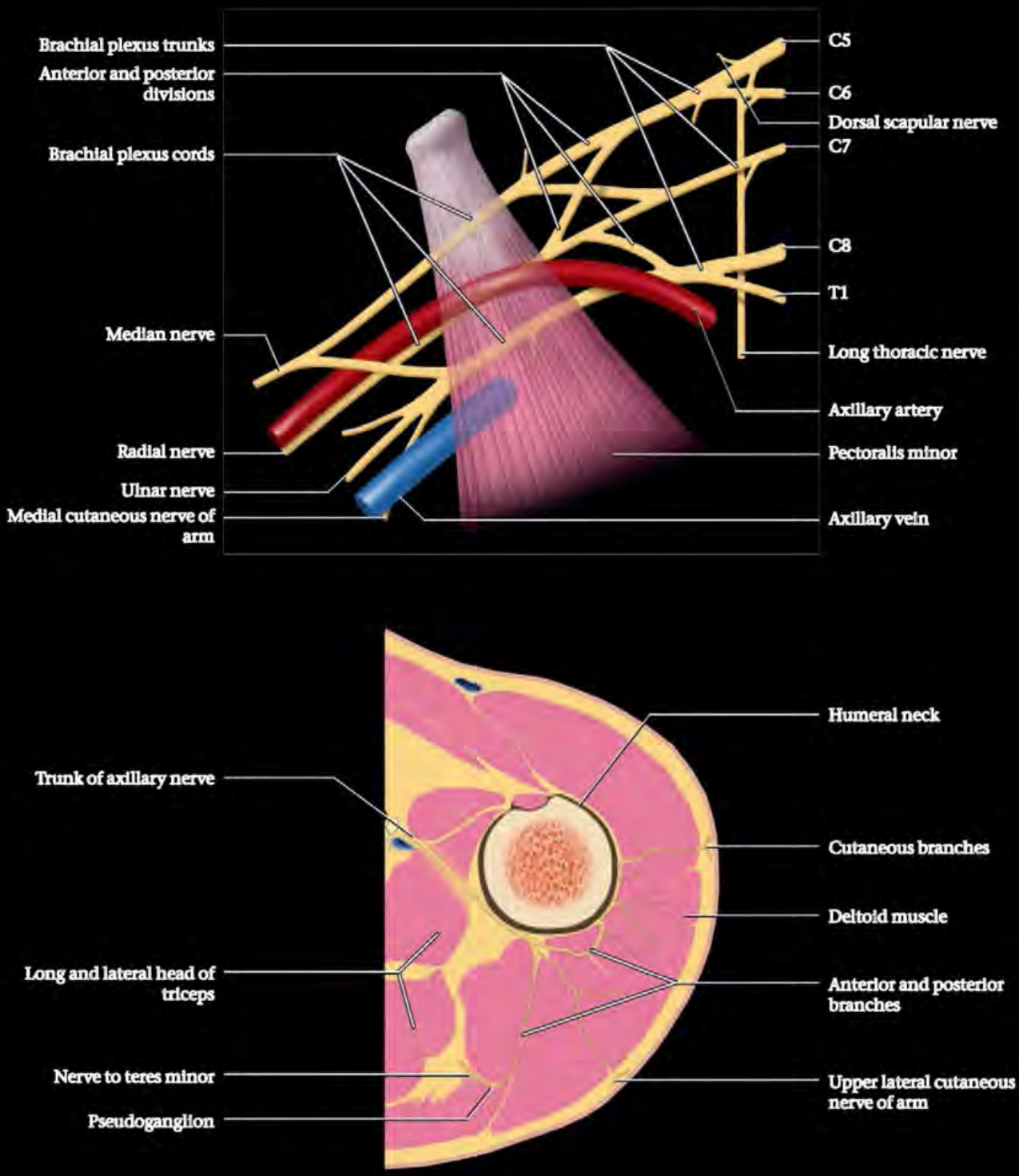
GRAPHICS, DEEPER STRUCTURES





(Top) Graphic of deep scapulohumeral dissection shows the course of the suprascapular nerve. (Bottom) Axial graphic shows the location of the suprascapular artery, nerve, and vein branches, just below the level of the spinoglenoid notch. The suprascapular nerve is a mixed motor and sensory nerve. It arises from the anterior rami of the C5 and C6 roots. It passes deep to the superior transverse scapular ligament of the suprascapular notch. It then passes deep to the inferior transverse scapular ligament of the spinoglenoid notch. It supplies the supraspinatus and the infraspinatus muscles with sensory fibers to the acromioclavicular (AC) joint and the glenohumeral joint capsules.

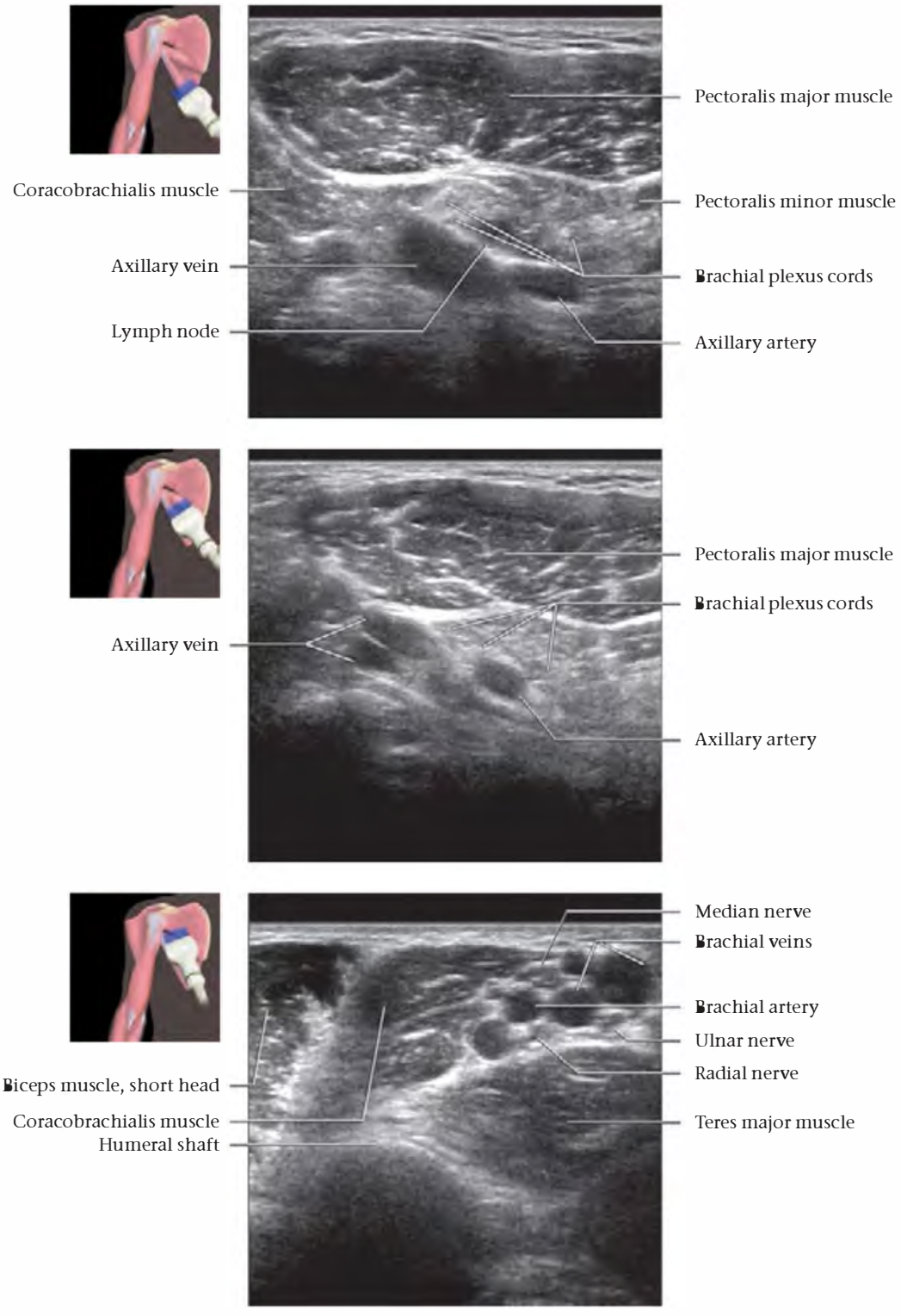
GRAPHICS, RELATIONS OF NEUROVASCULAR STRUCTURES



***(Top)** Graphic shows relations of the brachial plexus in the axilla. The brachial plexus arises from the anterior rami of the C5, C6, C7, C8, and T1 nerves. They first unite to form the superior, middle, and inferior trunks. The trunks then divide and reunite to form the lateral, posterior, and middle cords. Beyond the lateral margin of the pectoralis minor muscle, they continue as the terminal branches of the plexus (axillary, musculocutaneous, radial, medial, and ulnar nerves). **(Bottom)** Graphic shows a section through the upper arm with the axiliary nerve and its branches.*

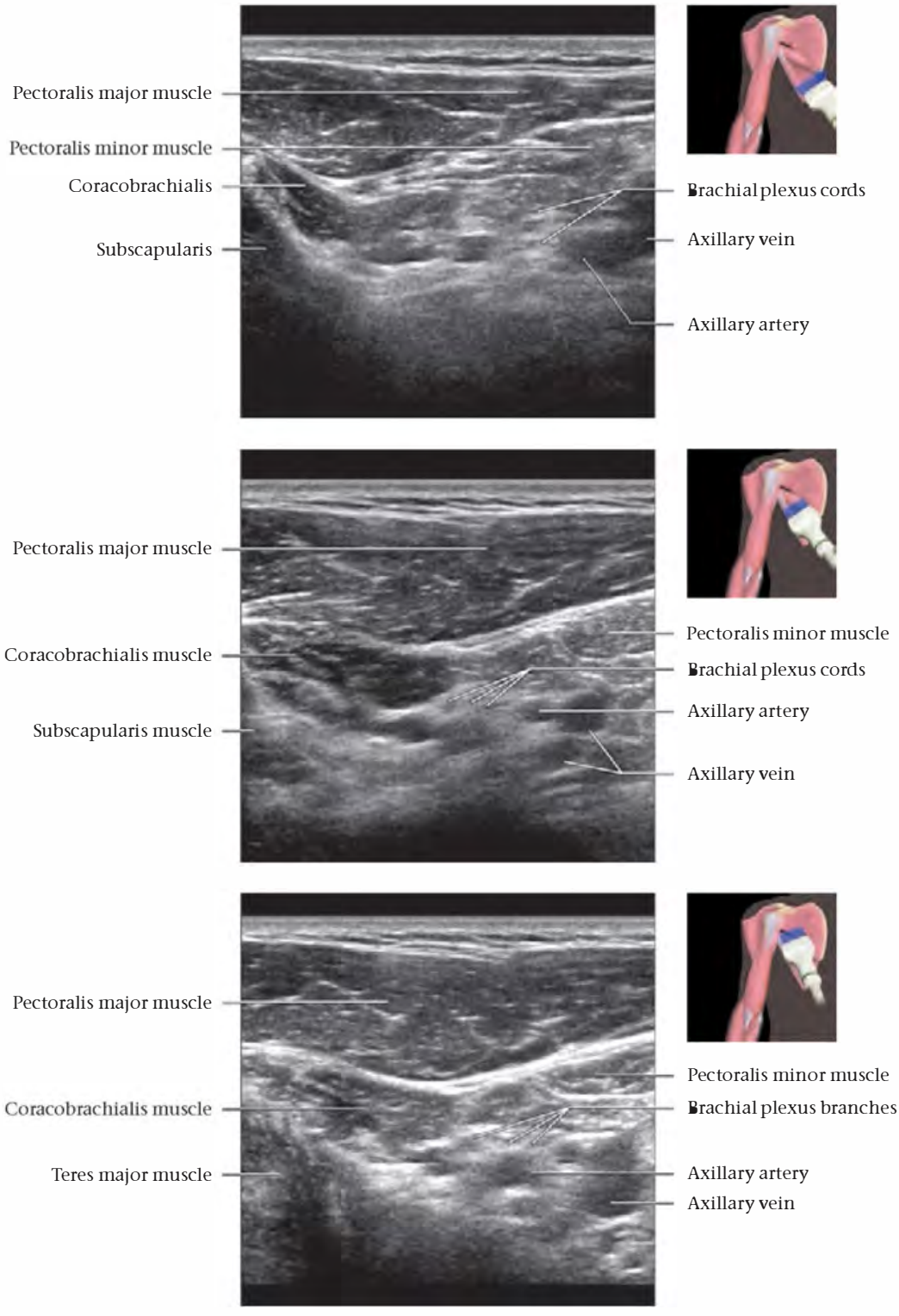
AXILLA

TRANSVERSE US, AXILLA



(Top) *Transverse grayscale ultrasound shows the proximal axilla with the arm abducted. The contents of the axilla are inspected with the arm fully abducted.* ***(Middle)*** *Transverse grayscale ultrasound shows the midportion of the axilla. The axillary artery and vein pass through the axilla surrounded by the cords of the brachial plexus. The cords (medial, lateral, and posterior) are named relative to their position alongside the axillary artery. Lymph nodes with variably fatty hila are commonly seen in the axilla around the neurovascular bundle.* ***(Bottom)*** *Transverse grayscale ultrasound shows the distal aspect of the axilla.*

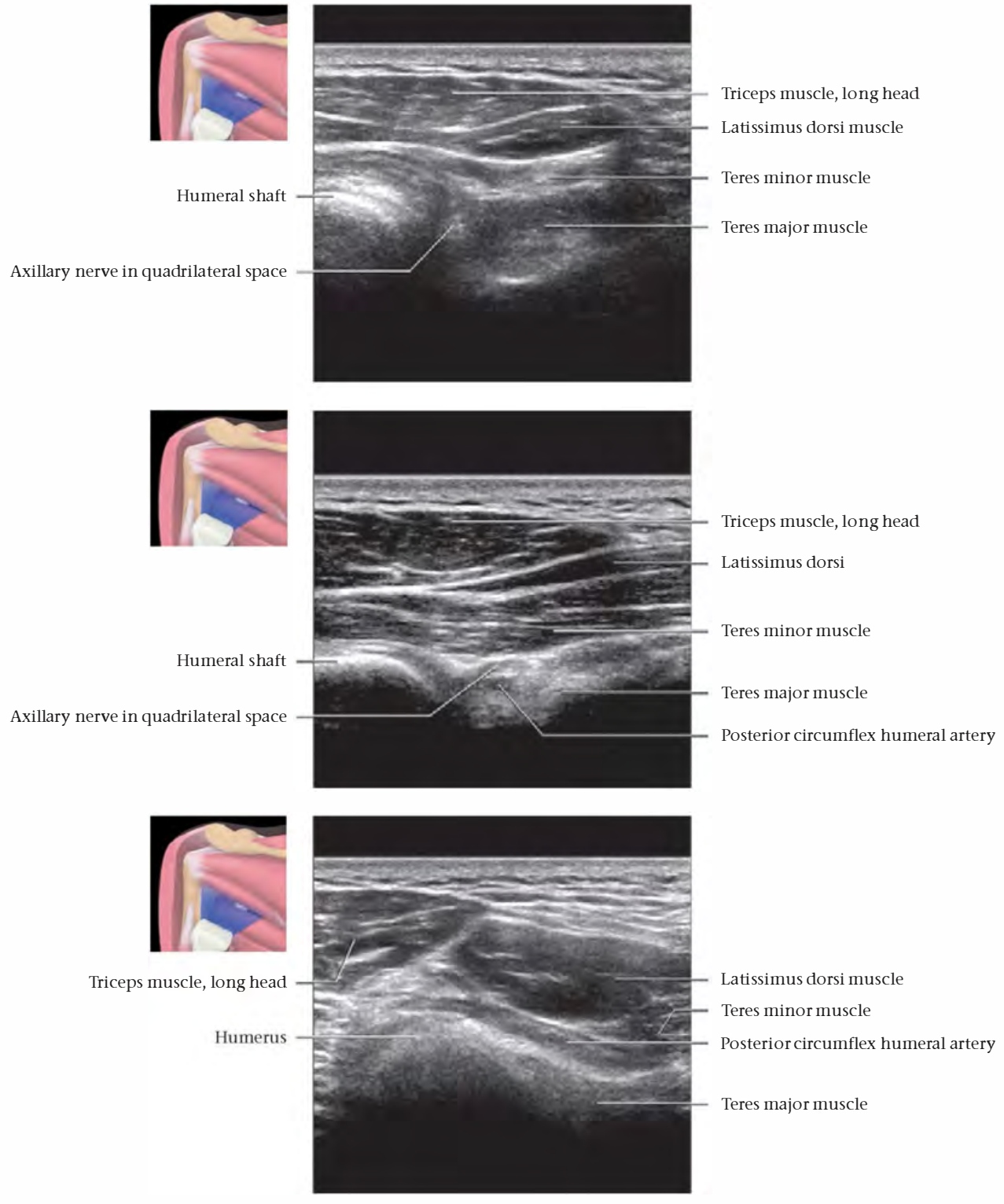
TRANSVERSE US, ANTERIOR AXILLARY WALL



(Top) *Transverse grayscale ultrasound shows the proximal anterior wall of the axilla. The anterior wall of the axilla can be examined with the arm by the side.* ***(Middle)*** *Transverse grayscale ultrasound shows the midsection of the anterior wall of the axilla. The anterior wall of the axilla is formed by the pectoralis major and pectoralis minor muscles.* ***(Bottom)*** *Transverse grayscale ultrasound shows the distal anterior wall of axilla.*

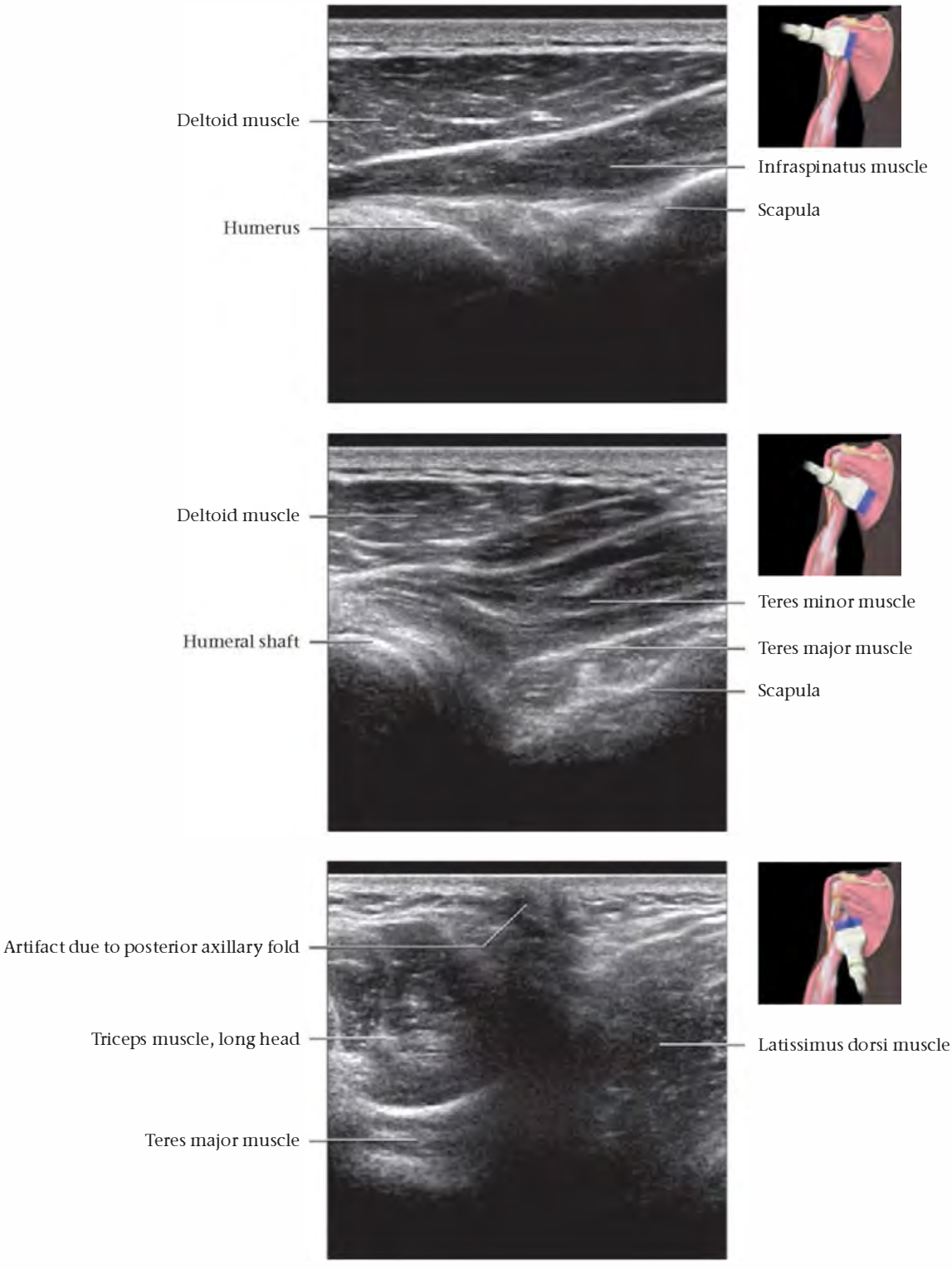
AXILLA

TRANSVERSE US, QUADRILATERAL SPACE



(Top) *Transverse grayscale ultrasound of the arm shows the anterior aspect of the quadrilateral space (quadrangular space) with the arm abducted. This space contains the axillary nerve and posterior circumflex humeral vessels.* ***(Middle)*** *Transverse grayscale ultrasound shows the quadrilateral space with the arm adducted. The contents of the space are more easily seen with the arm adducted.* ***(Bottom)*** *Transverse grayscale ultrasound in the more posterior position of the arm shows the posterior circumflex humeral artery posterior to the quadrilateral space.*

TRANSVERSE US, POSTERIOR AXILLARY WALL



(Top) *Transverse grayscale ultrasound shows the upper aspect of the posterior axillary wall.* ***(Middle)*** *Transverse grayscale ultrasound shows the middle aspect of the posterior wall of the axilla. The posterior wall of the axilla is composed of the teres major, latissimus dorsi, and subscapularis muscles.* ***(Bottom)*** *Transverse grayscale ultrasound shows the lowermost aspect of the axilla.*

ARM

IMAGING ANATOMY

Overview

- Muscles of upper arm are divided into anterior and posterior compartments

Anatomy Relationships

- **Anterior compartment of arm**
  - Coracobrachialis muscle
    - Origin: Coracoid process tip, in common with and medial to short head biceps tendon
    - Insertion: Medial surface of humeral midshaft, between brachialis and triceps muscle origins
    - Nerve supply: Musculocutaneous nerve, perforates muscle
    - Blood supply: Brachial artery, muscular branches
    - Action: Flexes and adducts shoulder, supports humeral head in glenoid
  - Biceps muscle, short head
    - Origin: Coracoid process tip, in common with and lateral to coracobrachialis tendon
    - Insertion: Radial tuberosity after joining long head
    - Nerve supply: Musculocutaneous nerve
    - Blood supply: Brachial artery, muscular branches
    - Action: Flexes elbow and shoulder, supinates forearm
  - Biceps muscle, long head
    - Origin: Predominantly supraglenoid tubercle; also superior glenoid labrum and coracoid base
    - Insertion: Radial tuberosity after joining with short head
    - Tendon runs along the bicipital groove, which is covered by transverse ligament
    - Transverse ligament spans proximal end of bicipital groove and comprises a deeper layer formed from subscapularis tendon fibers and a superficial fibrous layer in continuity with supraspinatus tendon and coracohumeral ligament
    - Nerve supply: Musculocutaneous nerve
    - Blood supply: Brachial artery, muscular branches
    - Action: Flexes elbow, supinates forearm
    - Variants, biceps muscle: 3rd head in 10% arising at upper medial aspect of brachialis muscle; 4th head can arise from lateral humerus, bicipital groove, or greater tuberosity
  - Brachialis muscle
    - Origin: Distal 1/2 of anterior humeral shaft and 2 intermuscular septa
    - Insertion: Tuberosity of ulna and anterior surface of coronoid process
    - Nerve supply: Musculocutaneous nerve plus branch of radial nerve
    - Blood supply: Brachial artery, muscular branches, and recurrent radial artery
    - Action: Flexes forearm
    - Covers anterior aspect of elbow joint
- **Posterior compartment of arm**
  - Triceps muscle, long head
    - Origin: Infraglenoid tubercle of scapula
    - Insertion: Proximal olecranon and deep fascia of arm after joining with lateral and medial heads
    - Nerve supply: Radial nerve
    - Blood supply: Deep brachial artery branches
    - Action: Elbow extension, adducts humerus when arm is extended
  - Triceps muscle, lateral head
    - Origin: Posterior and lateral humeral shaft, lateral intermuscular septum
    - Insertion: Proximal olecranon and deep fascia of arm after joining with long and medial heads
    - Nerve supply: Radial nerve
    - Blood supply: Deep brachial artery branches
    - Action: Elbow extension
  - Triceps muscle, medial head
    - Origin: Posterior humeral shaft from teres major insertion to near trochlea, medial intermuscular septum
    - Insertion: Proximal olecranon and deep fascia of arm after joining with lateral and long heads
    - Nerve supply: Radial and branches of ulnar nerve
    - Blood supply: Deep brachial artery branches
    - Action: Elbow extension
  - Anconeus muscle
    - Origin: Lateral epicondyle of humerus
    - Insertion: Lateral cortex of olecranon and posterior 1/4 of ulna
    - Nerve supply: Radial nerve
    - Blood supply: Deep brachial artery branch
    - Action: Assists elbow extension, abducts ulna
- **Fascia**
  - Brachial fascia
    - Continuous with fascia covering deltoid and pectoralis major
    - Varies in thickness; thin over biceps and thick over triceps muscles
    - Lateral intermuscular septum from lower aspect of greater tuberosity to lateral epicondyle
    - Medial intermuscular septum from lower aspect of lesser tuberosity to medial epicondyle
    - Perforated by ulnar nerve, superior ulnar collateral artery and posterior branch of inferior ulnar collateral artery
    - Provides traction on deep fascia of forearm
  - Bicipital fascia
    - Also known as lacertus fibrosus
    - Arises from medial side of distal biceps tendon at level of elbow joint
    - Passes superficial to brachial artery
    - Continuous with deep fascia of forearm

ANATOMY IMAGING ISSUES

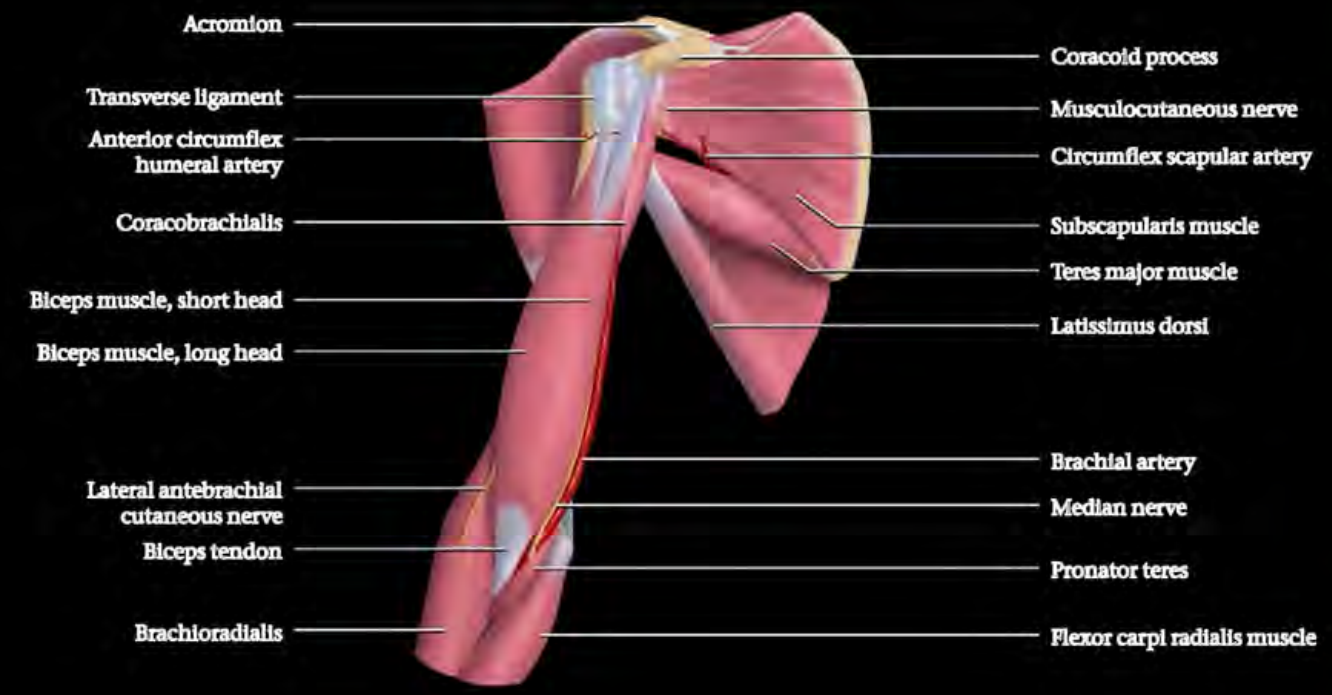
Imaging Recommendations

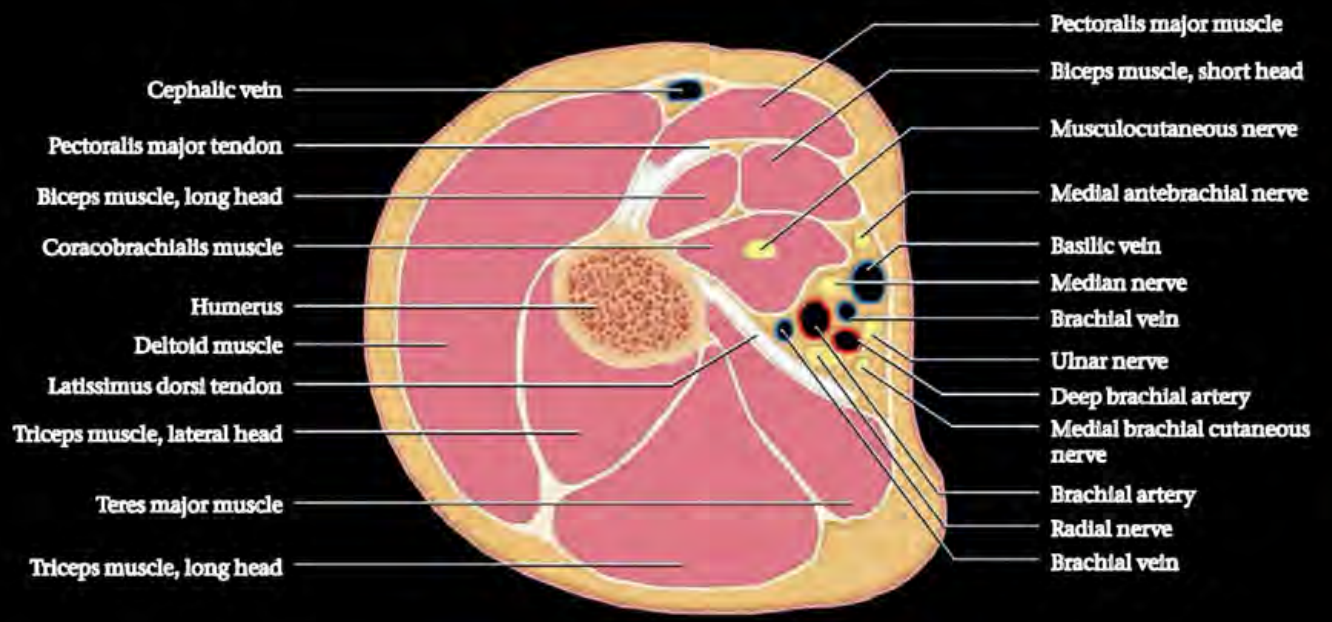
- Examine with arm extended in supine and prone positions
- Transverse plane most helpful to delineate borders of anterior and posterior compartments and relationship to neurovascular structures

Imaging Pitfalls

- Muscle may appear echogenic, simulating fatty replacement or edema when beam not aligned parallel to muscle fibers

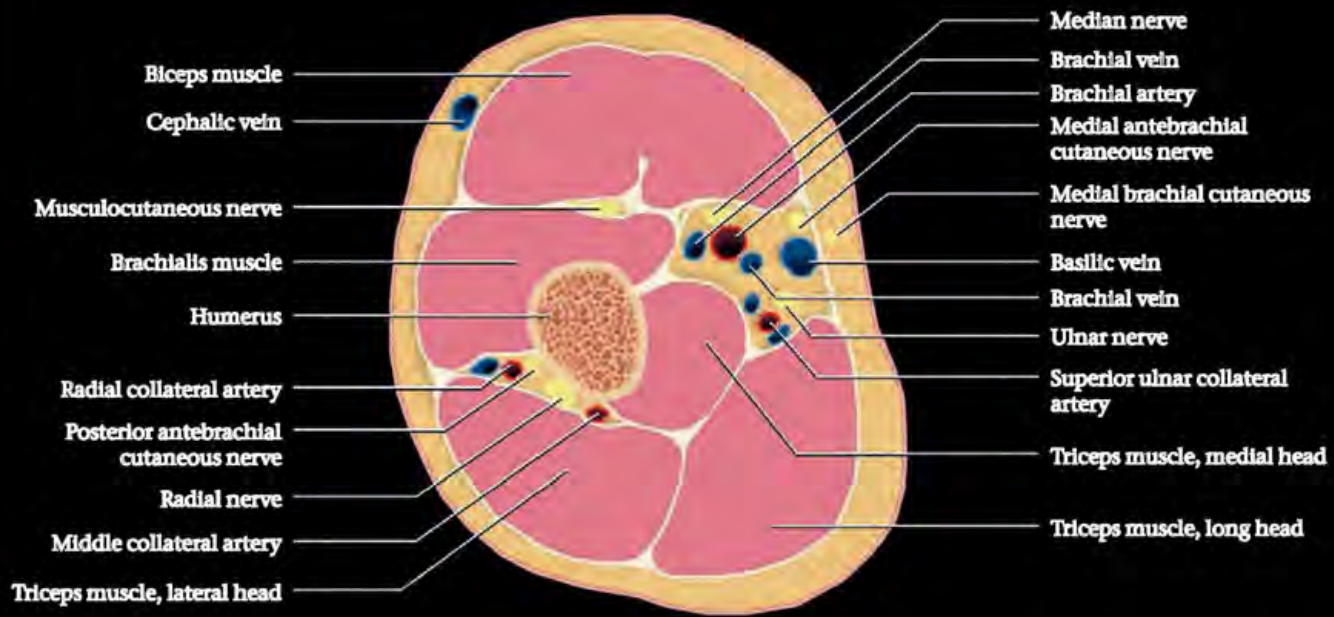
GRAPHICS, ARM

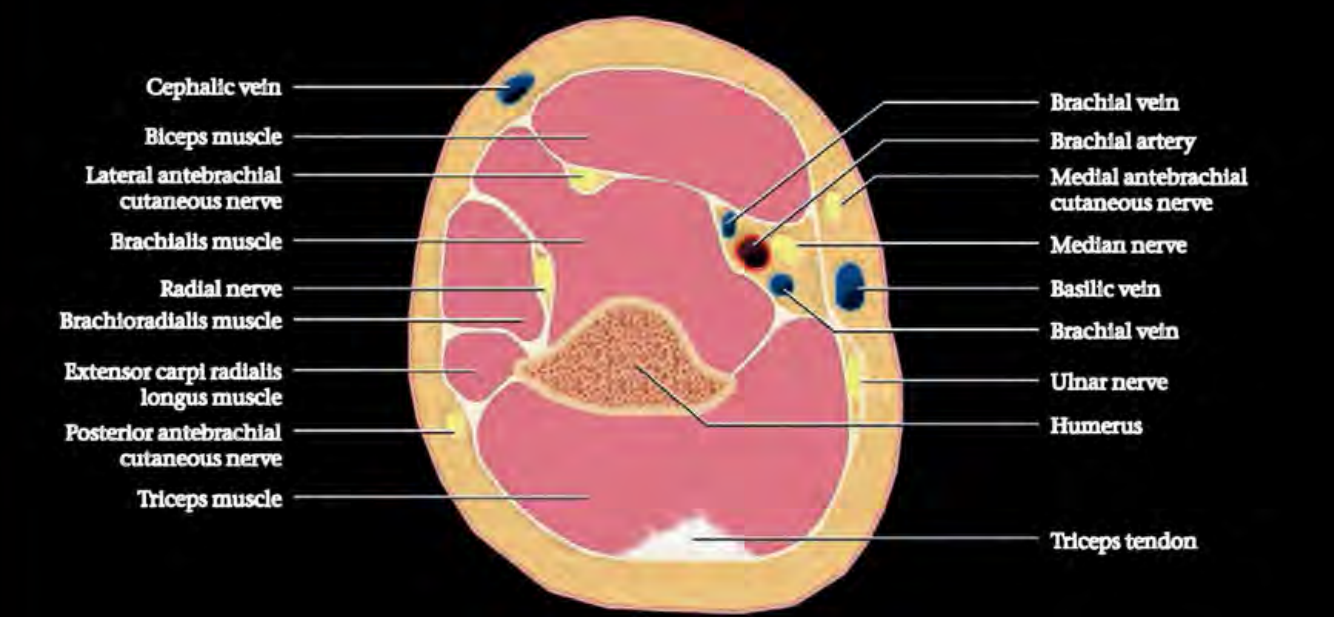




***(Top)** Anterior graphic of the arm is shown. The short head of the biceps originates from the coracoid process tip, in common with the coracobrachialis tendon. The long head of biceps tendon originates from the biceps labral complex at the supraglenoid tubercle and extends along the rotator cuff interval and bicipital groove of humerus to join with the short head and form the biceps muscle. The brachialis muscle originates from distal 1/2 of anterior humeral shaft. The transverse ligament spans the proximal bicipital groove from medial to lateral lip. Anatomical studies suggest that the transverse ligament is formed from fibers of the subscapularis tendon as well as a more superficial discrete fibrous band. **(Bottom)** Graphic shows the upper humeral level. Note that the coracobrachialis muscle is lying deep to the biceps muscle. In the posterior compartment, the lateral head and long heads of triceps muscles can be seen at this level. All the neurovascular bundles are lying on the medial side of the upper arm.*

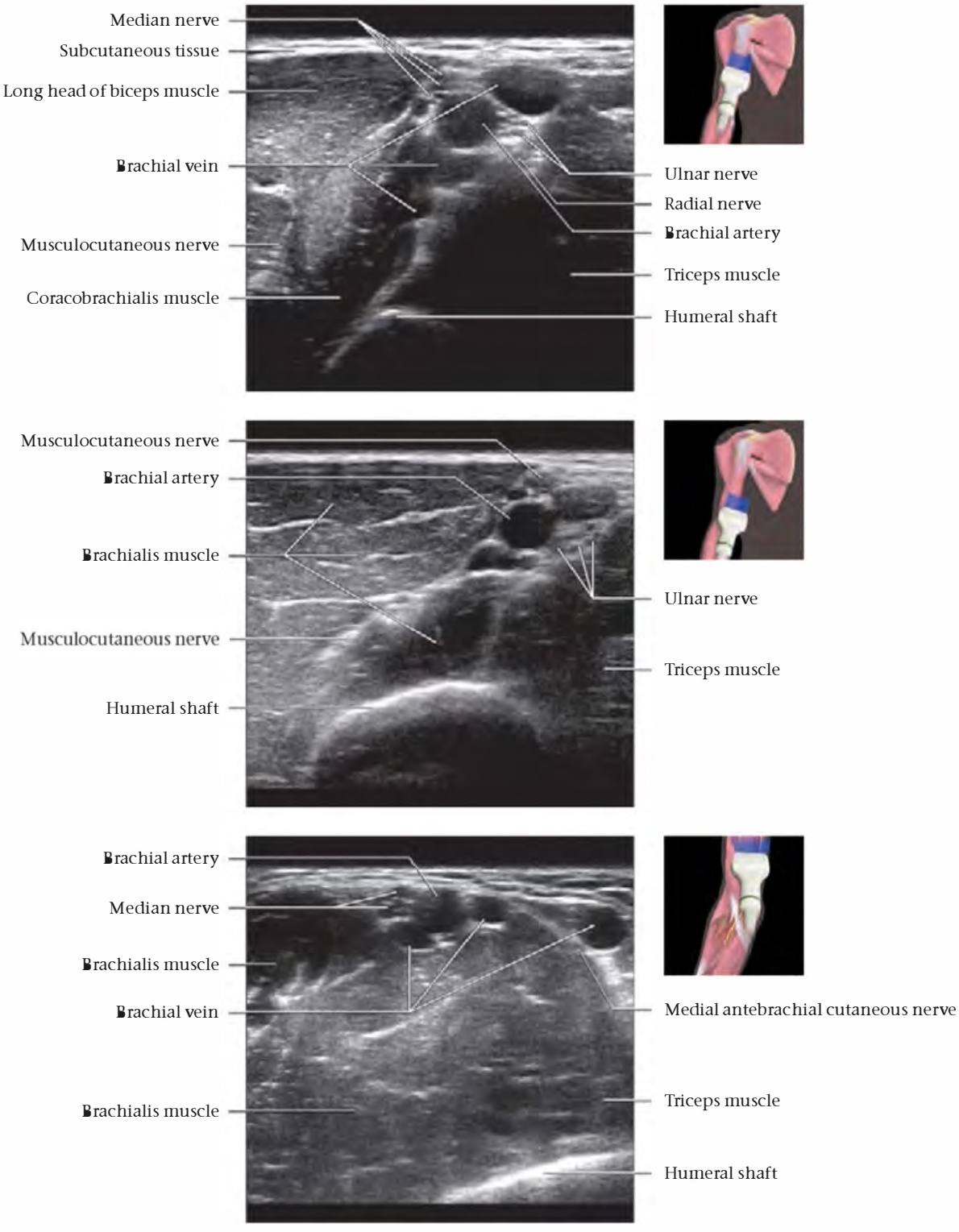
GRAPHICS, ARM





(Top) Axial graphic shows the right arm at the midhumeral level. The posterior compartment of the arm consists of 3 heads of triceps muscle and the medial head of the triceps can be delineated in this level. In the anterior compartment, the brachialis can be delineated at this midarm level. (Bottom) Axial section shows the distal humeral level. The deep brachial artery and radial nerve course along the posterolateral humerus reaching the anterolateral aspect of the humerus at this level. The median nerve is lying within the intermuscular septum. The biceps muscle is thinning anteriorly, and the triceps tendon appears.

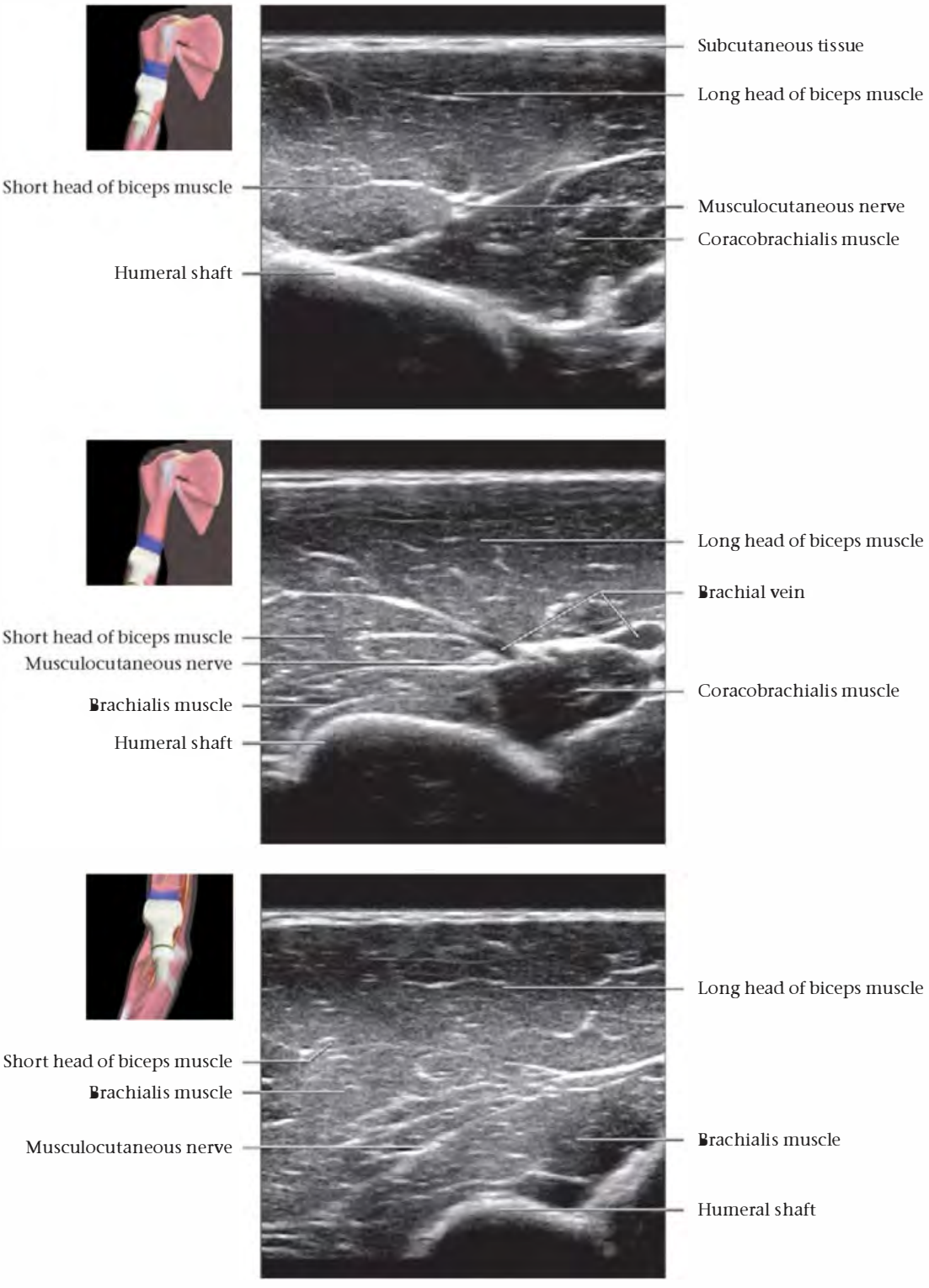
TRANSVERSE US, ANTEROMEDIAL ASPECT



(Top) *Transverse grayscale ultrasound shows the anteromedial aspect of the upper arm. The terminal branches of the brachial plexus (namely, the median nerve, ulnar nerve, and radial nerve) all lie around the brachial vein and artery. They can be recognized by their position relative to the brachial artery, the radial nerve lying deep, median nerve laterally, and ulnar nerve medially.* ***(Middle)*** *Transverse grayscale ultrasound shows the anteromedial aspect of the midarm. Compression of the median or ulnar nerve is uncommon in the midarm. The neurovascular bundle helps define the separation of the anterior and posterior compartments of the arm medially.* ***(Bottom)*** *Transverse grayscale ultrasound shows the anteromedial aspect of the distal arm. In the distal arm, the median nerve alone is closely associated with the brachial neurovascular bundle.*

ARM

TRANSVERSE US, ANTERIOR ASPECT



(Top) *Transverse grayscale ultrasound shows the proximal 1/3 of the arm. The anatomy of the upper arm is quite straightforward. The arm muscles are divided into 2 compartments. The anterior compartment is composed of the biceps, brachialis, and coracobrachialis muscles. The biceps muscle is midline, the brachialis muscle is midline and lateral, and the coracobrachialis muscle is midline and medial.* ***(Middle)*** *Transverse grayscale ultrasound shows the mid 1/3 of the anterior arm. Most of the neurovascular bundles in the arm lie anteromedially.* ***(Bottom)*** *Transverse grayscale ultrasound shows the distal 1/3 of the anterior arm. The musculocutaneous nerve is the main critical neurovascular structure of the anterior arm lying between the biceps, coracobrachialis, and brachialis muscles.*