

High Grade Sarcomas Arising from the Shoulder Girdle

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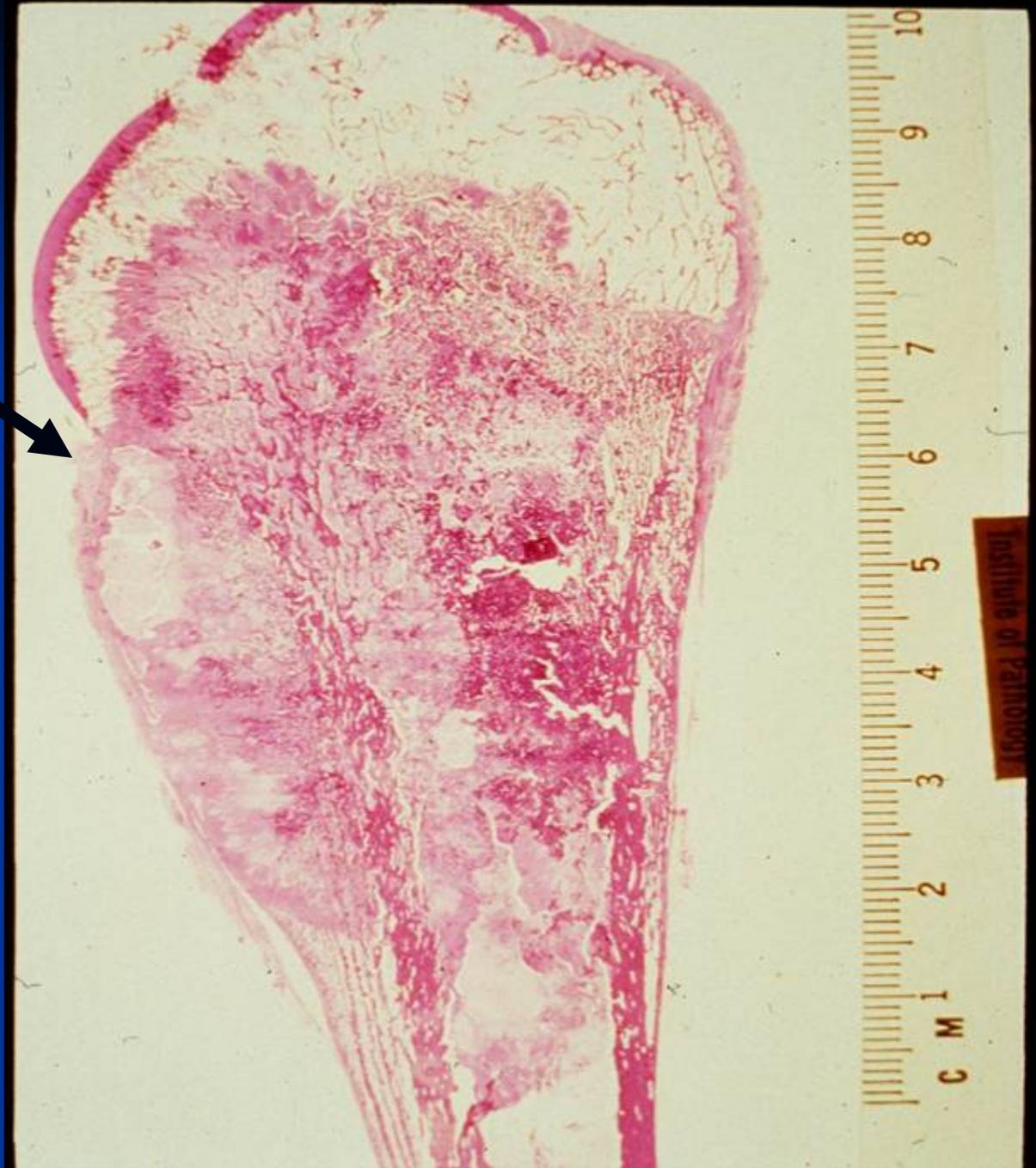
General Information

- Shoulder Girdle is the 3rd most frequent site to be affected by a sarcoma
- Proximal humerus is more commonly affected than the scapula
- Proximal humerus is the third most frequent site for an osteosarcoma (15% of all osteosarcomas)
- Clavicle is very rare site for developing a sarcoma

General Information

- **Proximal humerus:** osteosarcoma, chondrosarcoma, Ewing's sarcoma
- **Scapula:** chondrosarcoma, Ewing's Sarcoma, osteosarcoma, metastatic renal cell carcinoma
- Most (90%-95%) high grade sarcomas arise from the metaphysis of the proximal humerus or scapula and present as extracompartmental tumors (extend beyond the bony cortices of the proximal humerus or scapula)

**Metaphyseal Origin and
Extrasosseous Extension**





**Metaphyseal Origin and
Extraosseous Extension**

James H. Wang, MD

Limb Salvage

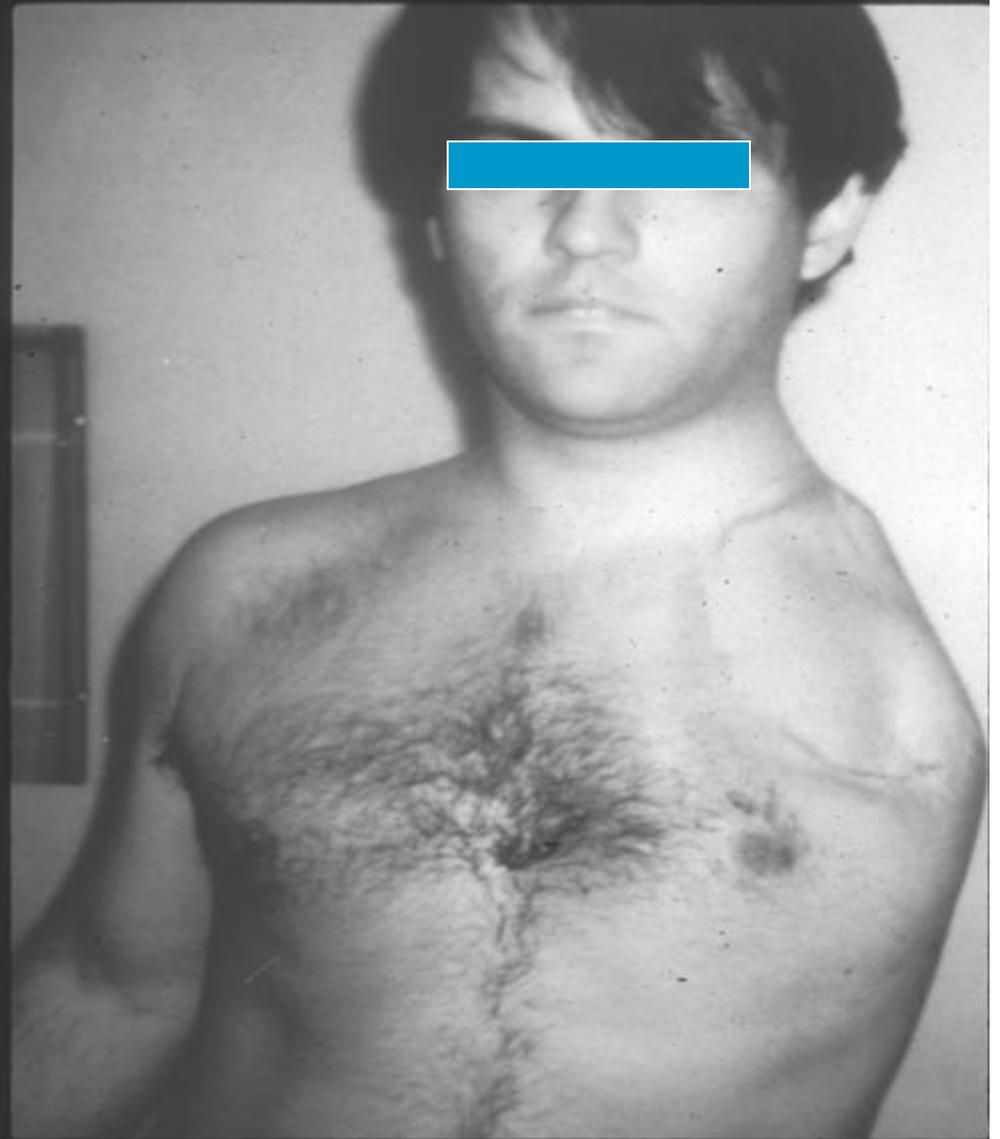
- Historically a forequarter amputation was performed for high grade sarcomas of the proximal humerus and scapula
- Early 1970s Marcove et al initiated limb sparing surgery and published their results in 1977; Local tumor control was the same as that achieved with a forequarter and a functional hand and elbow were preserved

Limb Salvage

- Today, 95% of high grade shoulder girdle sarcomas are treated with limb sparing surgery
- Increasing use of preoperative (induction) chemotherapy and radiotherapy
- Improvements in surgical techniques and prosthetic designs
- Advanced imaging modalities (CT, MRI)
- Better understanding of the local growth and biological behavior of sarcomas

Historical

- Earliest treatment until the 1970s was a forequarter amputation
- Debilitating and disfiguring
- Chronic phantom limb pain



James

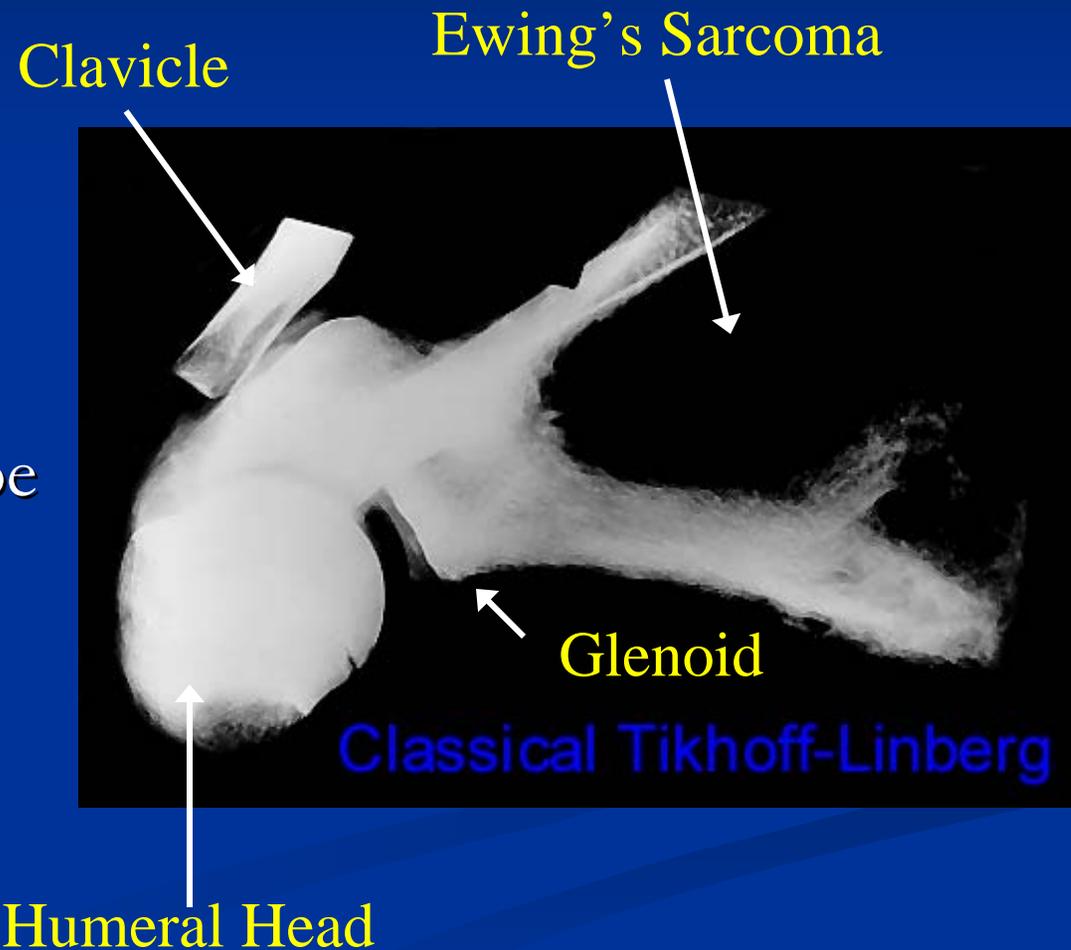
Historical

- 1977 Marcove et al published their results with limb sparing surgery for 17 patients
- **Standard Tikhoff -Linberg** resection for scapula tumors (Extraarticular total scapula resection, lateral clavicle, rotator cuff, deltoid, trapezius, rhomboids, portion of latissimus)
- **Extended-Tikhoff Linberg** for proximal humerus tumors

Tikhoff-Linberg

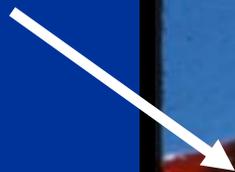
Limb-Sparing Resection

- Tikhoff-Linberg Type Resection (extraarticular total scapulectomy)

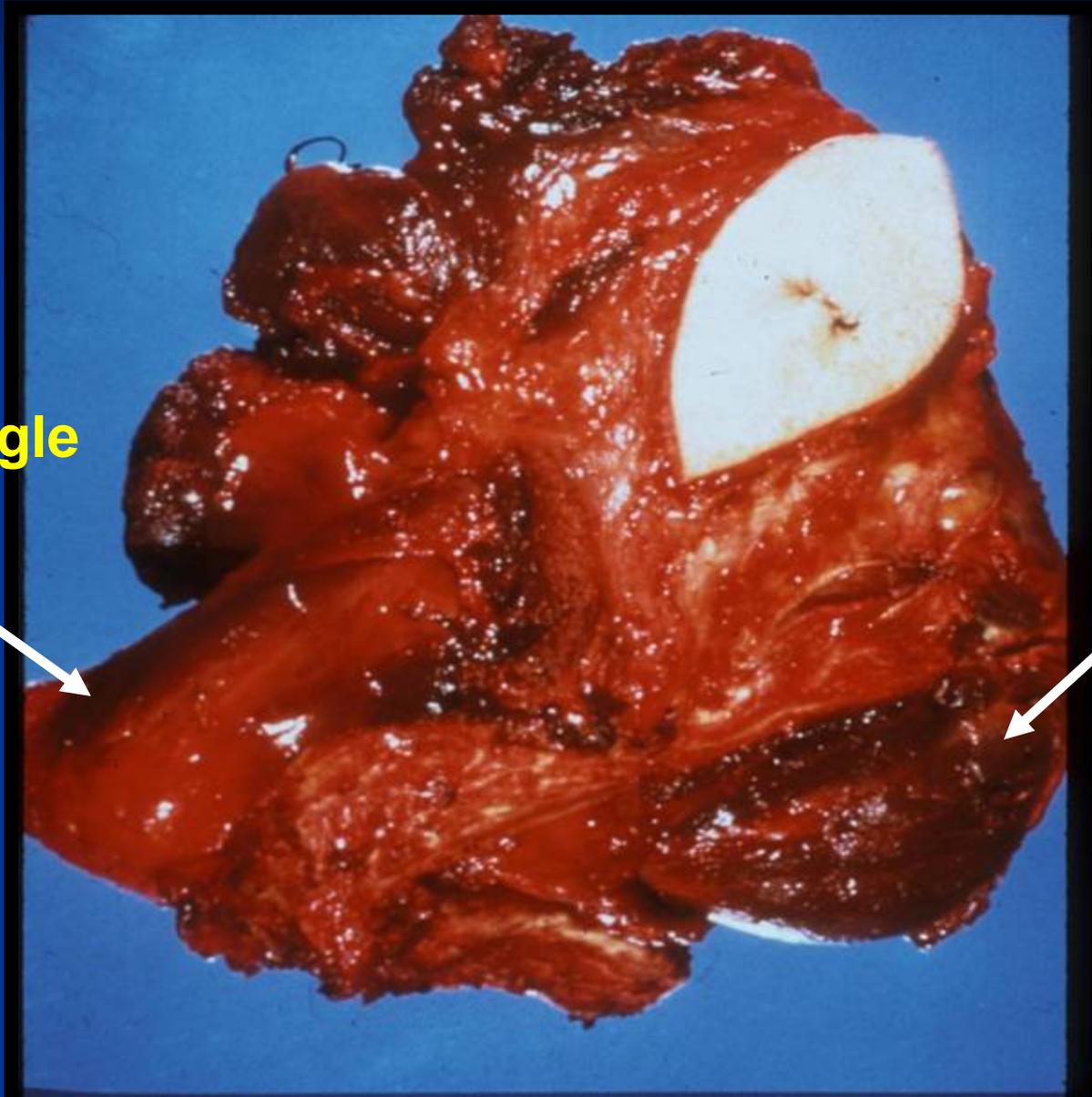


Tikhoff-Linberg

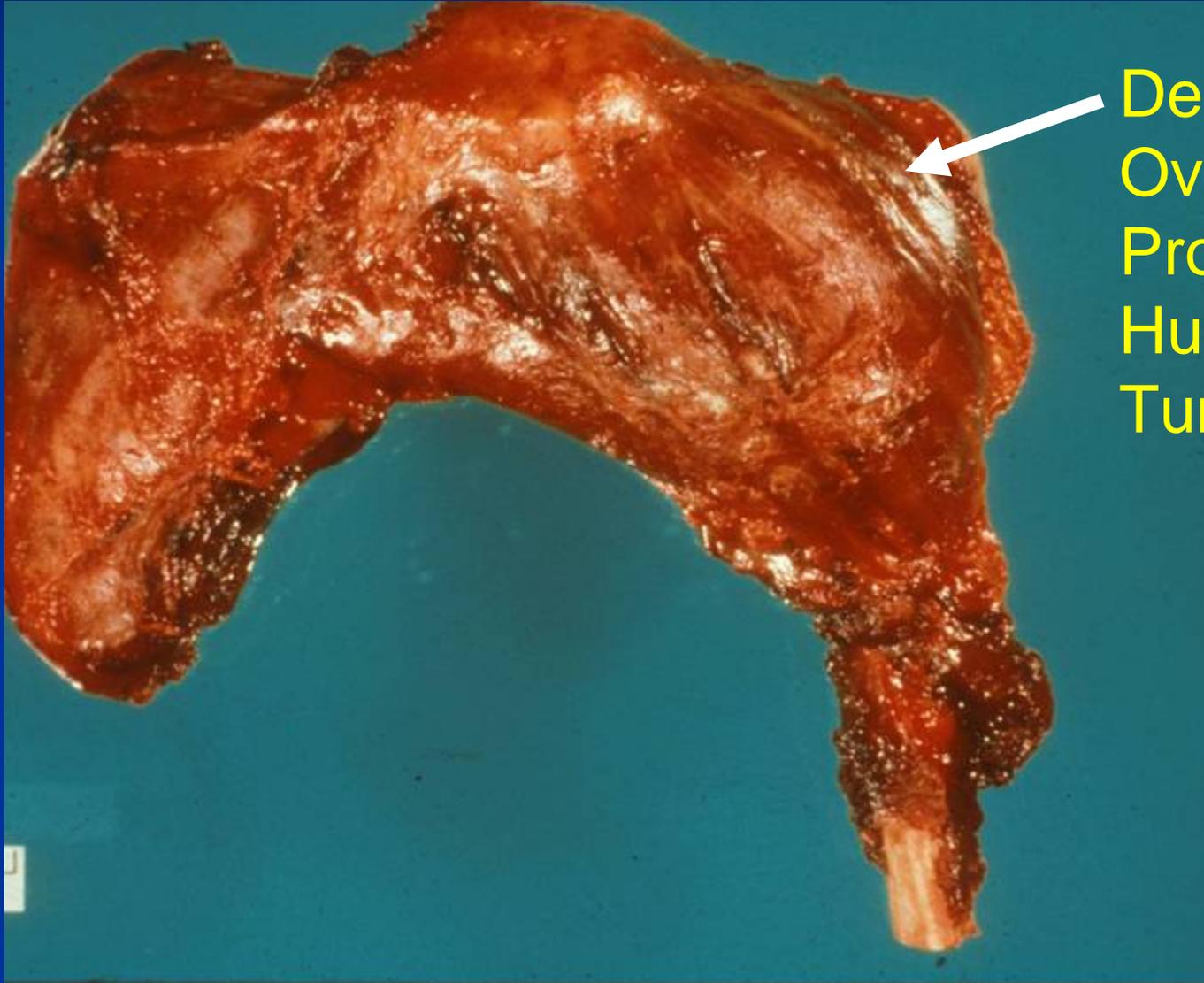
Inferior Angle
of Scapula



Deltoid



Extended Tikhoff-Linberg



Deltoid
Overlying
Proximal
Humerus
Tumor

Modified-Extended Tikhoff-Linberg

- Pathological study of specimens revealed that it was safe to perform an **osteotomy medial to the coracoid process**
- Resections of smaller magnitude
- Body of scapula remained to facilitate reconstruction



Early Reconstruction Options

- Proximal humerus stabilized to clavicle or rib (earliest)
- Flail shoulder
- Poor strength and stability
- Traction neuropraxia (brace or sling for support)
- Poor cosmesis



Early Results



Reconstruction Options

- Intramedullary rod stabilized to clavicle or rib
- Hardware failure
- Painful unstable shoulder
- Frequent wound complications
- Traction neuropraxia
- Poor cosmesis



Wound Complications from IM Rod



Reconstruction Options



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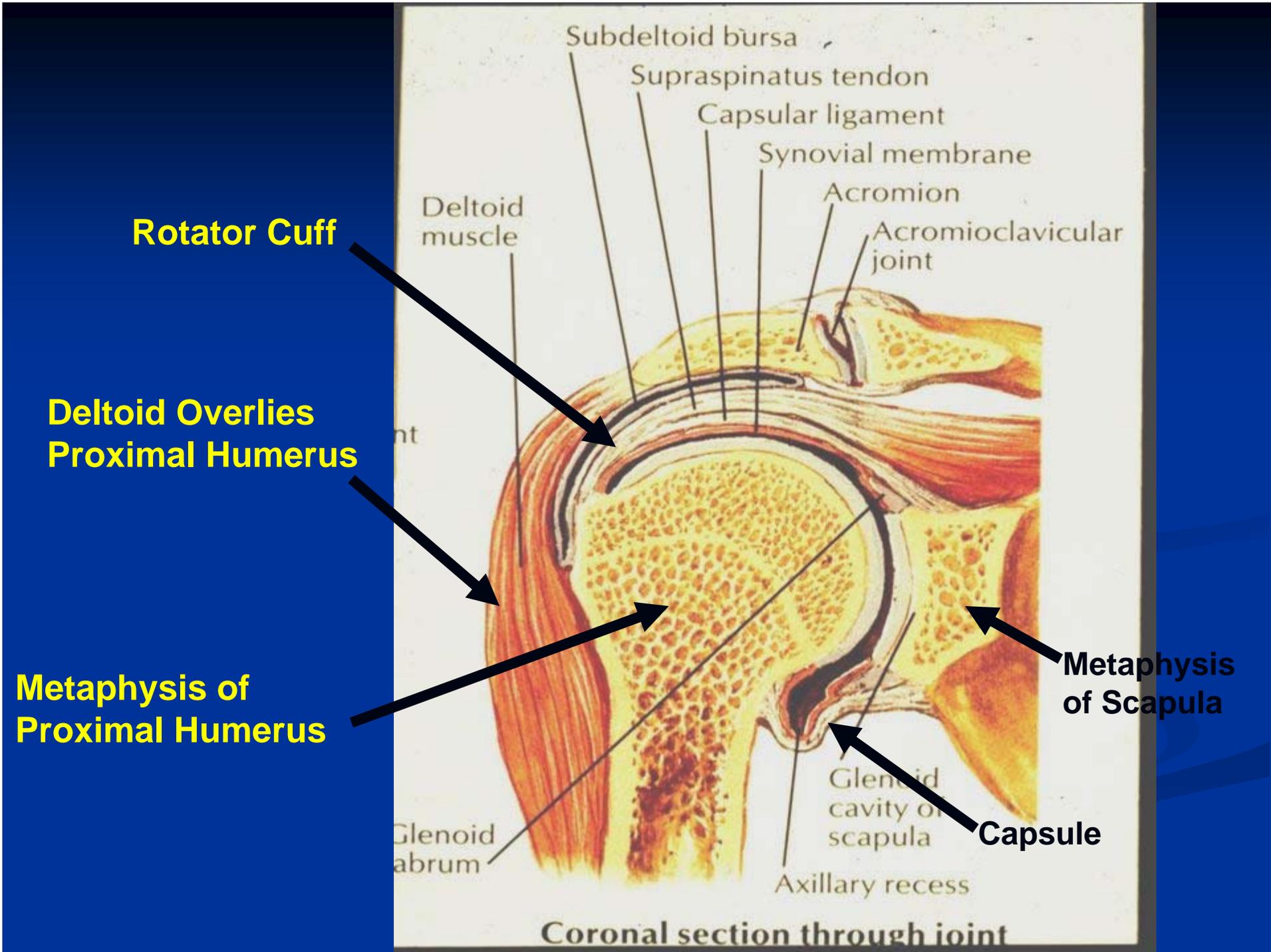
Other Reconstruction Options

- **Free vascularized fibulas for fusions:**

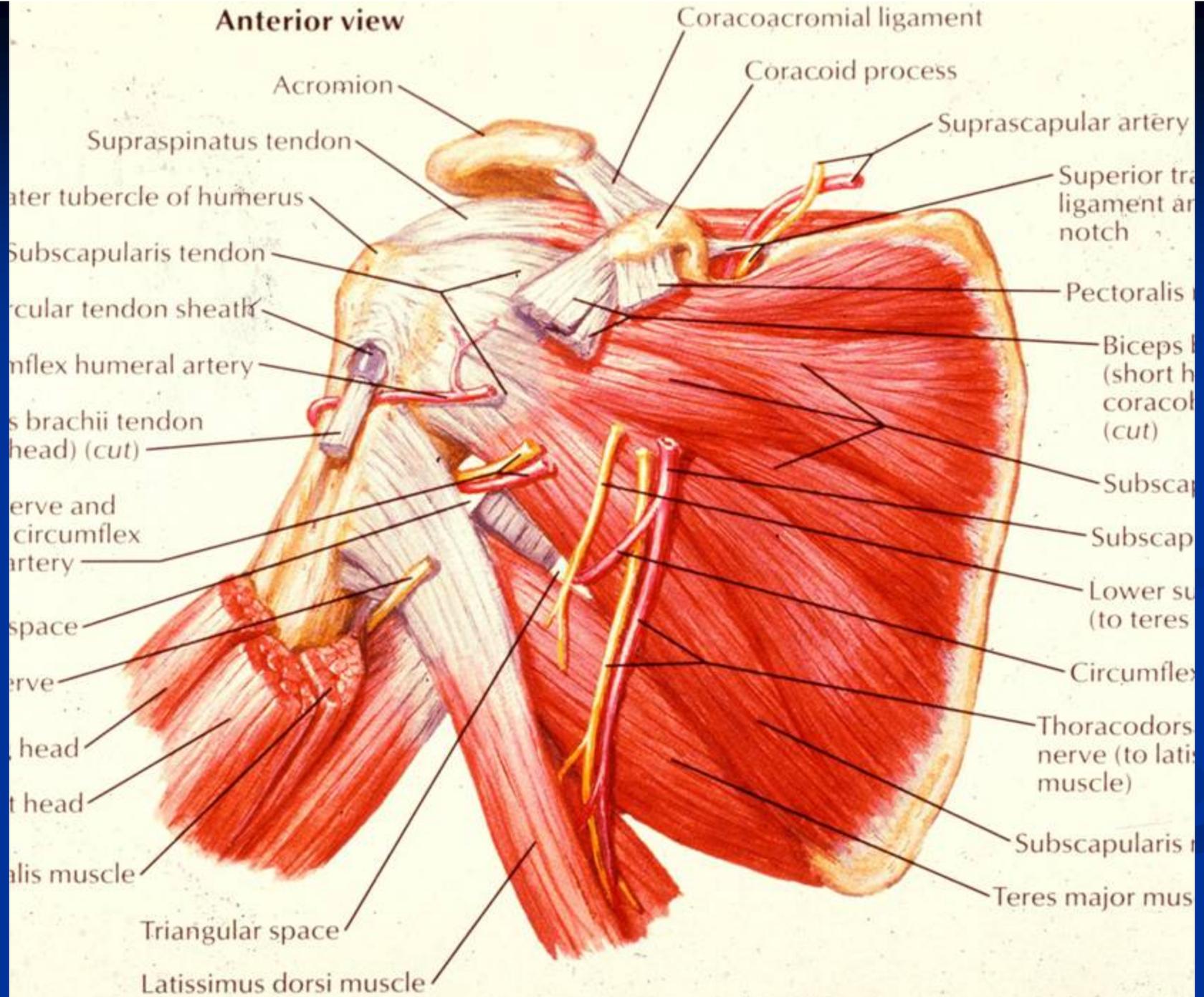
prolonged immobilization, fractures, infections, high complication rates, if succeed lose rotation below shoulder level

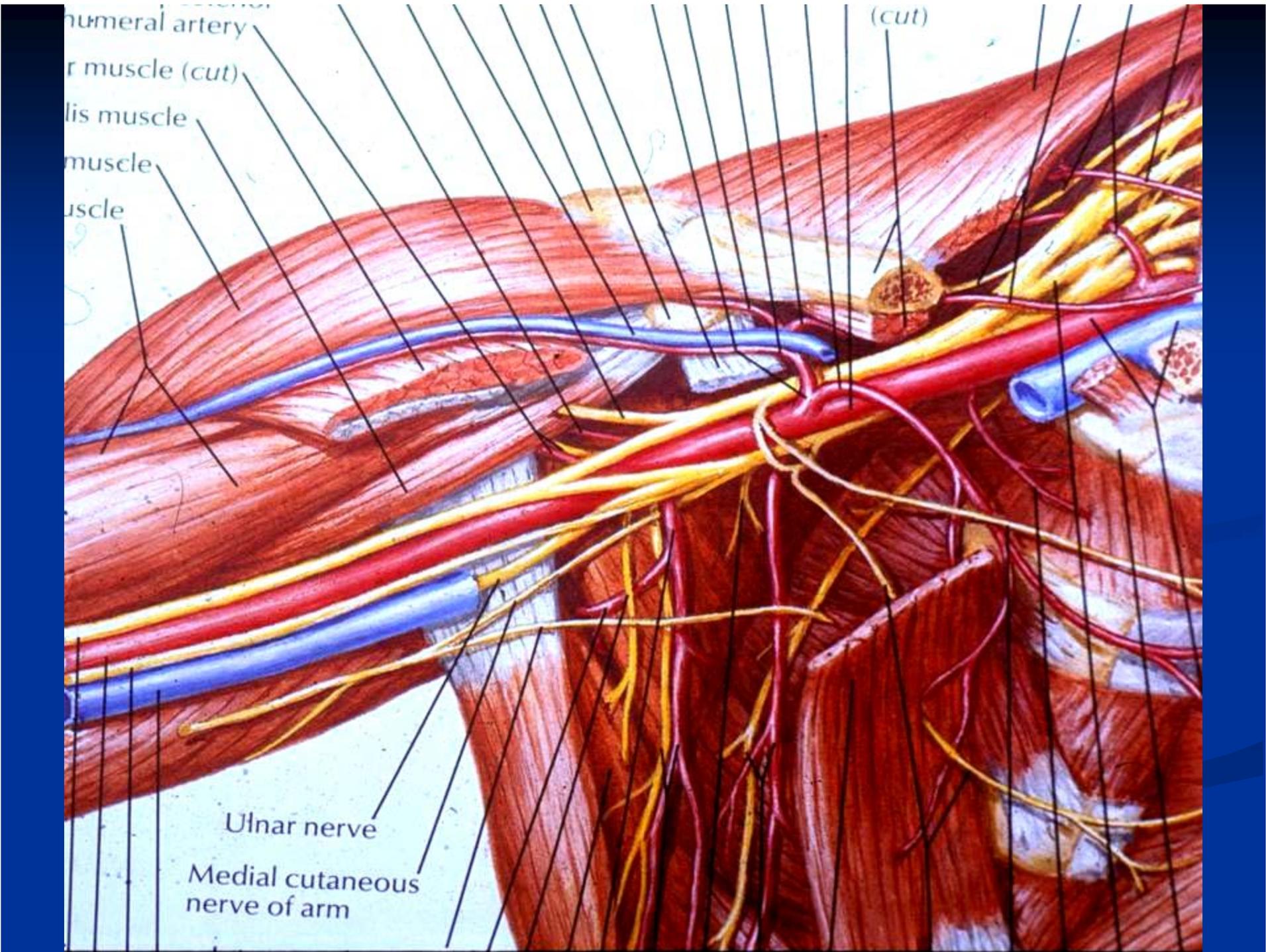
- **Allografts and allo-prosthetic composites:**

abandoned, high infection and fracture rates (performed for intraarticular resections---high local recurrence rates); function not better than prostheses despite an intraarticular resection



Anterior view





humeral artery

r muscle (cut)

lis muscle

muscle

muscle

(cut)

Ulnar nerve

Medial cutaneous
nerve of arm

Local Growth of Sarcomas

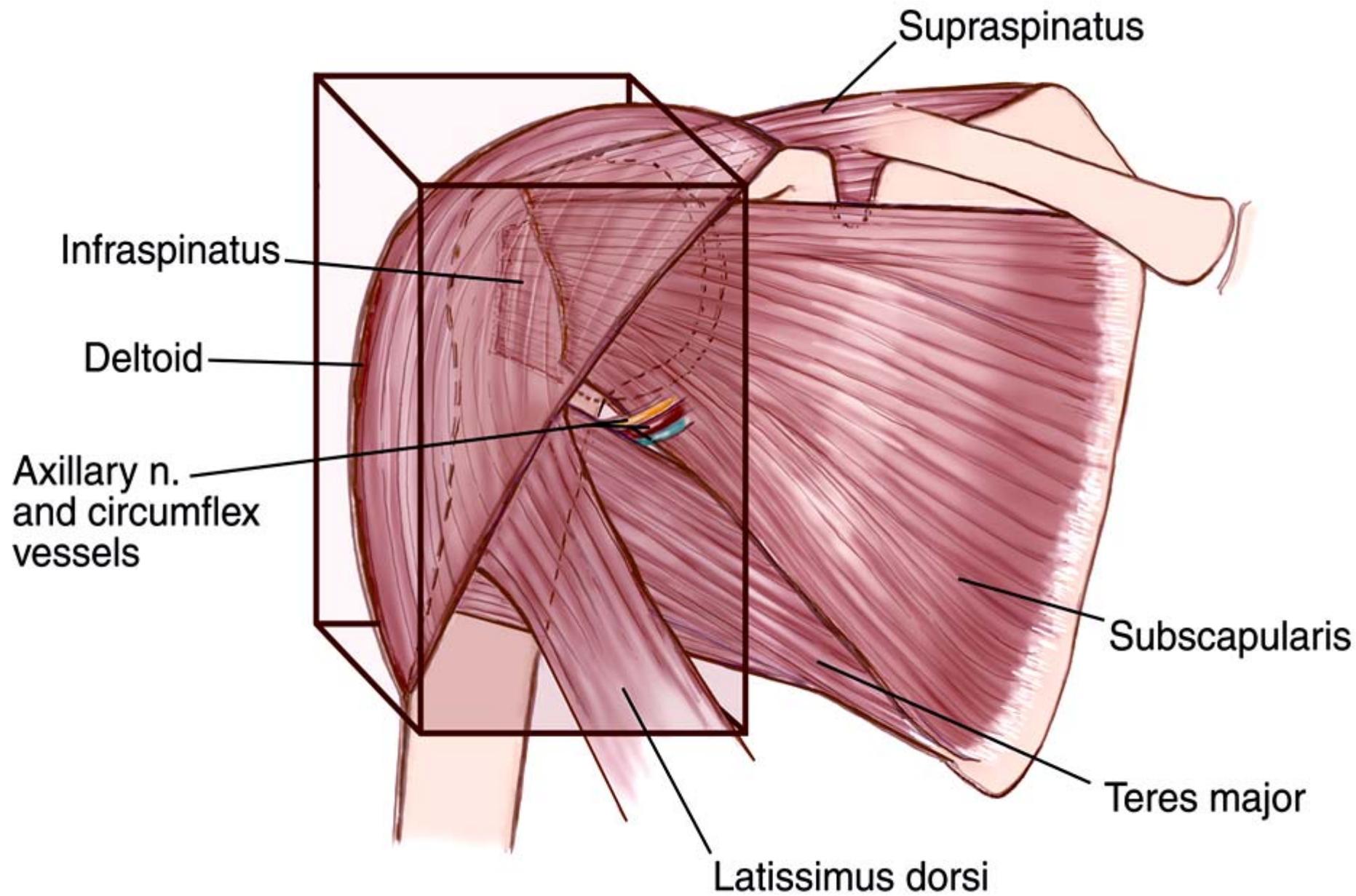
- Sarcomas grow locally in a **centripetal manner** and form ball like masses
- Obey fascial borders and grow along the path of least resistance
- Investing fascial layers of muscles form **compartmental borders** and form a barrier to tumor penetration; sarcomas rarely penetrate beyond adjacent fascial borders (compartmental borders)
- Adjacent muscles and their fascial layers are compressed into a **pseudocapsule** that contains microscopic tumor nodules (satellite nodules)

Compartments of the Shoulder Girdle

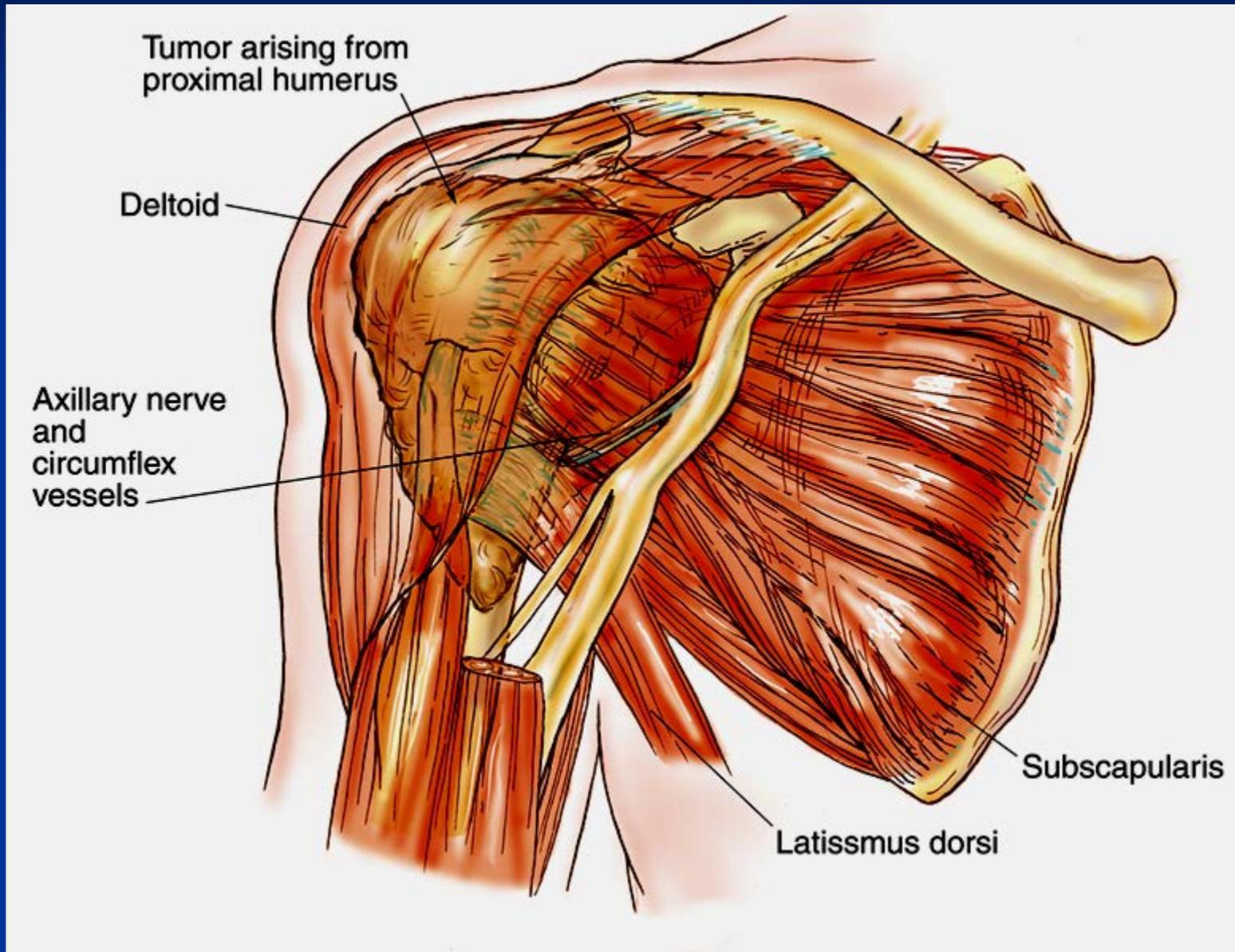
- A compartment refers to a fascial boundary to tumor extension (investing fascial layers of muscles that immediately surround a bone)
- Space that is bound by fascial borders
- Functional Anatomic Compartment exists around the proximal humerus and scapula

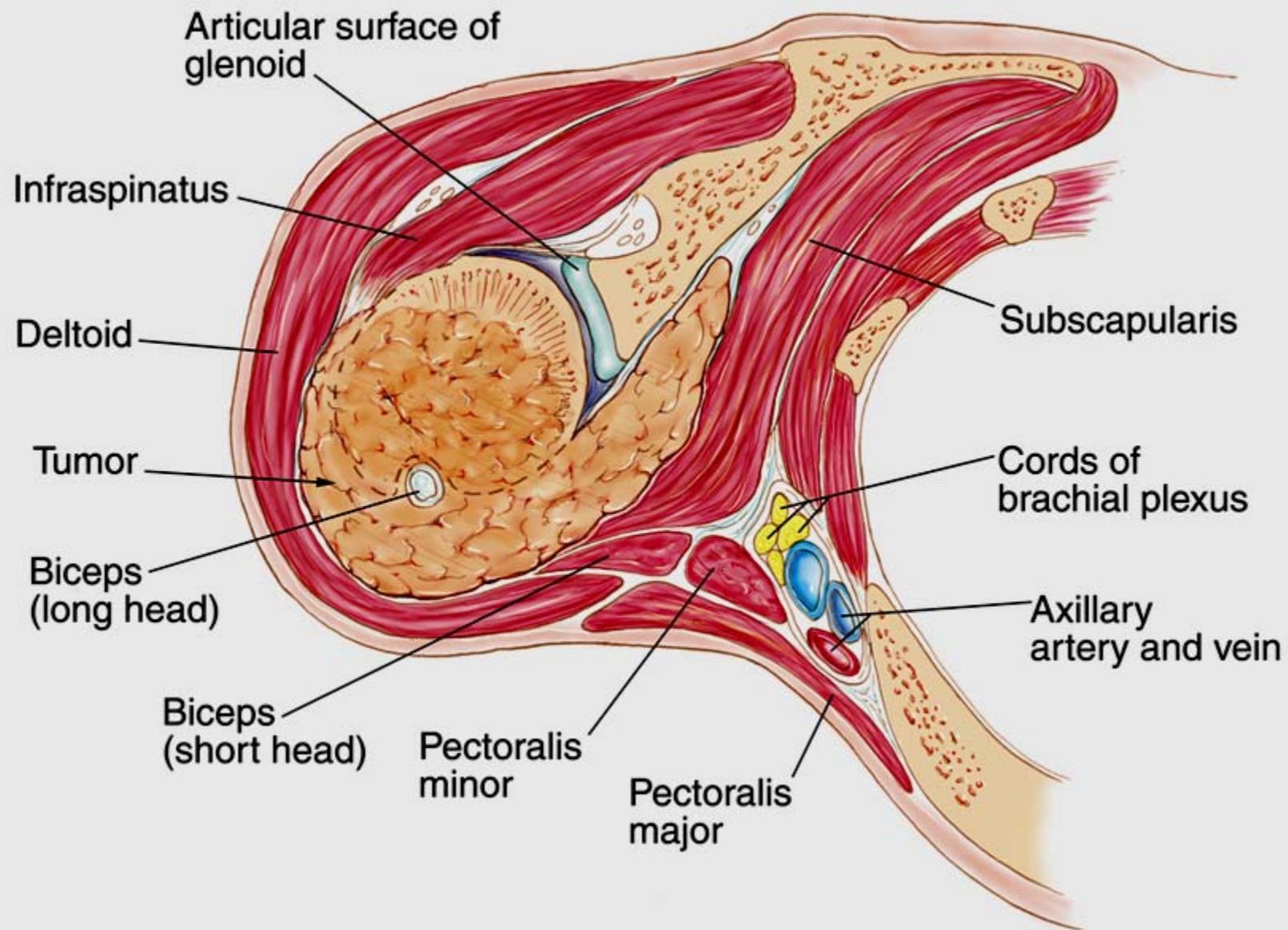
Compartments of the Shoulder Girdle

- **Proximal humerus:** deltoid, lateral subscapularis and lateral portion of the remaining rotator cuff, coracobrachialis, axillary nerve and circumflex vessels
- **Scapula:** Rotator cuff muscles
- The glenoid and proximal humerus reside within the same functional compartment
- **The subscapularis is a crucial boundary:** protects the axillary vessels and brachial plexus from tumor involvement along with the axillary sheath
- The muscles that form the compartmental borders also form the pseudocapsule of the tumor. Resection of these muscles with the tumor essentially confers a compartmental resection of the tumor

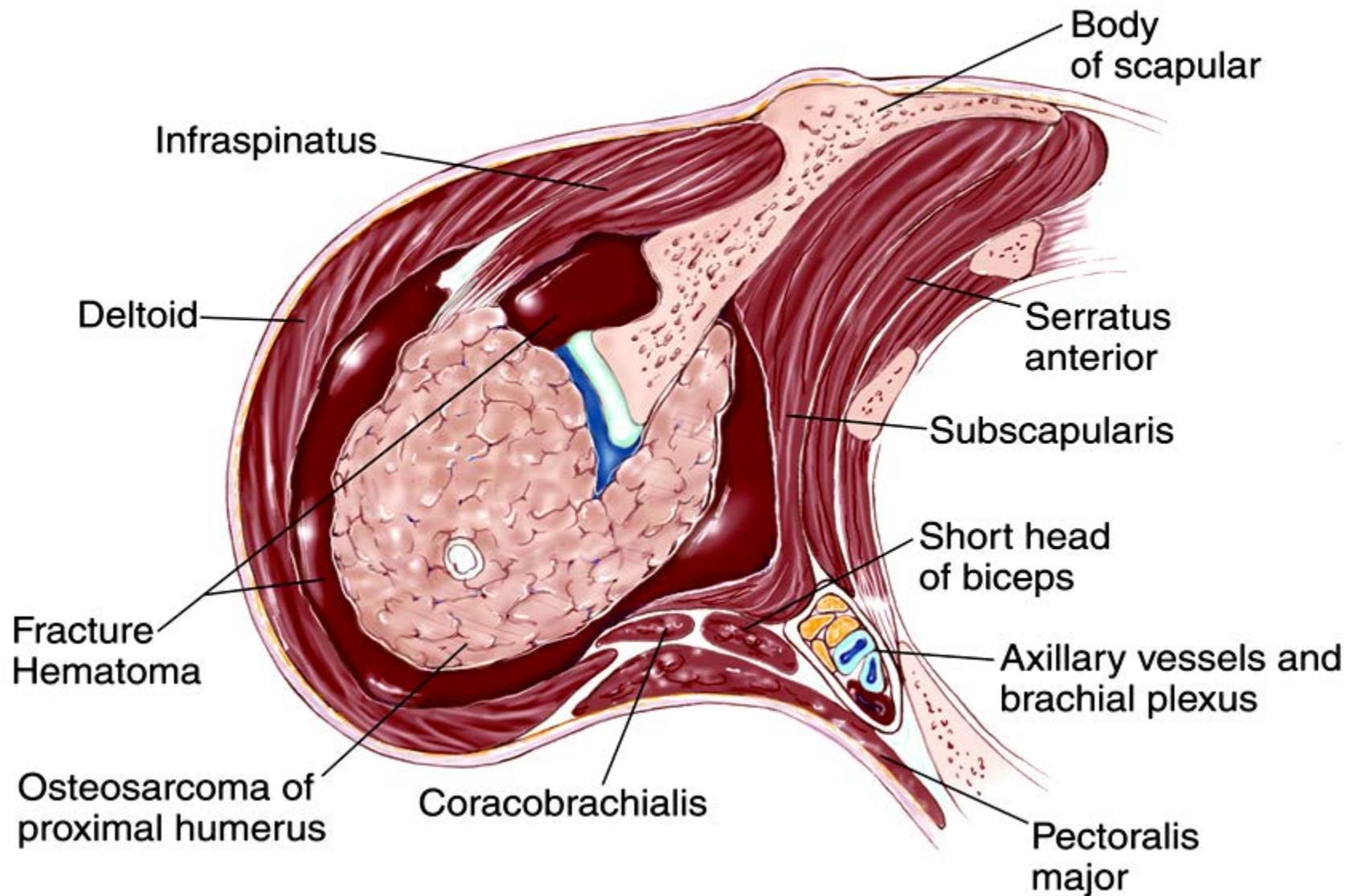


Local Growth of Proximal Humerus Sarcomas

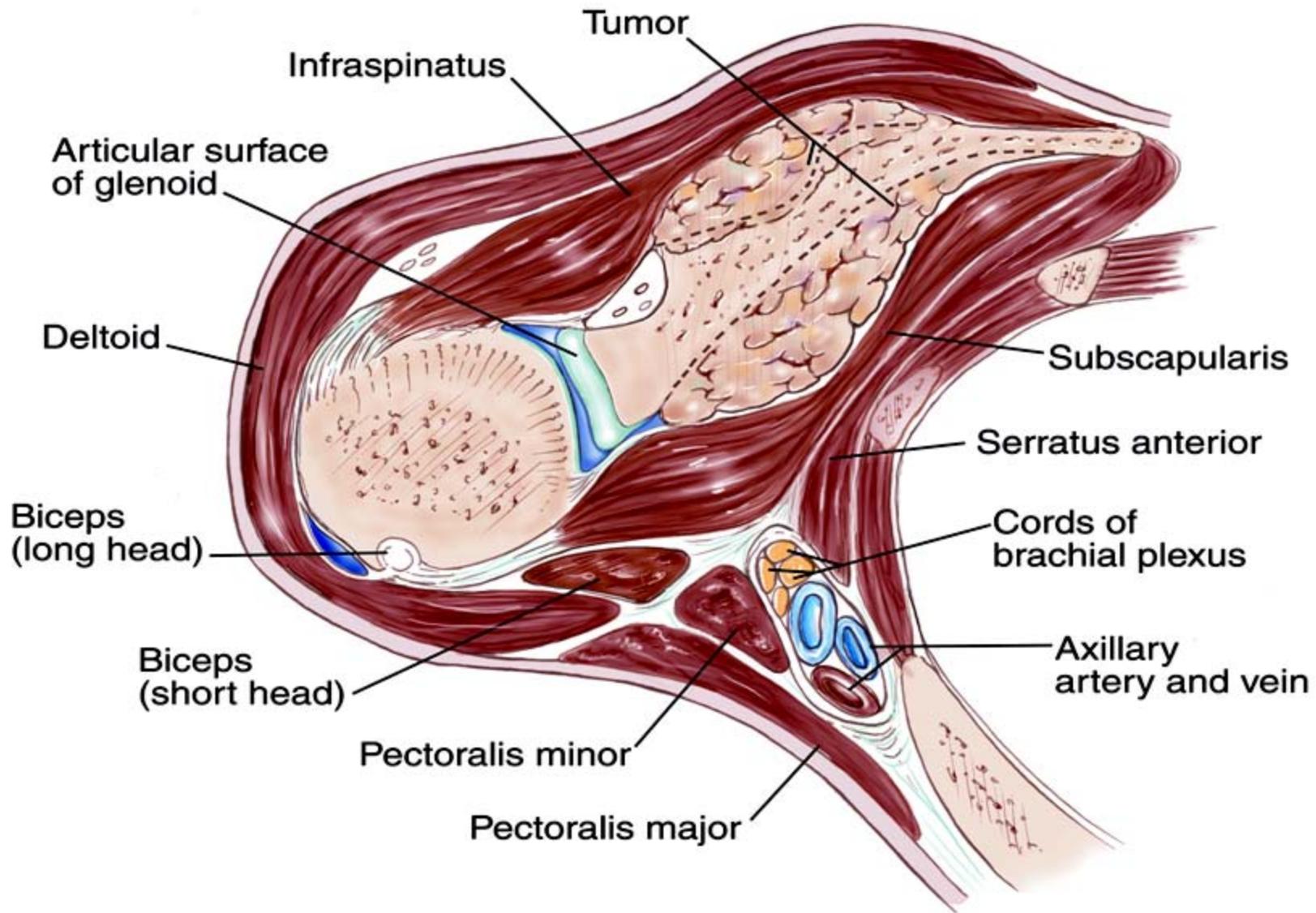




LOCAL SPREAD OF HEMATOMA SECONDARY TO PATHOLOGICAL FRACTURE



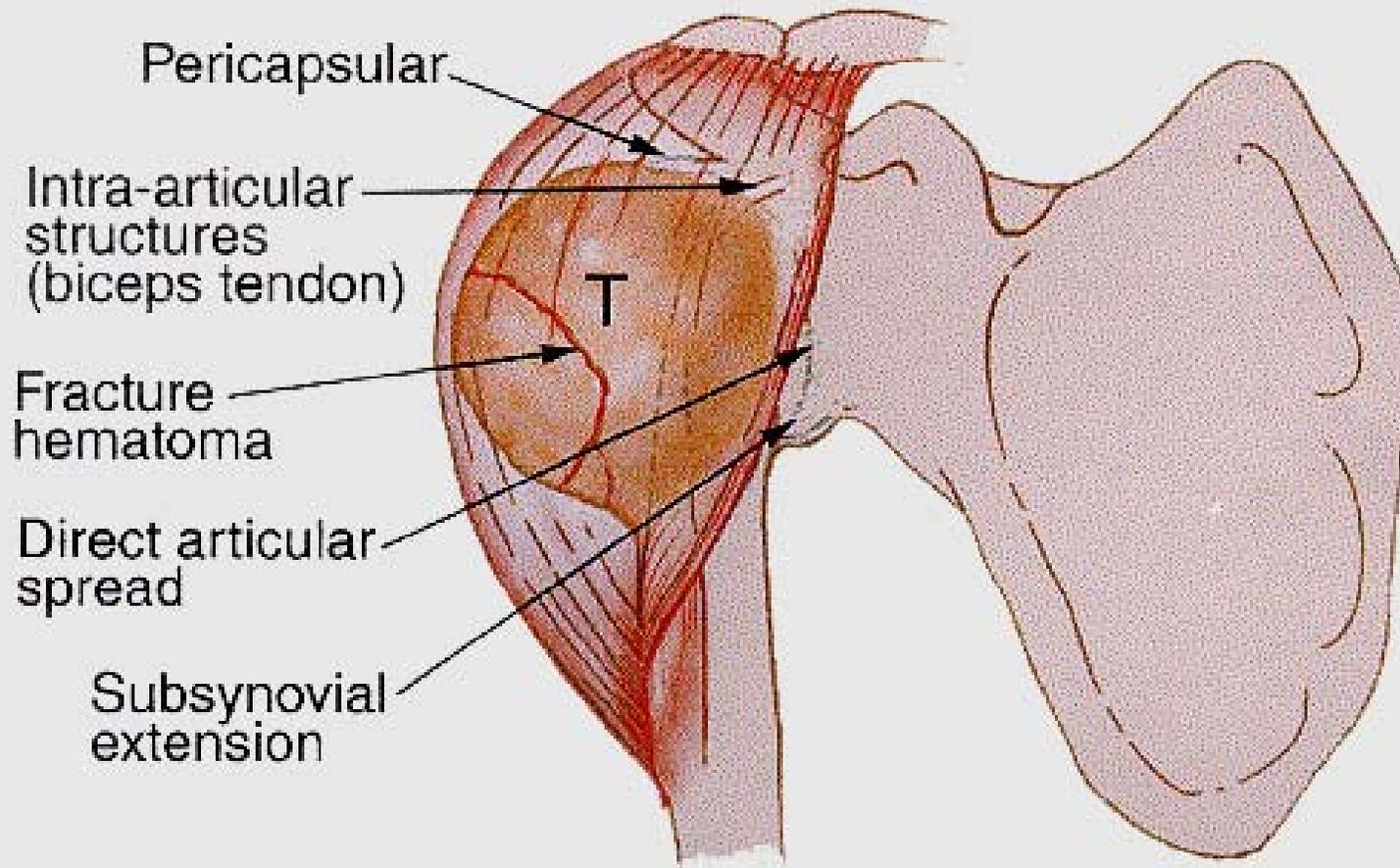
Local Growth of Scapular Sarcomas



Extraarticular vs Intraarticular Resection

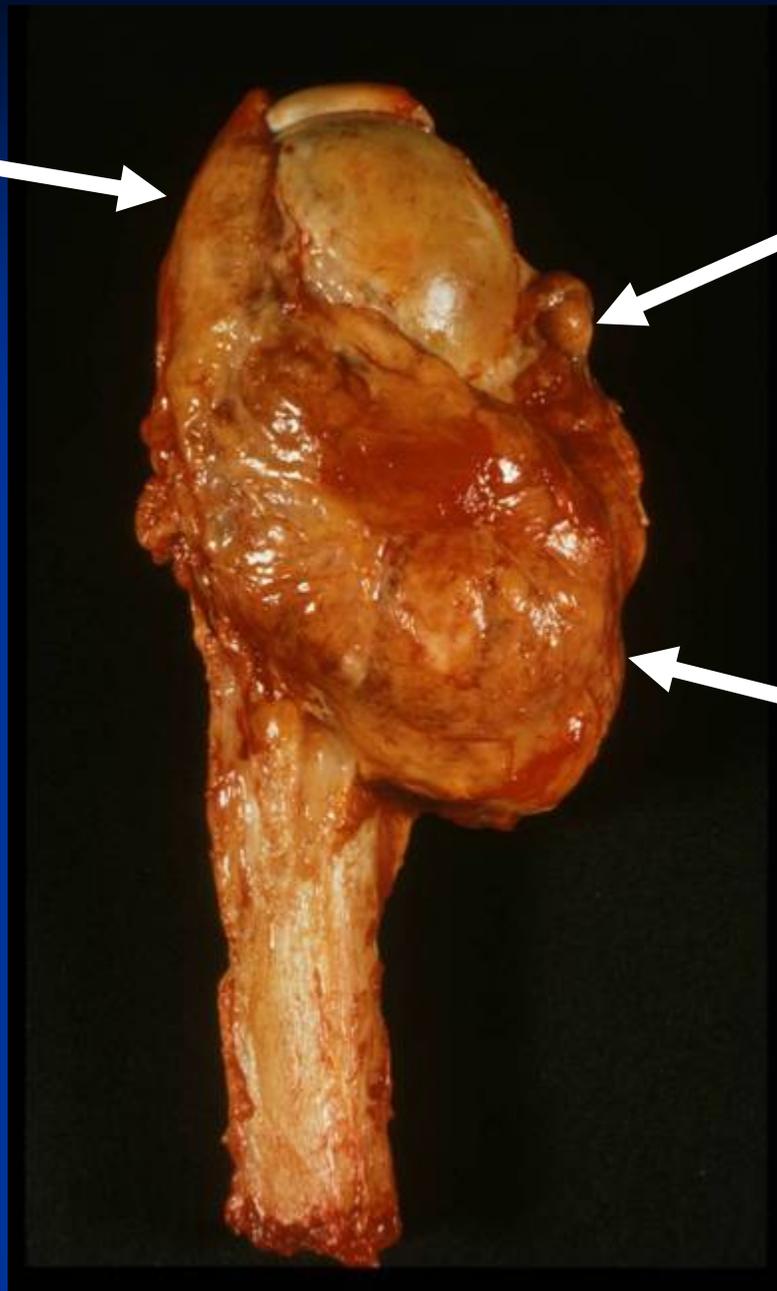
- High grade shoulder girdle sarcomas (extracompartmental) routinely contaminate the glenohumeral joint (grossly and microscopically) and readily spread to the apposing articular surface
- **Proximal humerus:** deltoid and overlying rotator cuff form the pseudocapsule (satellite nodules) and must be resected for an adequate margin (compartmental resection)
- Proximal humerus: axillary nerve involved by tumor and must be removed
- Retention of the glenoid confers no functional benefit with axillary nerve and abductor muscle involvement
- Extraarticular resection permits medialization, stabilization and soft tissue coverage

Mechanisms of Local Tumor Spread for Sarcomas of the Shoulder

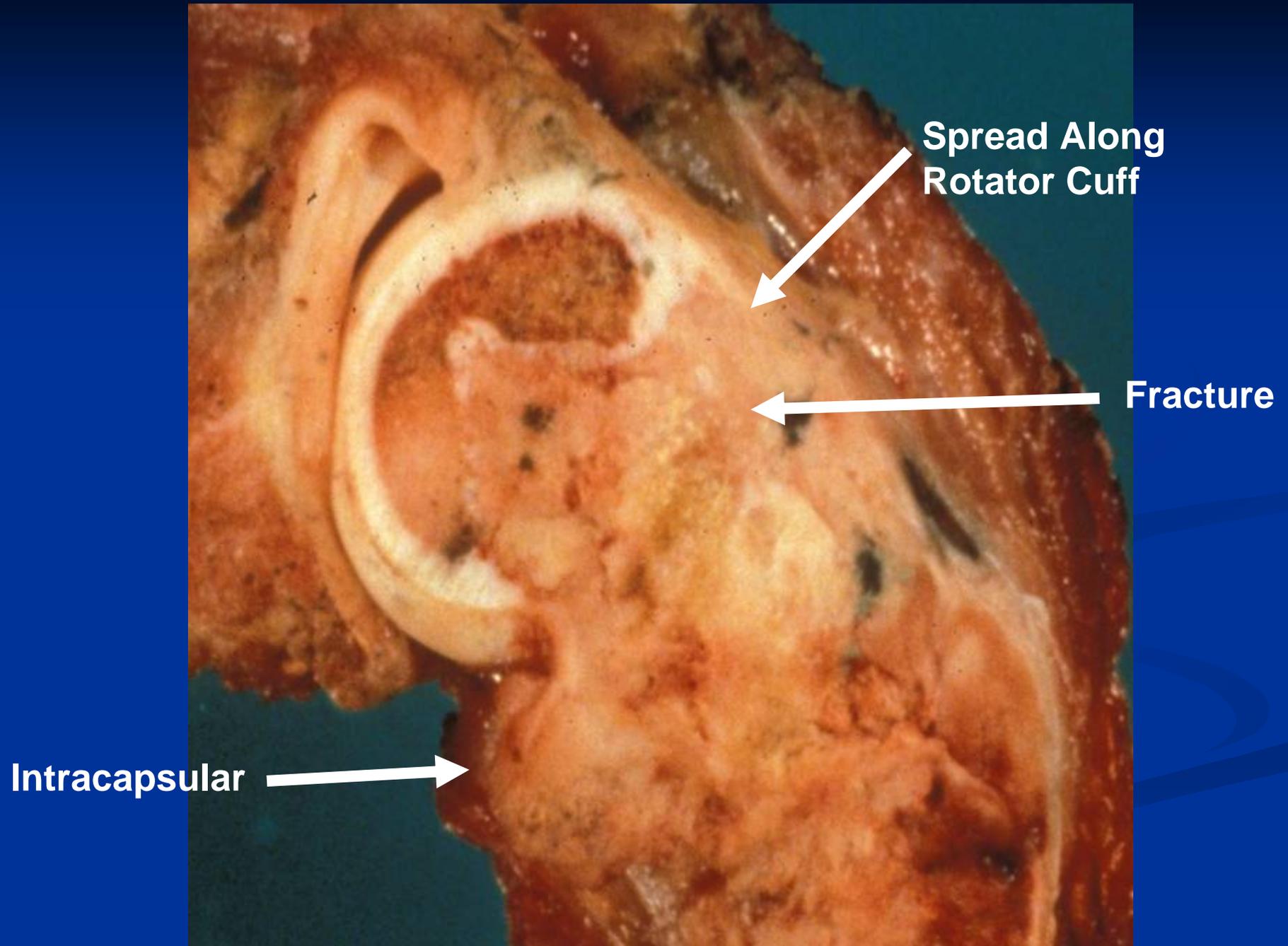


Spread along Biceps

**Joint
Contamination**



**Metaphyseal
Origin and
Centripetal
Growth**

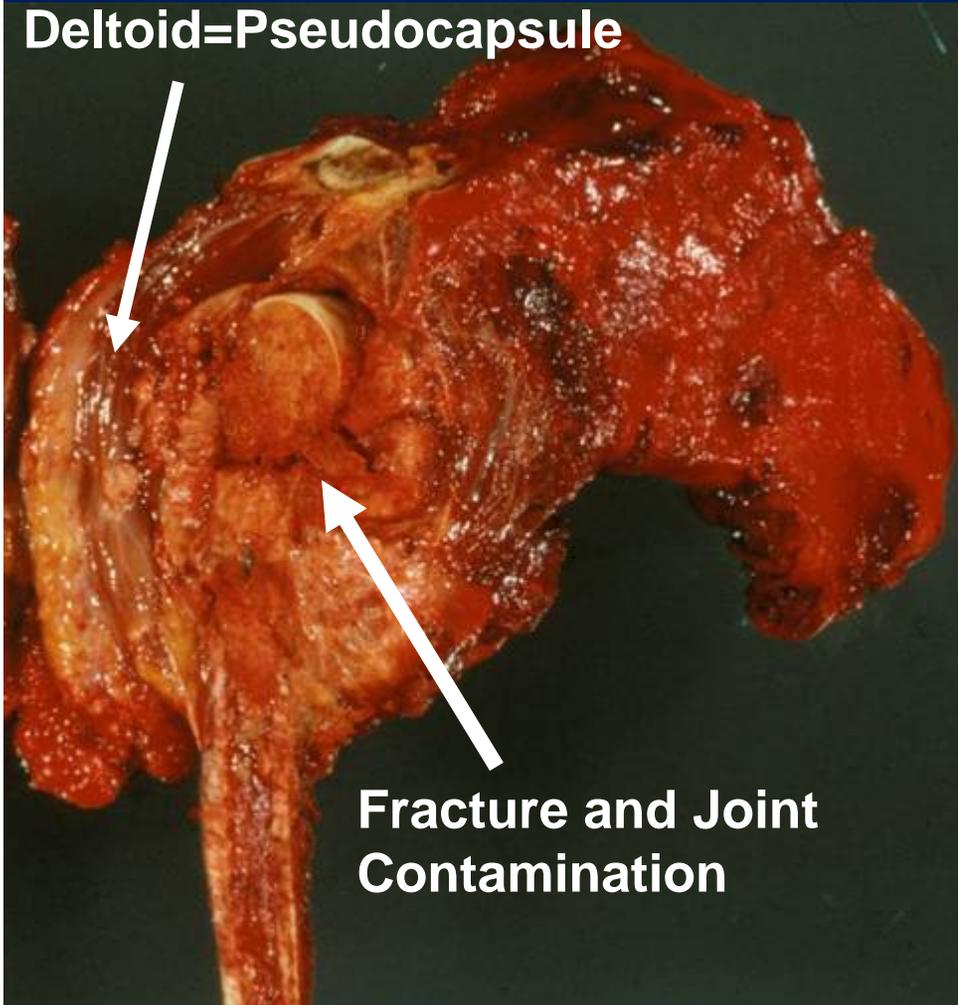


**Spread Along
Rotator Cuff**

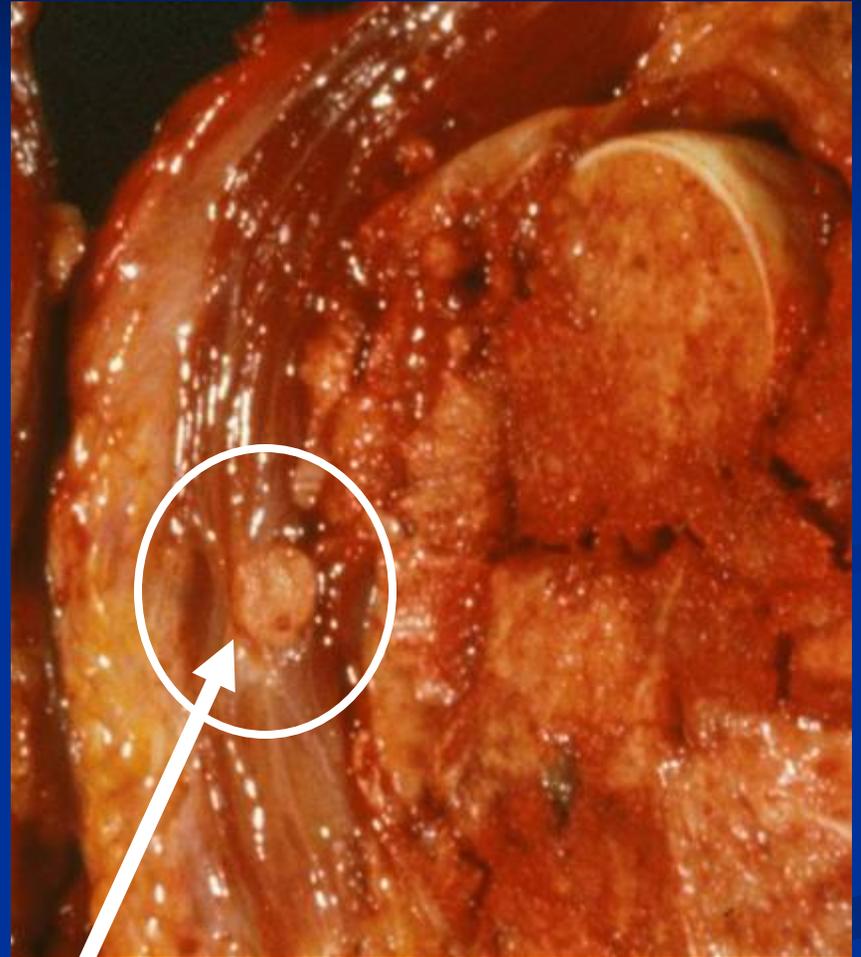
Fracture

Intracapsular

Deltoid=Pseudocapsule

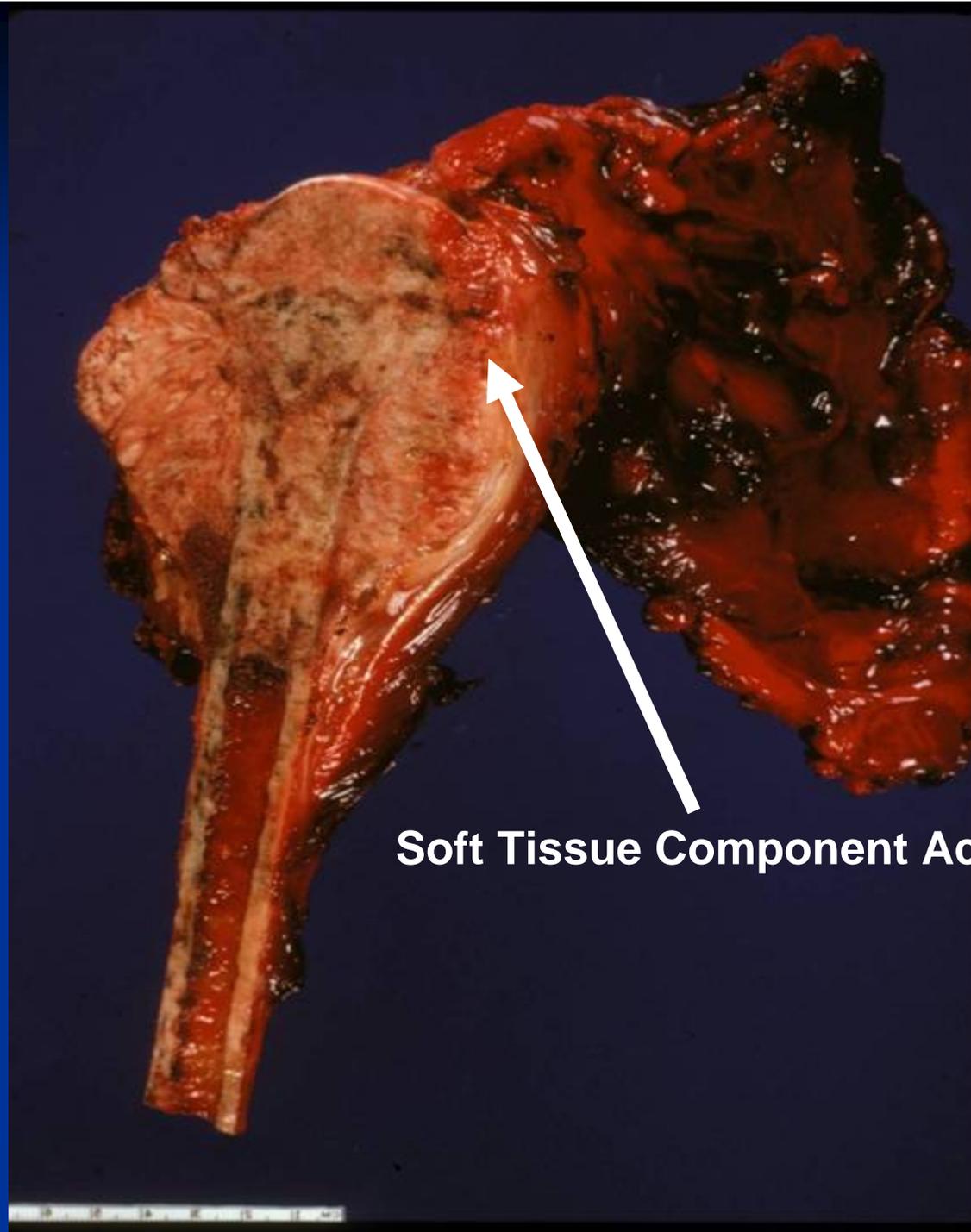


Fracture and Joint Contamination

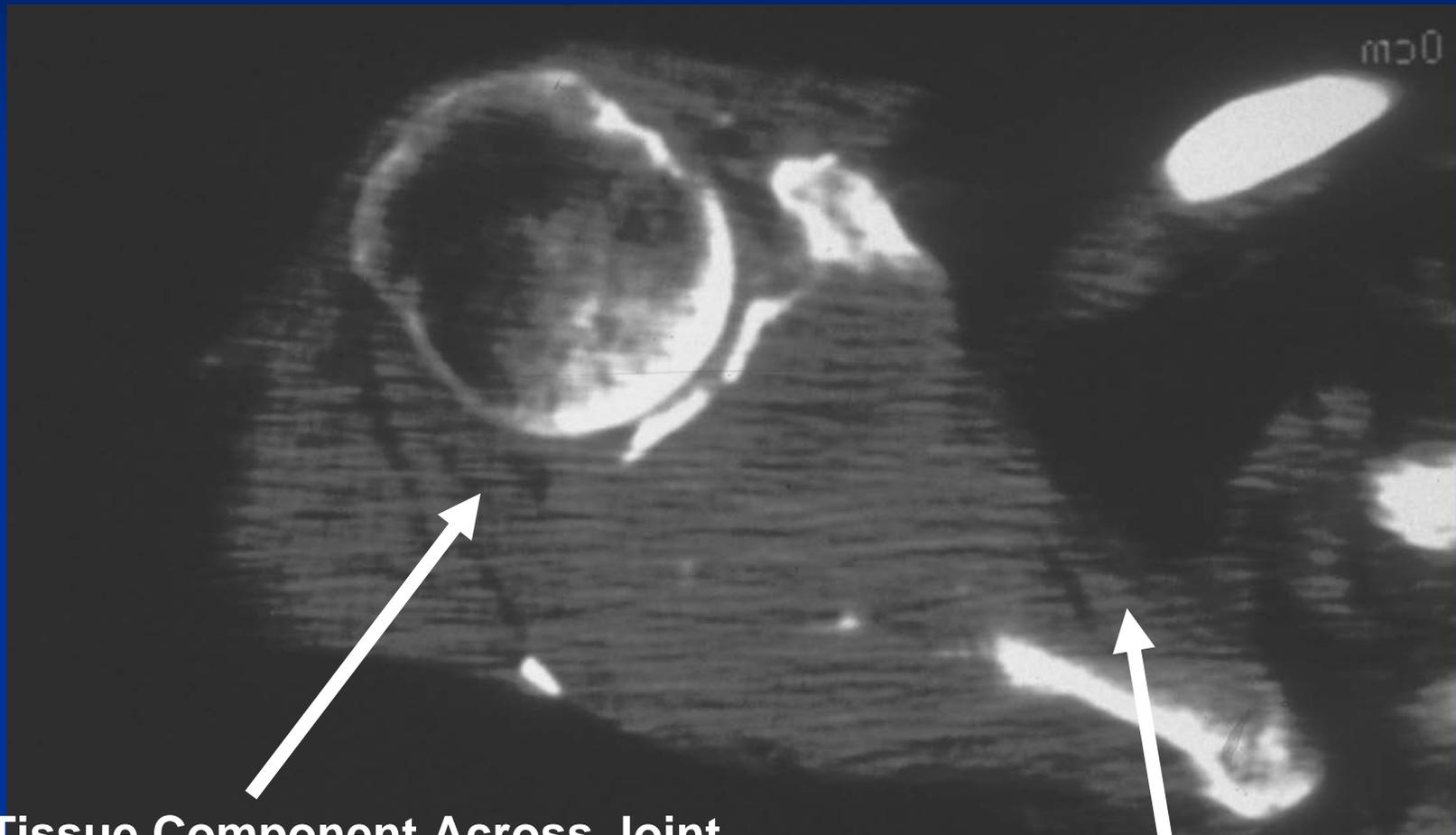


Satellite Nodule in Deltoid

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Soft Tissue Component Across Joint



Soft Tissue Component Across Joint

Subscapularis Muscle

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Deltoid Involved

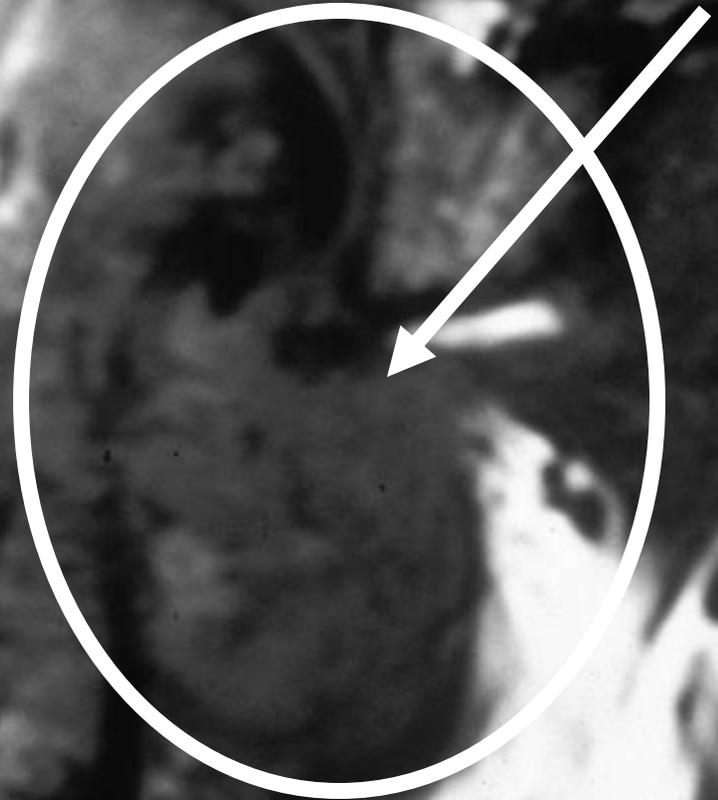
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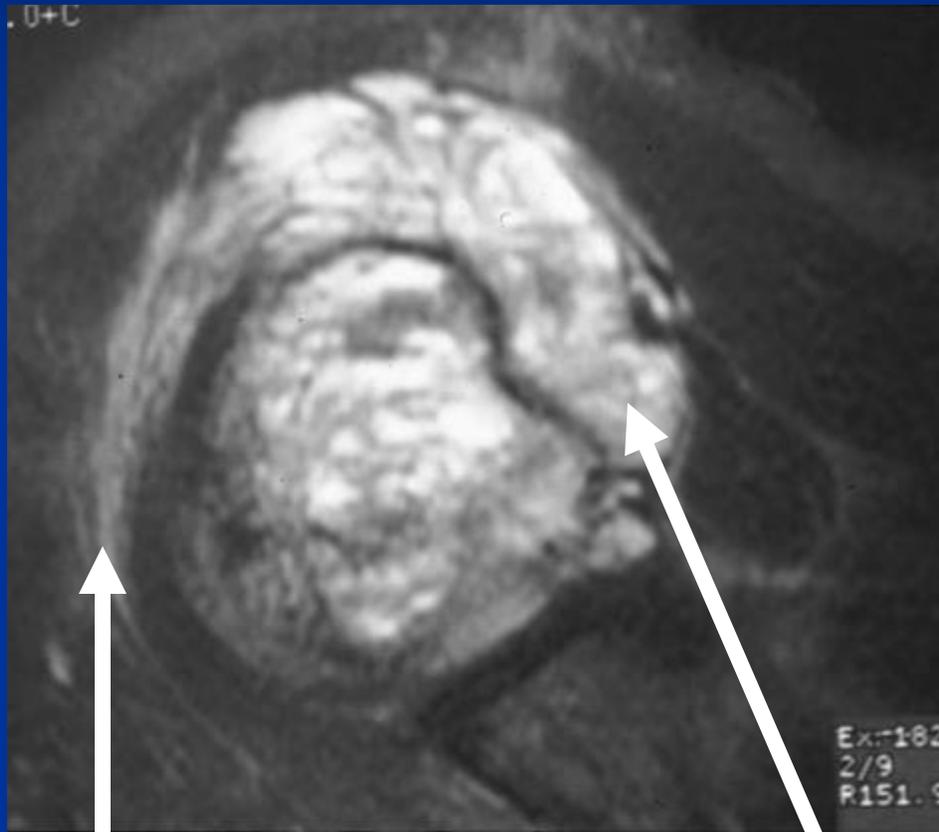


Across Joint

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Tumor Crossing Joint





Deltoid Involvement

Joint Contamination

Deltoid Involvement

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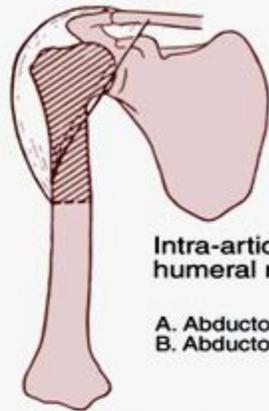
Classification of Shoulder Girdle Resections

- Based on local growth of sarcomas
- Biological behavior and grade
- Response to adjuvants
- Tumor extent

Goals of Resection

- Oncologically safe procedure
- Minimal risk of local recurrence (local recurrence in this region is usually treated with a forequarter amputation and local recurrence may adversely effect survival)

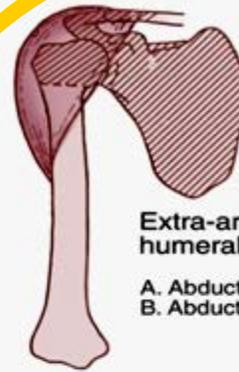
SURGICAL CLASSIFICATION OF SHOULDER GIRDLE RESECTIONS



TYPE I

Intra-articular proximal humeral resection

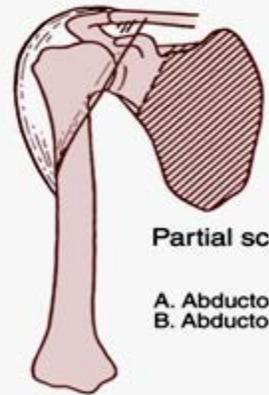
A. Abductors retained (shown)
B. Abductors resected



TYPE IV

Extra-articular scapular and humeral head resection

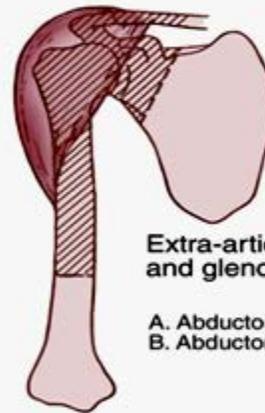
A. Abductors retained
B. Abductors resected (shown)



TYPE II

Partial scapulectomy

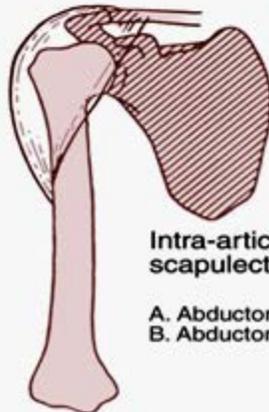
A. Abductors retained (shown)
B. Abductors resected



TYPE V

Extra-articular humeral and glenoid resection

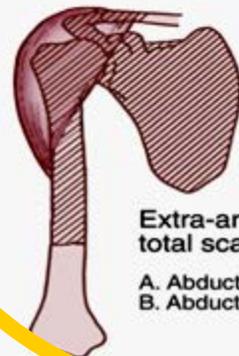
A. Abductors retained
B. Abductors resected (shown)



TYPE III

Intra-articular total scapulectomy

A. Abductors retained (shown)
B. Abductors resected

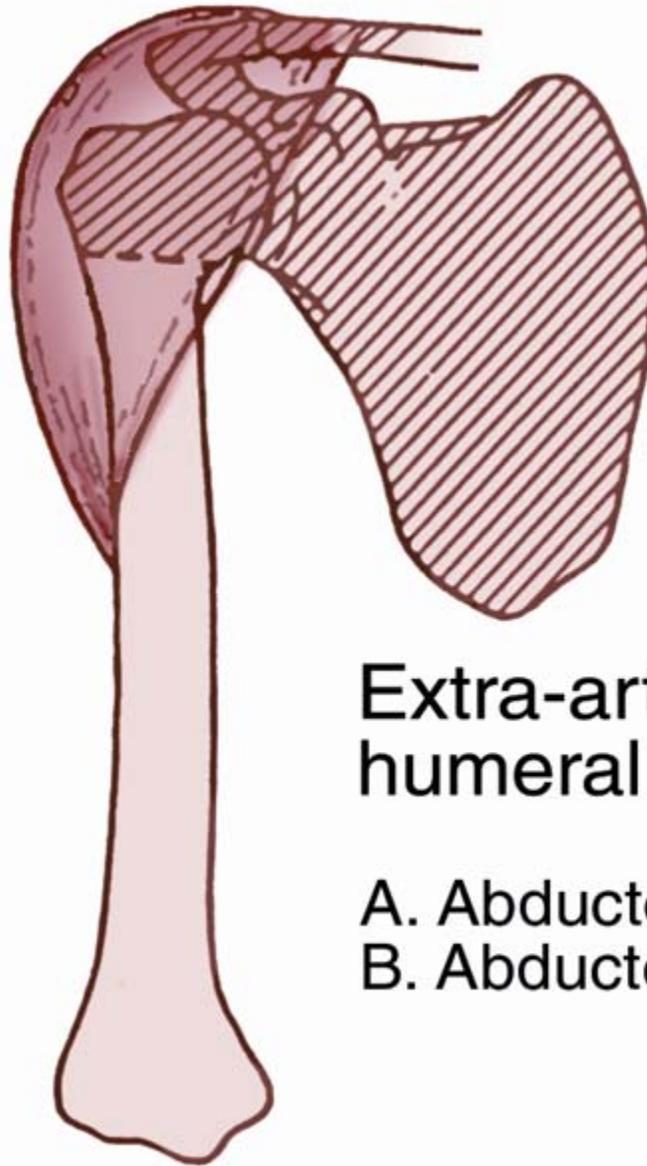


TYPE VI

Extra-articular humeral and total scapula resection

A. Abductors retained
B. Abductors resected (shown)

Classical Tikhoff-Linberg

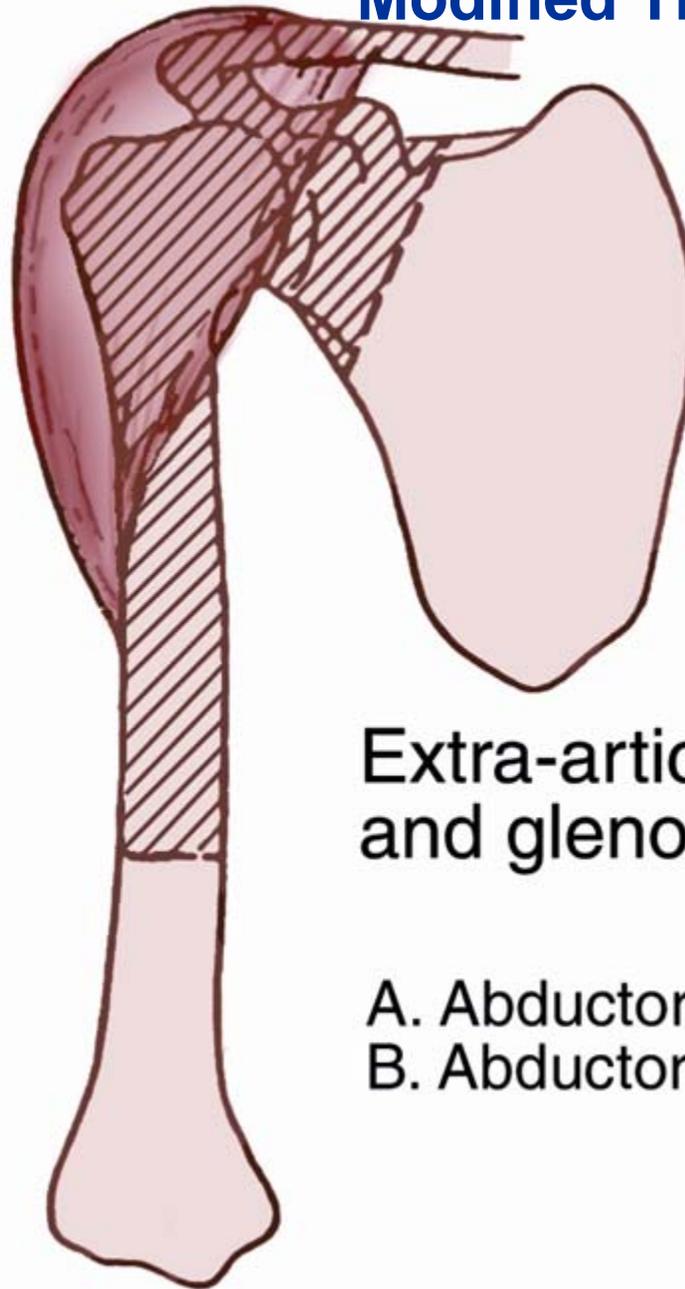


TYPE IV

Extra-articular scapular and humeral head resection

- A. Abductors retained
- B. Abductors resected (shown)

Modified Tikhoff-Linberg

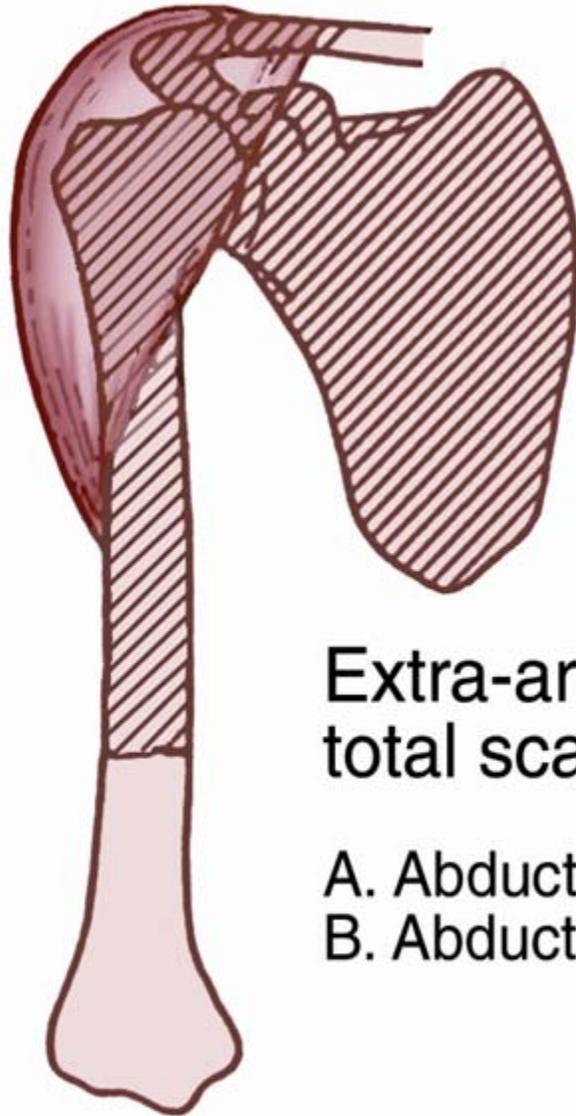


TYPE V

Extra-articular humeral
and glenoid resection

- A. Abductors retained
- B. Abductors resected (shown)

Extended Tikhoff-Linberg



TYPE VI

Extra-articular humeral and
total scapula resection

- A. Abductors retained
- B. Abductors resected (shown)

LITERATURE REVIEW OF INTRA VS EXTRA-ARTICULAR RESECTION OF THE PROXIMAL HUMERUS FOR STAGE IIB BONE SARCOMAS

Analysis of 156 cases

EXTRA-ARTICULAR RESECTION			
Author	#PTs	#LR	%LR
Kaealin	8	0	0
Meller	9	1	11
Frassica	8	1	12.5
O'Connor	28	3	10.7
Capanna	24	1	4
Kumer	6	0	0
Wittig	23	0	0
OVERALL	106	6	5.60%
INTRA-ARTICULAR RESECTION			
Author	#PTs	#LR	%LR
Asav (Eckardt)	34	6	17.6
Gebhardt	3	2	67
Getty	6	0	0
Jensen	7	2	28.6
OVERALL	50	10	20
P < .05			

Goals of Reconstruction

- Restore shoulder girdle stability
- Painless shoulder
- Preserve a functional hand and elbow
- Maintain motion (rotation) below shoulder level where most activities of daily living are performed
- A reliable means of reconstruction that will permit prompt resumption of chemotherapy and allow early return to activity/functional use

Methods of Reconstruction

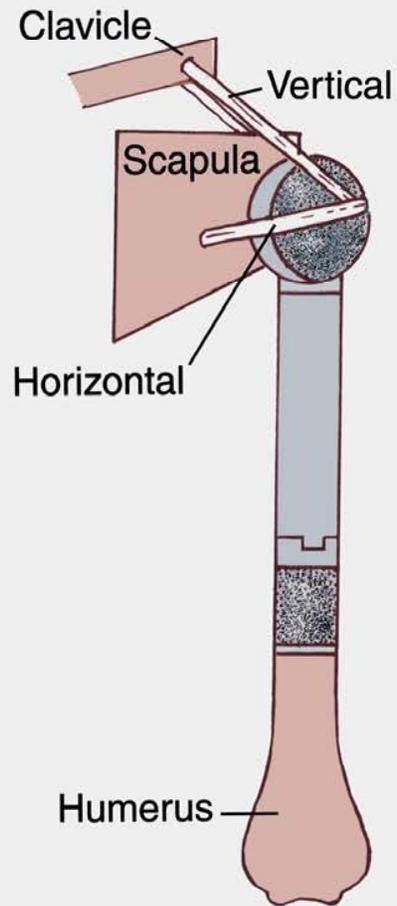
■ Bony Reconstruction

- Modular Segmental Proximal Humerus Prosthesis
- Total Scapula Prosthesis (if specific muscles preserved)
 - Nonconstrained
 - Constrained

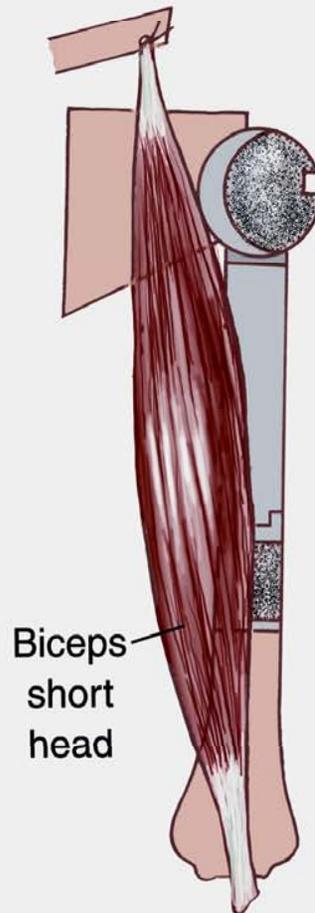
■ Soft Tissue Reconstruction

- Static and Dynamic Methods of Soft Tissue Reconstruction

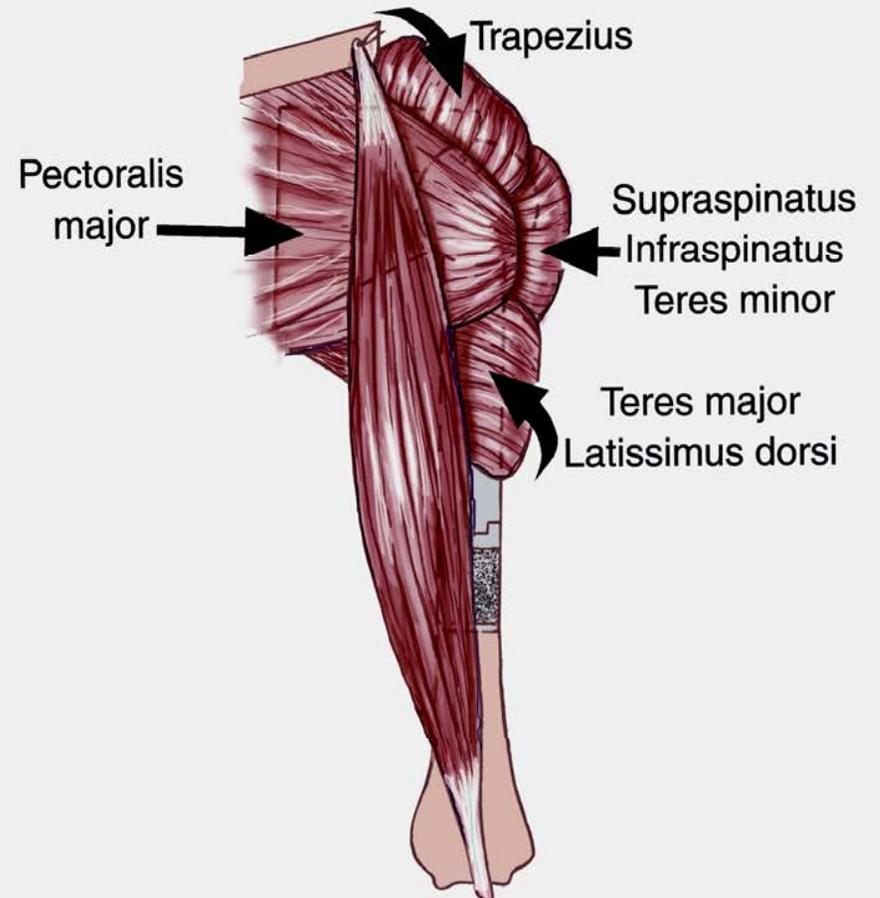
STATIC SUSPENSION



DYNAMIC SUSPENSION



MOTOR RECONSTRUCTION SOFT TISSUE RECONSTRUCTION



TIKHOFF-LINBERG RESECTION AND TOTAL SCAPULAR REPLACEMENT

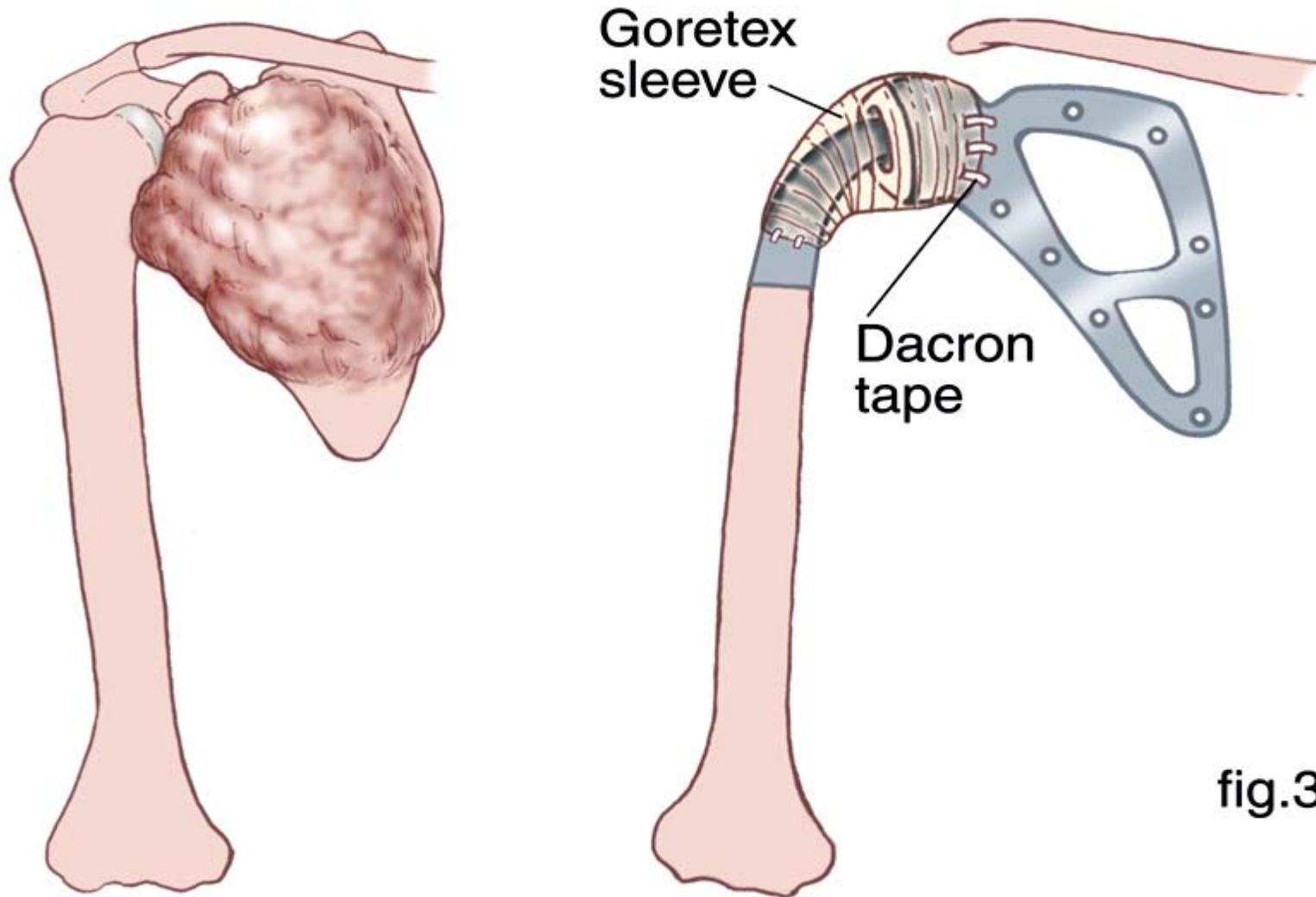


fig.3

Radiological Imaging

- Plain Radiograph
- MRI
- CT
- Angiogram
- Venogram
- Bone Scan
- Thallium Scan
- CT of Chest

Estimating Response to Induction Chemotherapy

- Plain Radiograph
- Arteriogram (“Gold Standard”)
- CT scan
- Quantitative Thallium Scan
- Quantitative Bone Scan

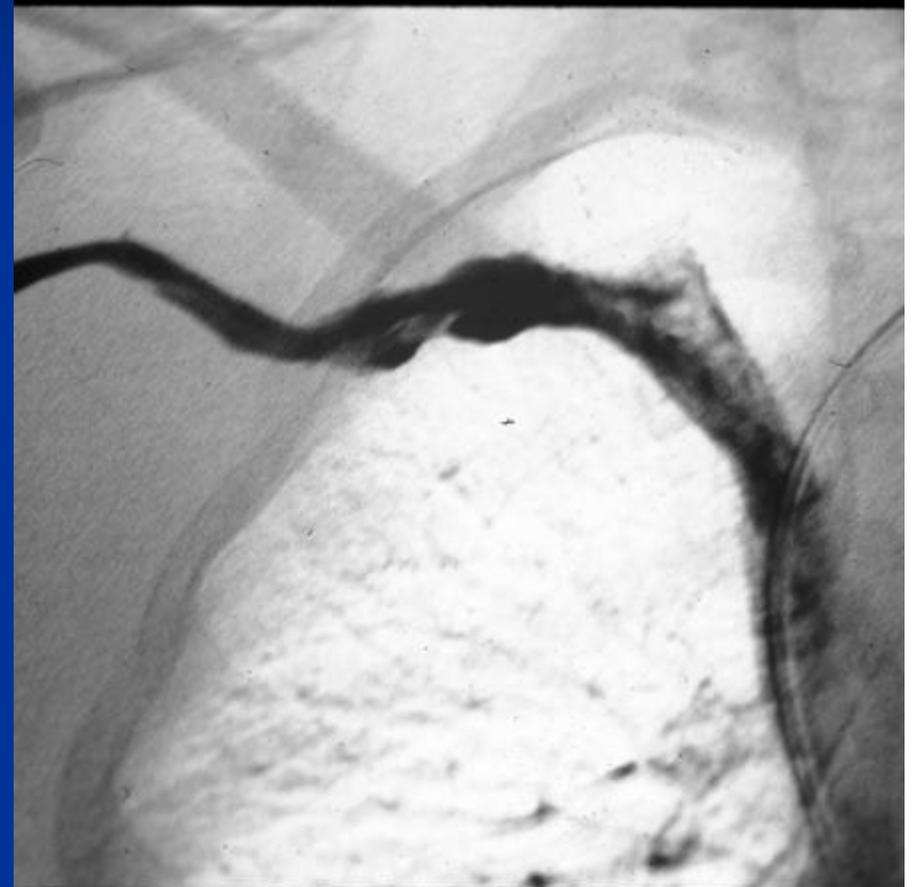
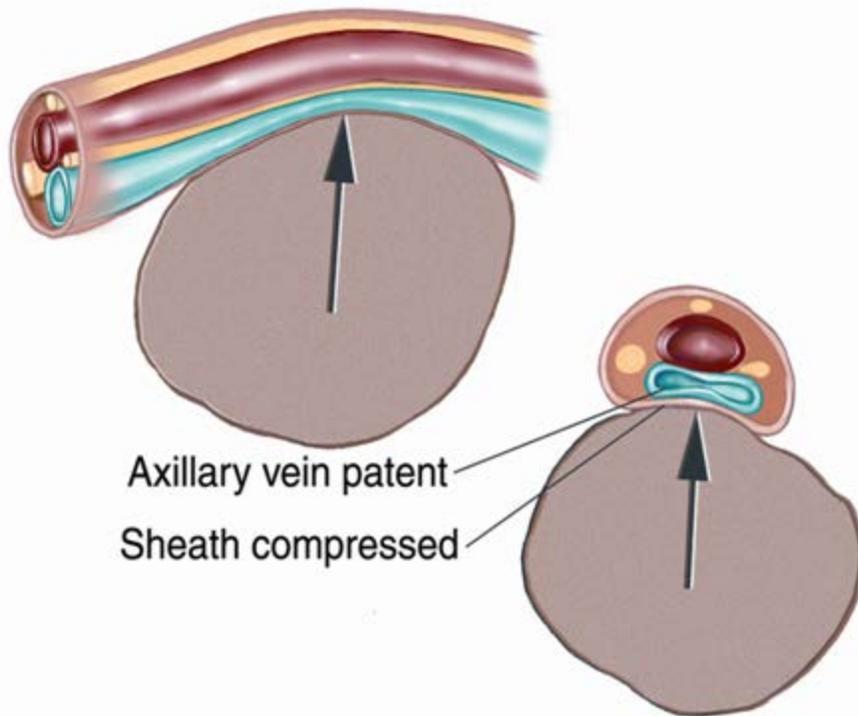
Estimating Resectability

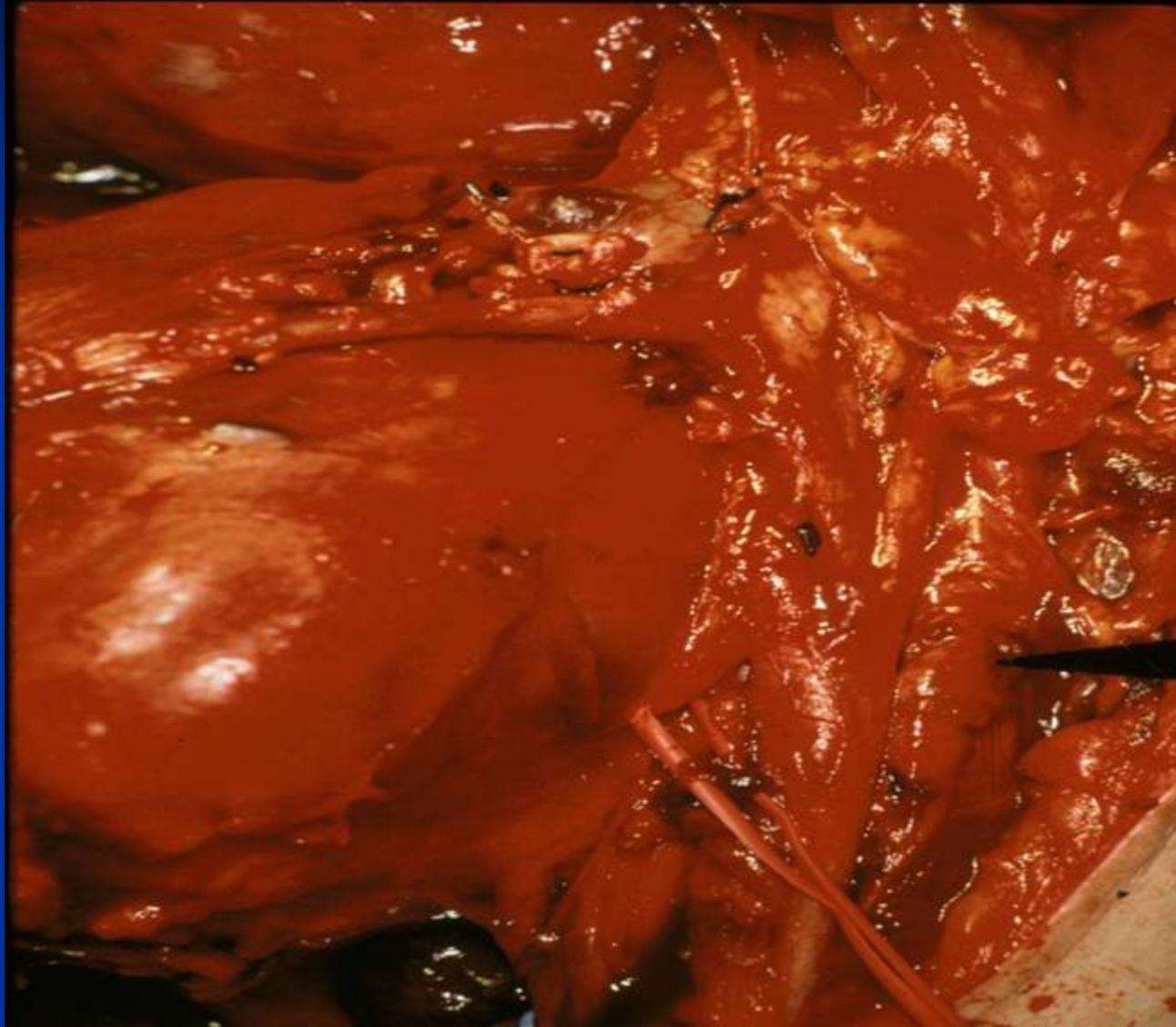
- Clinical Triad for an Unresectable Tumor
 - Intractable Neurogenic Pain
 - Motor Loss
 - **Venogram demonstrating an obliterated axillary vein**

- **Final Decision made after intraoperative Exploration!!!**

Resectable Tumor

BRACHIAL PLEXUS
(TUMOR RESECTABLE)

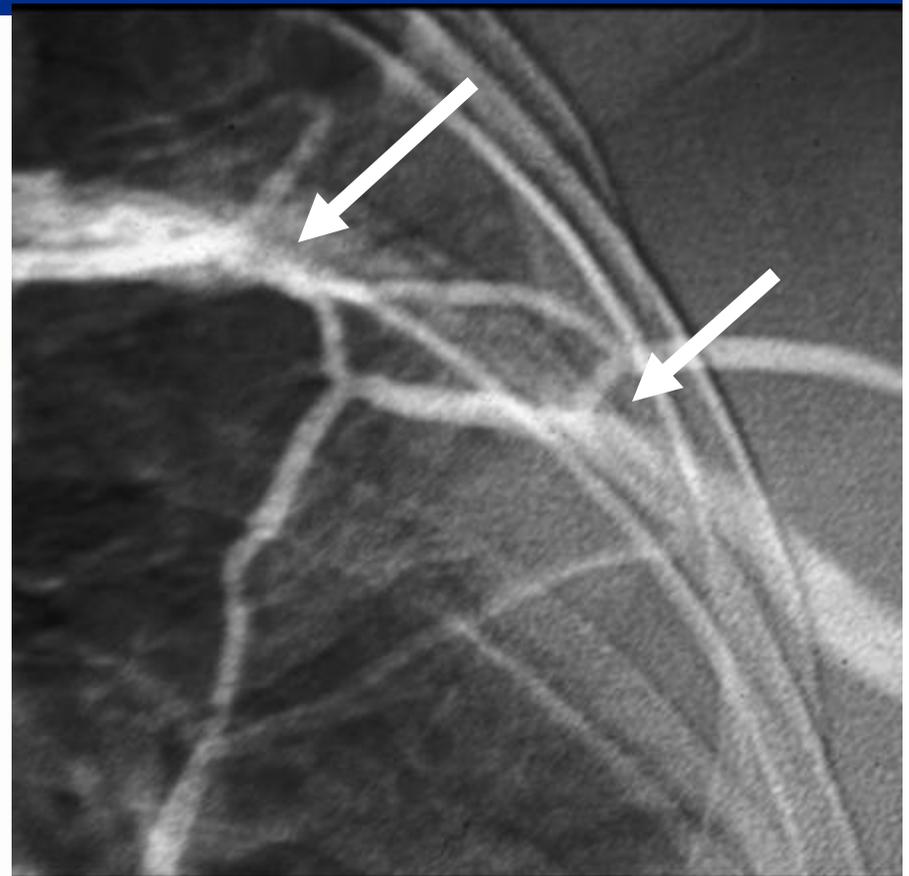
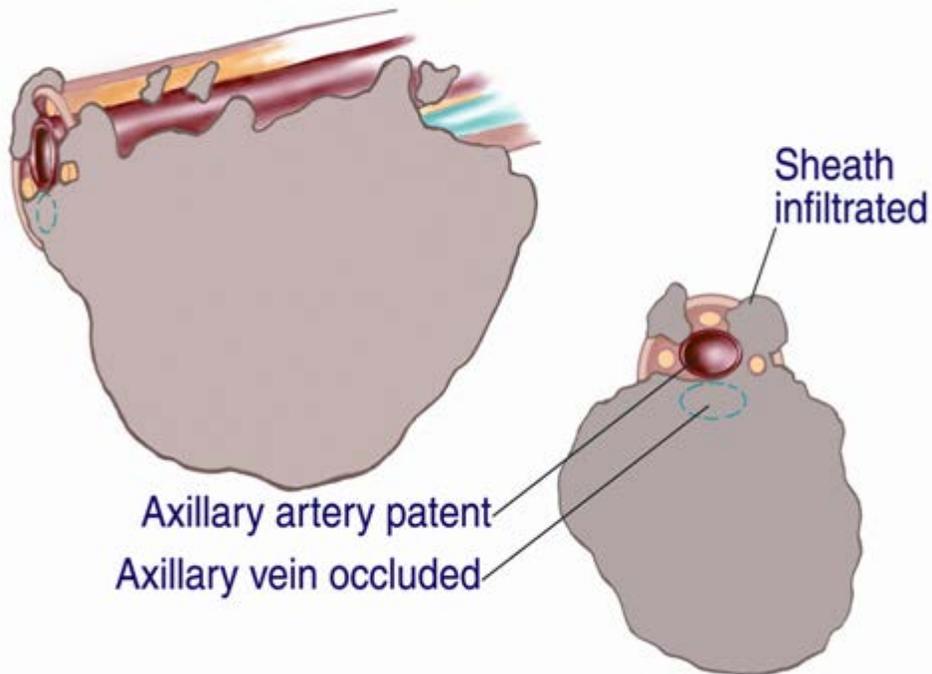




James C. Wittig, MD

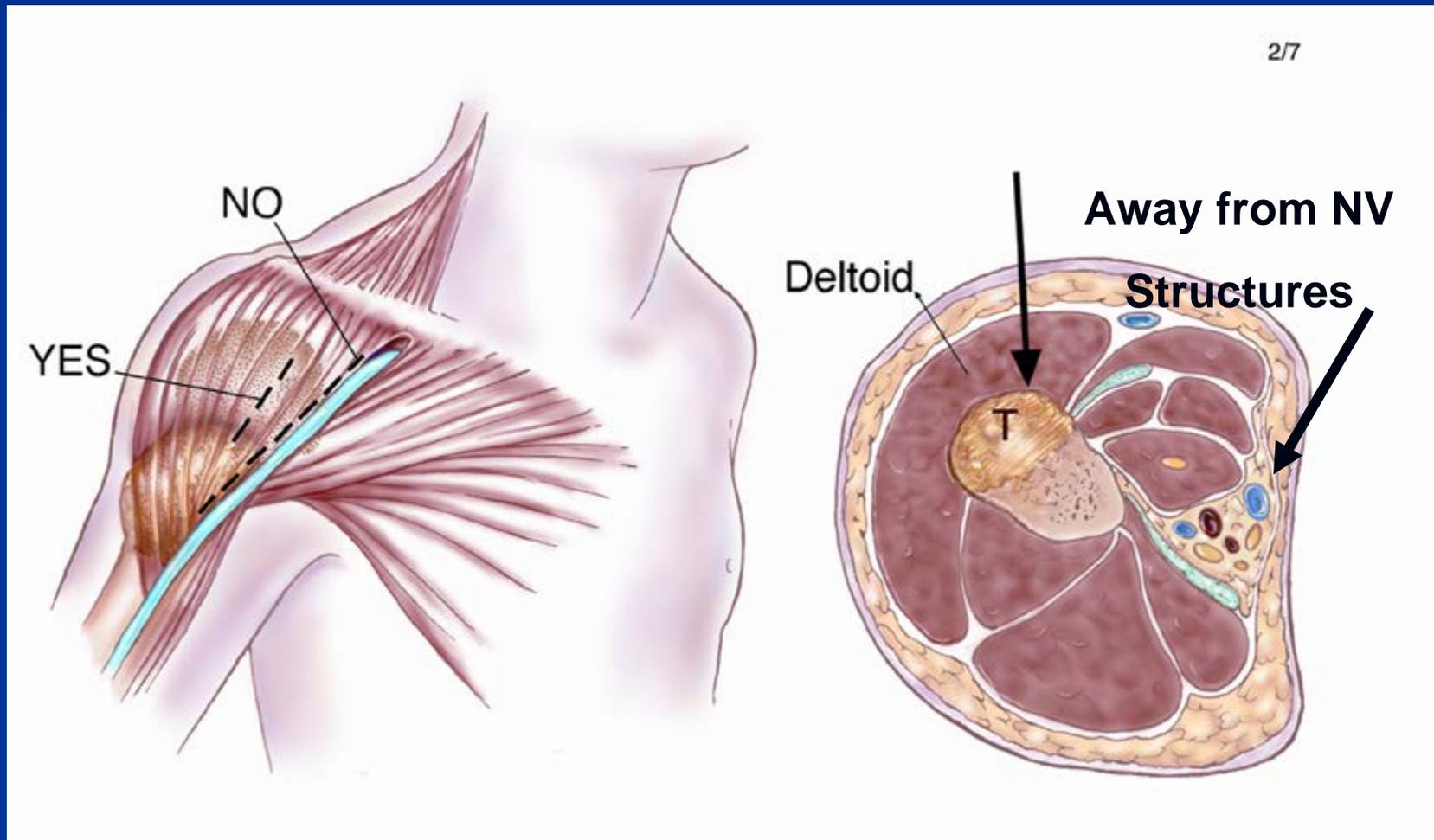
Unresectable Tumor

BRACHIAL PLEXUS
(TUMOR UNRESECTABLE)

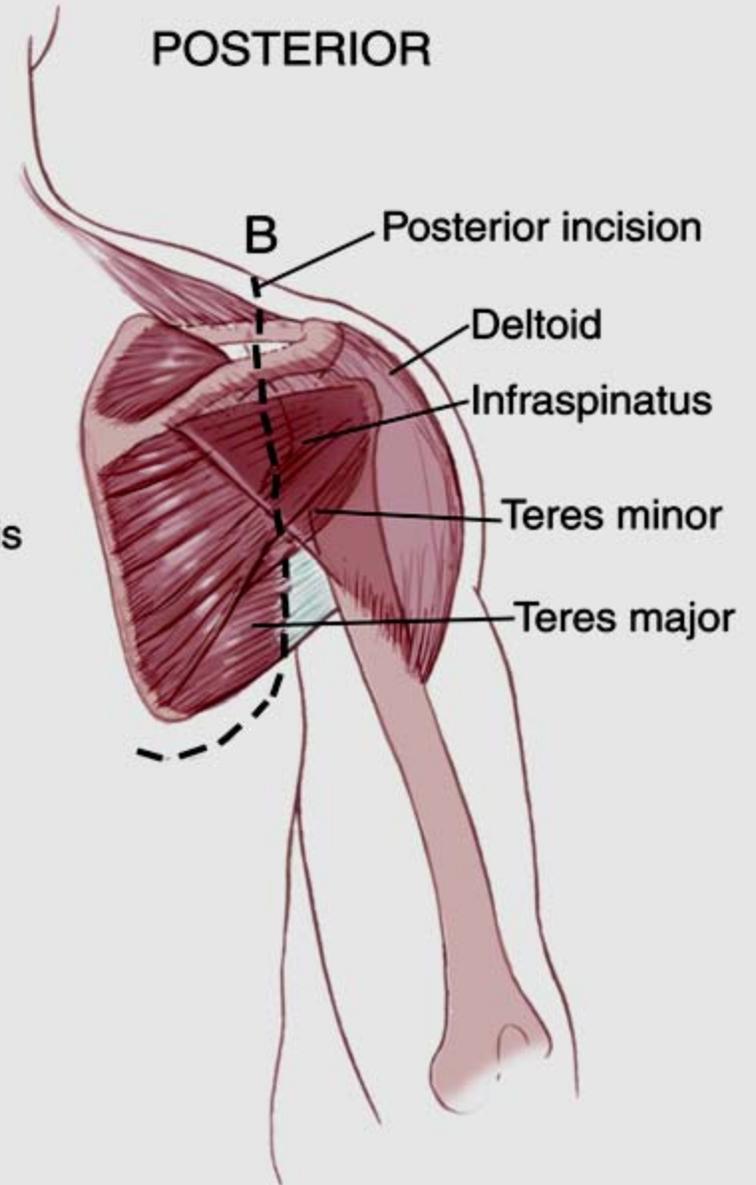
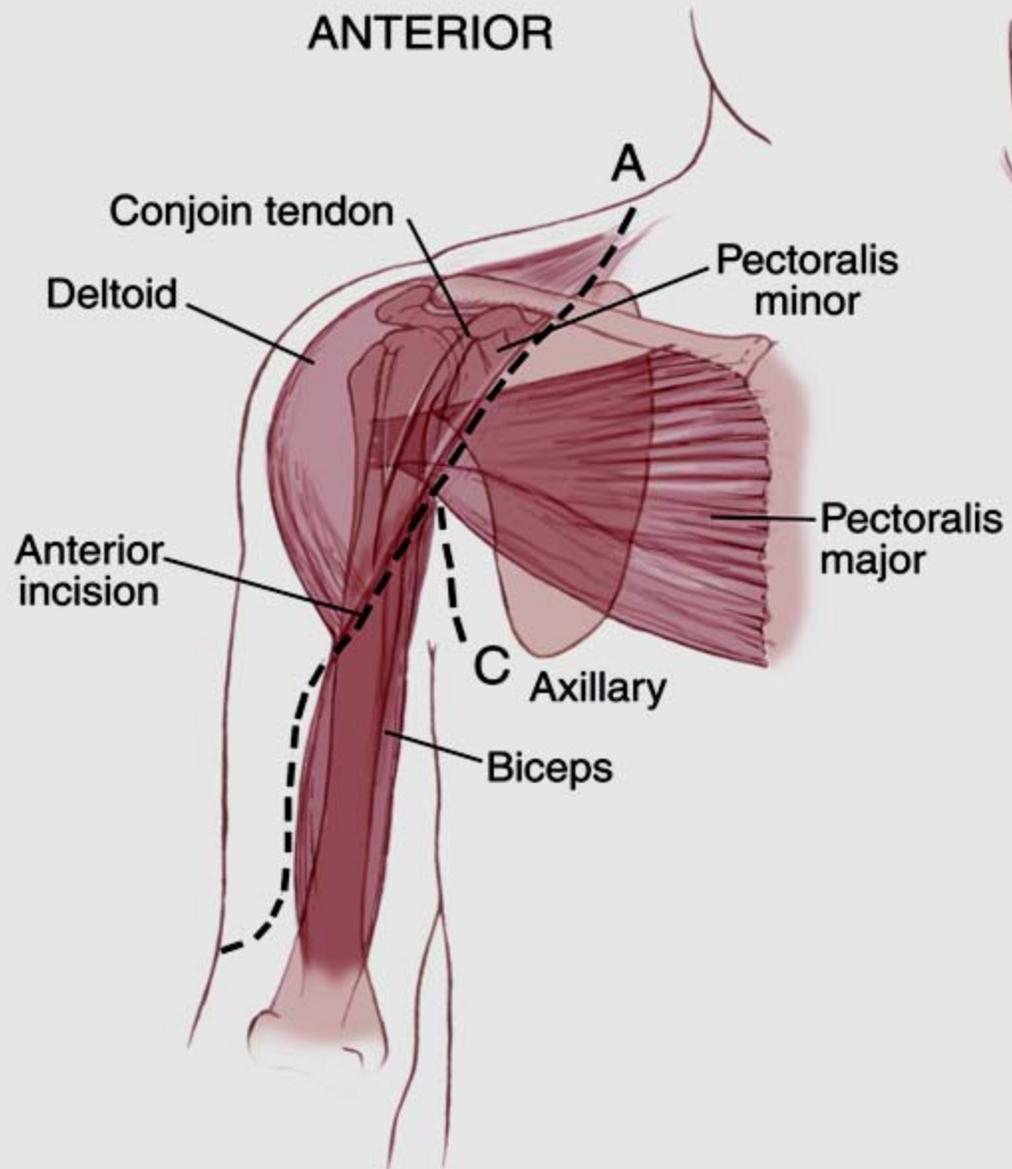


Biopsy

Inappropriately Performed Biopsies are Leading Cause for Amputations!!!!

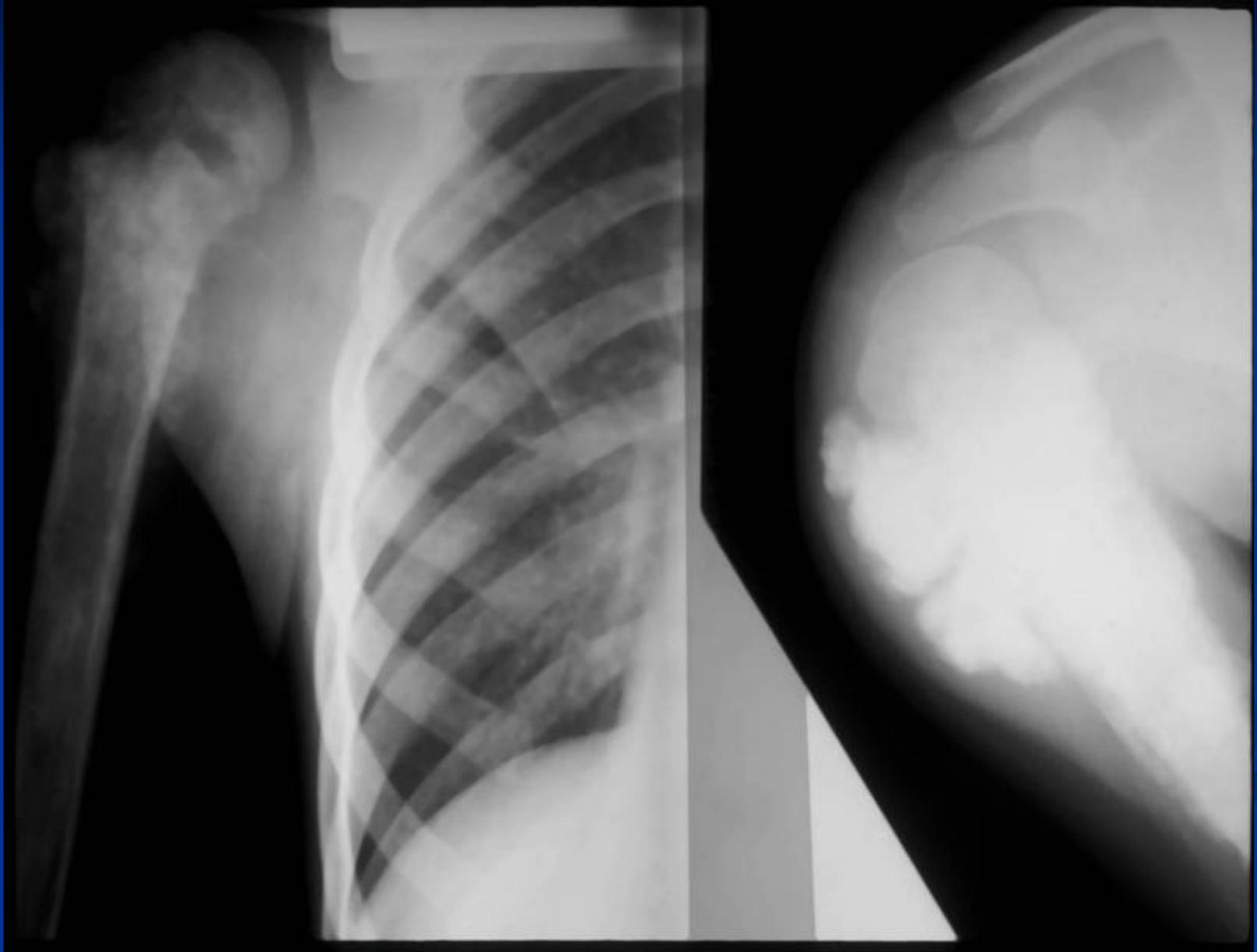


UTILITARIAN SHOULDER GIRDLE INCISION

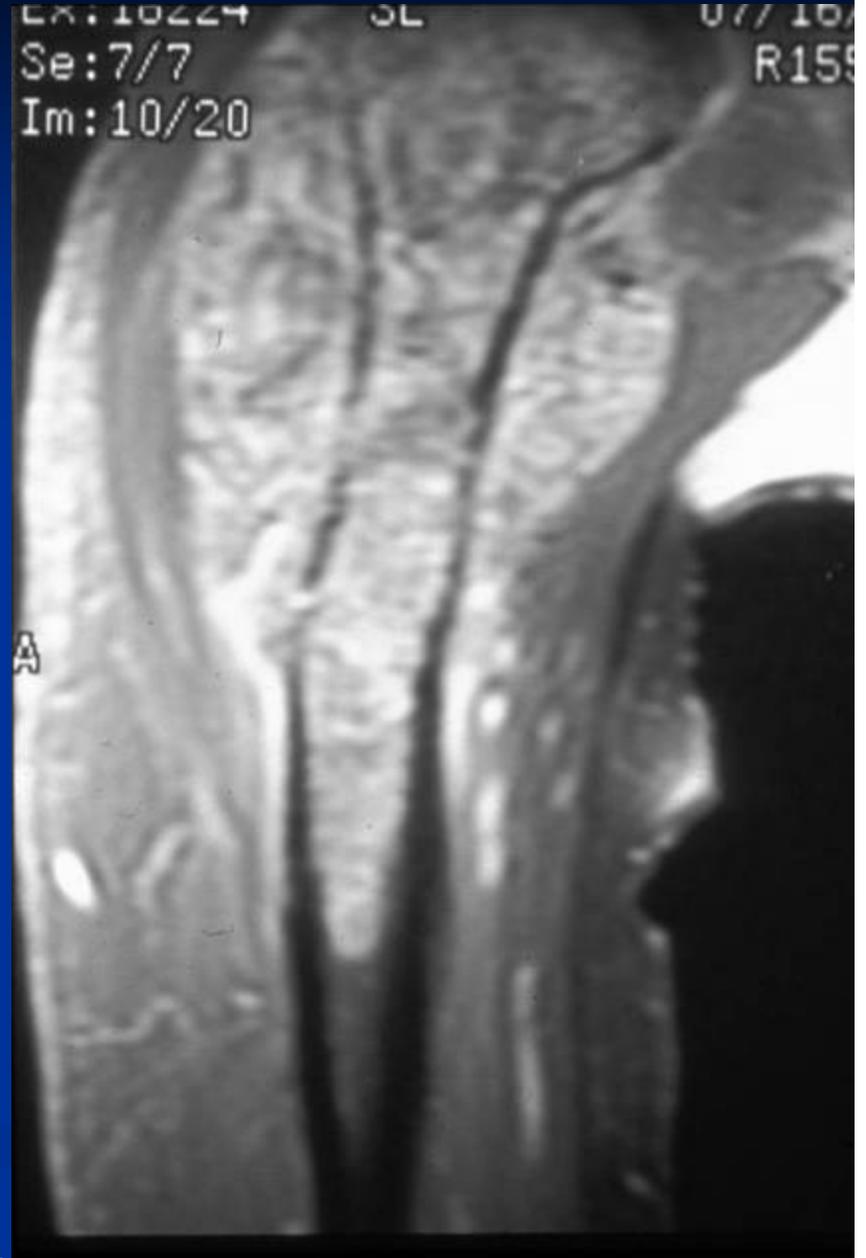


Proximal Humerus Resection and Reconstruction

James C. Wittig, MD



James C. King, MD



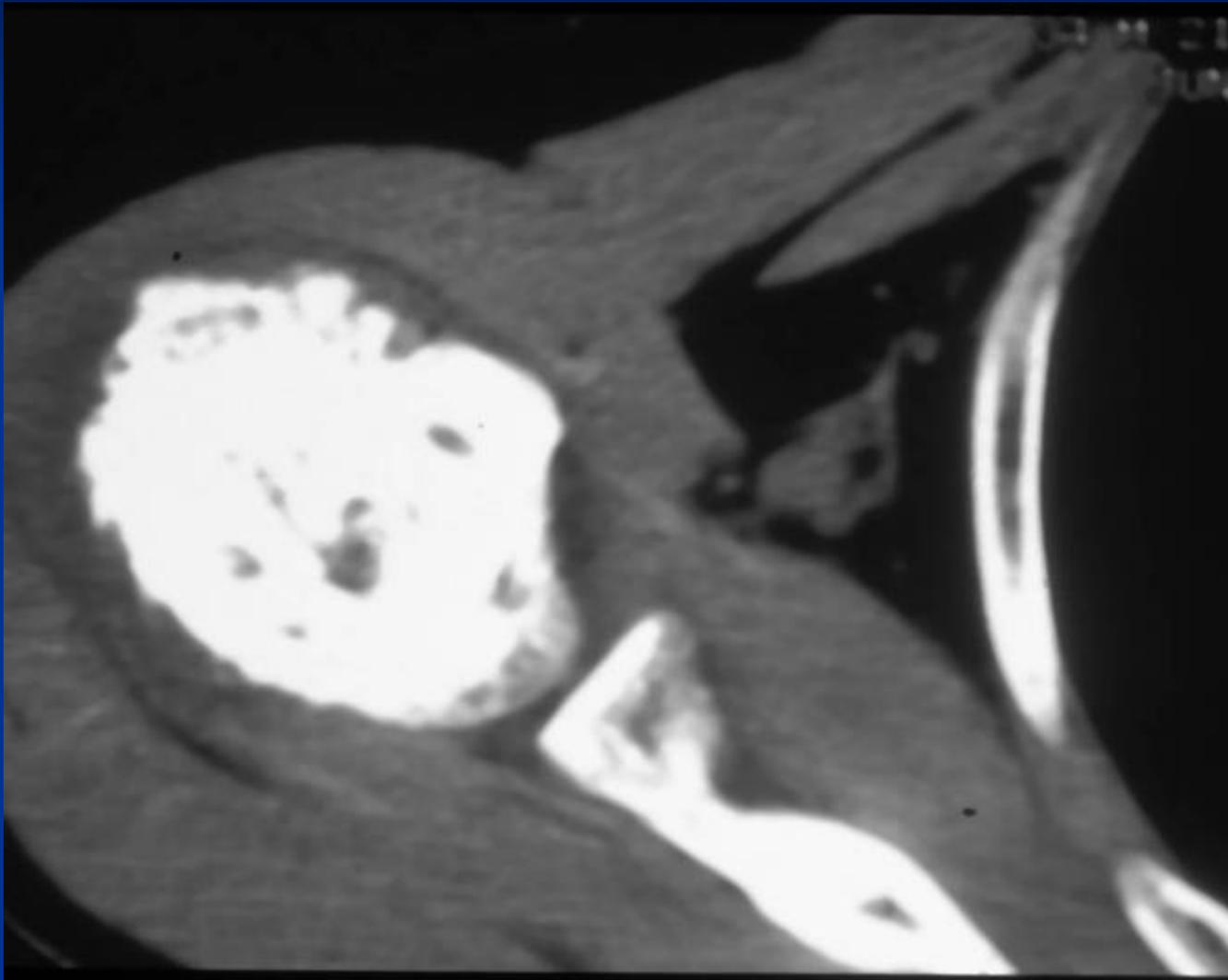
James C. Wittig, MD



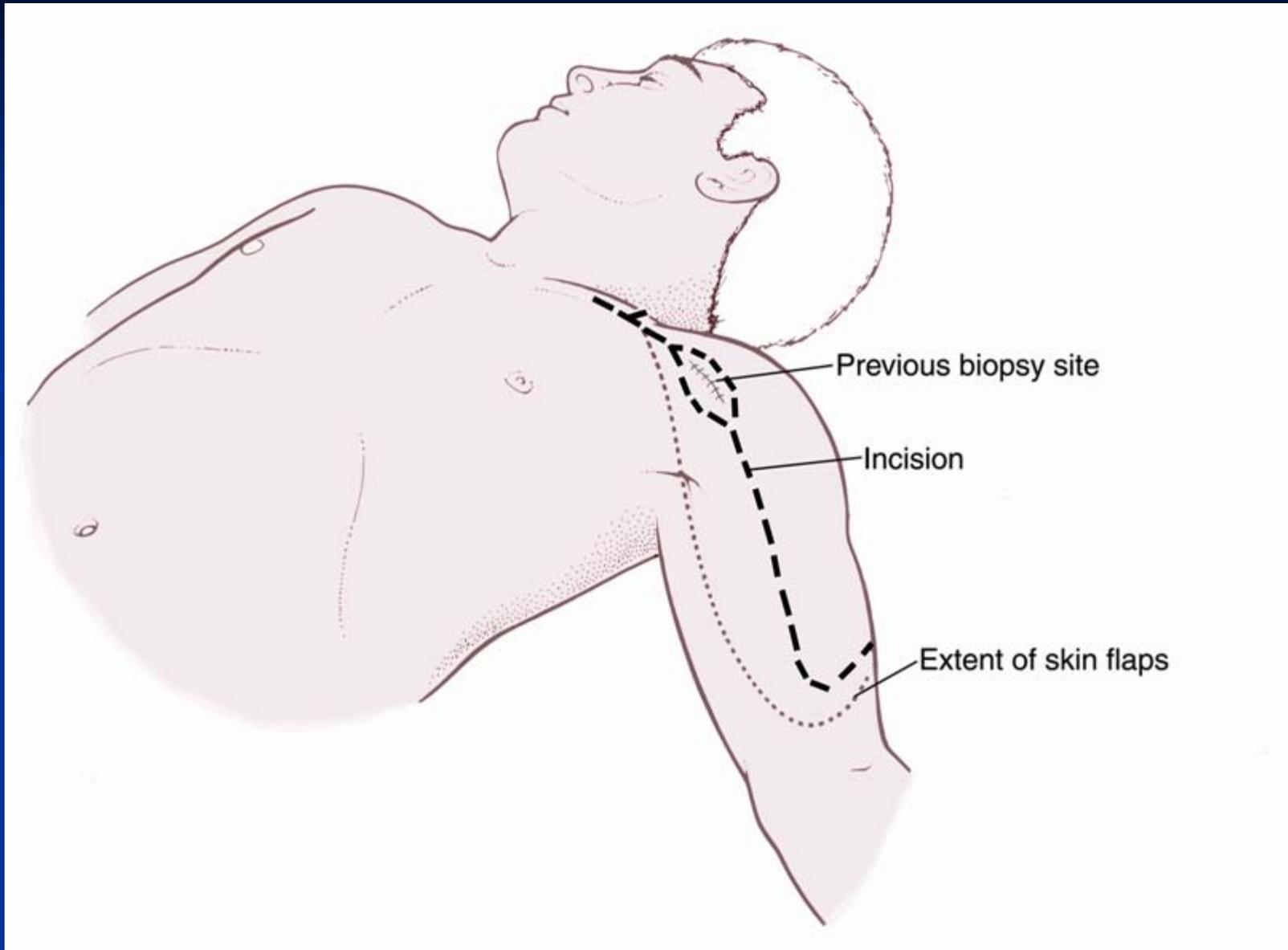
James C. [unclear], MD

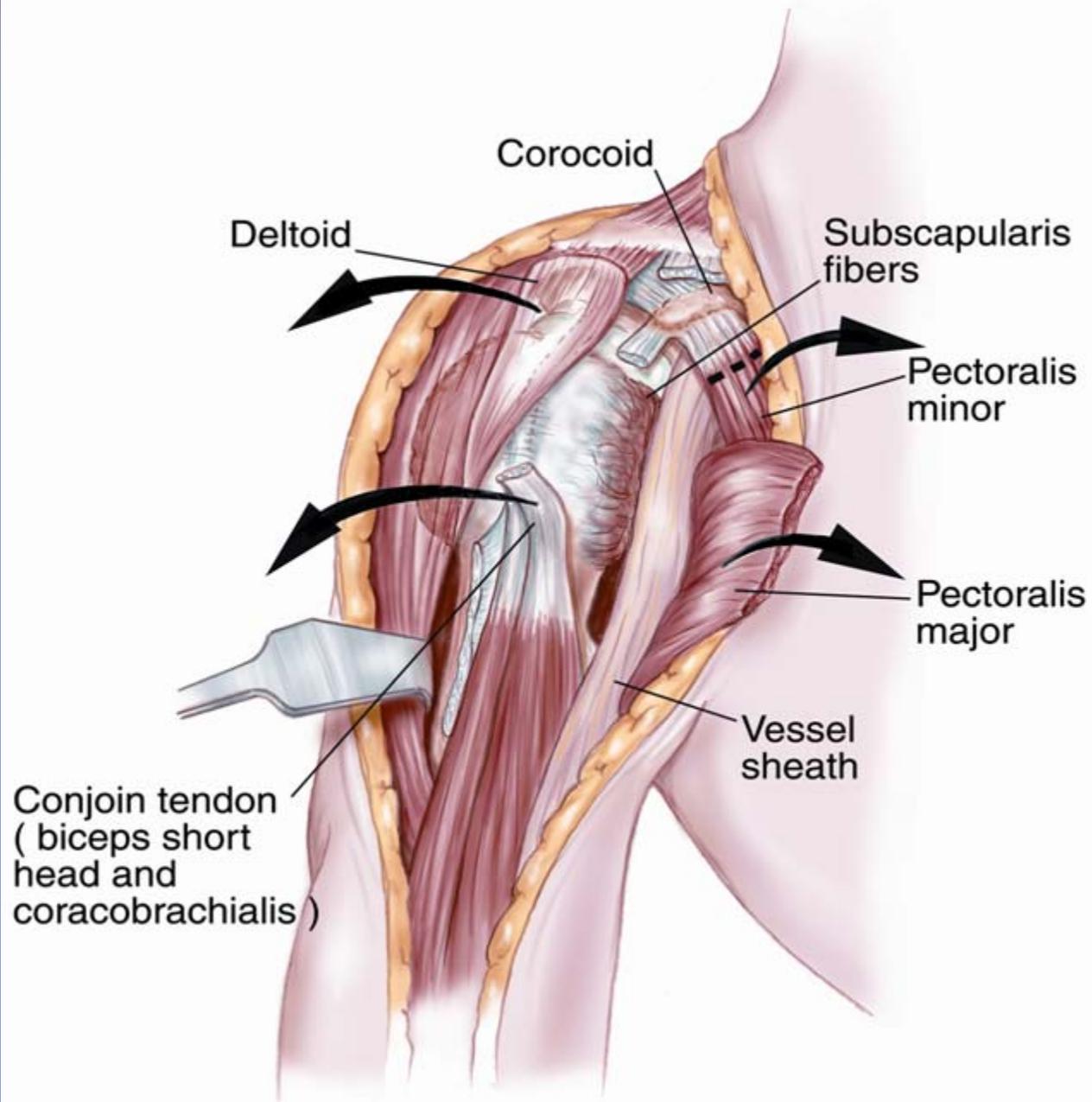


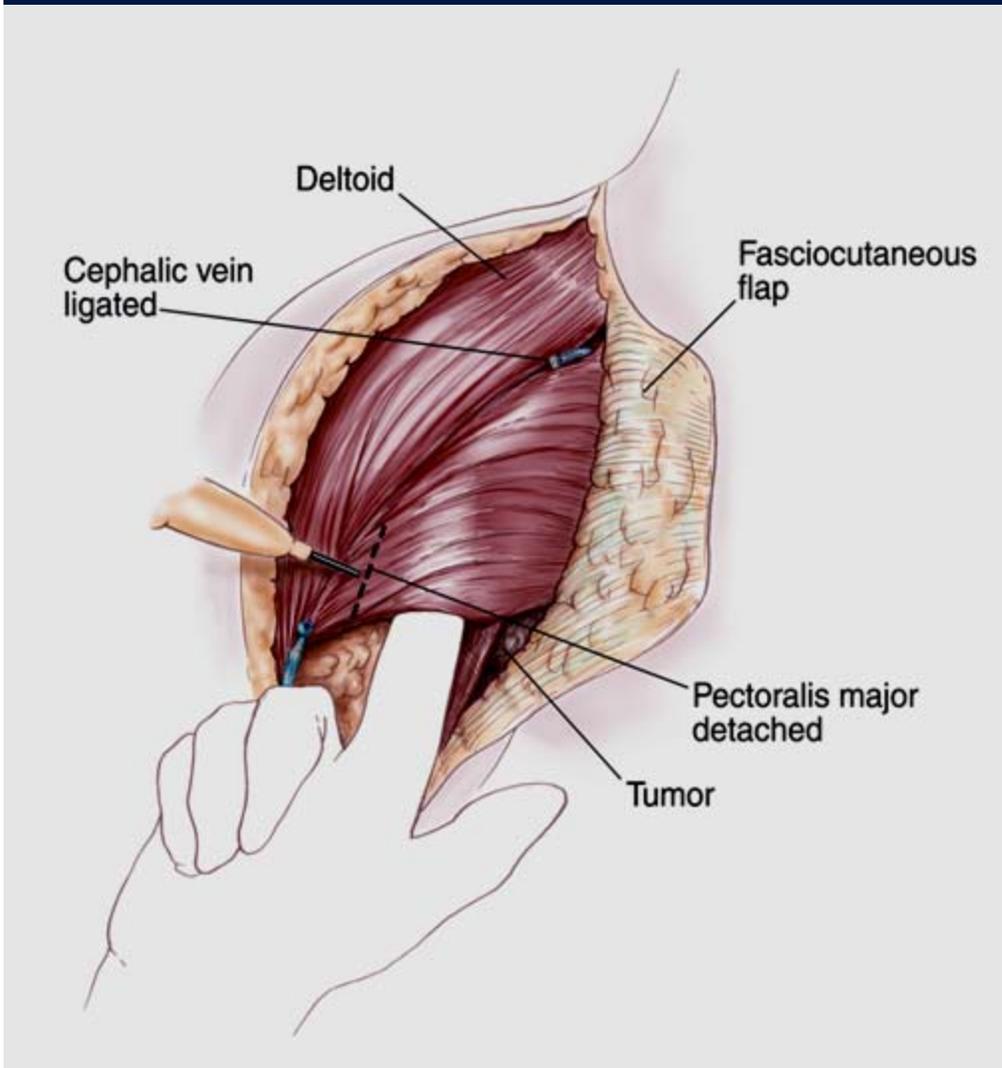
James C. Wittig, MD

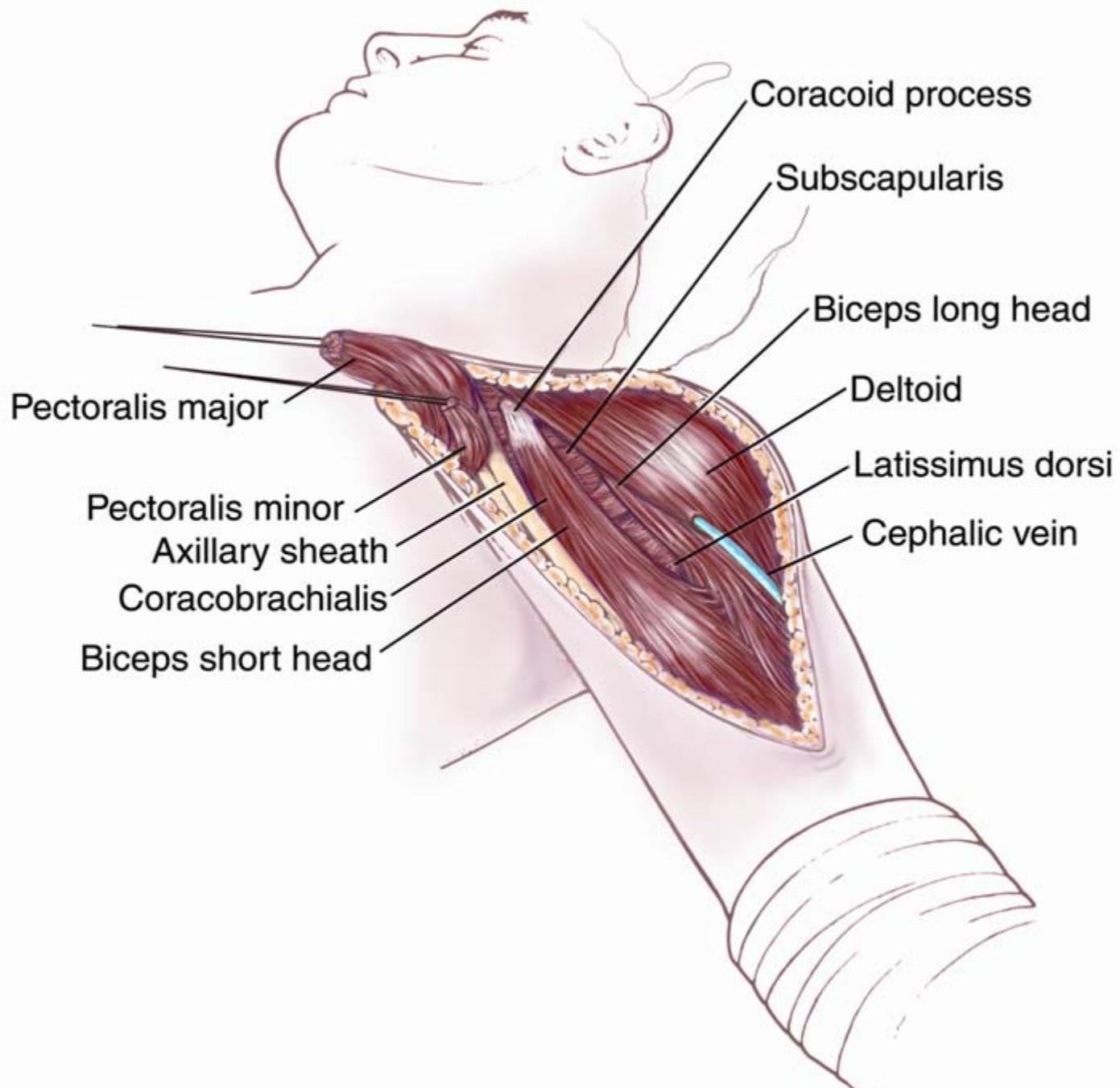


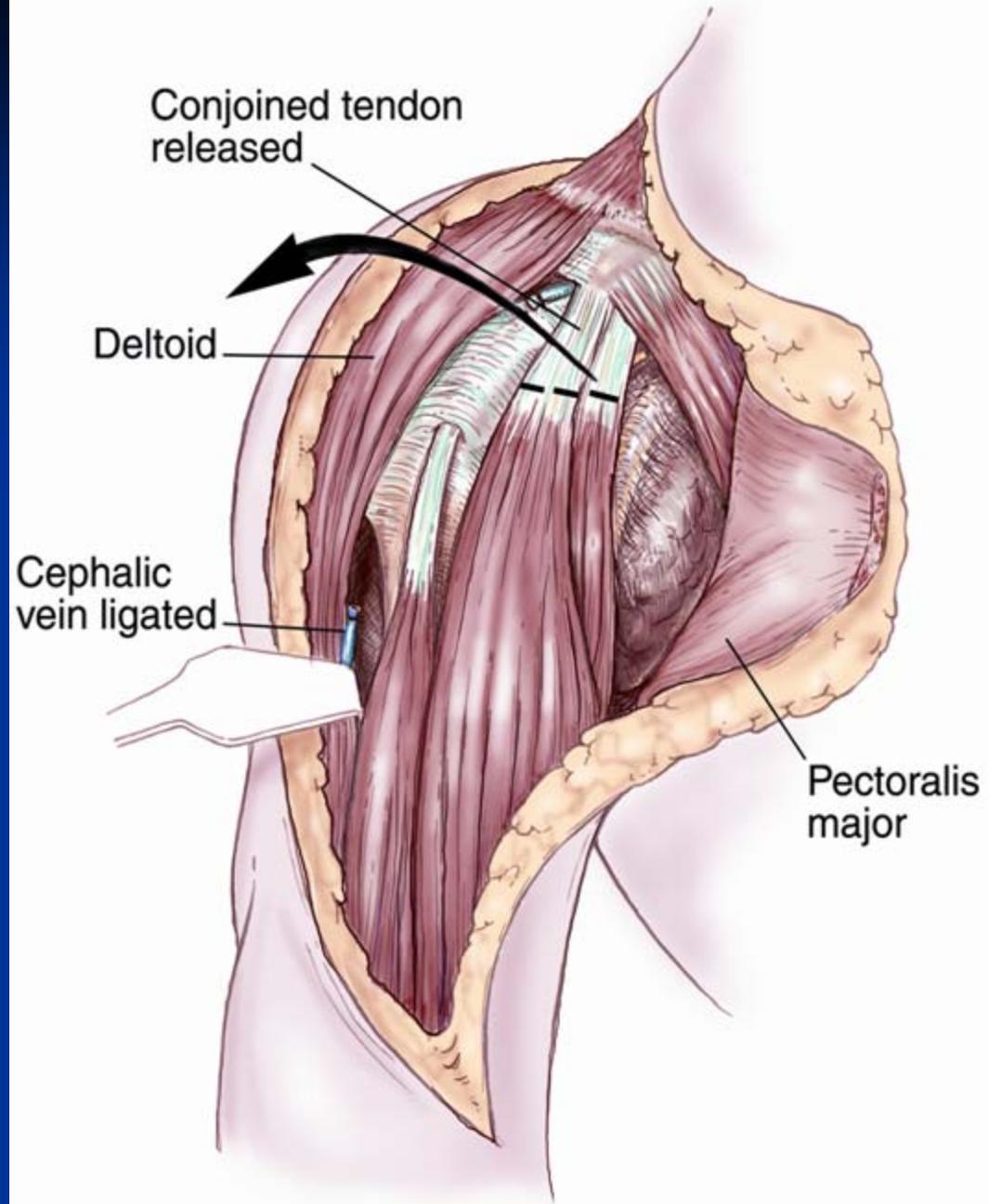
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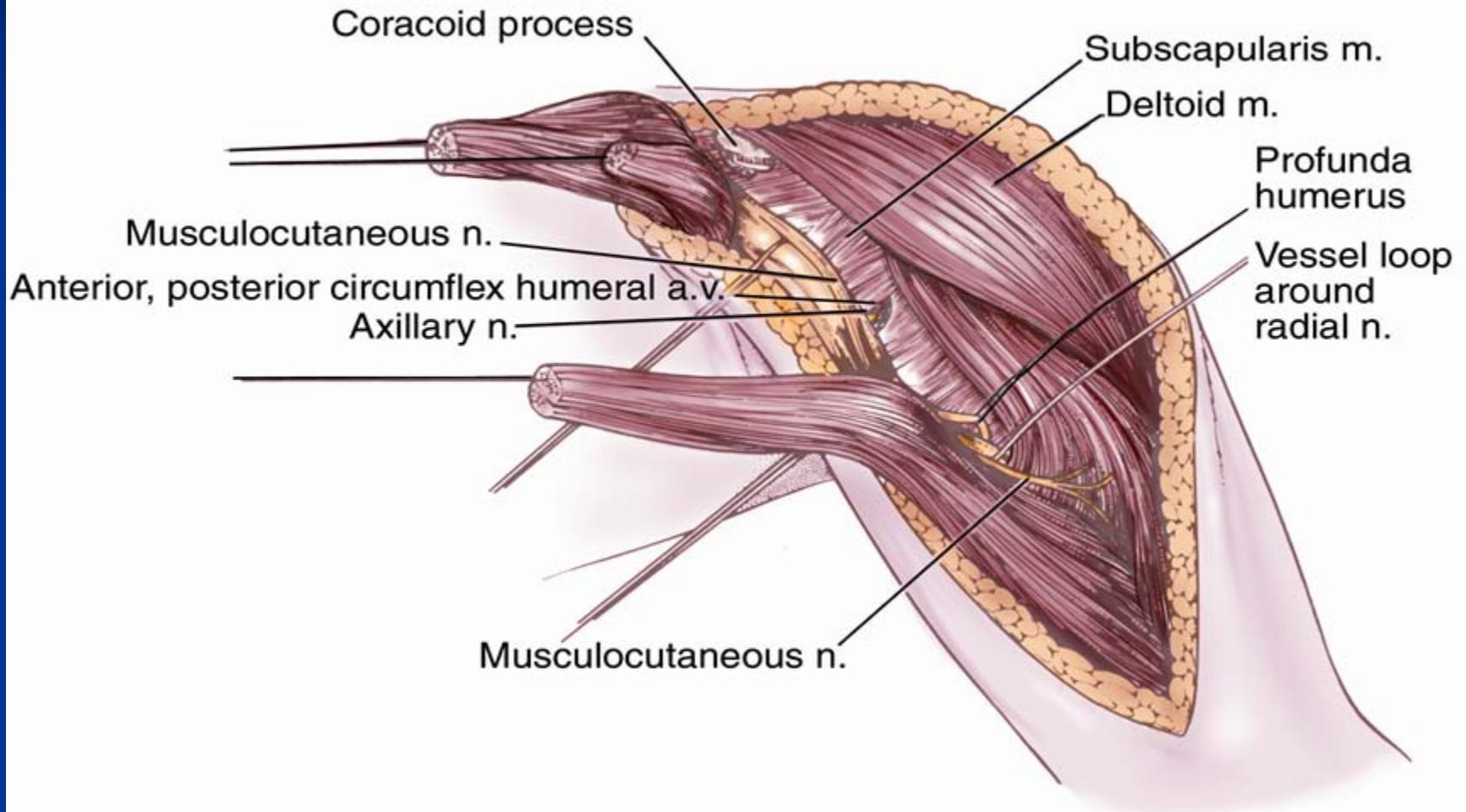


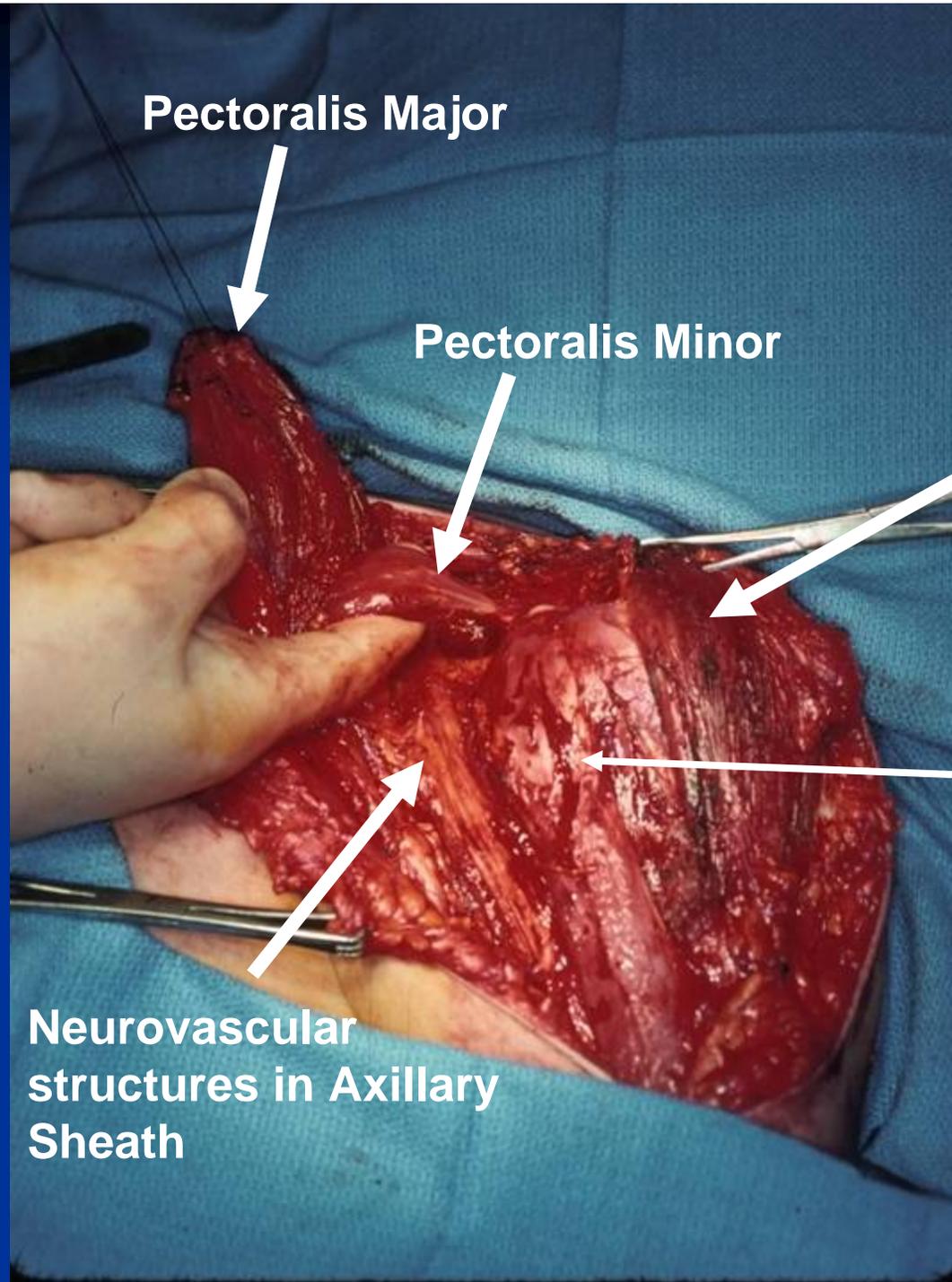












Pectoralis Major

Pectoralis Minor

**Deltoid
Overlying
Tumor**

**Biceps Short
Head**

**Neurovascular
structures in Axillary
Sheath**

**Subscapularis
Overlying
Tumor**

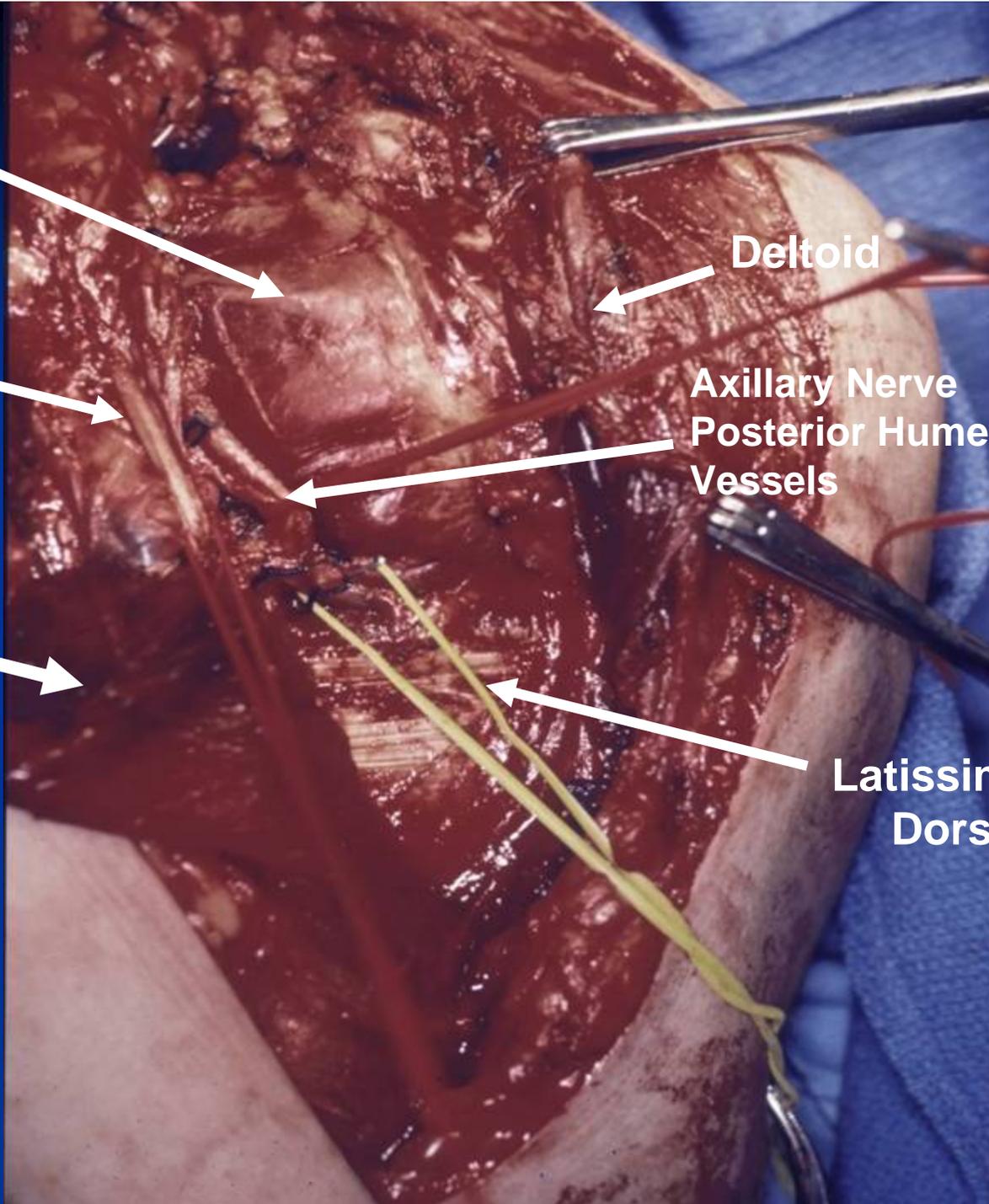
**Musculocutaneous
Nerve**

**Biceps
Short Head**

Deltoid

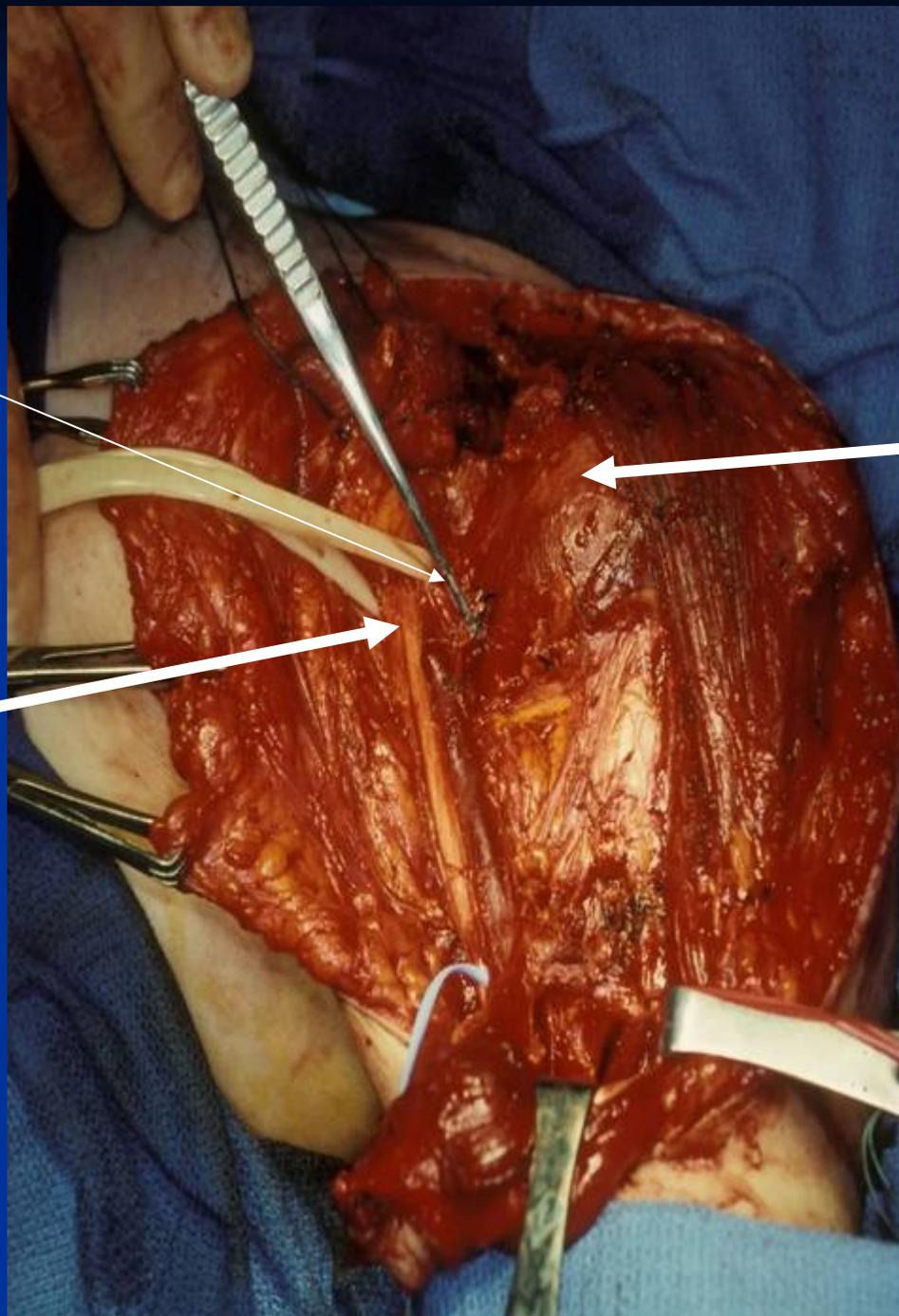
**Axillary Nerve
Posterior Humeral Circ
Vessels**

**Latissimus
Dorsi**

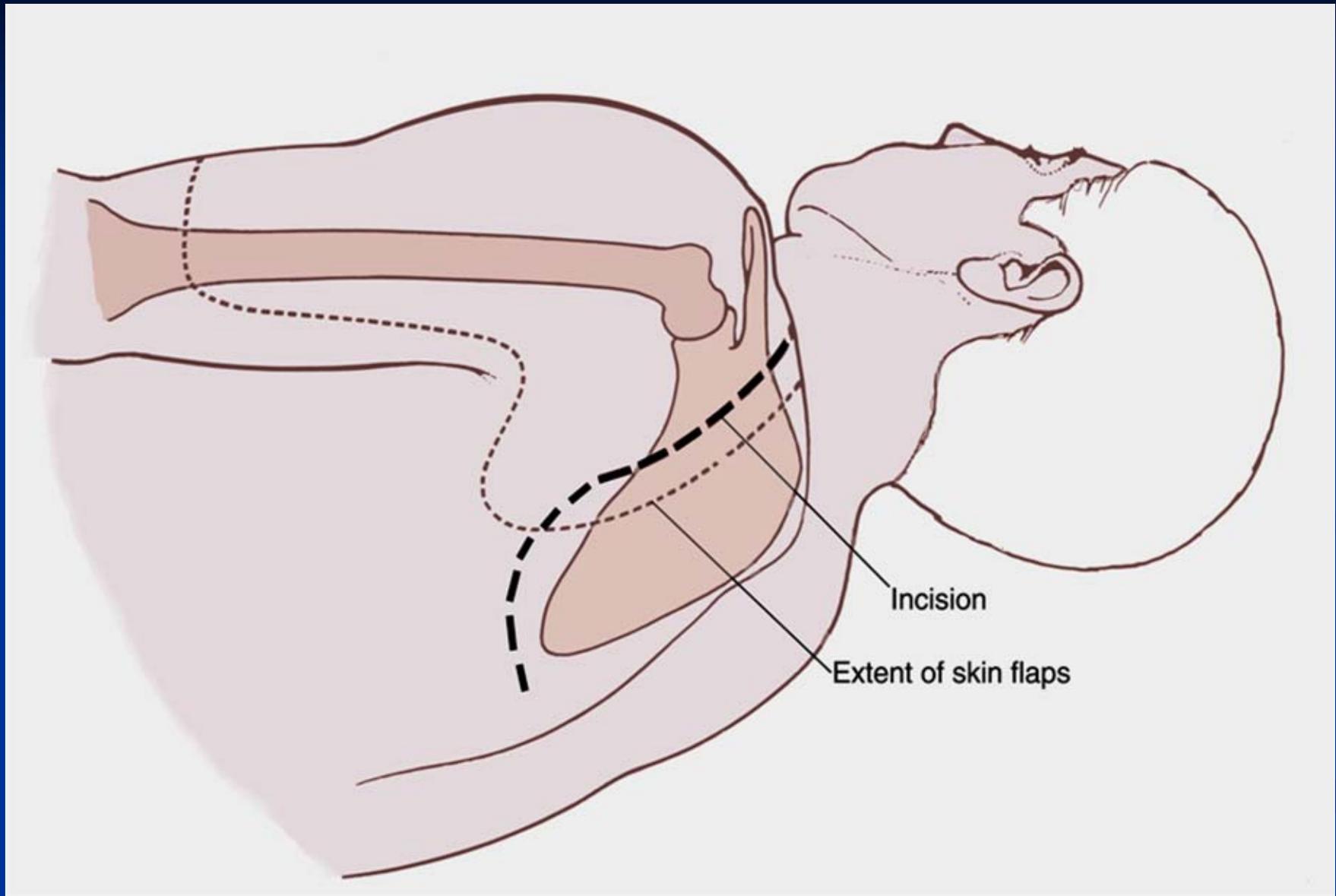


**Ligation of
Circumflex
Vessels and
Axillary Nerve**

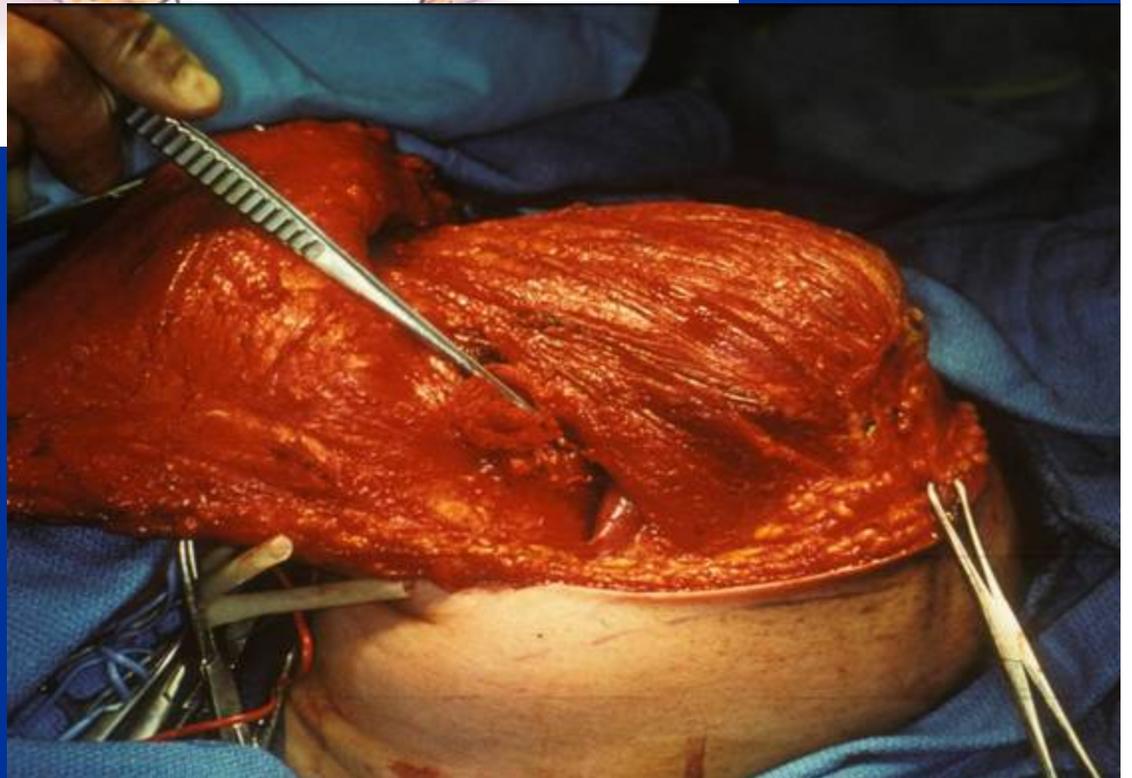
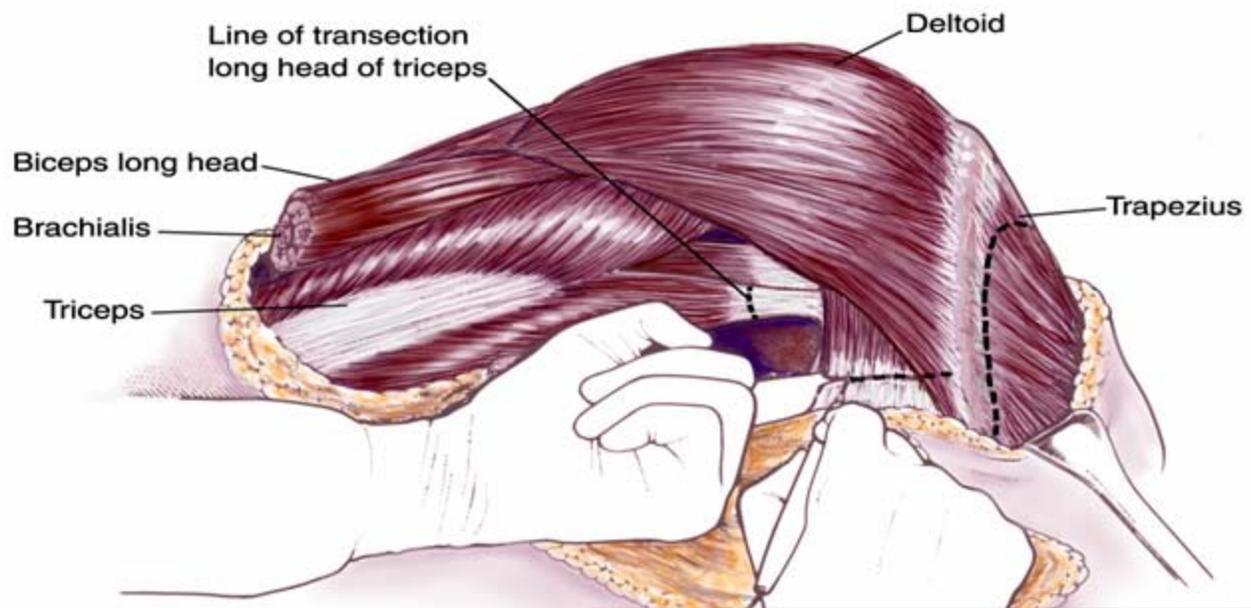
**Axillary Vessels
and Brachial
Plexus**

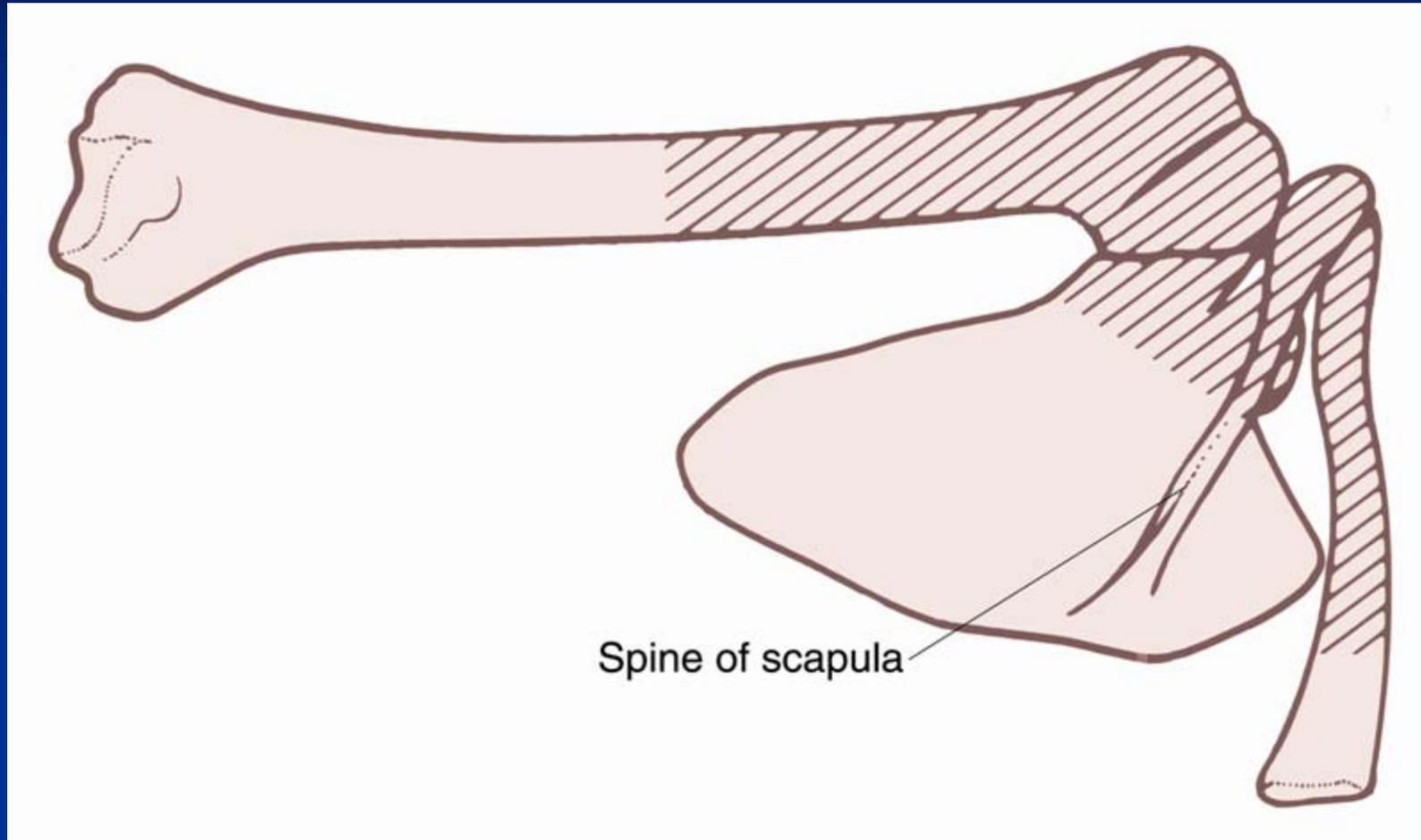


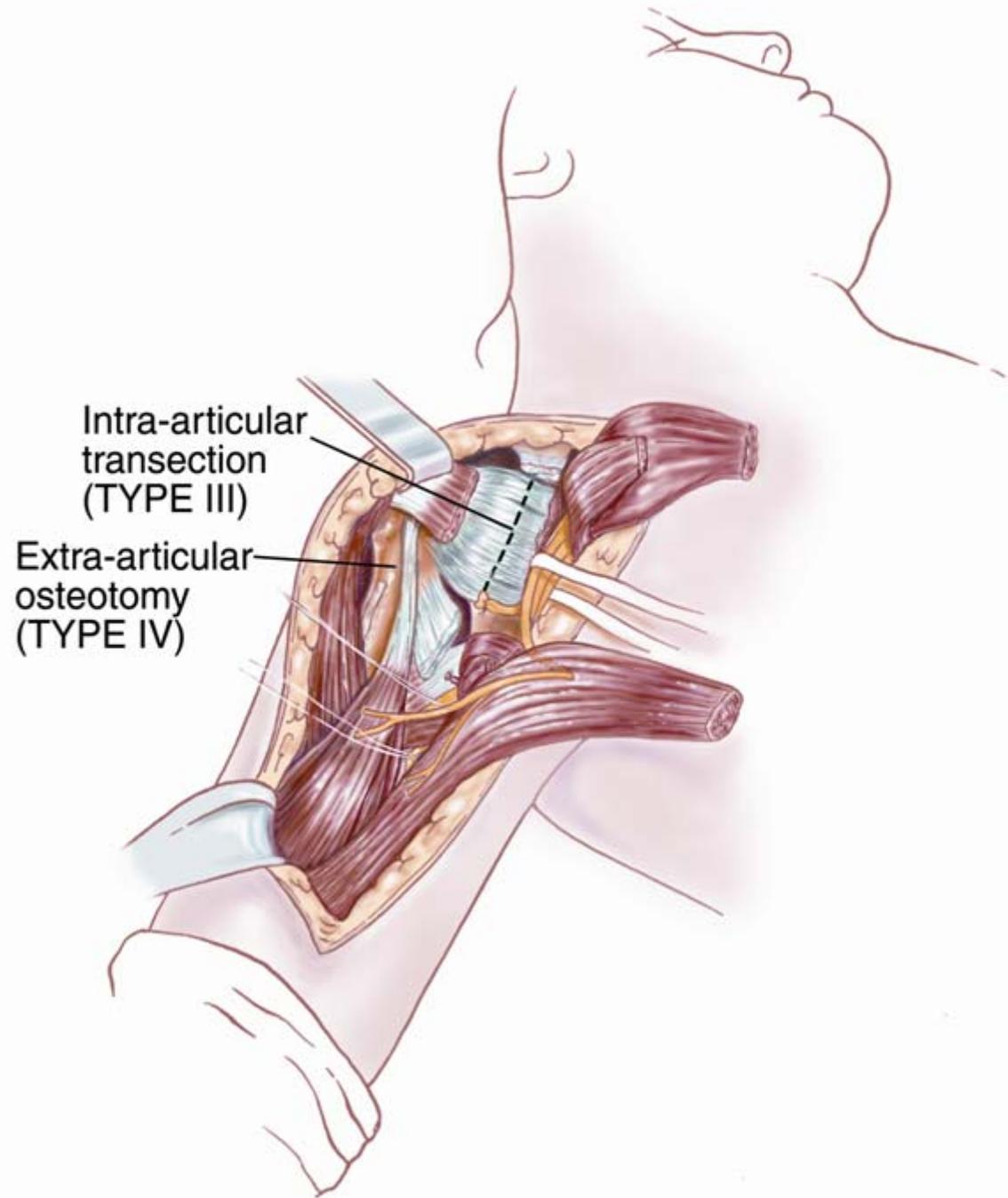
**Tumor Deep to
Subscapularis
and Deltoid**



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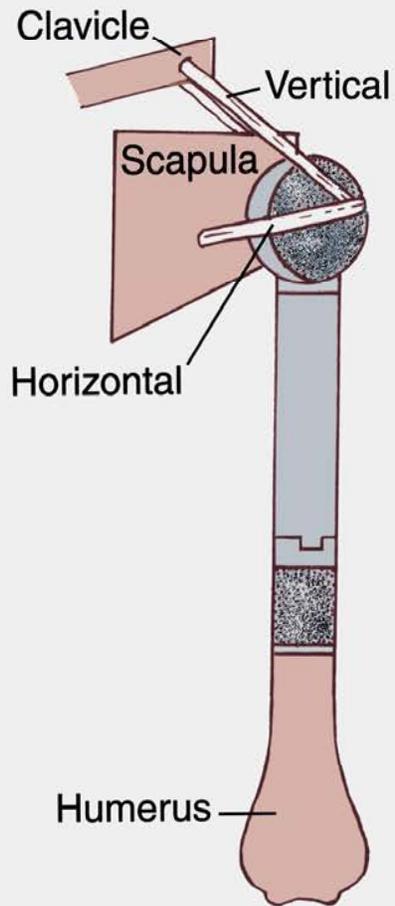




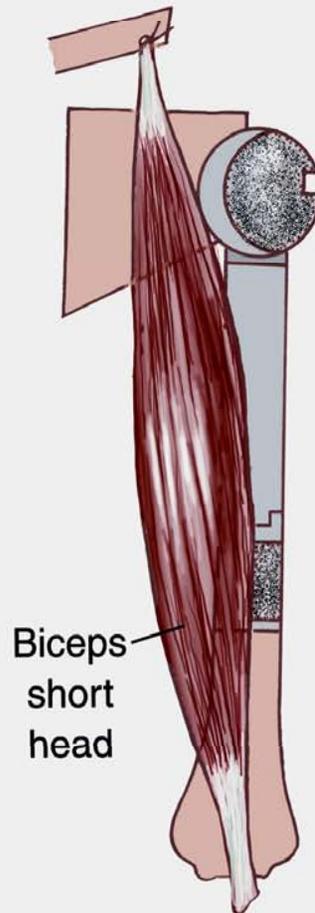
Intra-articular
transection
(TYPE III)

Extra-articular
osteotomy
(TYPE IV)

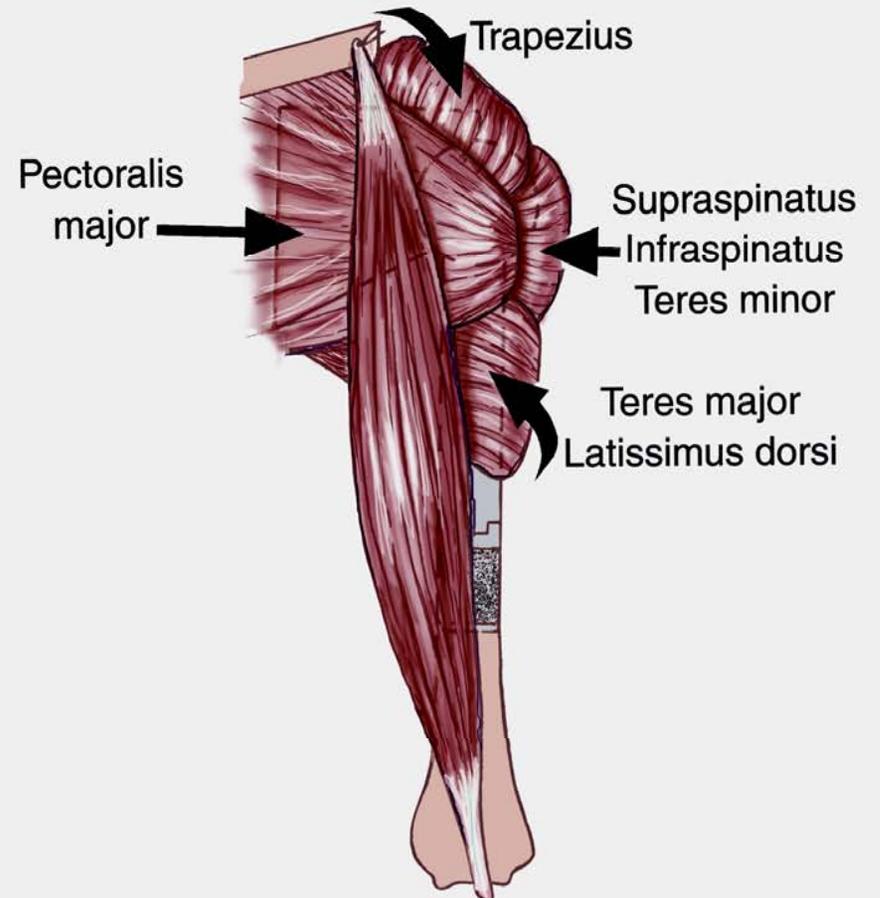
STATIC SUSPENSION



DYNAMIC SUSPENSION

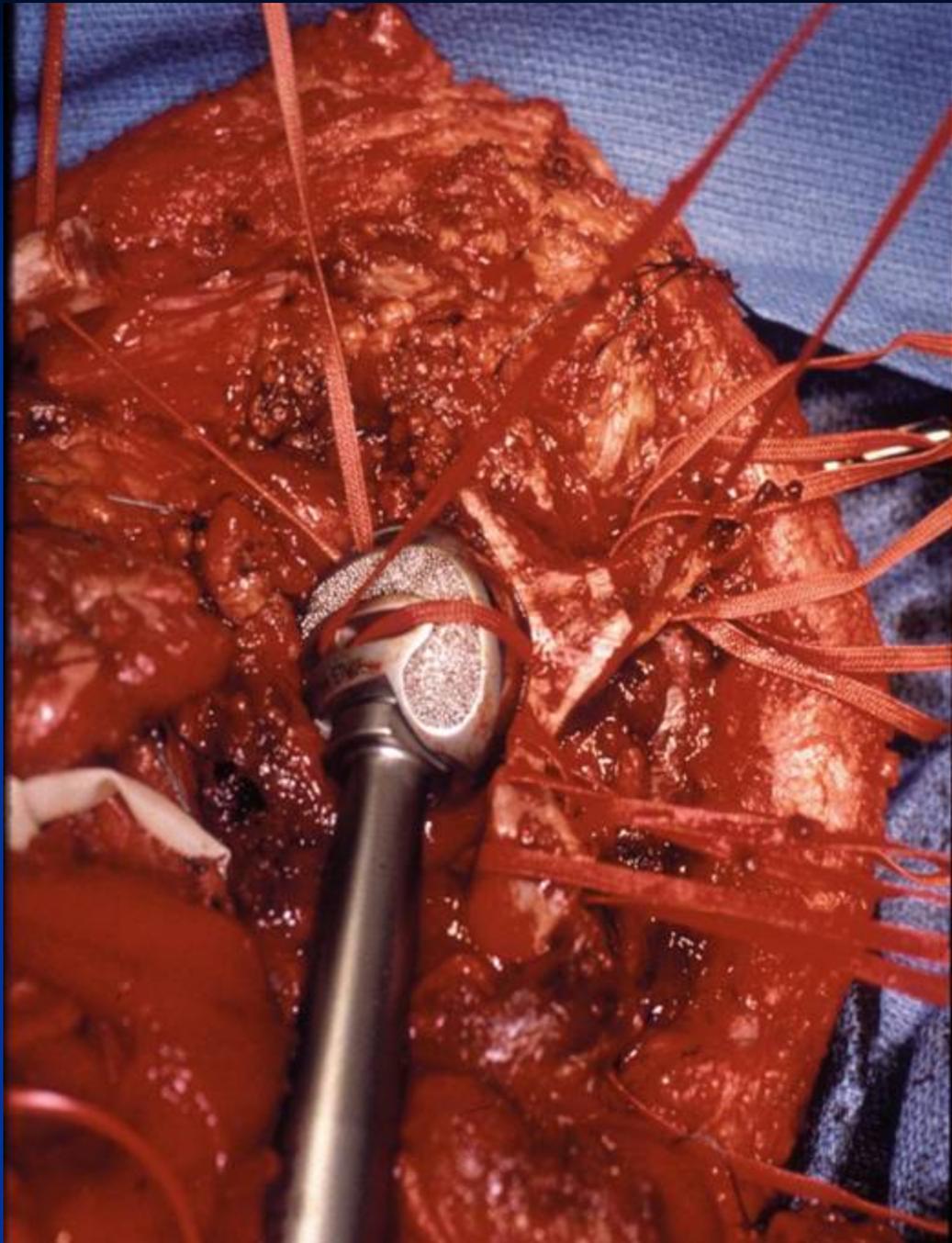


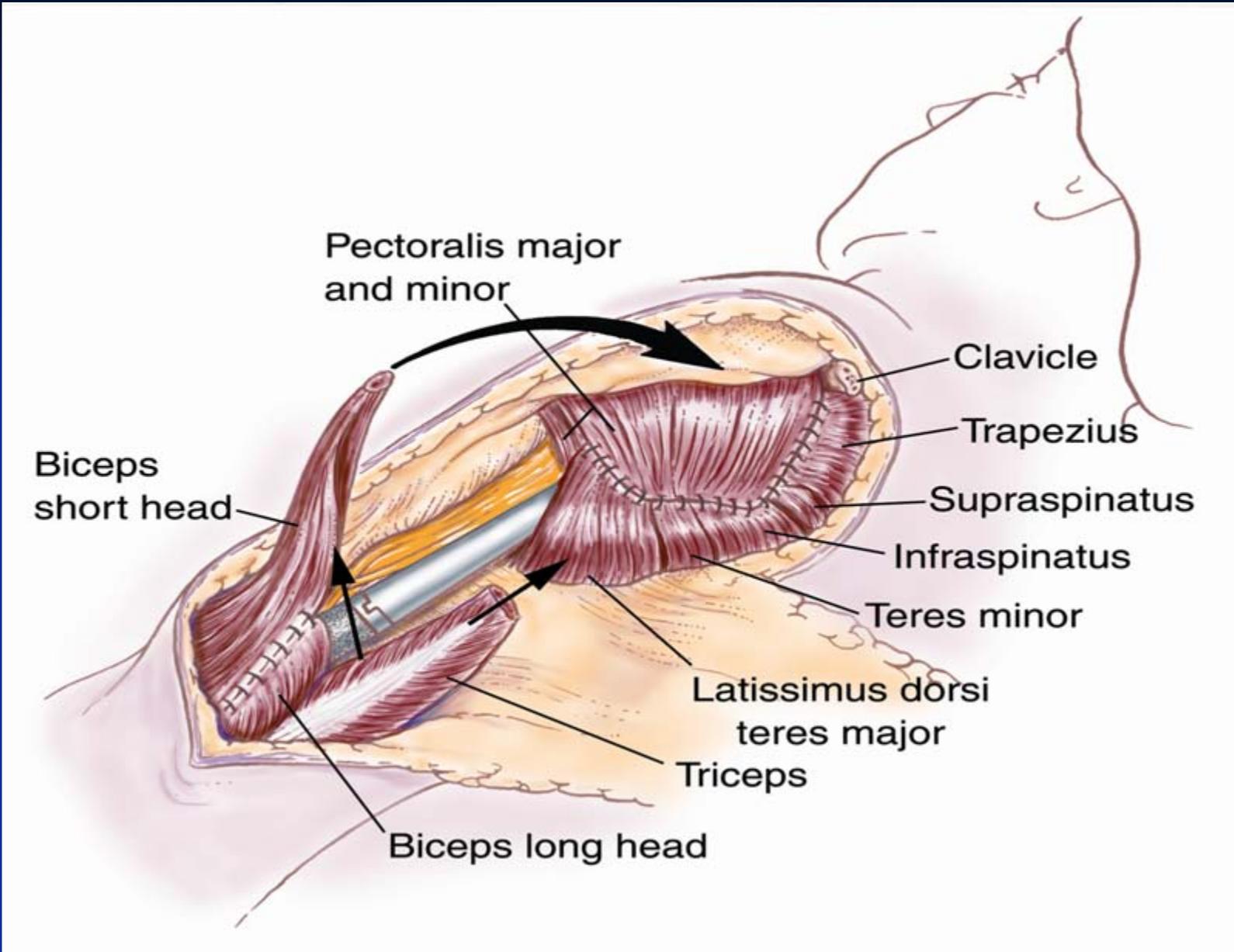
MOTOR RECONSTRUCTION SOFT TISSUE RECONSTRUCTION

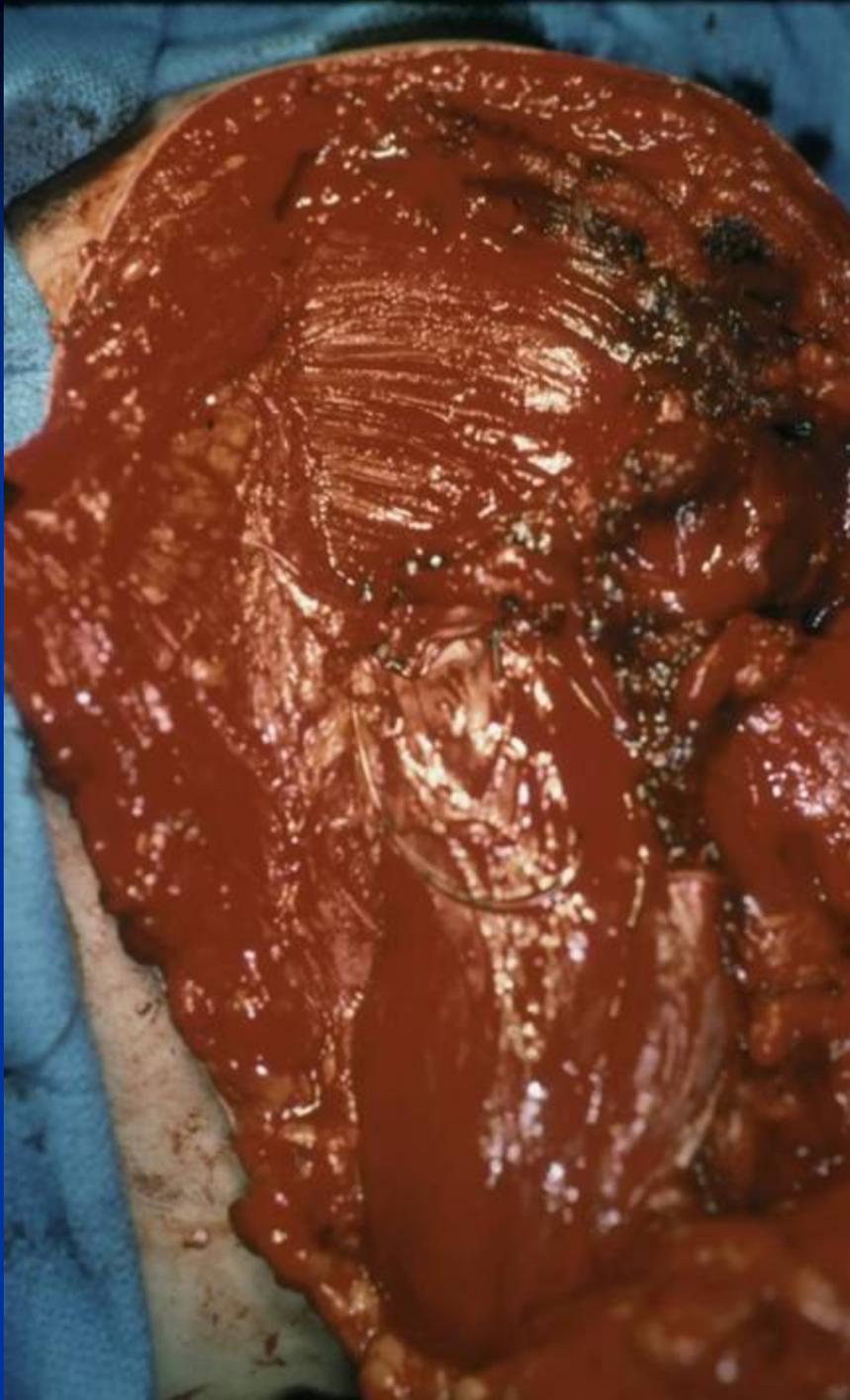


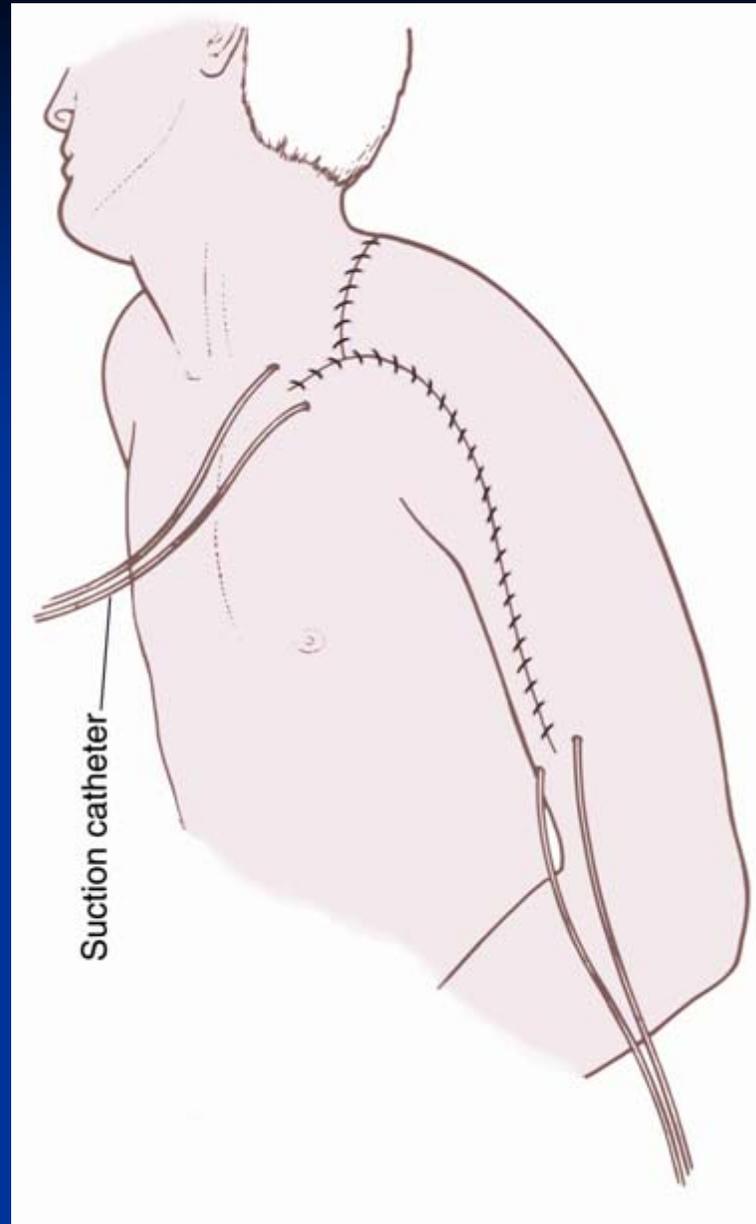
MODULAR REPLACEMENT SYSTEM: PROXIMAL HUMERUS







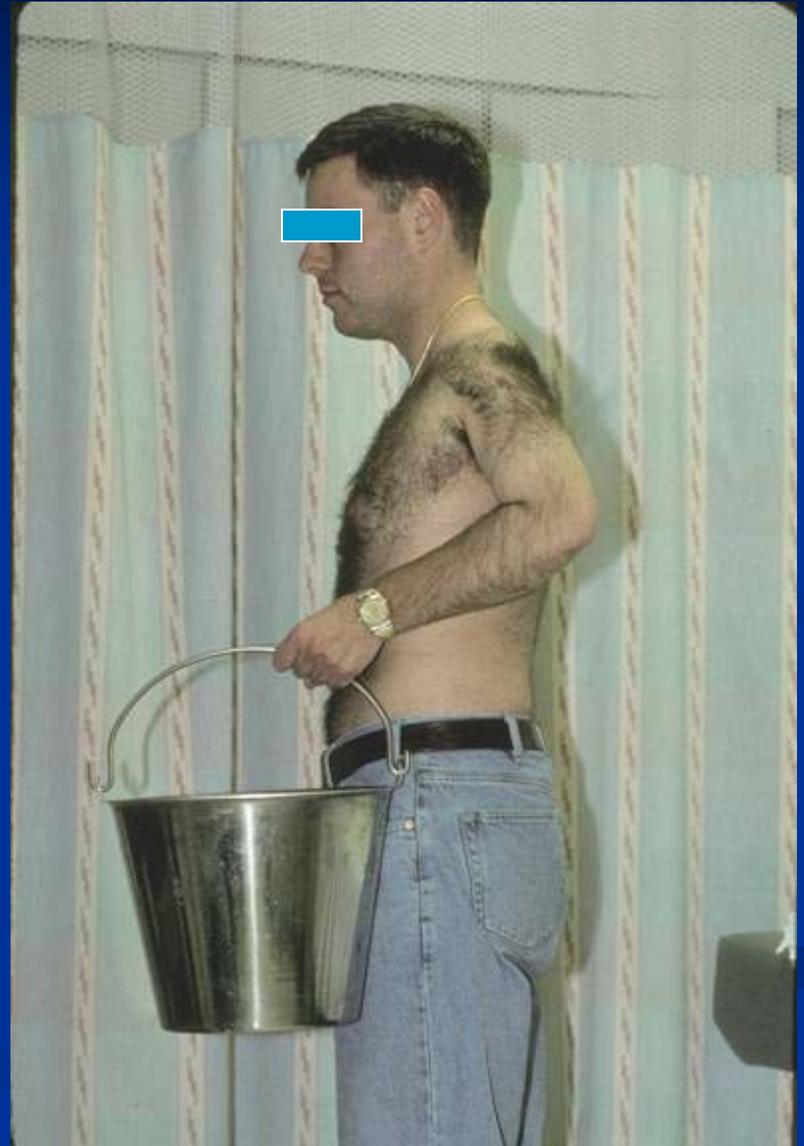




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R
MJ





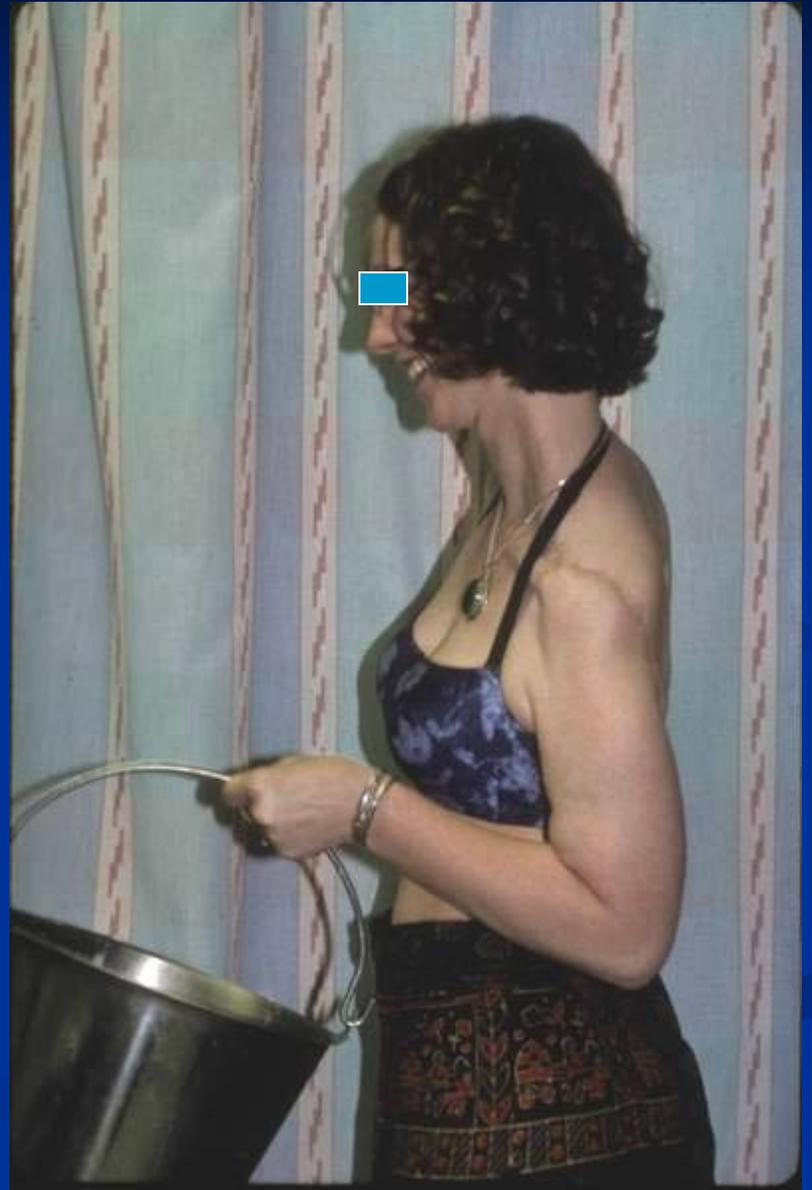
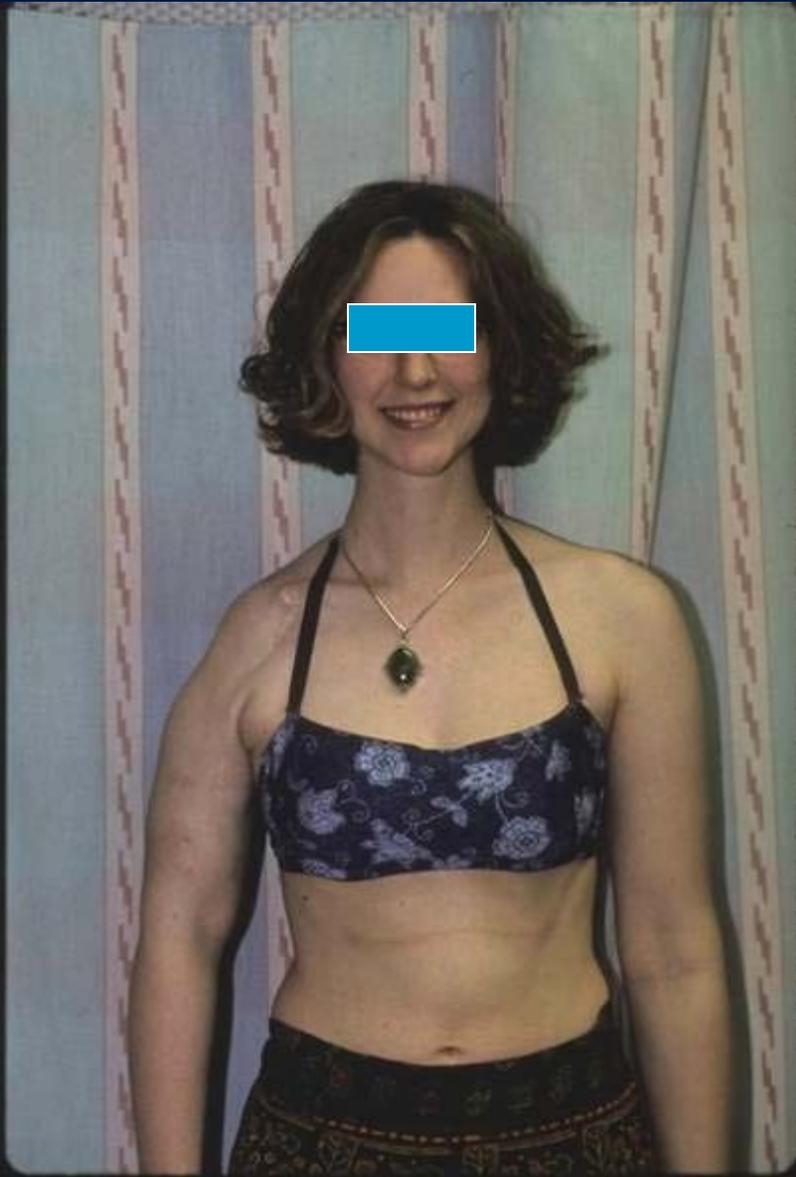
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**Proximal Humerus
Resection with
Prosthetic
Reconstruction:
3 yr Follow-up**

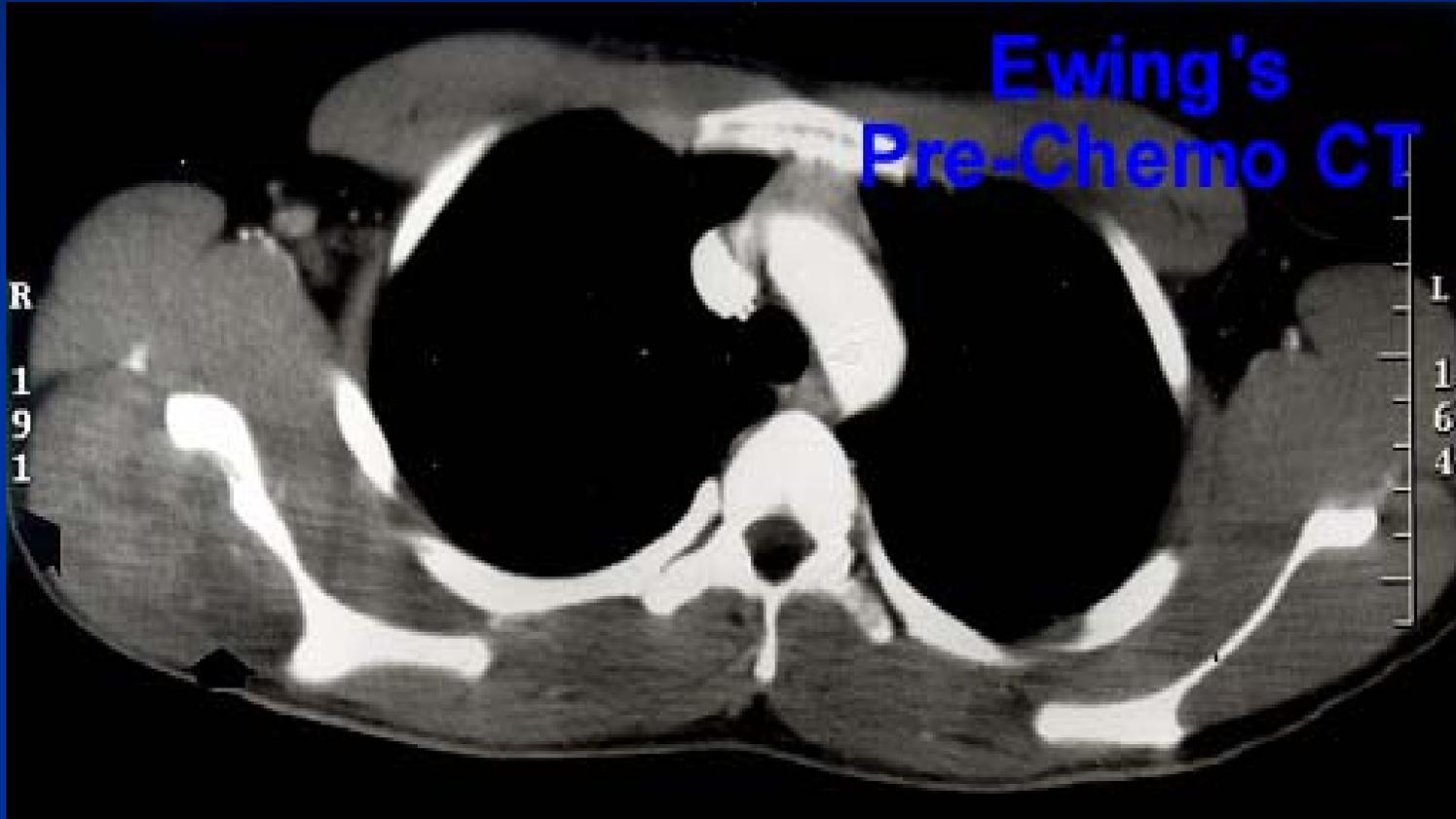
Scapulectomy and Total Scapula Reconstruction

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**Ewing's
Pre-Chemo**



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HISpeed Adv SYS#CT01
26051
3 RETRO
I105.7
11 +C
V 16.0cm
E

Ewing's Post Chemo CT Complete Response

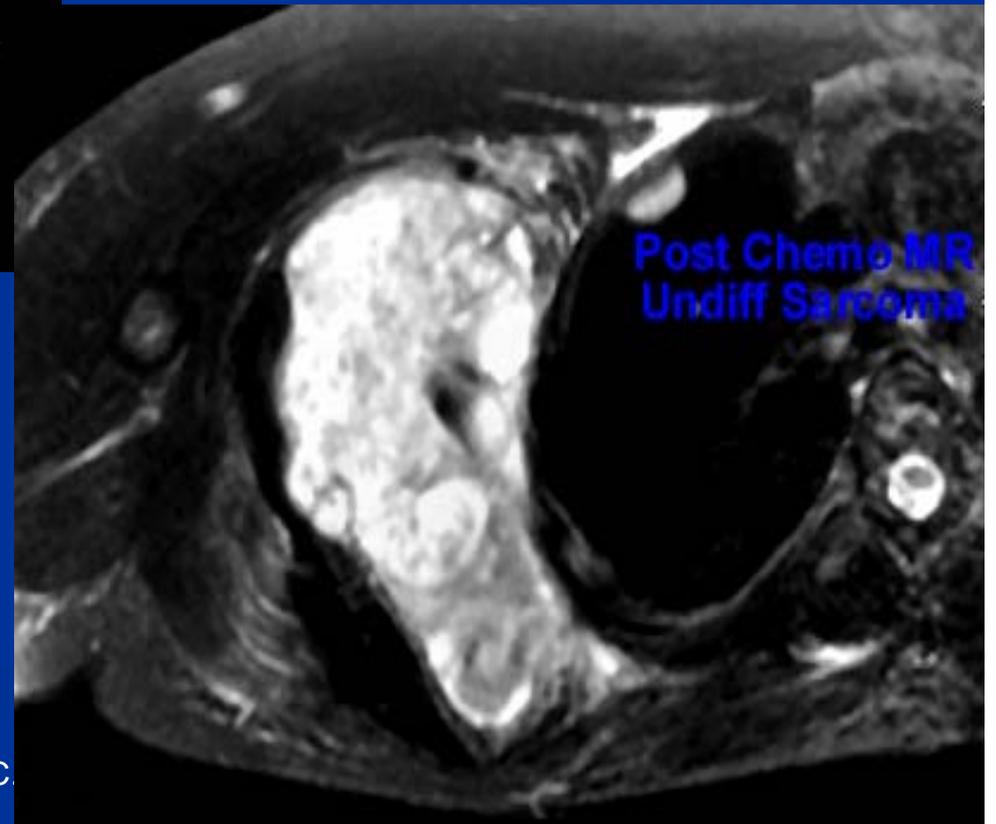


120
200



CT Post Chemo
Undifferentiated Sarcoma

P125

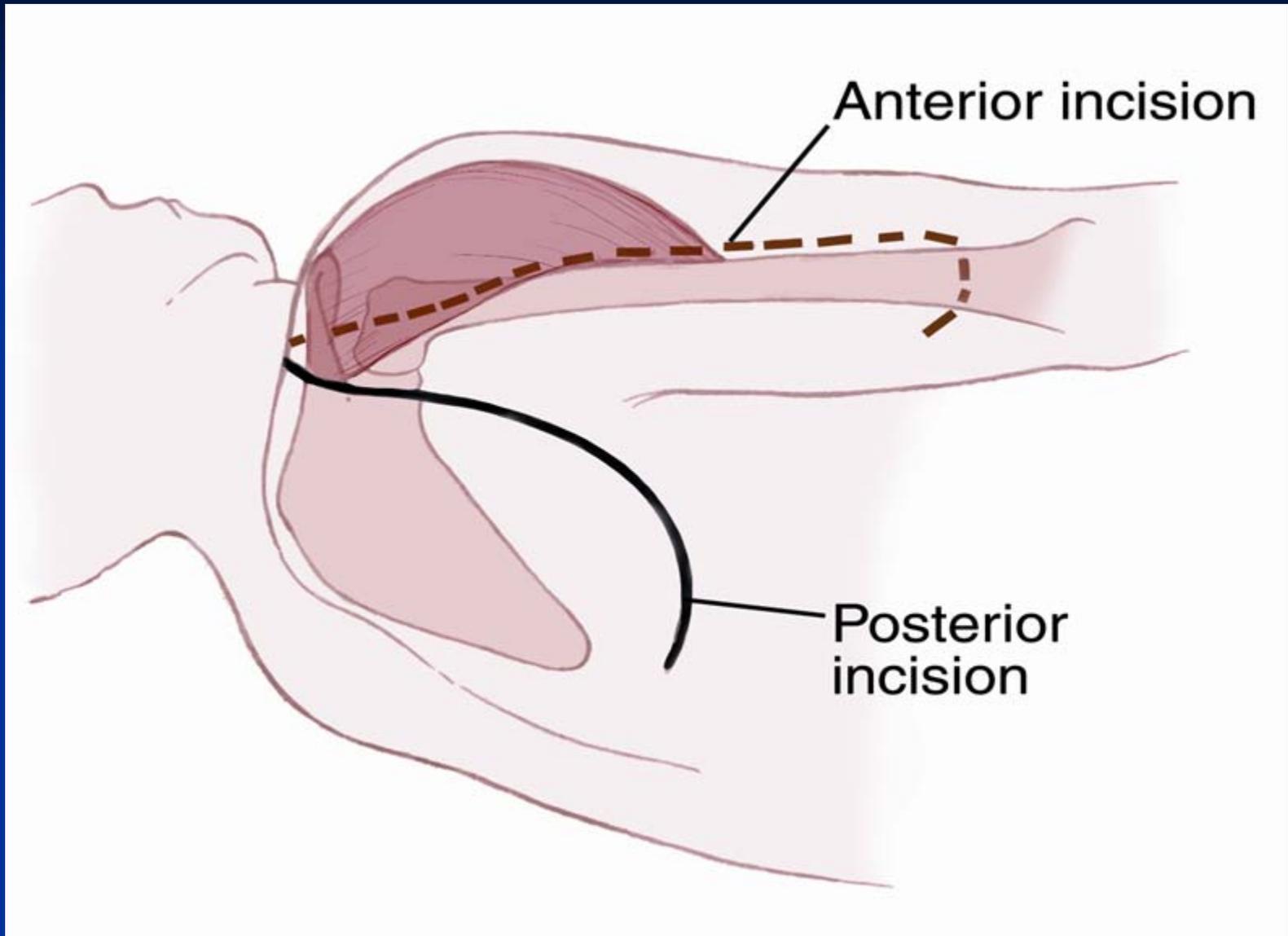


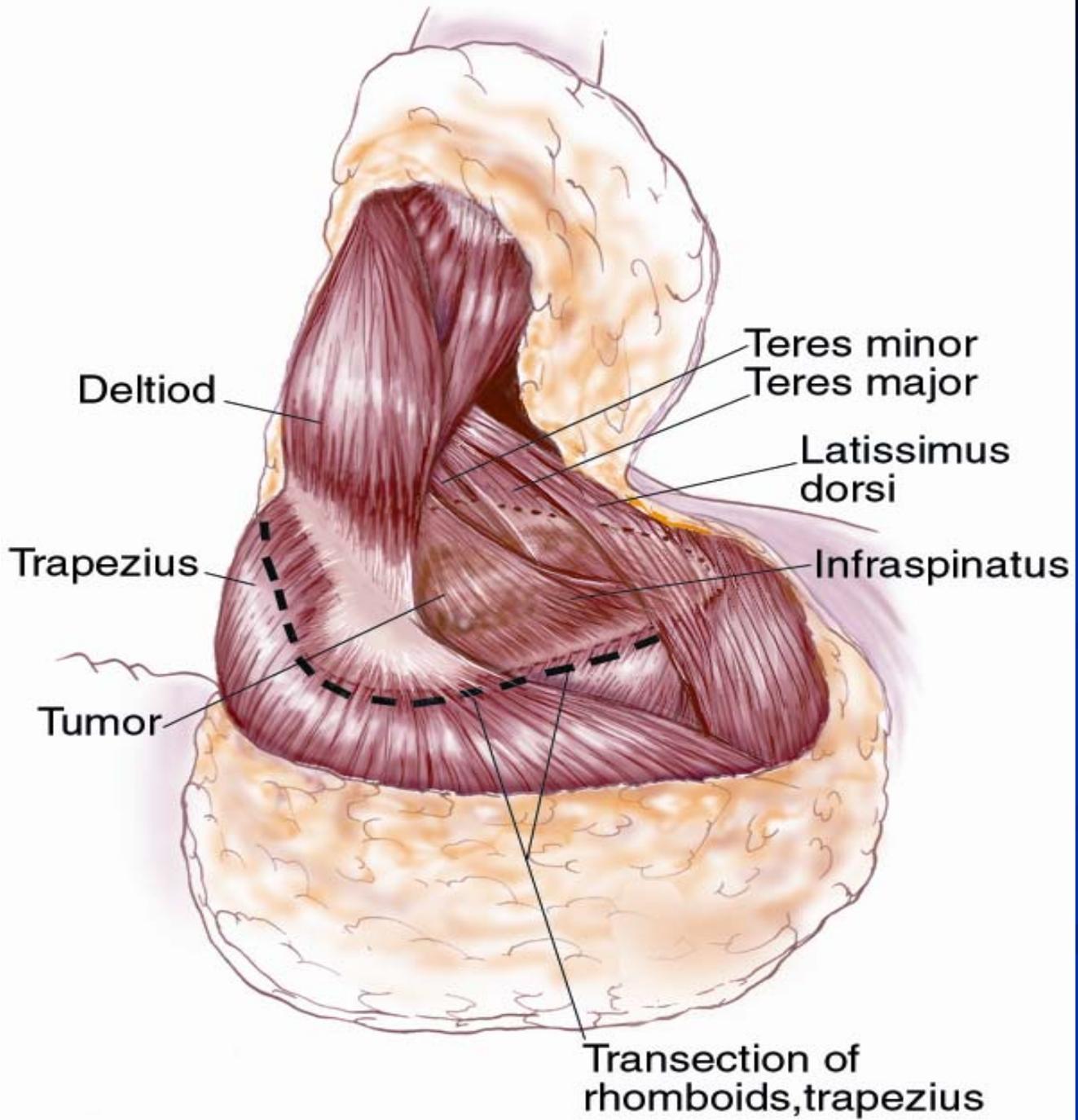
Post Chemo MR
Undiff Sarcoma

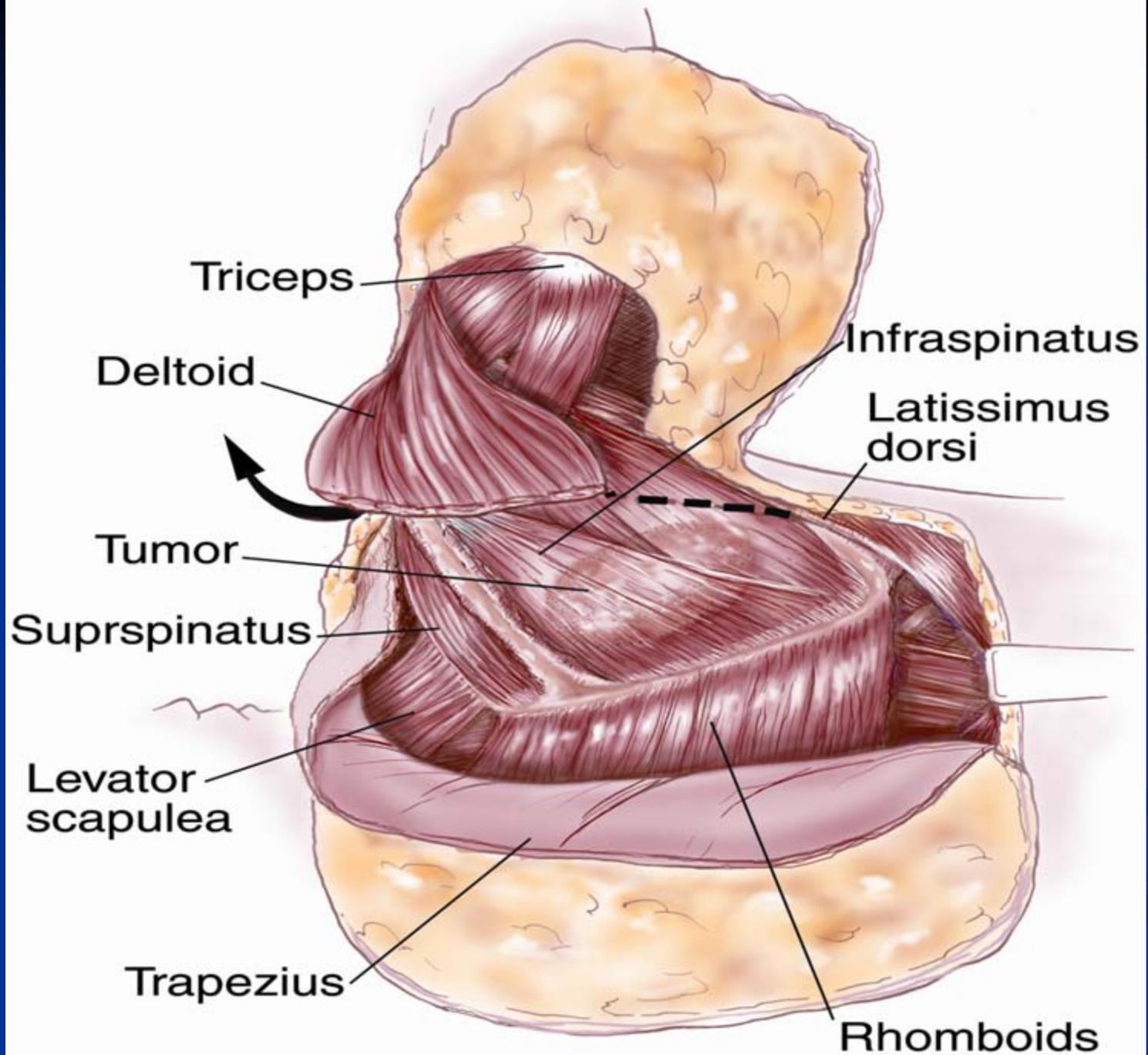


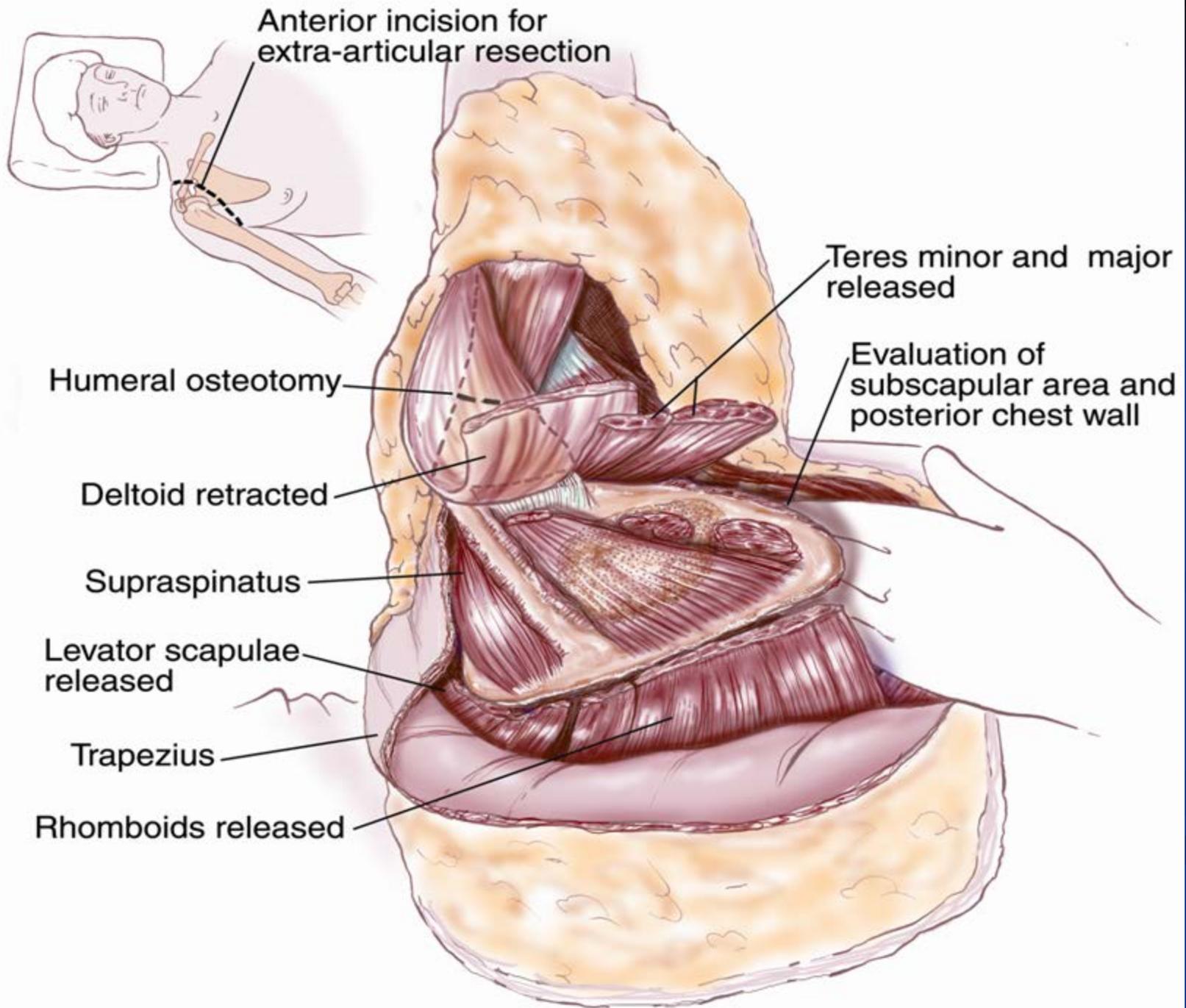
Local Recurrence
S/P Intra-artic Resection
Telangiectatic OS

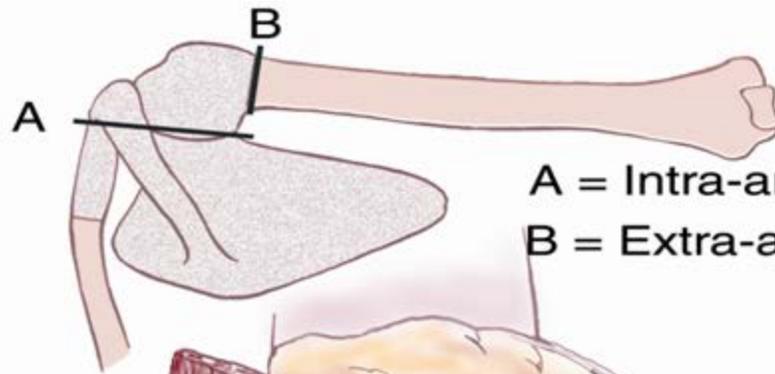
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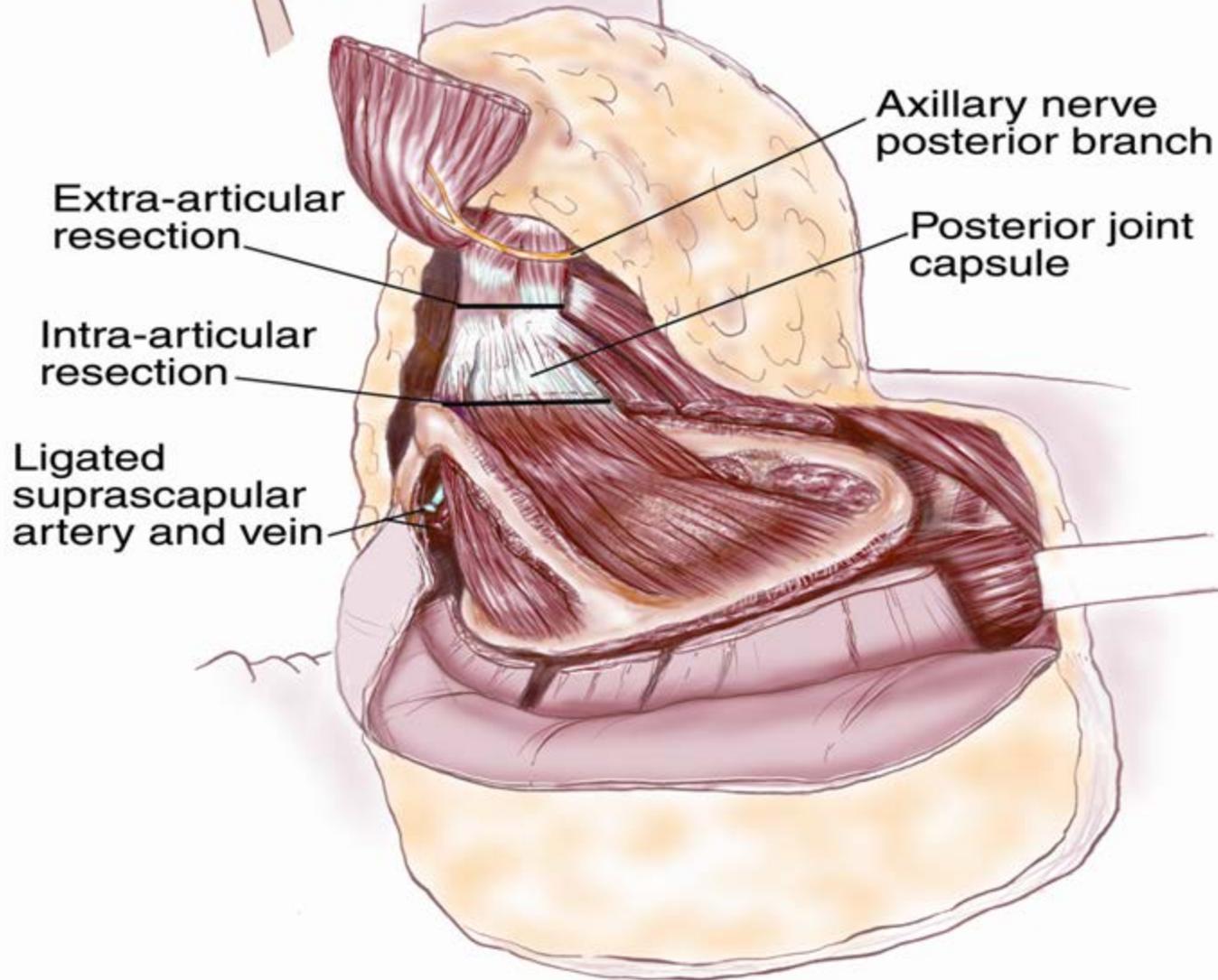








A = Intra-articular resection
B = Extra-articular resection

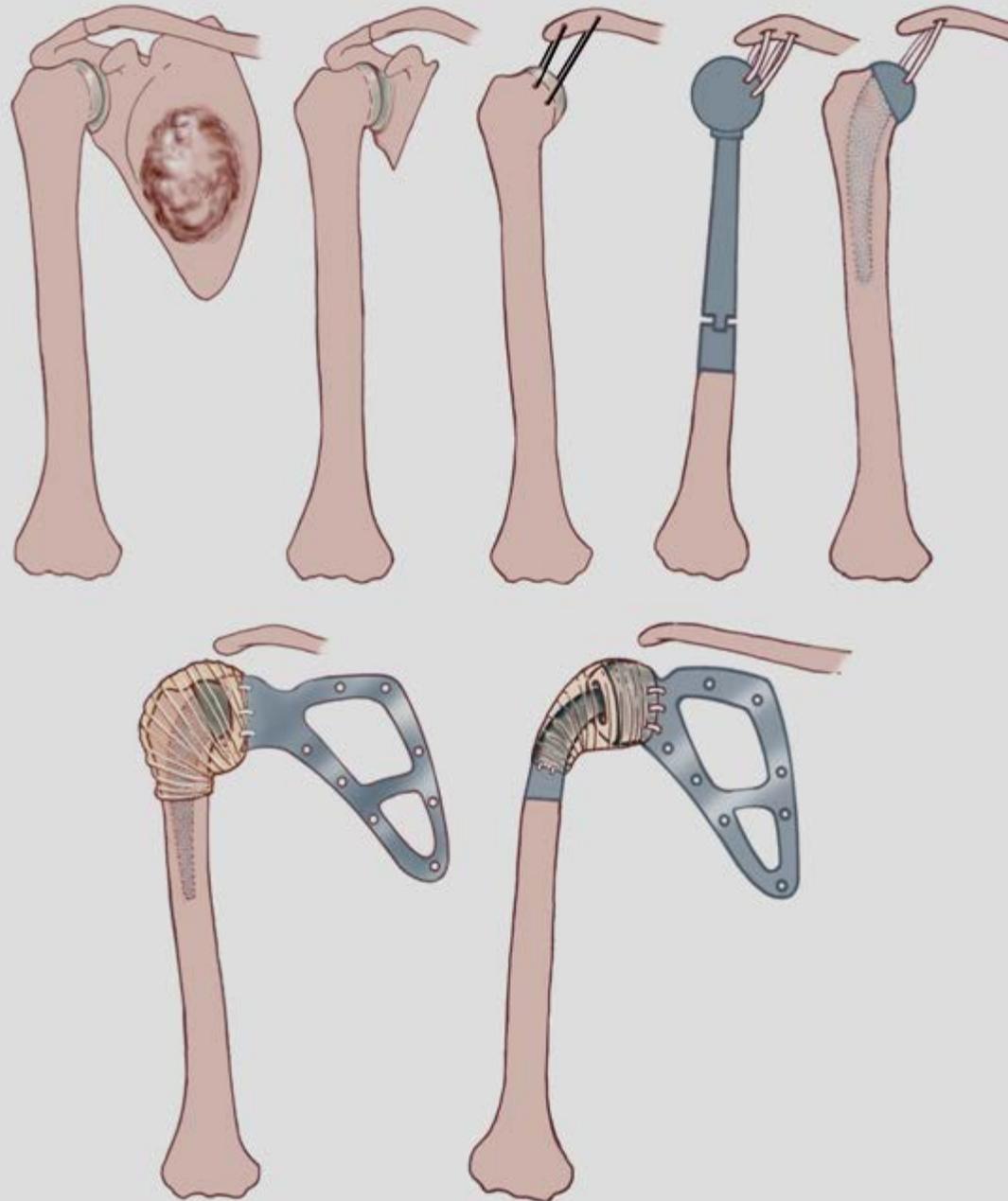


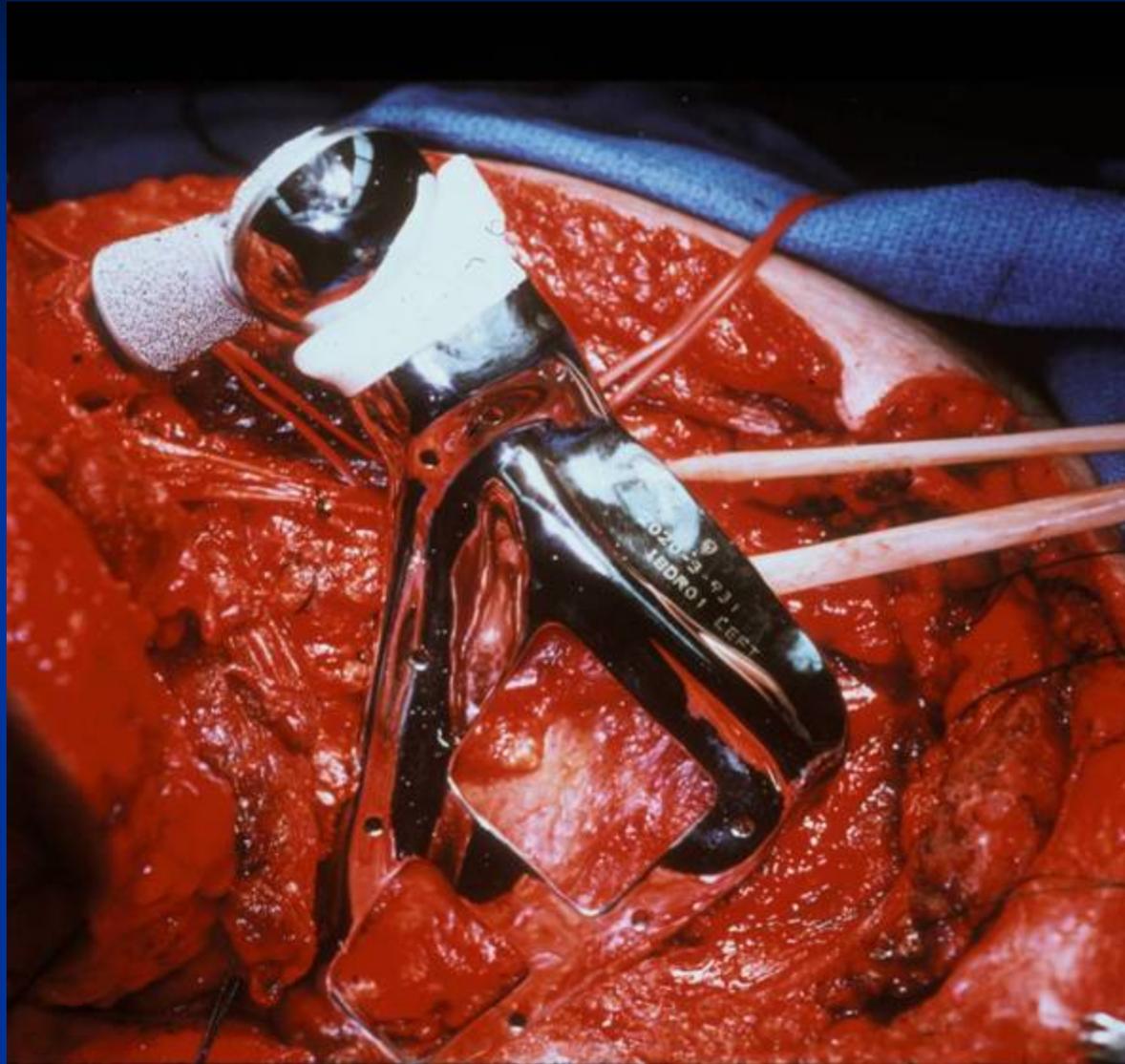
Total Scapula Reconstruction

Crucial Periscapular Muscles

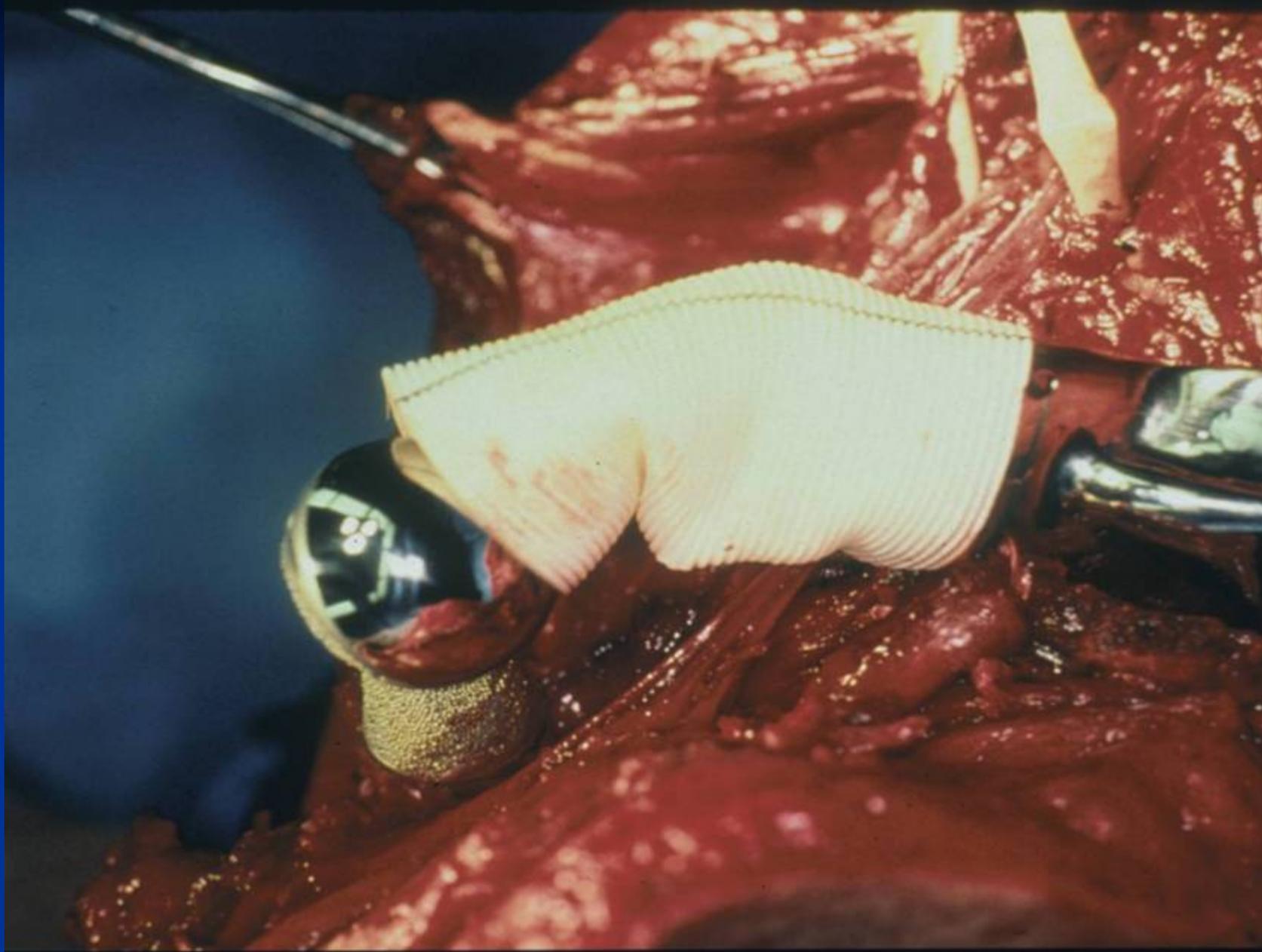
- A Total Scapula Reconstruction is recommended if the axillary nerve and specific periscapular muscles can be preserved
- Deltoid
- Trapezius
- Serratus Anterior
- Rhomboids
- Latissimus
- These are essential for soft tissue coverage, stabilizing and suspending the prosthesis and for providing the necessary muscle force couples to power the prosthesis

TYPES OF SCAPULAR RECONSTRUCTION





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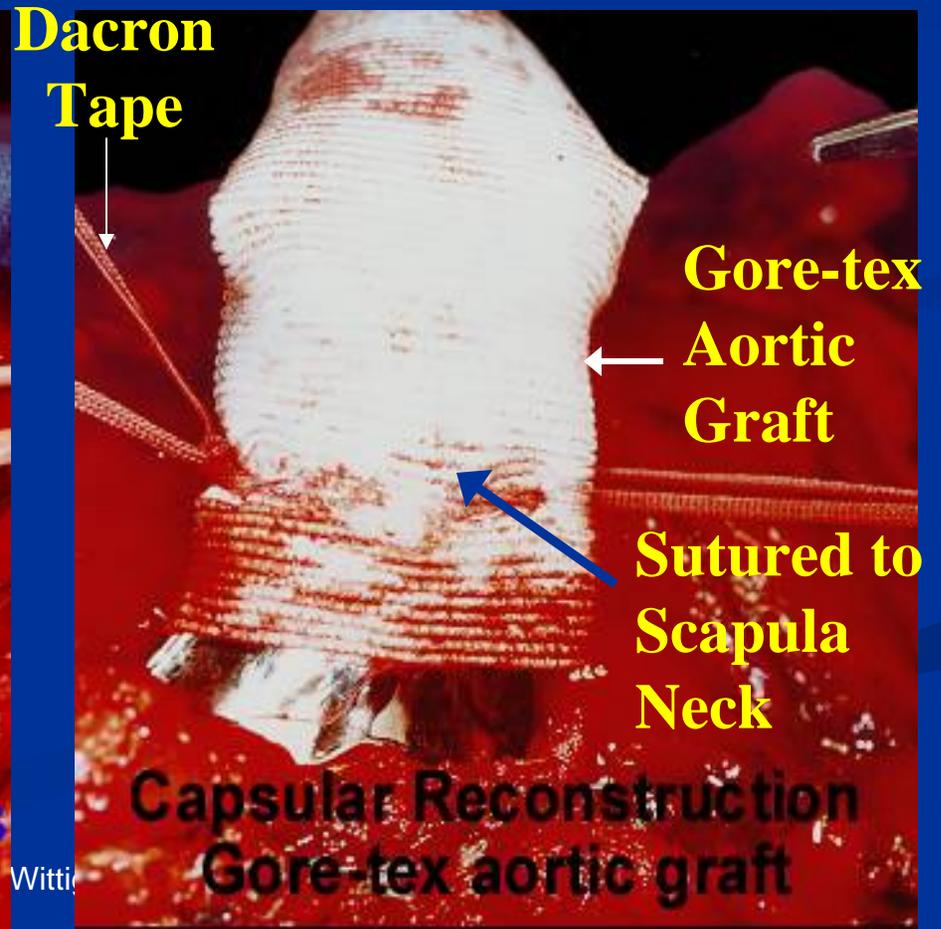
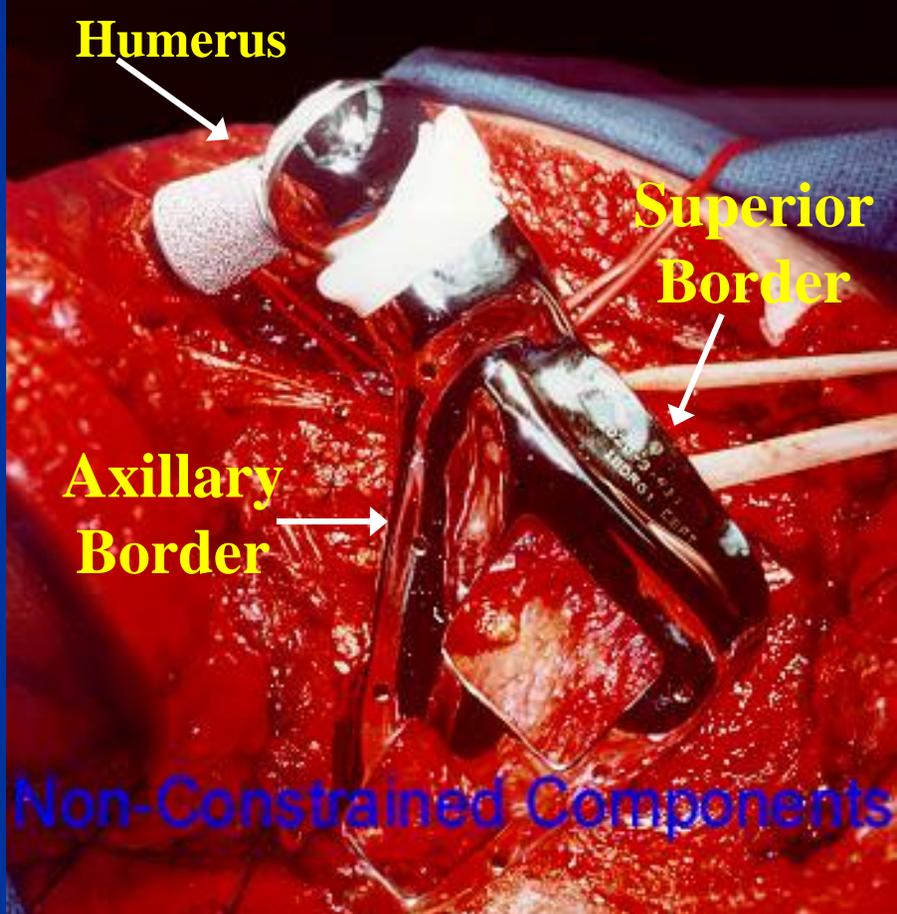


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Scapular Design

- Non-Constrained Components (Earlier Versions)
- Gore-tex aortic graft for capsular reconstruction

Modular Proximal



Constrained Total Scapula Prosthesis

- Facilitate intraoperative attachment
- **Rotator cuff substituting** (fixed fulcrum; passively stabilize humeral head in glenoid; improve active motion)
- Enhance stability

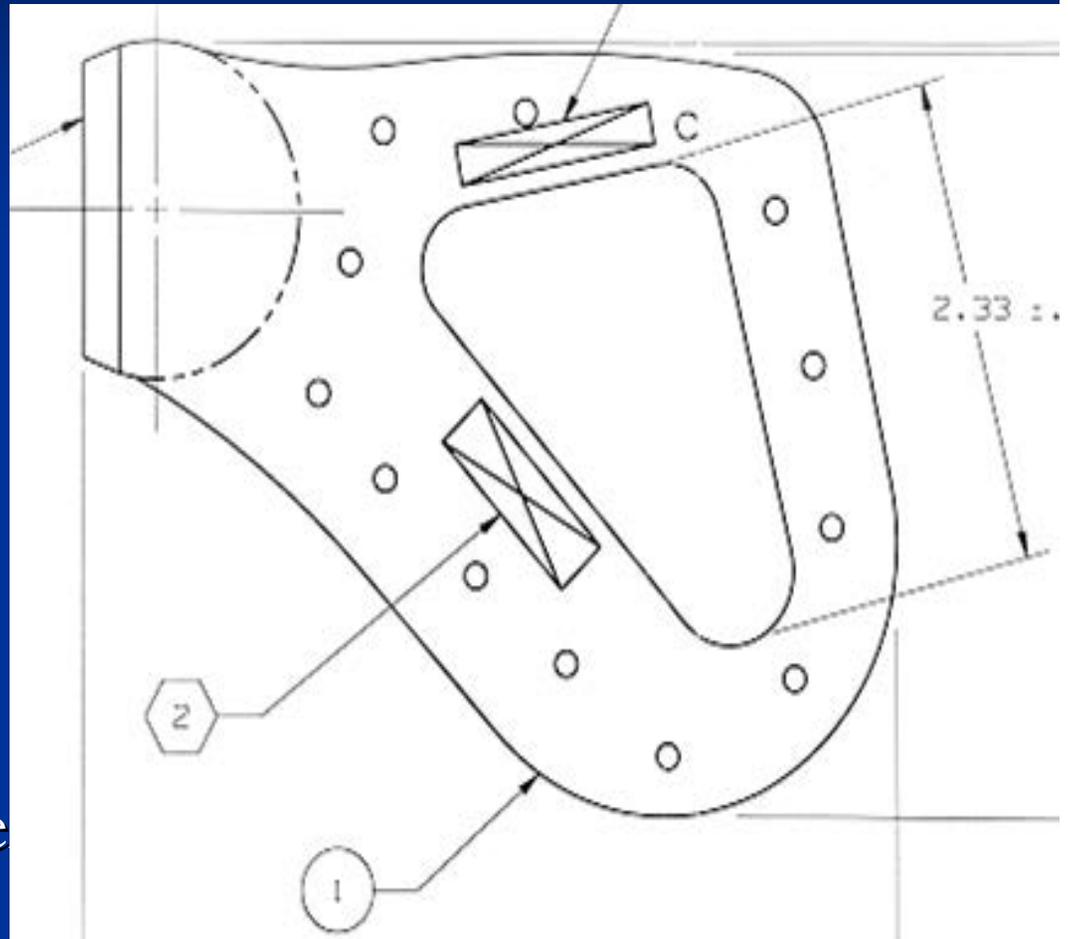
Constrained Components

Body

- Down-sized compared to normal
- Holes for Myodesis
- Vacant area—scarring of muscles

Glenoid

- Bipolar hip
- Captured polyethylene line



Constrained Total Scapula

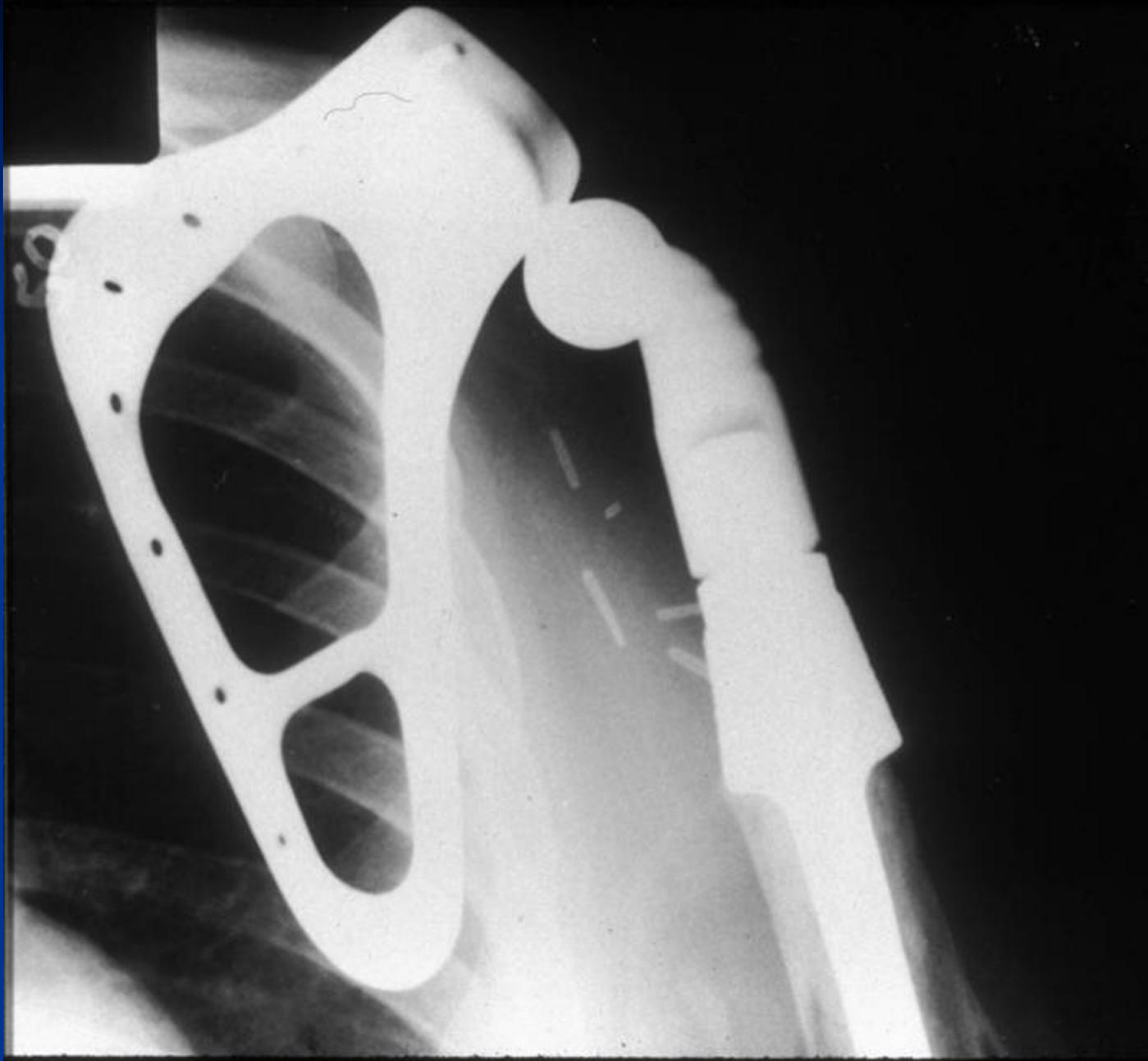


Constrained Glenoid

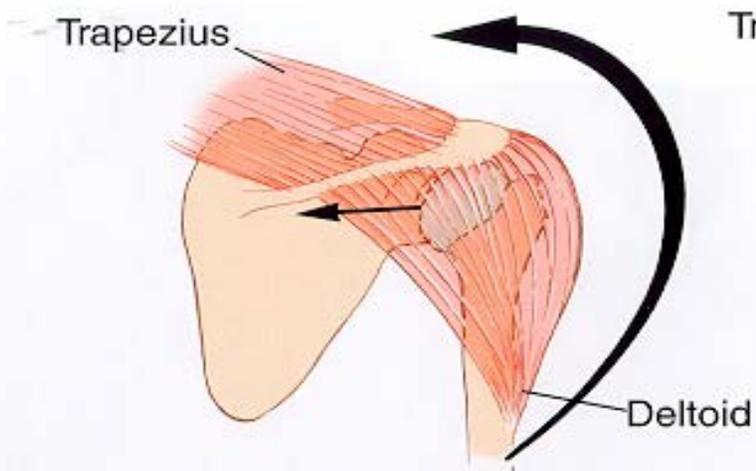


SNAP FIT DESIGN

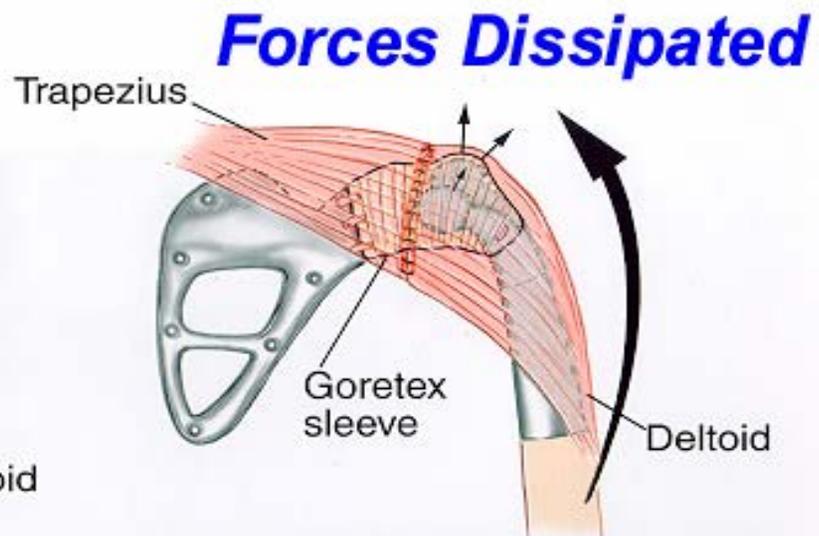
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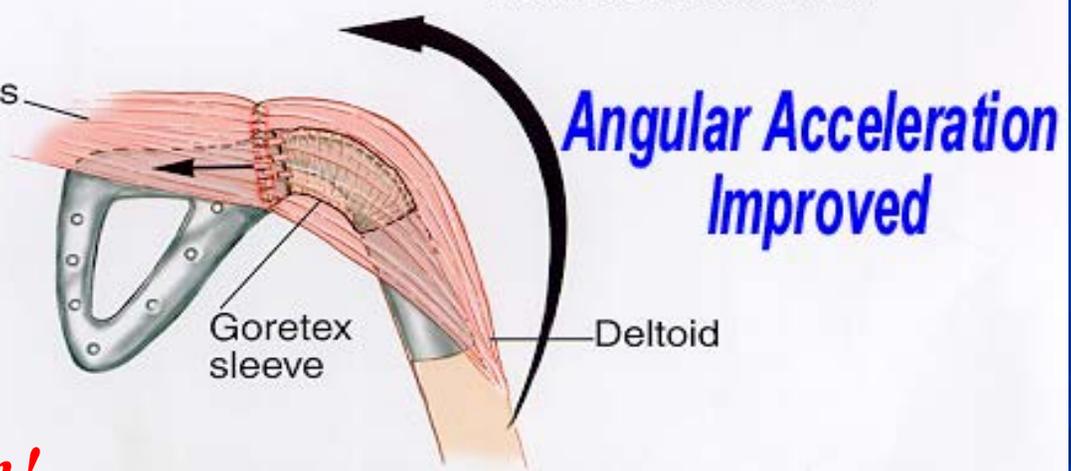


NORMAL ANATOMY



NON CONSTRAINED (GORE-TEX) RECONSTRUCTION

Prevents Superior Humeral Migration!



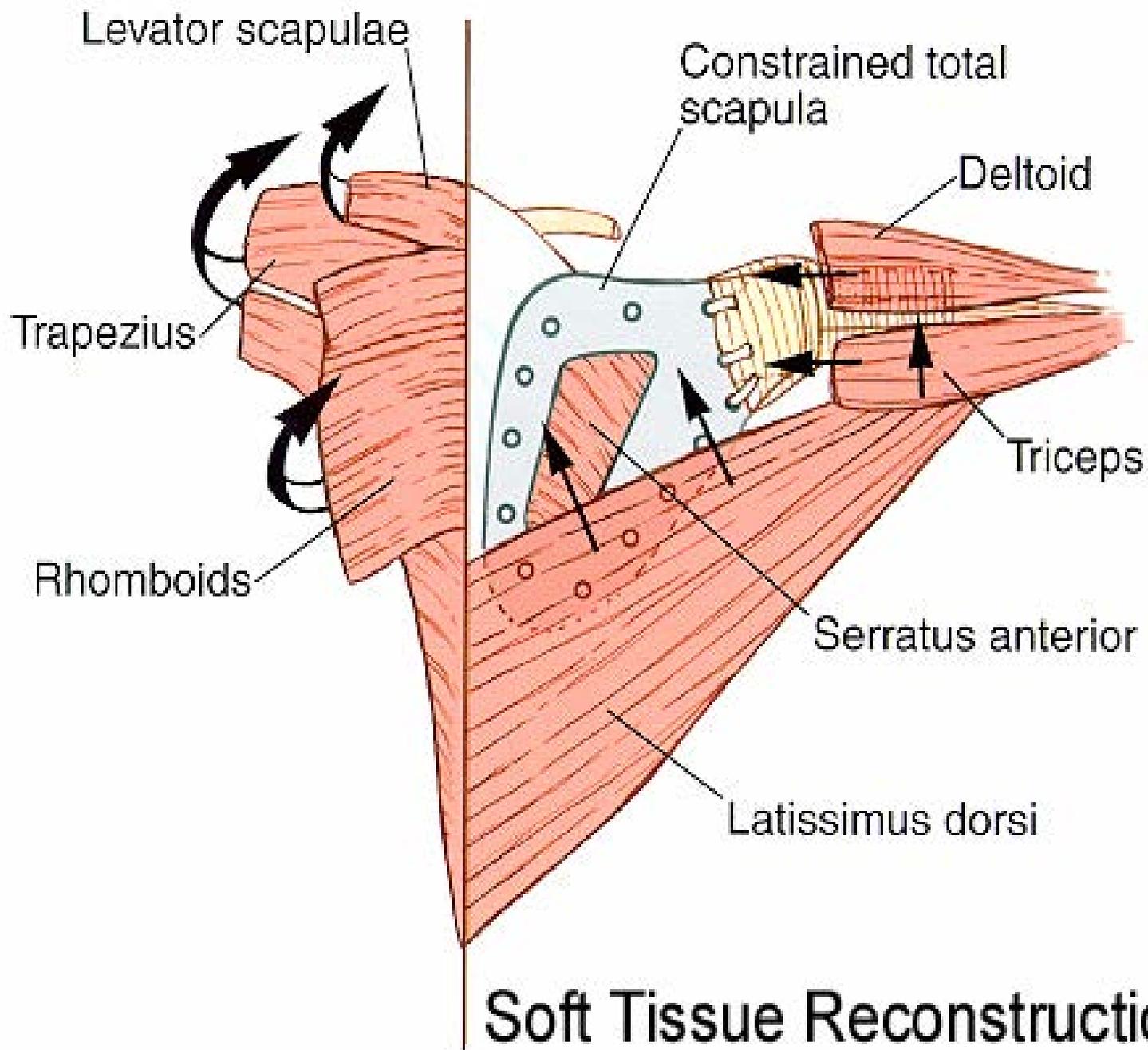
CONSTRAINED RECONSTRUCTION

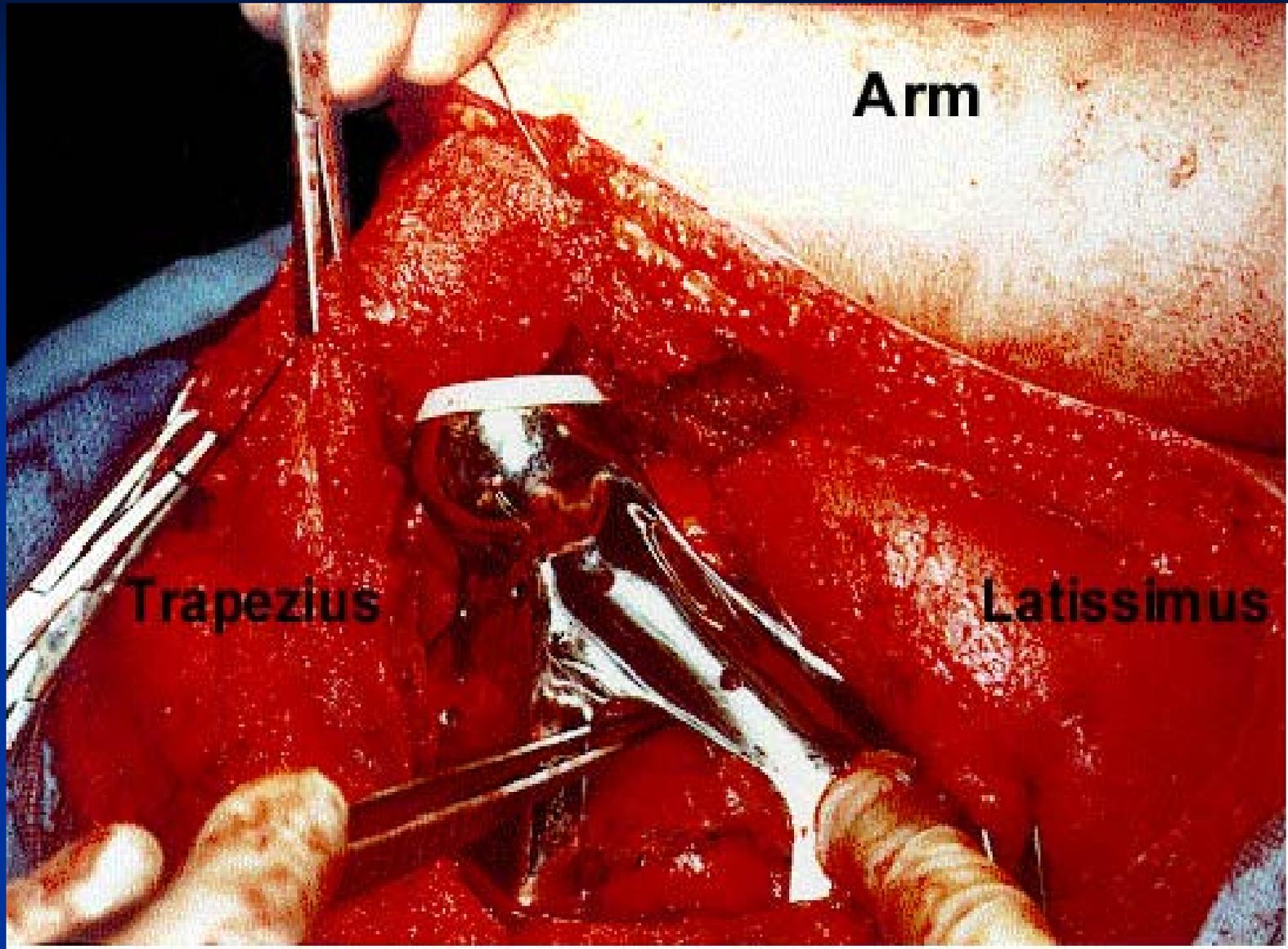
Motion

Holes for Myodesis of
Periscapular Muscles



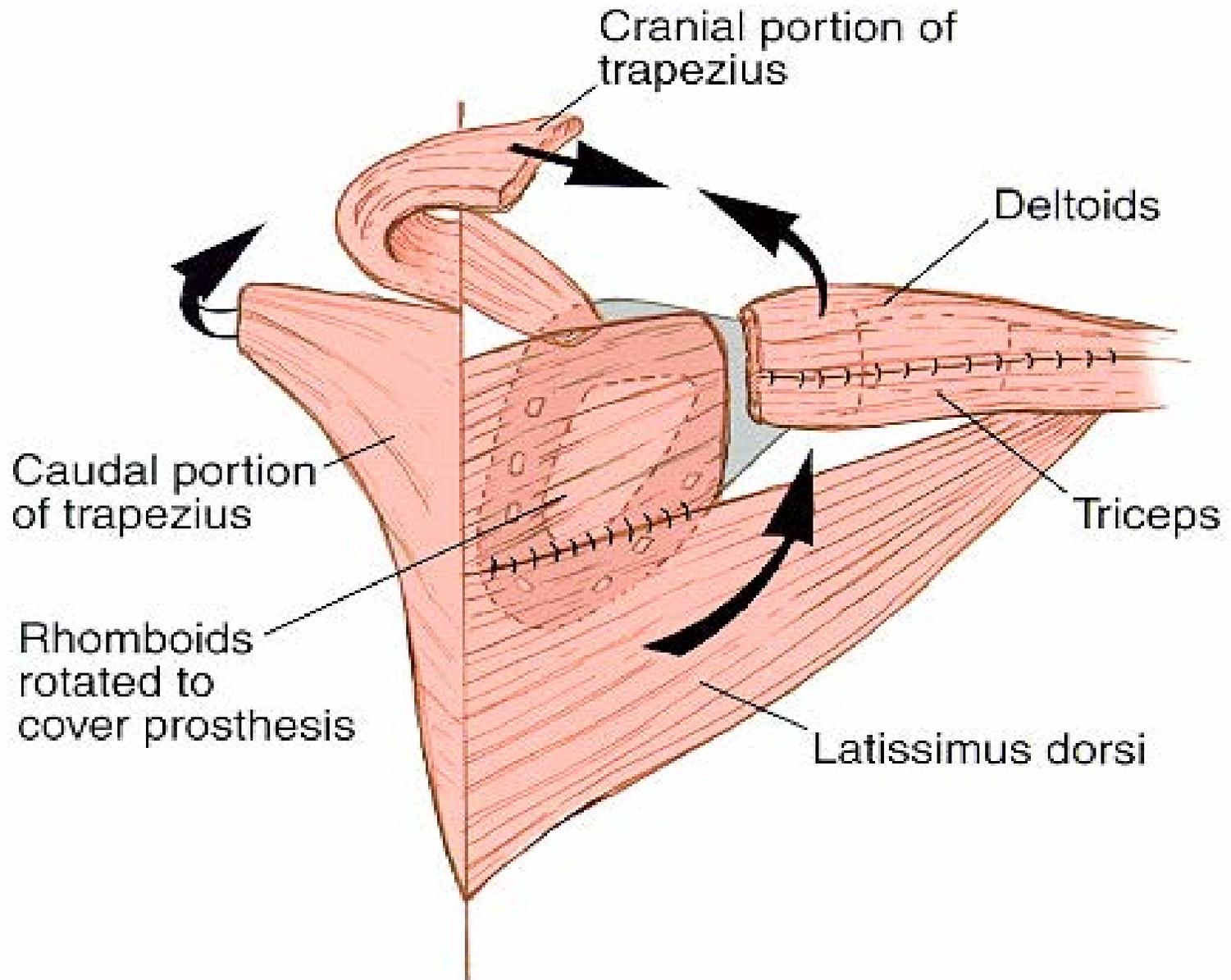
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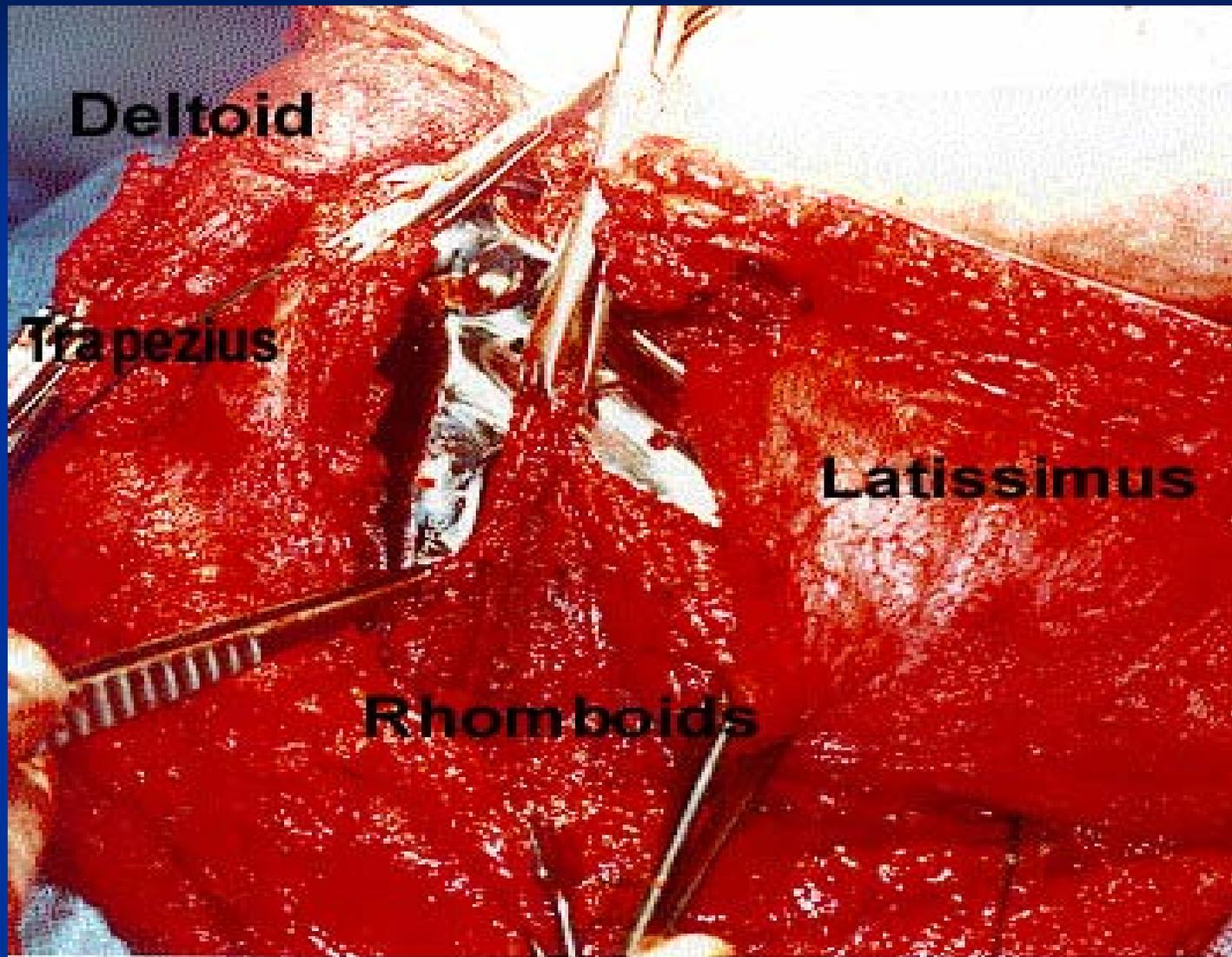




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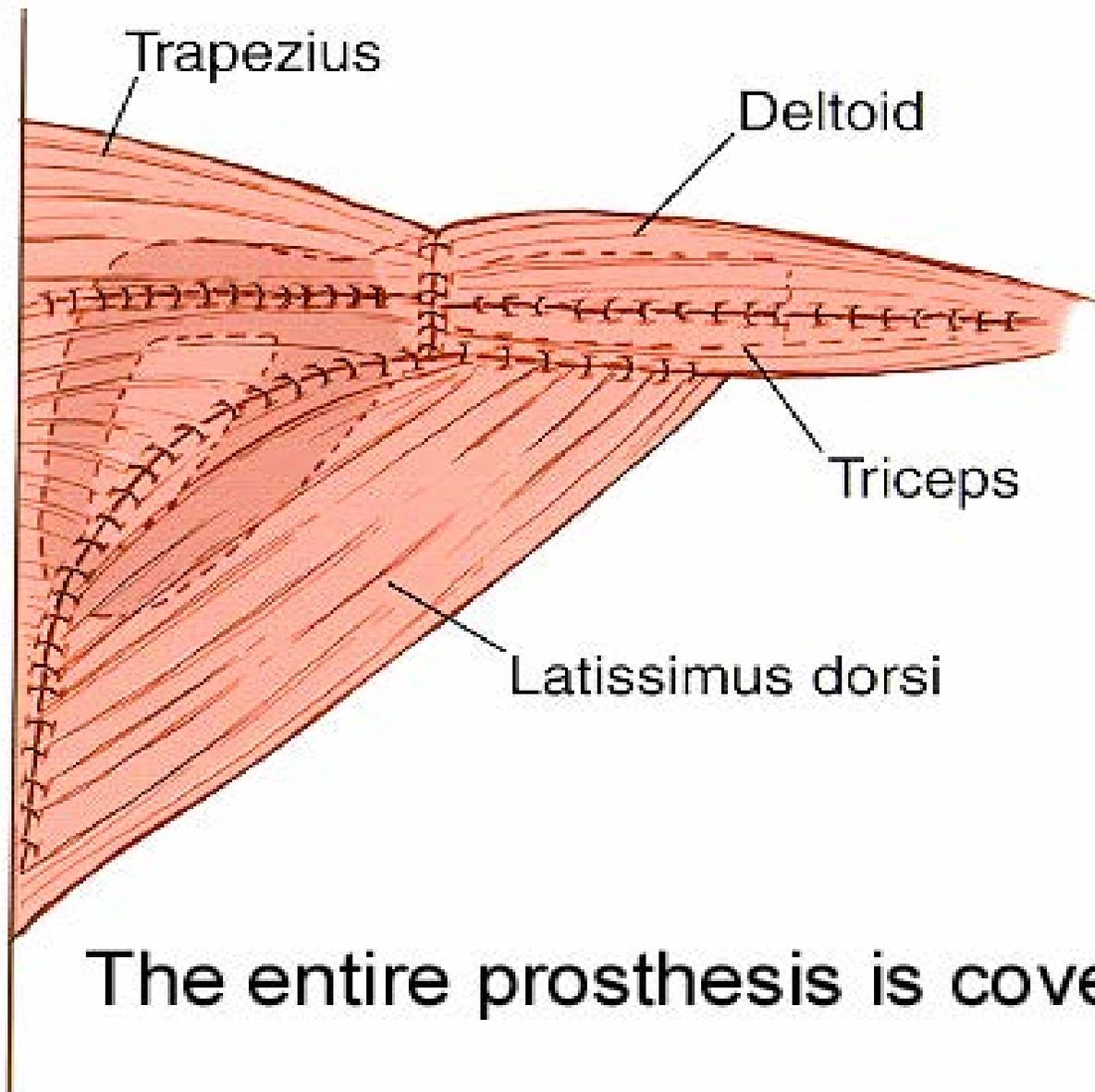
Soft Tissue Reconstruction



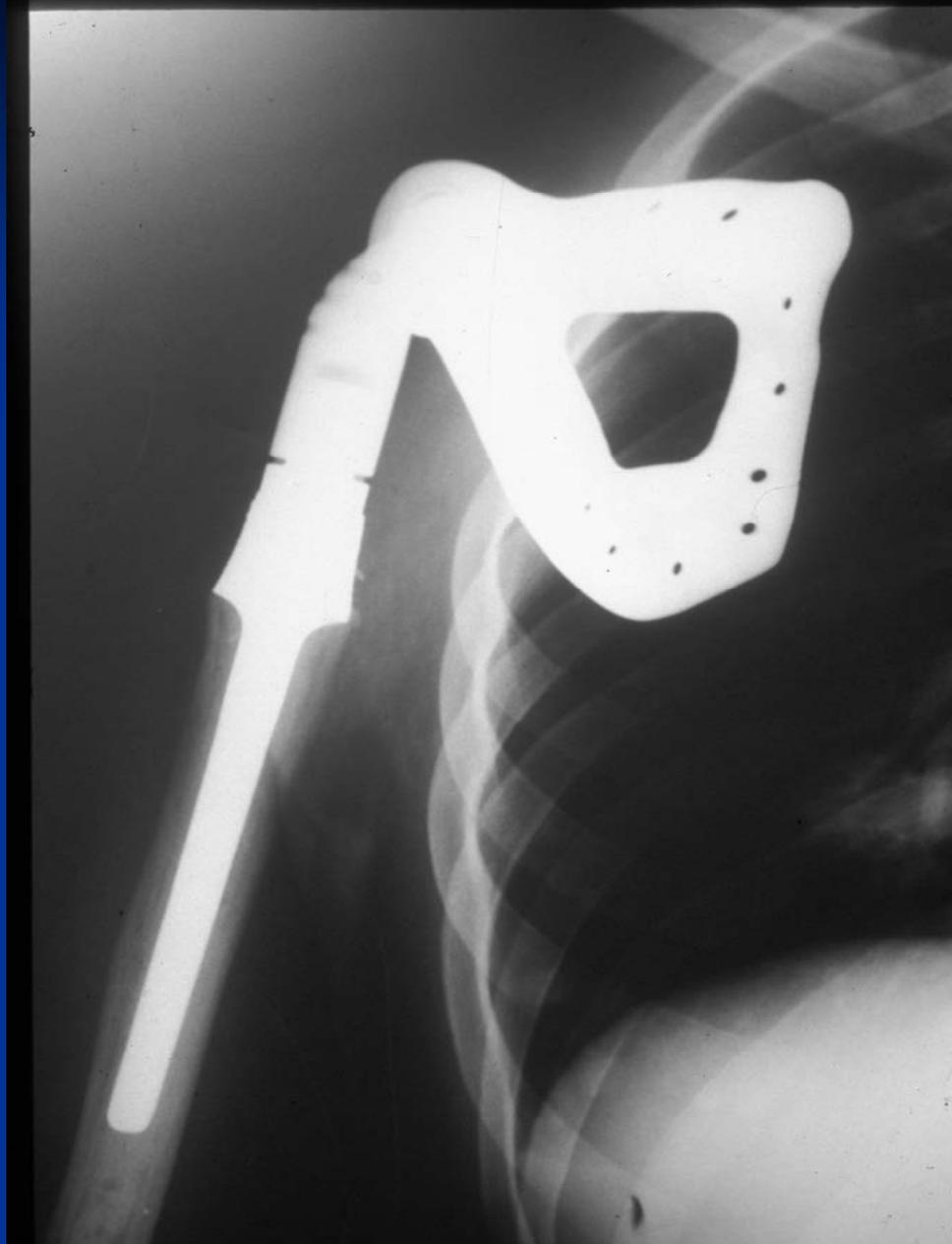


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Soft Tissue Reconstruction



The entire prosthesis is covered!



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**Post-op
Lateral Radiograph**

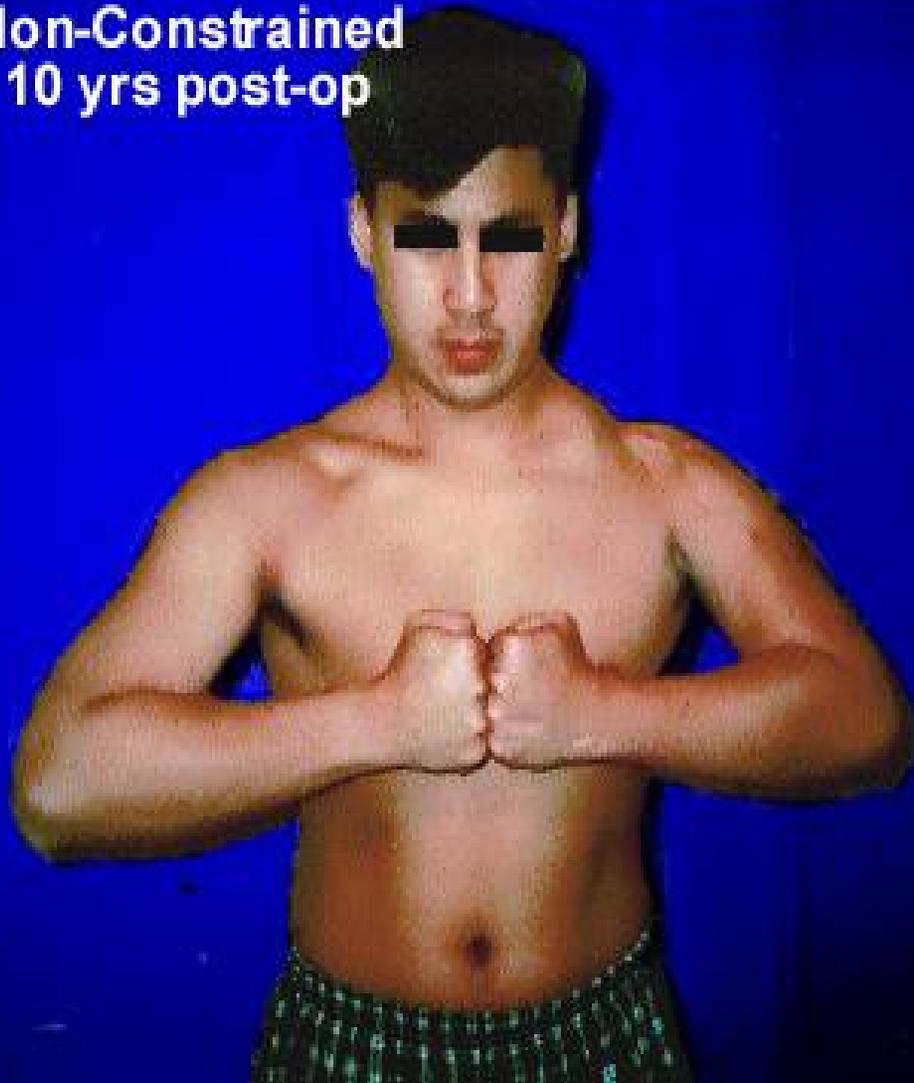
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Post-op
Axillary Radiograph

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**Non-Constrained
10 yrs post-op**



**Non-Constrained
10 years post-op
Excellent elbow flexion**



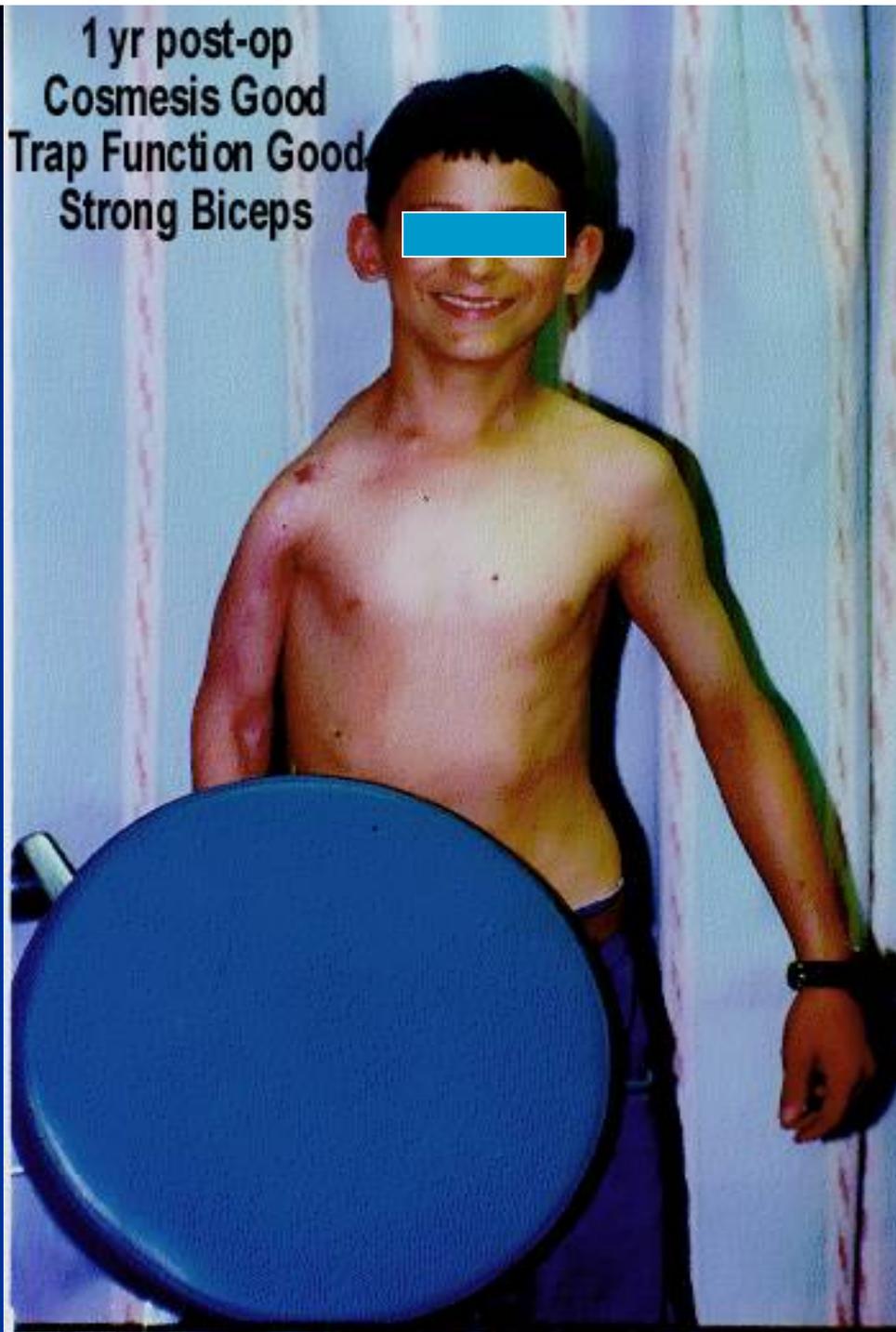
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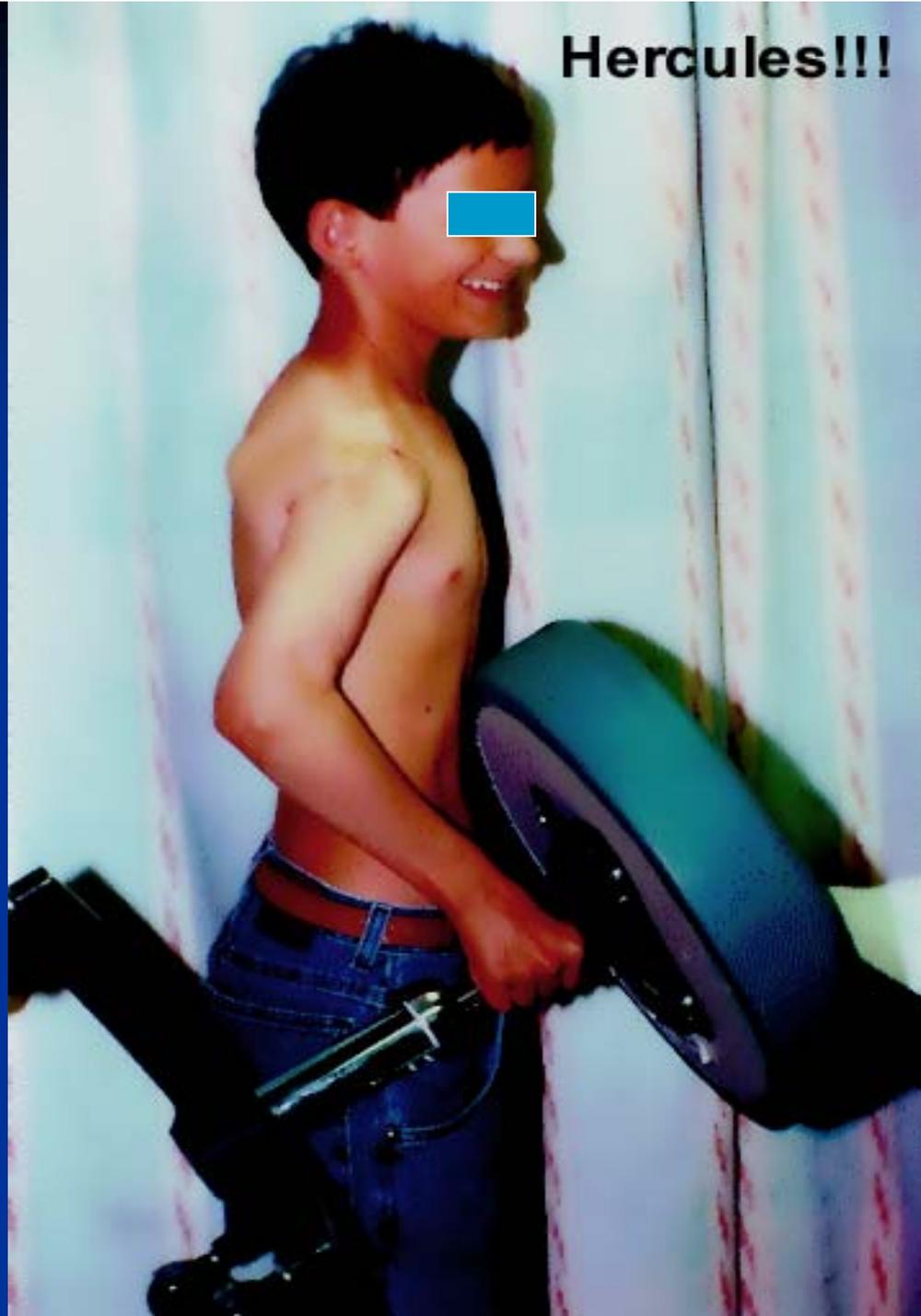


13 y.o.
6 mos post op
Normal elbow flexion
Some FF of Shoulder

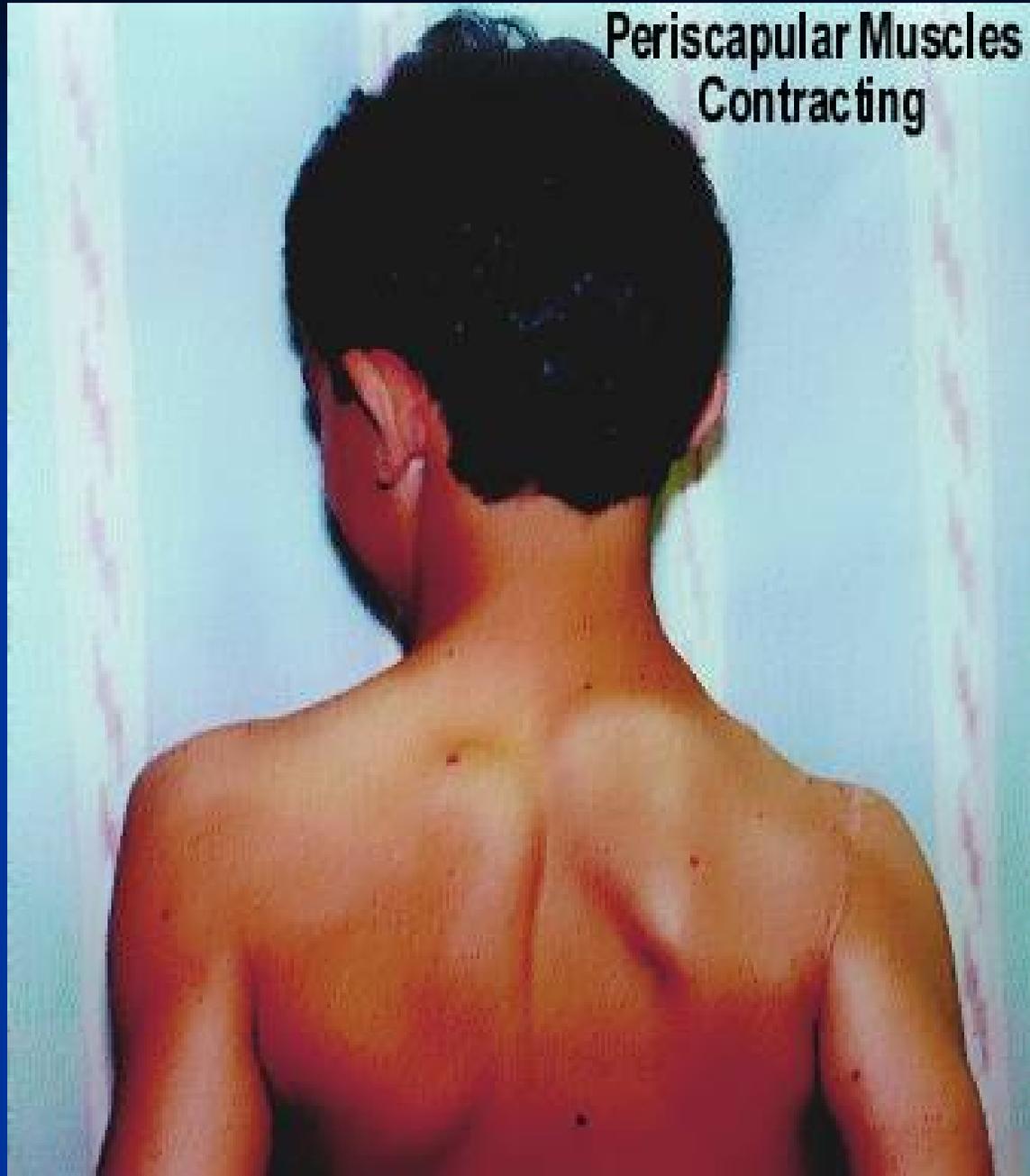
1 yr post-op
Cosmesis Good
Trap Function Good
Strong Biceps

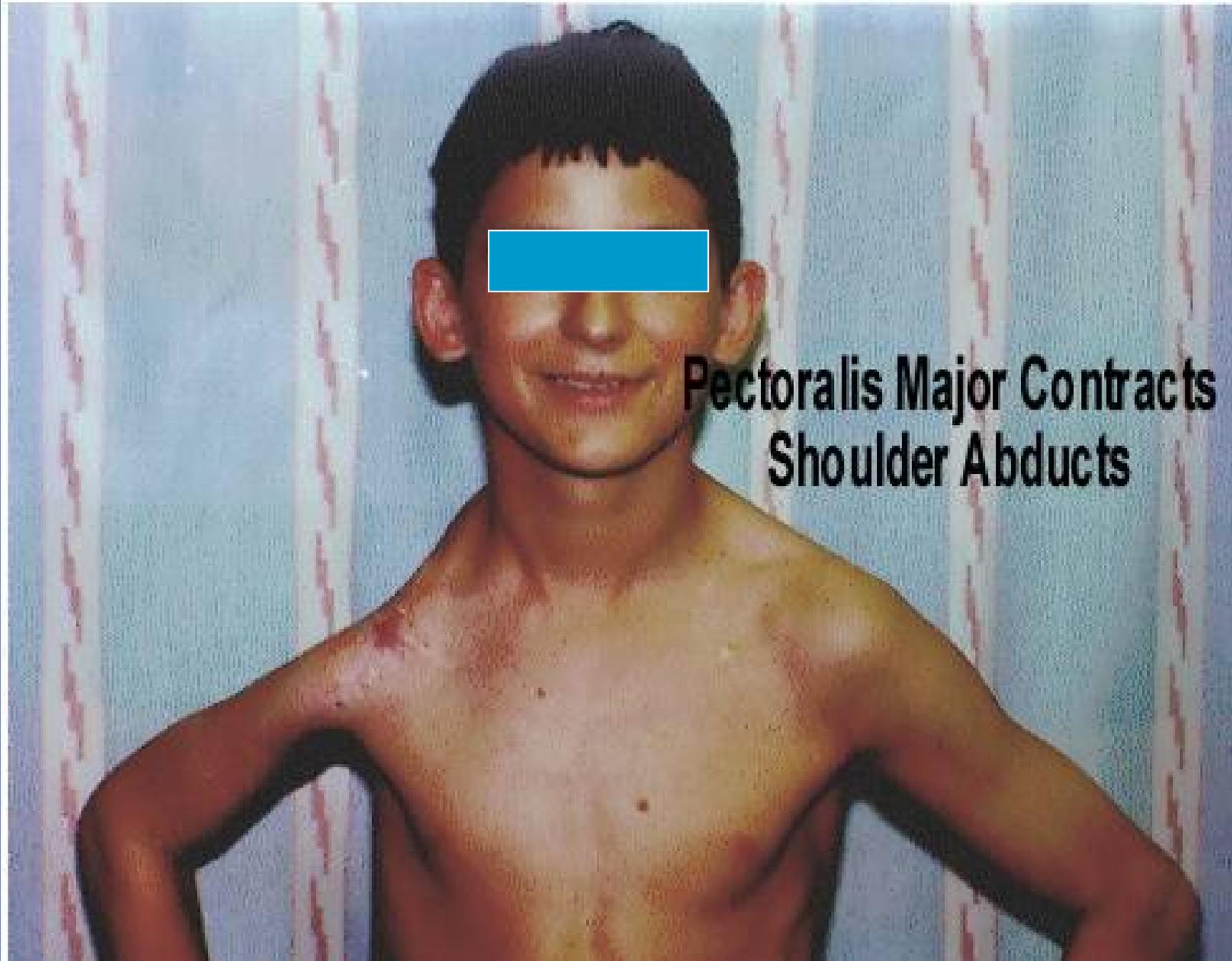


Hercules!!!



**Periscapular Muscles
Contracting**





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Results

- 89 Patients with high grade sarcomas arising from the shoulder girdle who underwent prosthetic reconstruction
 - 74 proximal humerus
 - 15 scapula
 - Follow-up 2-20 years (median: 10 years)
 - Most common dx: osteosarcoma, chondrosarcoma and Ewing's sarcoma

Results

- Overall Local Recurrence: <5%
- No patient required a forequarter amputation
- Subgroup of patients with osteosarcomas (n=43): No local Recurrences
- 10 patients with pathological fractures: No local recurrence
- 65% are prolonged survivors

MSTS Scoring System

- Pain (5=No Pain)
- Emotional Acceptance (5=Cosmetically acceptable)
- Function (3-4: All ADLs but can not participate in high level athletic activities)
- Hand positioning (3-4: Not unlimited but can position above shoulder)
- Dexterity (5: Normal Hand Dexterity)
- Lifting Ability (3-4: Virtually Normal)
- Score: 24-27/30 points

Results

- All survivors are pain free with a stable shoulder
- All can carry out ADLs with operative extremity
- No braces required
- Virtually normal hand and elbow function; Biceps strength: Grade 4+
- MSTTS score of 24-27 (80%-90%)
- Abd/FF: 30⁰-60⁰
- IR: Normal; ER: -15⁰ to Neutral (Improved with latissimus dorsi transfer)
- Kaplan-Meier Survival at 10 years: 95%-100%

Complications

- Transient Nerve Palsy: 12% (All in patients who received preoperative chemotherapy)
- Skin Necrosis and Wound Infection: 2% (No prosthesis required removal)
- Aseptic loosening: 1%-2%
- 1 glenohumeral dislocation of a total scapula
- No instability with proximal humerus reconstructions
- No traction neuropraxia

Summary

- Extraarticular resection including the muscles that form the pseudocapsular layer is a reliable method of resection for high grade shoulder girdle tumors that present with an extraosseous component. It provides an oncologically safe margin.
- Reconstruction with proximal humerus and total scapular prostheses and with static and dynamic methods of soft tissue reconstruction provides a durable method of reconstruction and restores a functional, pain free and stable extremity

Thank You!

James C. Wittig, MD