Anatomy and MRI Findings of Common Pathologies

BRACHIAL PLEXUS

Introduction

- Interpretation of Brachial Plexus imaging can be intimidating for many radiologists. Reasons include:
  - lack of familiarity with:
    - the anatomy of the brachial plexus
    - the relationship of the brachial plexus to the thoracic outlet
    - the compartments of the thoracic outlet and the structures that define them

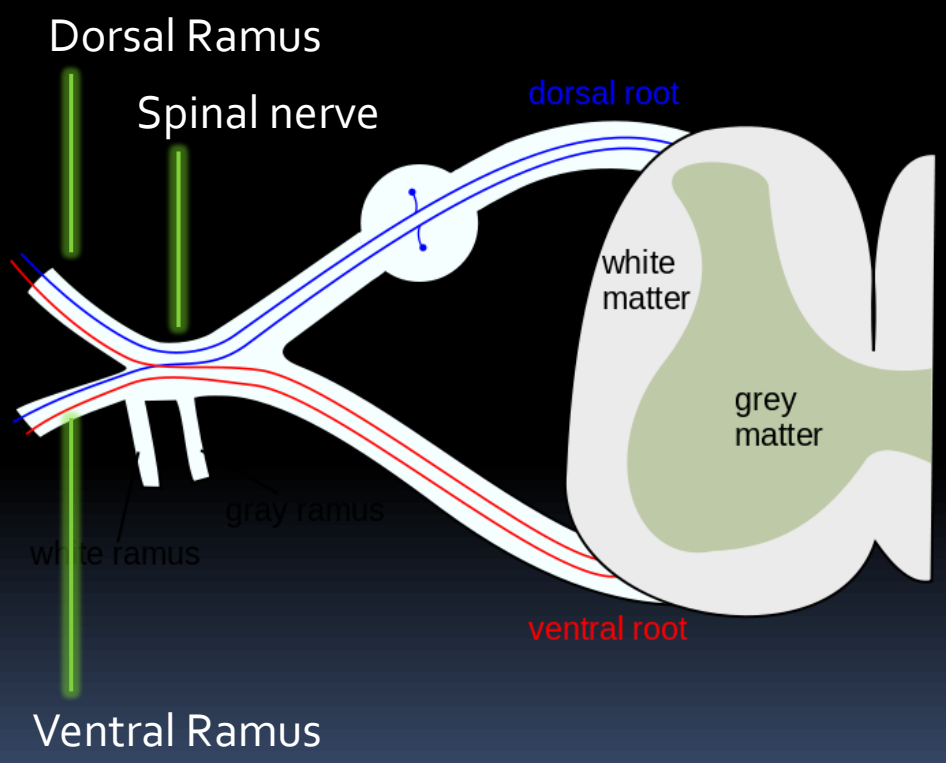
In this talk…

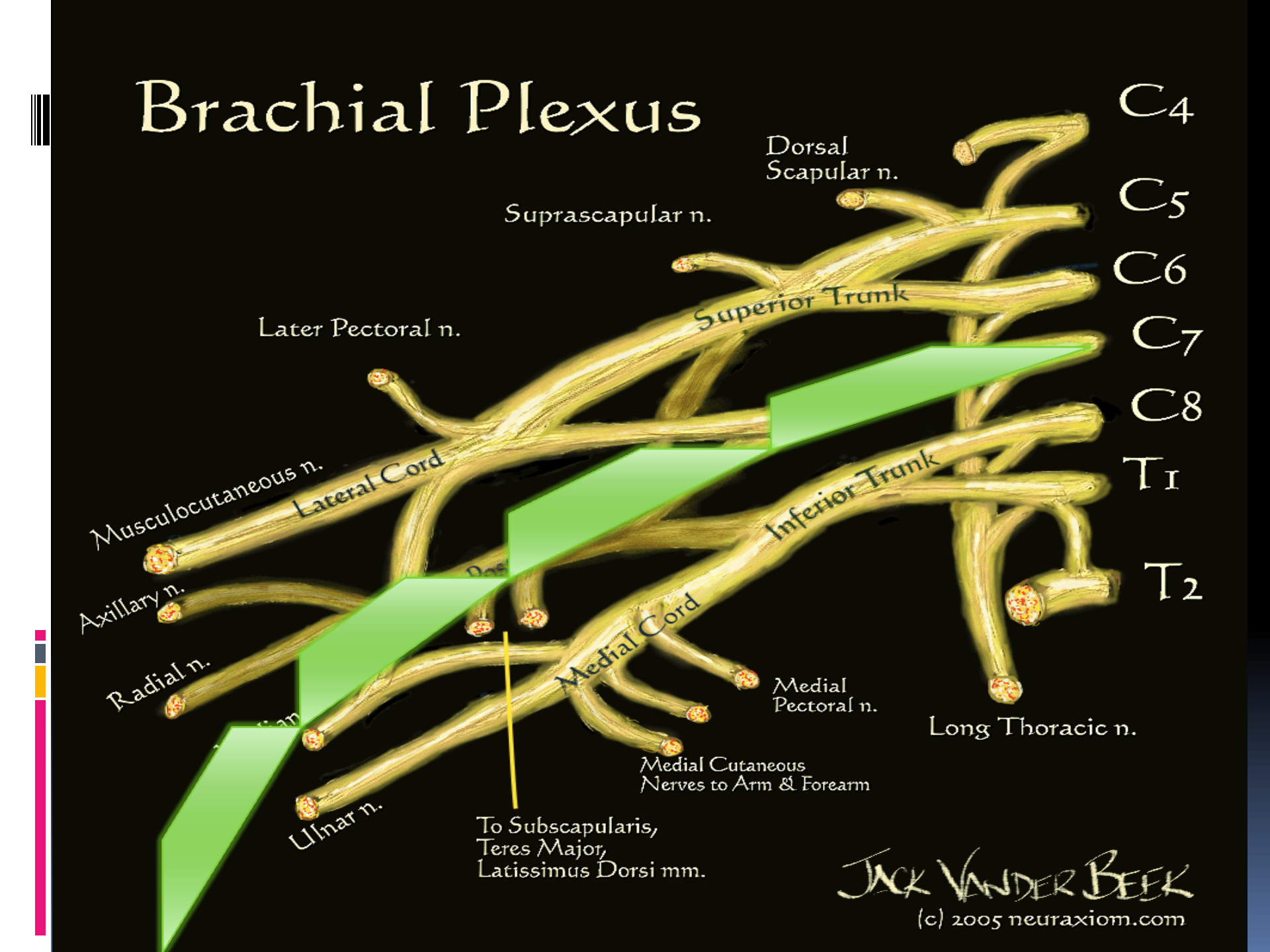
- Anatomy of the Brachial Plexus
- Compartments of the Thoracic Outlet and the structures that define them
- Review anatomic findings associated with the Neurogenic Thoracic Outlet Syndrome
- Review common pathology affecting the adult brachial plexus
- Review imaging findings of brachial plexus trauma, the most common cause of brachial plexopathy

ANATOMY OF THE BRACHIAL PLEXUS

What is the Brachial Plexus?

- Neuronal network innervating chest, shoulder, arm, and hand
- Composed entirely of ventral rami C5-T1
  - Prefixed plexus: C4-C7
  - Postfixed plexus: C6-T2
- Post-ganglionic structure
- Motor and sensory elements

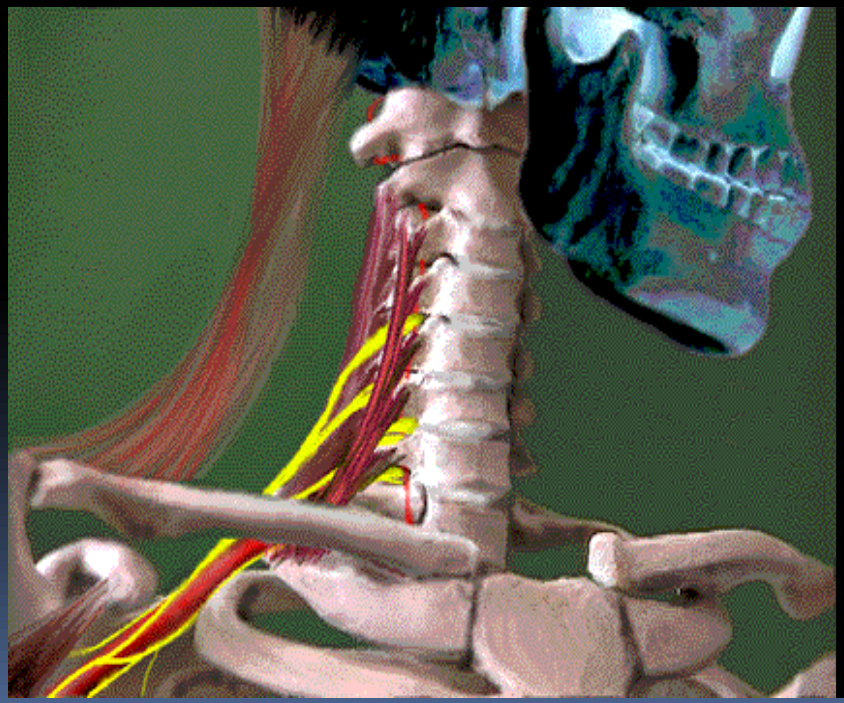


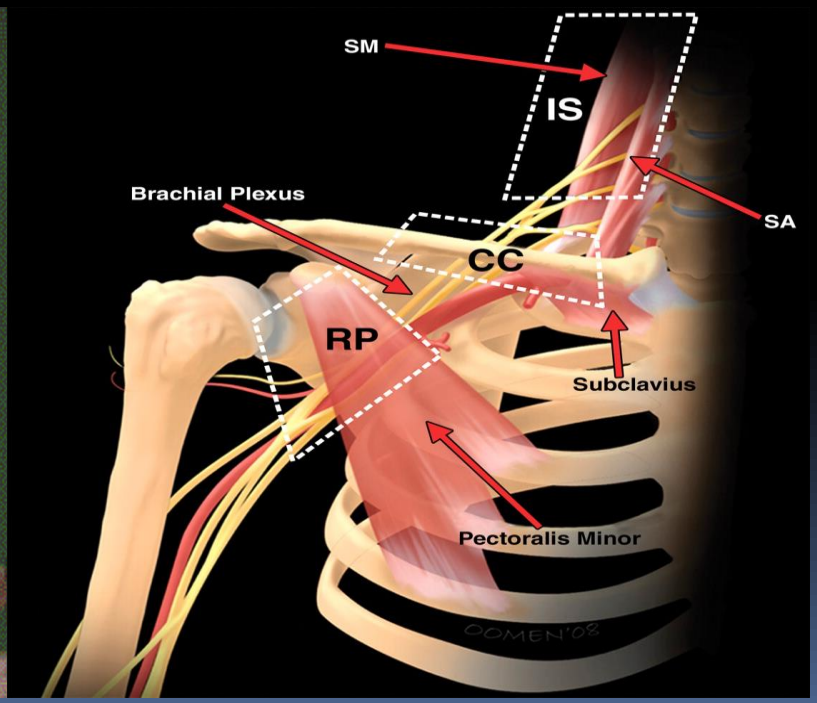

Brachial Plexus
C4
C5
C6
C7
C8
T1
T2
Dorsal Scapular n.
Suprascapular n.
Superior Trunk
Later Pectoral n.
Musculocutaneous n.
Lateral Cord
Inferior Trunk
Axillary n.
Radial n.
Medial Cord
Medial Pectoral n.
Long Thoracic n.
Medial Cutaneous Nerves to Arm & Forearm
Ulnar n.
To Subscapularis, Teres Major, Latissimus Dorsi mm.
Jack VanderBeek
(c) 2005 neuraxiom.com

BRACHIAL PLEXUS & ITS RELATIONSHIP TO THE THORACIC OUTLET

Relationship of BP to TO

Segment of Brachial Plexus	Thoracic Outlet compartments
Supraclavicular Plexus	Interscalene triangle
Retroclavicular Plexus	Costoclavicular Space
Infraclavicular Plexus	Retropectoralis minor space

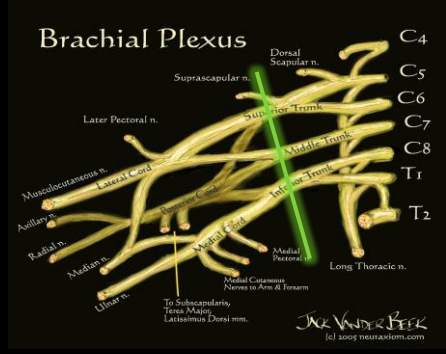




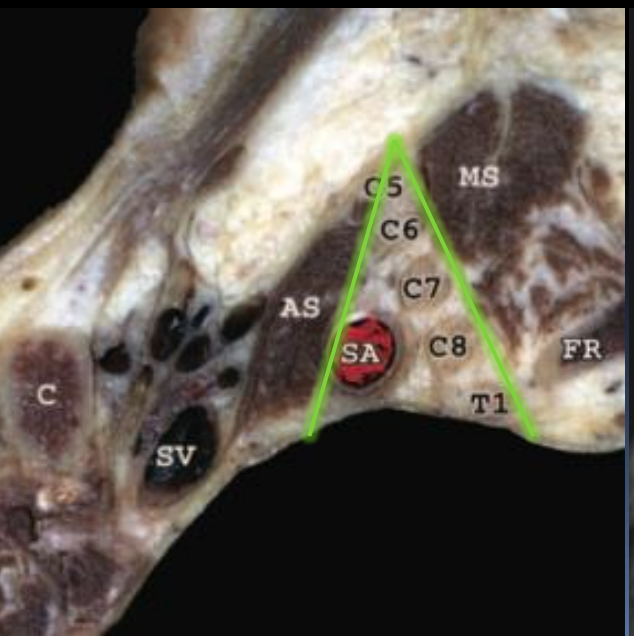
Linda, D. Radiographics. 2010 Sep;30(5):1373-400

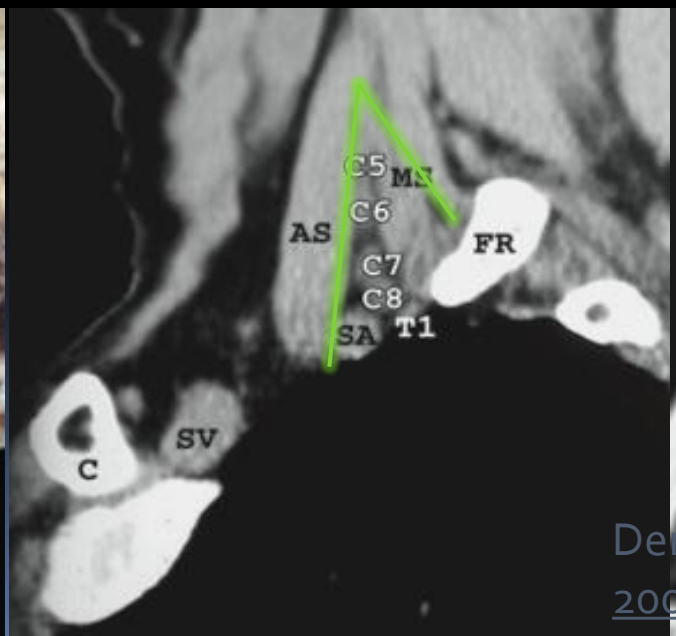
COMPARTMENTS OF THORACIC OUTLET & STRUCTURES THAT DEFINE THEM

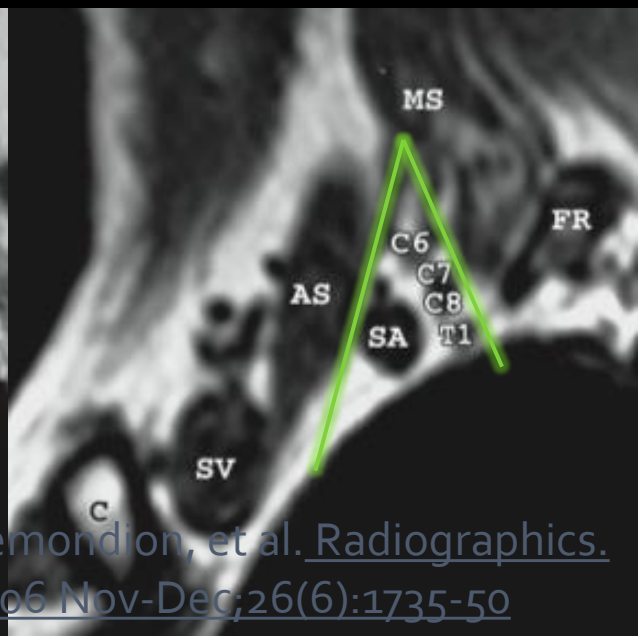
Interscalene Triangle



- Most medial compartment of the thoracic outlet.
  - Anterior wall – AS
  - Posterior wall – MS
  - Inferior wall – SCA and 1st rib
- Contains the supraclavicular plexus: Roots and Trunks of the





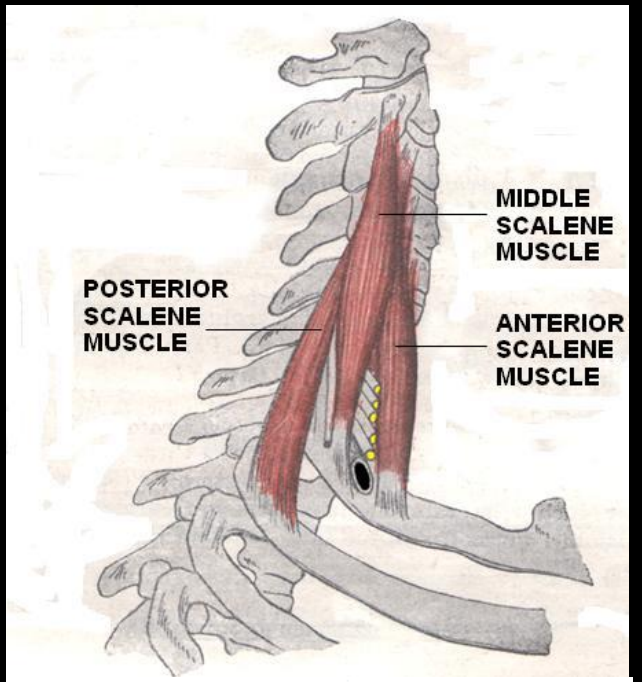


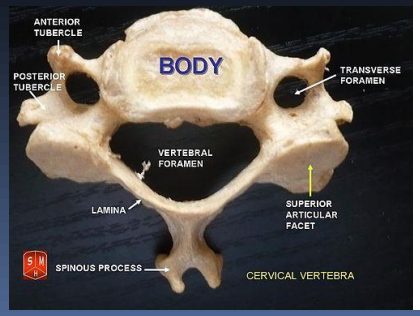
Demondion, et al. Radiographics. 2006 Nov-Dec;26(6):1735-50

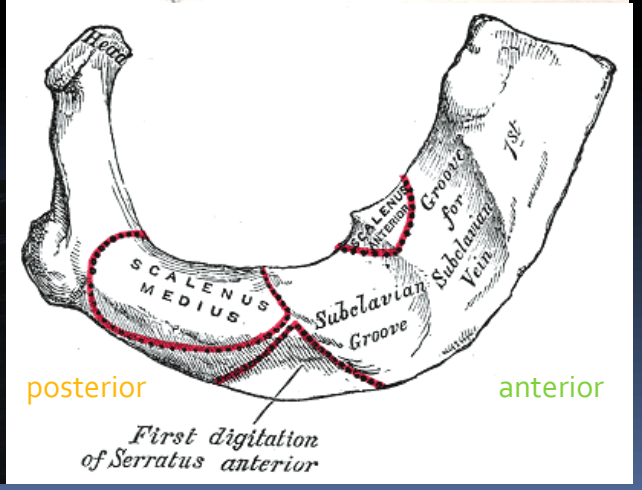
Scalene Muscles

- 3 sets of paired muscles in the lateral neck

Muscle	Origin	Insertion
Anterior Scalene	Anterior Tubercle, C3-C6	1st Rib, Scalene tubercle
Middle Scalene	Posterior Tubercle, C2-C7	1st Rib, posterior part
Posterior Scalene	Posterior tubercle C4-C6	2nd Rib

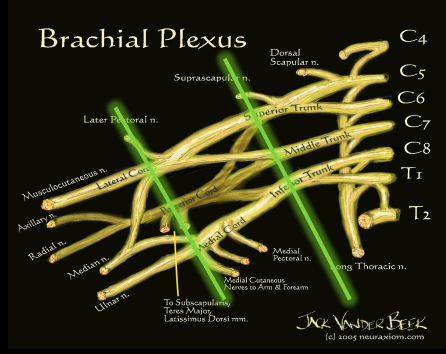




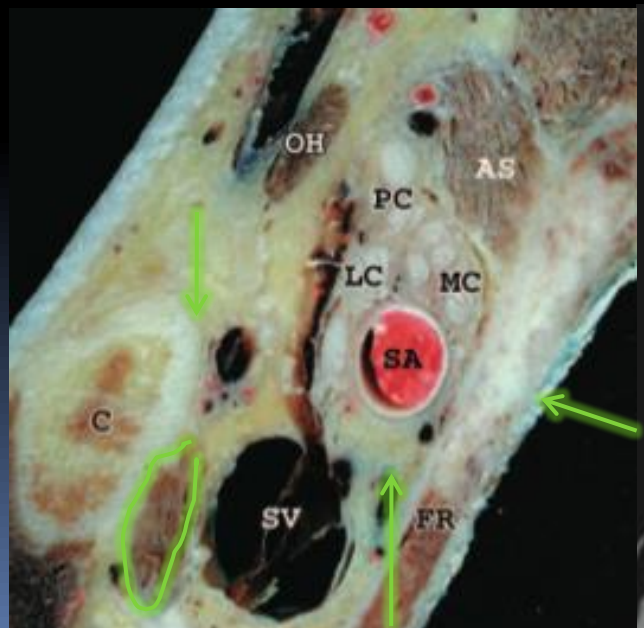


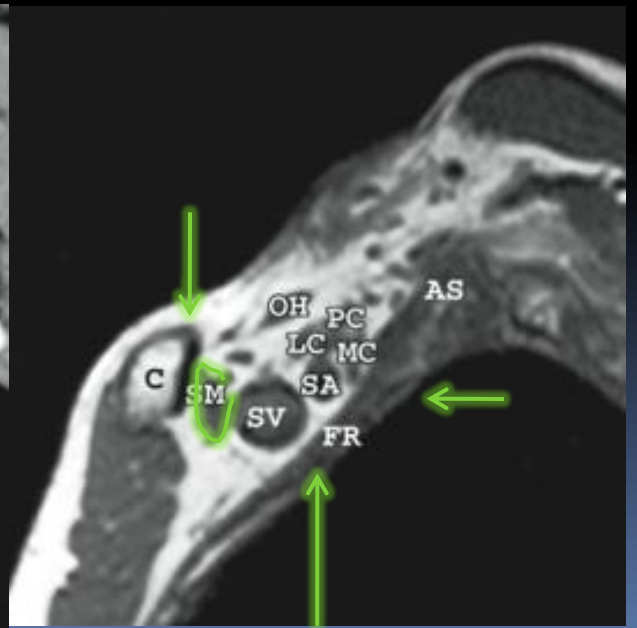
Wikipedia.org

Costoclavicular Space



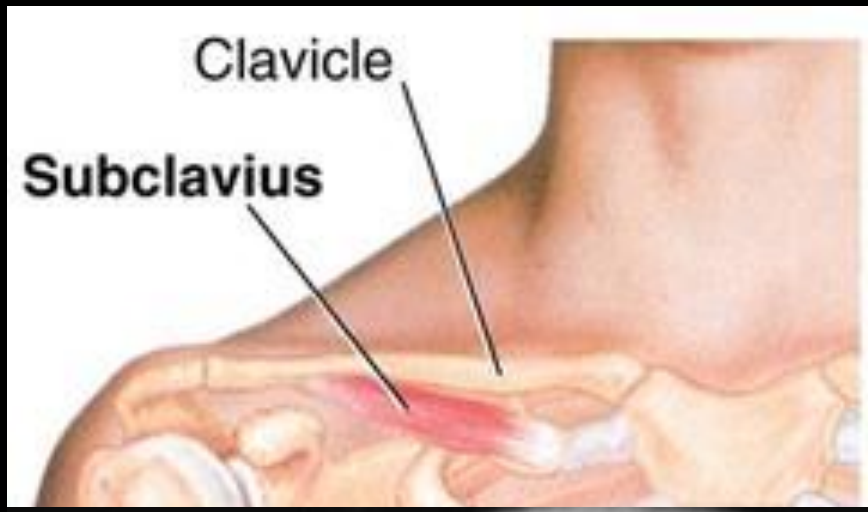
- Intermediate compartment of the thoracic outlet
  - Anterior Wall: subclavius muscle
  - Posterior Wall: 1st rib and middle scalene
  - Inferior Wall: SCV/SCA
  - Superior Wall: Clavicle
- Contains retroclavicular plexus: Divisions (& proximal cords) of BP

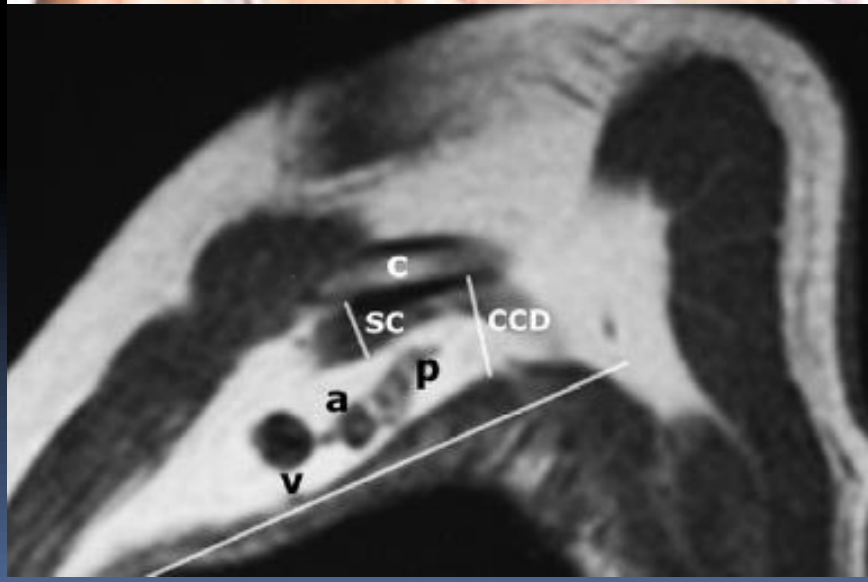




Subclavius Muscle

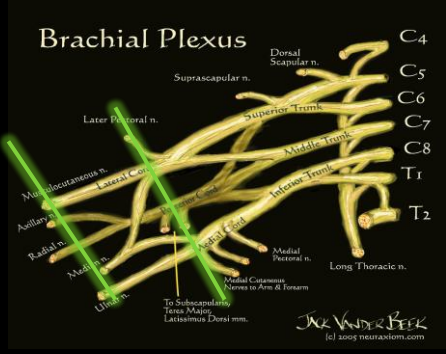
- Triangular muscle, positioned between clavicle and first rib
- Origin: 1st costochondral junction
- Course: superolateral
- Insertion: Undersurface of clavicle between two components of the CC ligament



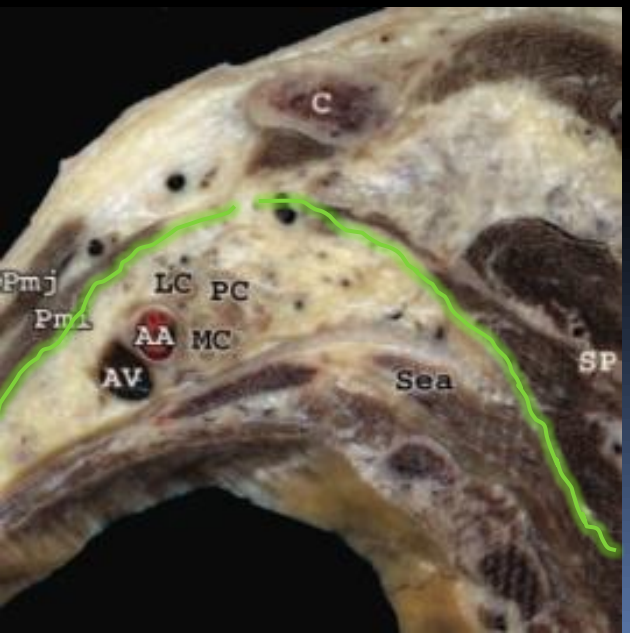


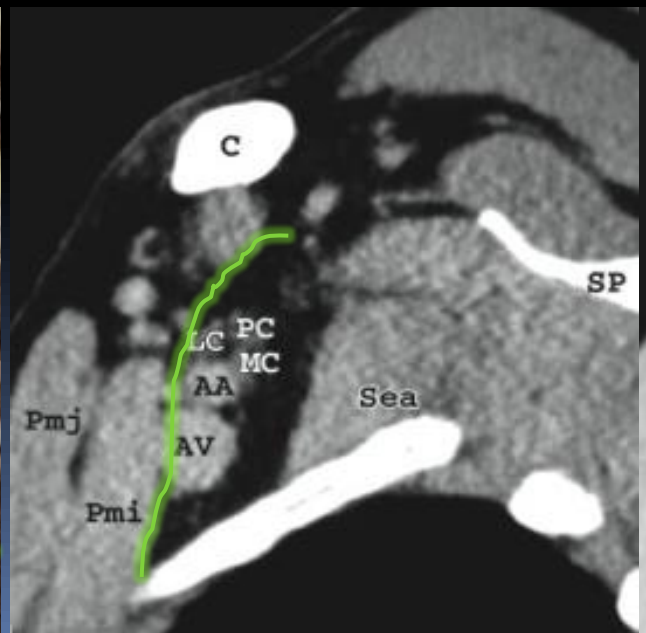
Sagittal Depiction of the Subclavius

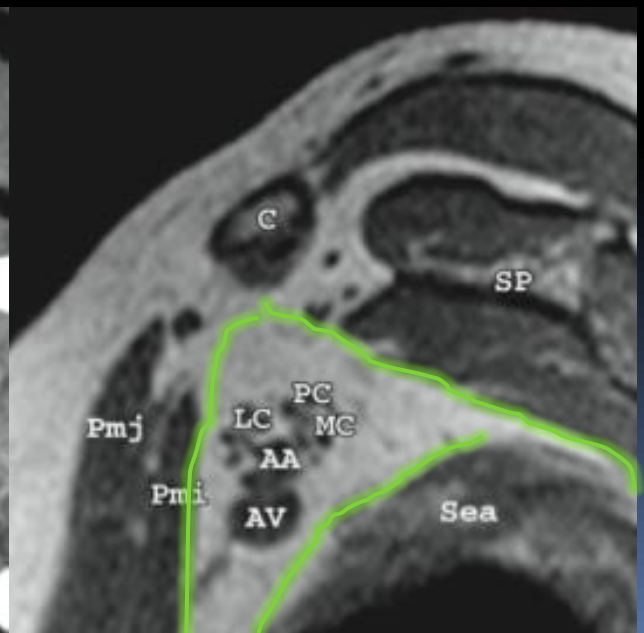
Retropectoralis Minor Space



- Most lateral compartment of the thoracic outlet
  - Anterior wall: Pectoralis minor
  - Posteroinferior wall: anterior chest wall
  - Posterosuperior wall: subscapularis muscle
- Contains the infraclavicular plexus: Cords & terminal branches







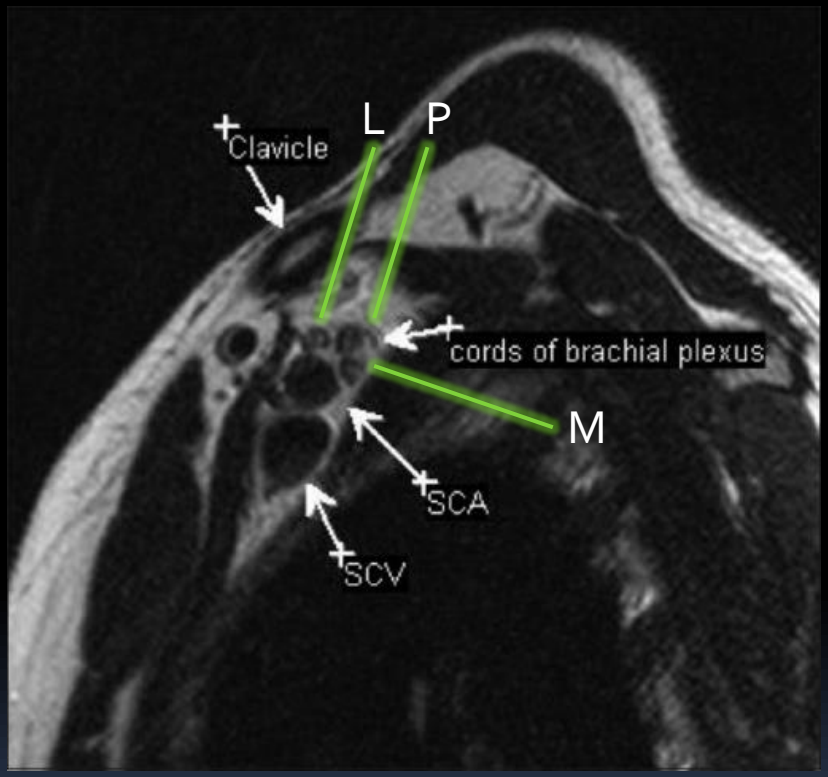
Retropectoralis Minor Space

Cords

- visualized posterosuperior to axillary artery on sagittal view
  - Medial: most inferior
  - Posterior : most posterior
  - Lateral: most superior

Terminal Branches

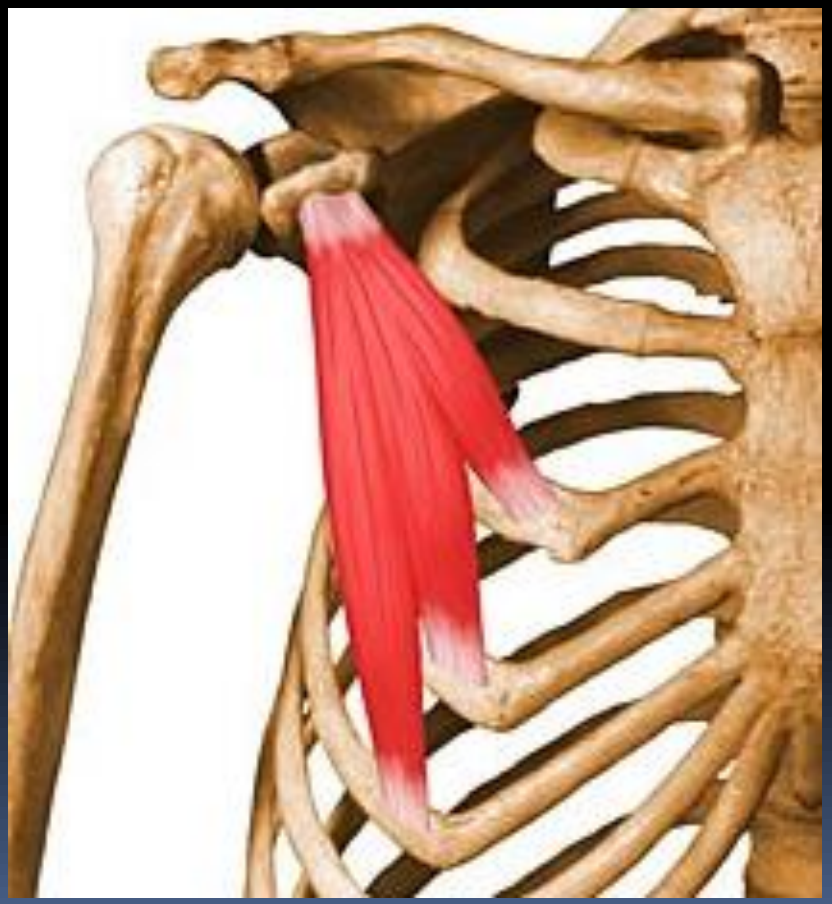
- seen in lower axilla and proximal arm:
  - Musculocutaneous (C5,6,7)
  - Axillary (C5,6)
  - Radial (C5,6,7,8, T1)
  - Median (C5,6,7,8, T1)
  - Ulnar (C7, 8, T1



Pectoralis Minor

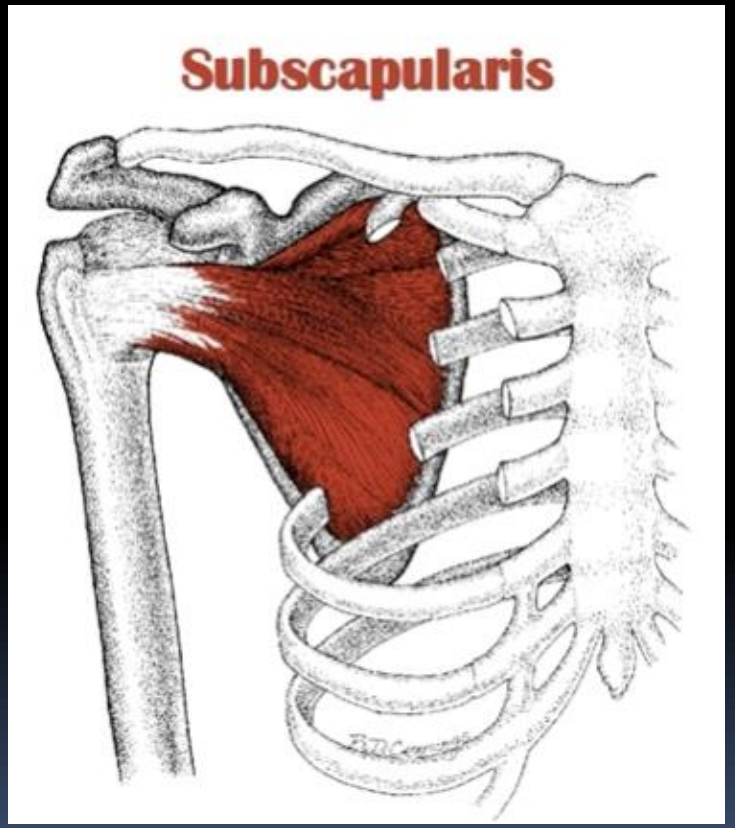
- Thin triangular muscle, deep to pectoralis major
- Origin: upper margins and outer surfaces of 3rd through 5th ribs near their cartilages
- Course: superolateral
- Insertion: medial and upper border of coracoid process

Pectoralis Minor



Subscapularis muscle

- Origin: Subscapularis fossa
- Insertion:
  - Superior 2/3 of the muscle has a tendinous distribution,
  - converges into a single large tendon laterally
  - Inserts onto lesser tuberosity



APPROACH TO BRACHIAL PLEXUS IMAGING AND INTERPRETATION

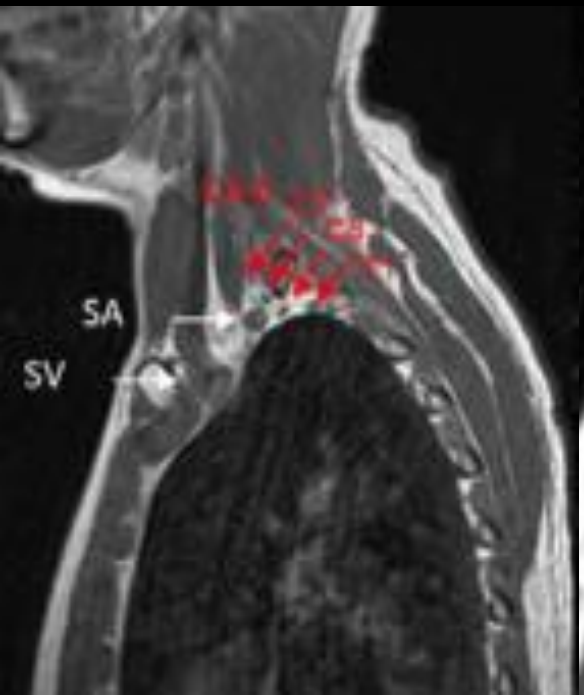
Imaging Approach

- Understand the course of the individual components of the BP
- Obtain best planes for visualization of the brachial plexus and its surrounding non-neural structures
- Know when to use contrast

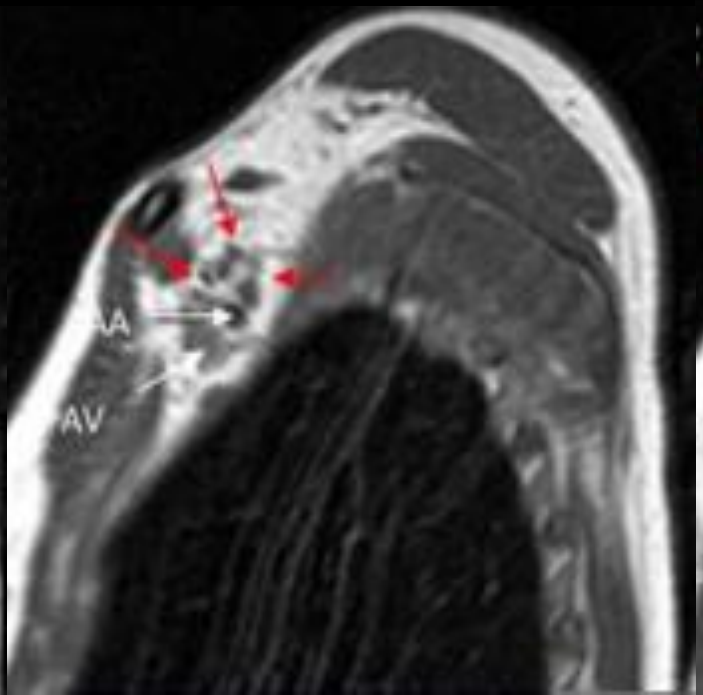
Approach: Planes

- Sagittal non-FS T1WI
  - Relationship between plexus & bony/vascular structures
  - Assessment of fat planes – determines if compression of plexus or not

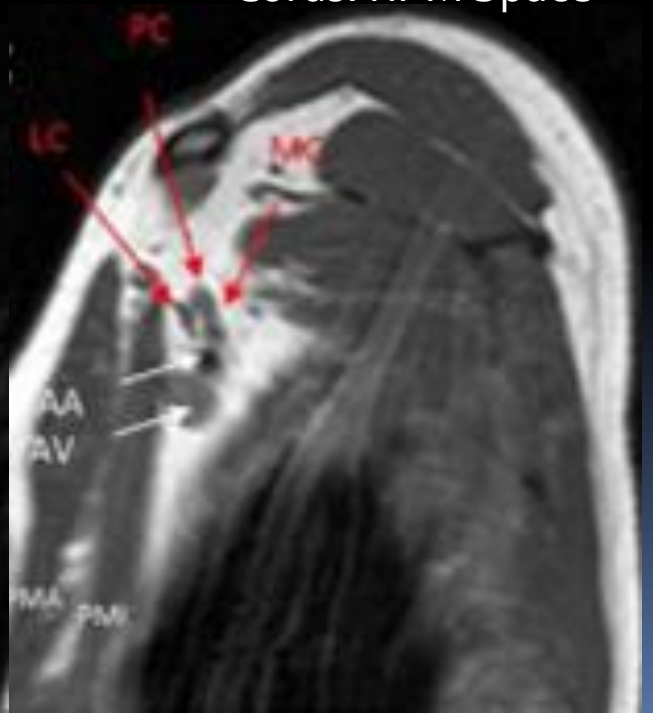
Roots: IS Triangle



Divisions: CC Space

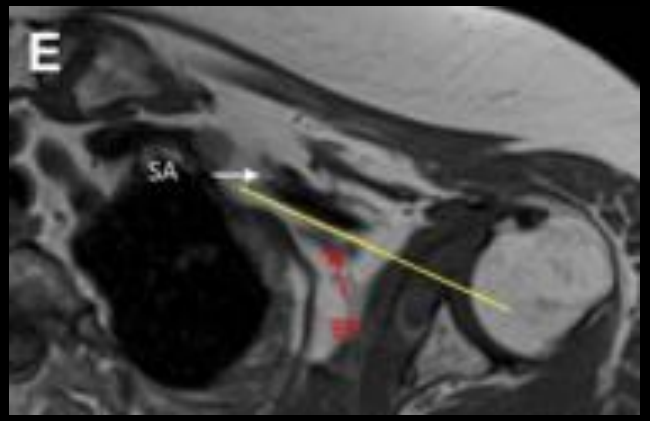


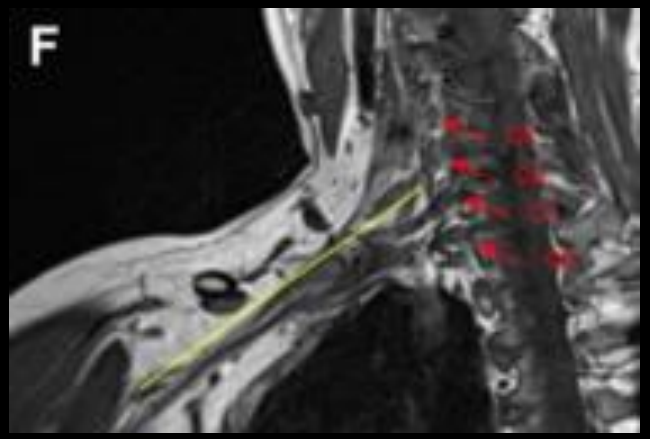
Cords: RPM Space

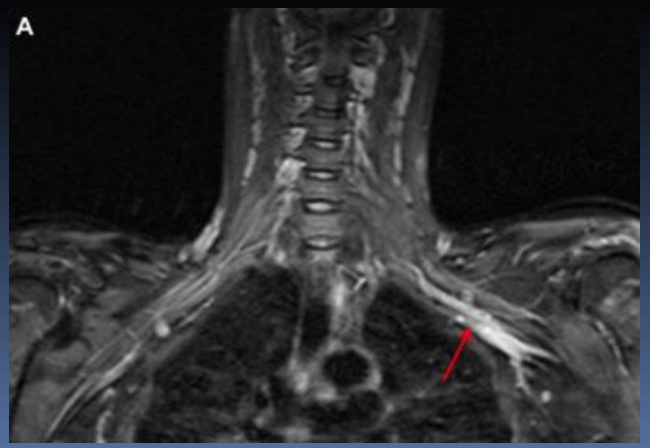


Approach: Planes

- Hi-Res Axial & oblique coronal
  - Best for visualization of the nerve roots and cords along their course
- Large FOV coronal FS T2WI
  - Best for side to side comparison, using the contralateral normal plexus as a control:
    - Signal intensity (normal = intermediate on T1/T2)
    - Size
    - Enhancement
- Unilateral coronal STIR
  - Edema
  - Enhancement
  - Enlargement of the components of the BP







Approach: Contrast

- Contrast?
  - Not required routinely
    - FS T2WI: show location & extent of pathology
    - T1: relationship to adjacent structures, allows for precise localization of the portion of the plexus that's affected
  - Infection
    - Defines extent of infection
    - Assess for drainable fluid collections
  - Tumor
    - Extent of involvement of secondary neoplasms
    - ?differentiate tumor recurrence from radiation changes based upon progressive nodular enhancement

Approach: Protocols

- Impossible to custom tailor examination for each type of study
- Categorization of protocols is important
  - No trauma Hx:
    - MRI w/ contrast, especially if mass suspected
  - Trauma Hx:
    - MRI with T_2W MR myelography
    - High-resolution isotropic imaging
    - CT myelograpy: if contraindications to MR. Otherwise, it's too invasive to warrant it

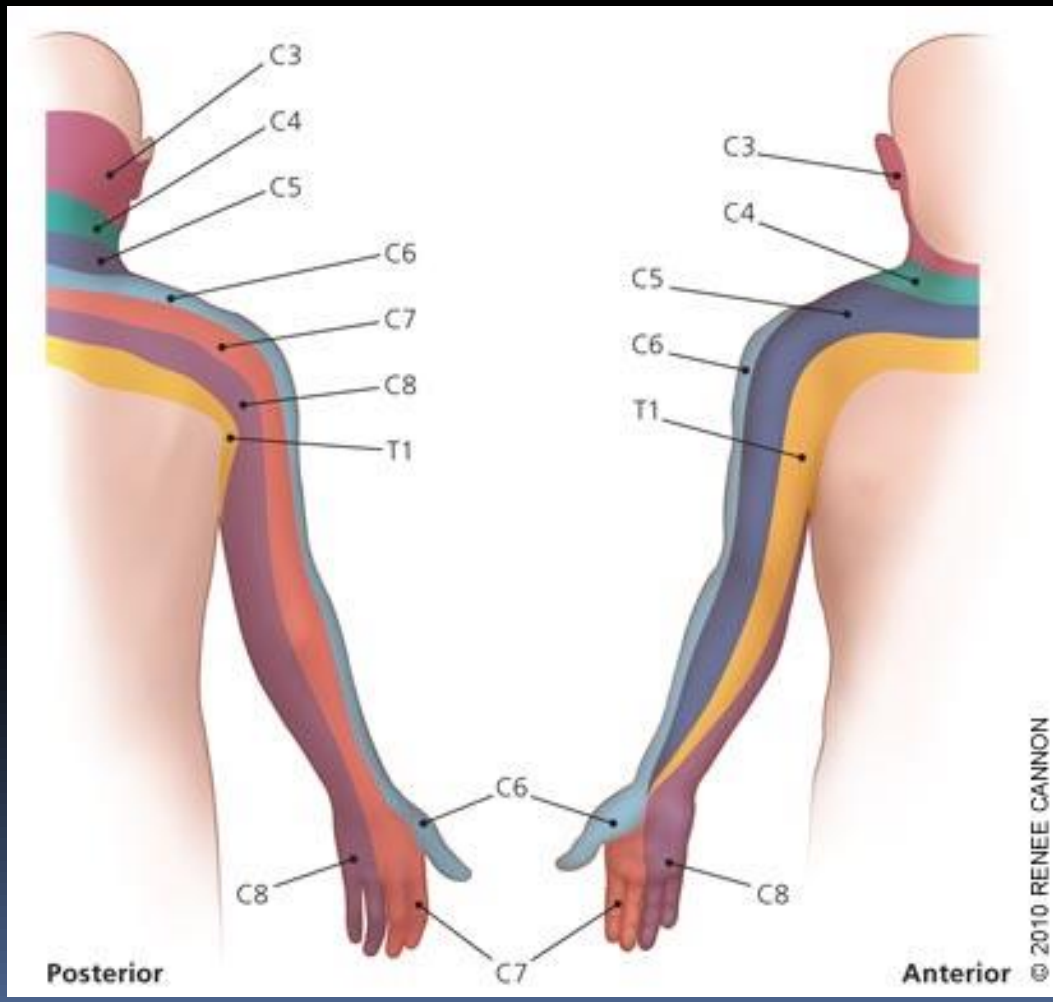
COMMON PATHOLOGIC CONSIDERATIONS OF THE BRACHIAL PLEXUS

Compressive Plexopathy

- Thoracic Outlet Syndrome
  - Classification
    - Arterial
    - Venous
    - Neurogenic
- Neurogenic TOS
  - 95% to 98% of cases of all TOS
  - MC women between 20-40 years

Neurogenic TOS

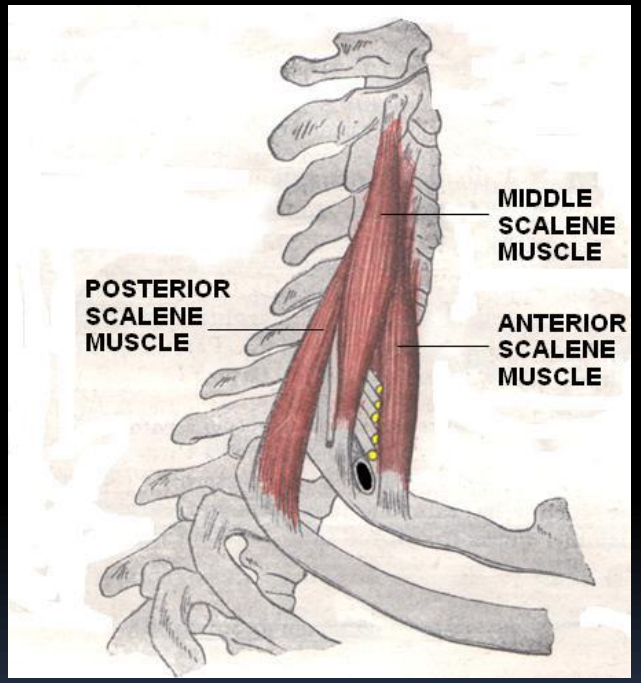
- Symptoms
  - Most common
    - C8-T1/lower plexus sensory distribution (90%)
      - Medial brachial area pain
      - Parasthesias in ring and little fingers
      - "Klumpke-like"
  - Less common:
    - Upper plexus Sensory distribution (C5-C7)
      - Neck, ear, occiput
      - Rhomboids, trapezius, deltoids
      - Pectoralis (pseudoangina)
    - Autonomic Involvement
      - Raynaud's phenomenon



Neurogenic TOS, Etiology

- "space problem" due to congenital abnormalities, with superimposed traumatic injury & muscle spasm, causing compression upon the neural structures of the BP

- Typical injury:
  - Acute: hyperextension-flexion (whiplash); these cause chronic muscle spasm
  - Chronic: repetitive activities requiring repeated elevation/heavy lifting
    - Violinists
    - Athletes
    - Assembly line work



Proposed mechanism of TOS

1. ASM spasm→elevation of 1st rib traction on BP → Nerve edema
2. ASM spasm → muscle edema → nerve impingement

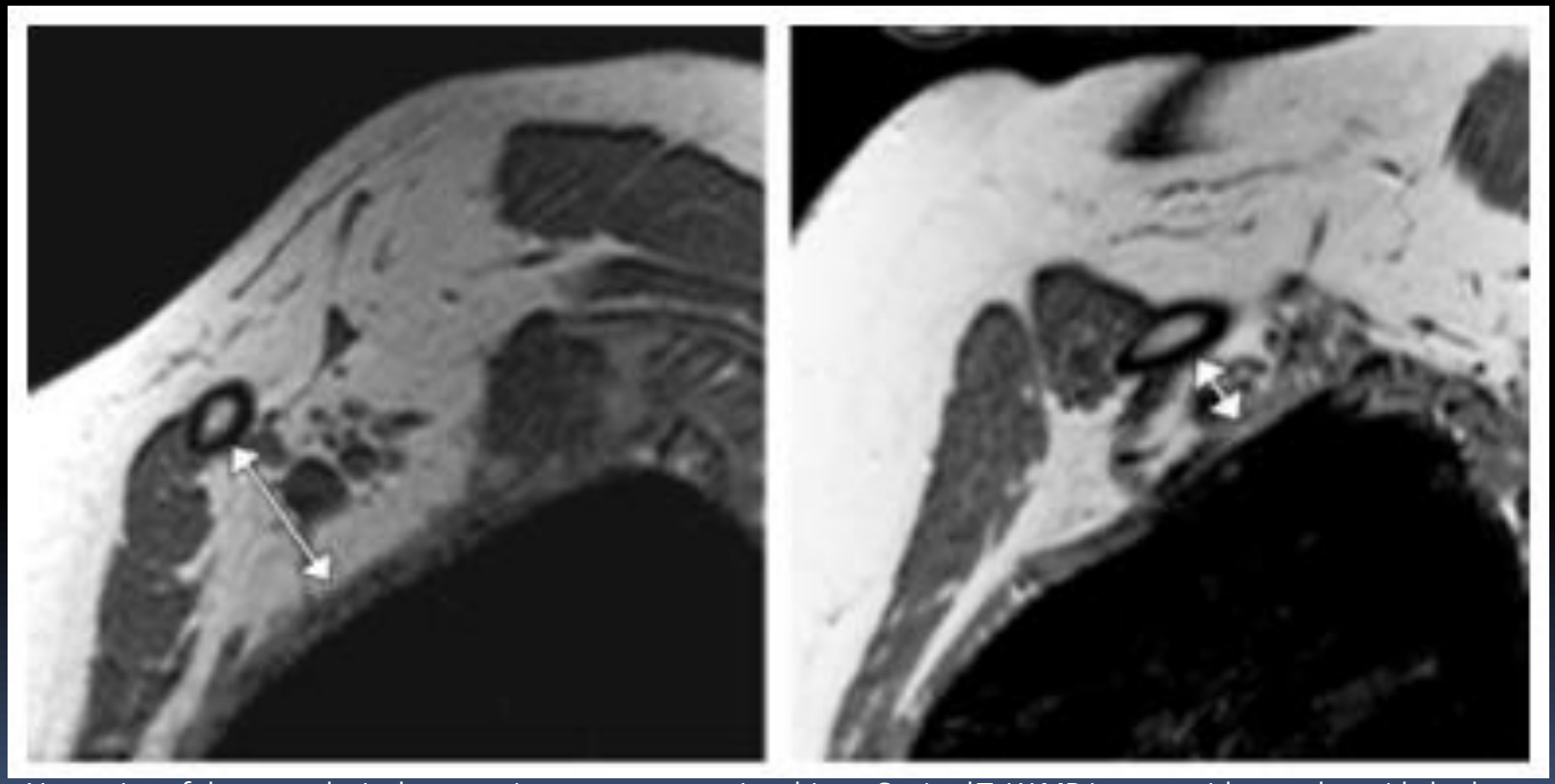
Christo, McGreevy. Curr Pain Headache Rep. 2011 Feb;15(1):14-21.

Neurogenic TOS, etiology

- Demondion, et al.
  - Dynamic mechanical compression within the anatomic spaces of the thoracic outlet (IST, CCS, RPMS)
  - Thoracic outlet compression can be induced by arm abduction in healthy patients
    - Narrowing of costoclavicular & retropectoralis minor spaces with
    - No change in interscalene triangle

Demondion, et al. Radiographics. 2006 Nov-Dec;26(6):1735-50

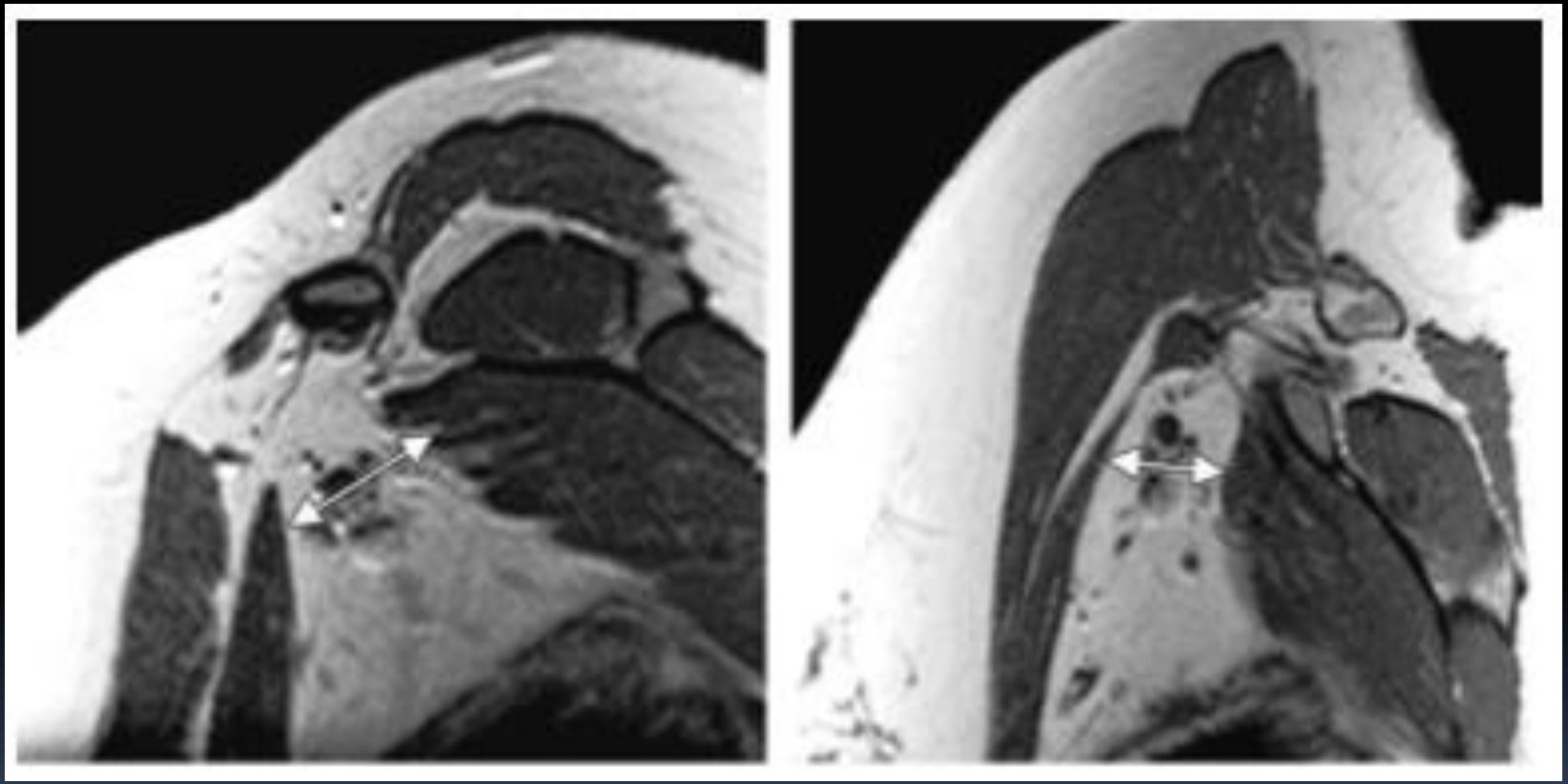
Effect of Abduction: CC space



Narrowing of the costoclavicular space in an asymptomatic subject. Sagittal T1W MR images with arm alongside body (left) and after arm elevation (right) showing narrowing of the costoclavicular space

Demondion, et al. Radiographics. 2006 Nov-Dec;26(6):1735-50

Effect of Abduction: RPM space



Narrowing of the retropectoralis minor space in an asymptomatic subject. Sagittal T1W MR images with arm alongside body (left) and after arm elevation (right) showing narrowing of the retropectoralis minor space

Demondion, et al. Radiographics. 2006 Nov-Dec;26(6):1735-50

Neurogenic TOS

- NTOS is classified into 2 categories: true vs. nonspecific
  - True NTOS
    - objective findings
    - 1% of NTOS
  - Nonspecific NTOS
    - no objective findings
    - 99% of NTOS

Anatomic associations with NTOS

- Bone Abnormalities
  - Cervical Ribs
  - Elongated Transverse Process of C7
  - Abnormal First Rib or Clavicle

- Soft-Tissue Abnormalities
  - Variations of Scalene Muscles
    - Hypertrophy of the ASc
    - Passage of BP through substance of ASc
    - Supernumerary muscles (i.e. scalenus minimus)
    - Fibrous bands: insert onto the 1st throacic rib or cupola of the lung
    - Common belly origin of ASc and MSc
    - Broad MSc muscle, inserting more anteriorly onto first rib
    - Interdigitation between middle scalene muscles
  - Acquired Soft Tissue Abnormalities
    - Lipoma
    - Post-traumatic/Post-operative fibrous scarring
    - increased connective tissue
      - spasm of scalene muscles → elevation of first rib and impingement on the neurovascular structures.

Bone Abnormalities

CERVICAL RIB

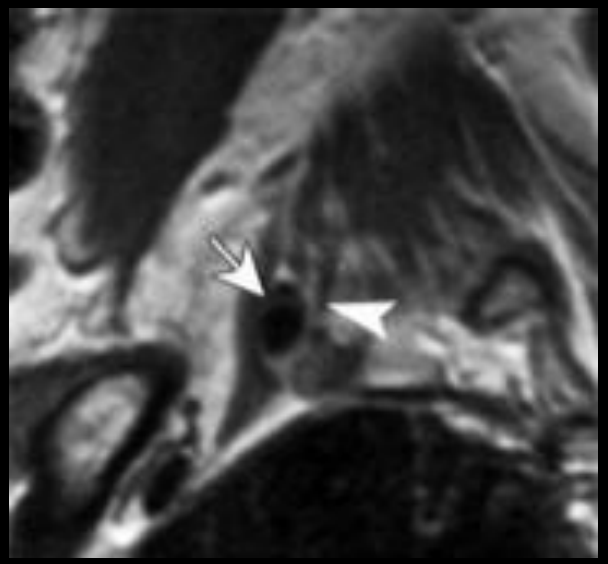
- Aka anomalous accessory rib or "Eve's rib"
- C7 origin (usually)
- Criterion for diagnosis
  - Presence of supernumerary rib articulating with cervical-type horizontal transverse process
    - Complete
      - fused with tubercle on 1st thoracic rib
    - Incomplete
      - Fibrous band inserts onto the first thoracic rib
  - Full-sized or riblet

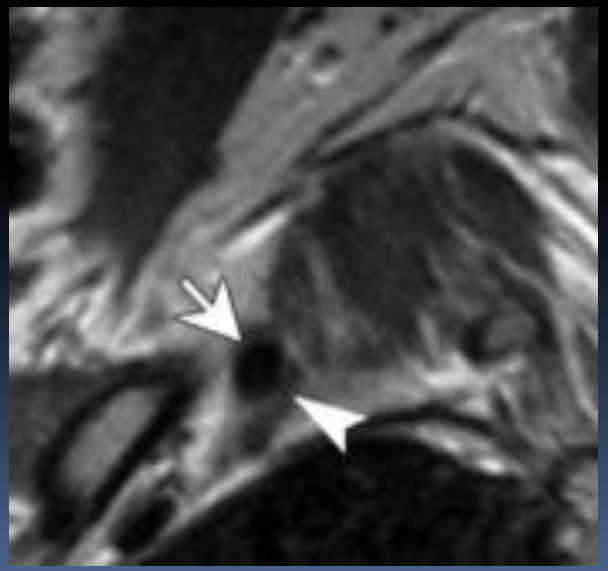
Jeung, May 1999 RadioGraphics, 19, 617-637.

Bone Abnormalities

CERVICAL RIB, Incomplete (see right)

- Site of bony fusion/fibrous band insertion is onto a tubercle just posterior to ASM
- Fusion site/fibrous band displaces the subclavian artery anteriorly & narrows IS Triangle





Cervical rib, statistics

- Cervical rib = <1% of normal population
- Cervical rib reported in 5-9% of patients with TOS
- 90% of pts with cervical ribs are asymptomatic

Demondion, et al. Radiographics. 2006 Nov-Dec;26(6):1735-50

Bone Abnormalities

ELONGATED C7 TRANSVERSE PROCESS

- Extends beyond tip of the T1 process immediately below
- Direct compression
- Indirect compression
  - Fibrous band insertion
  - Abnormal Middle Scalene Muscle

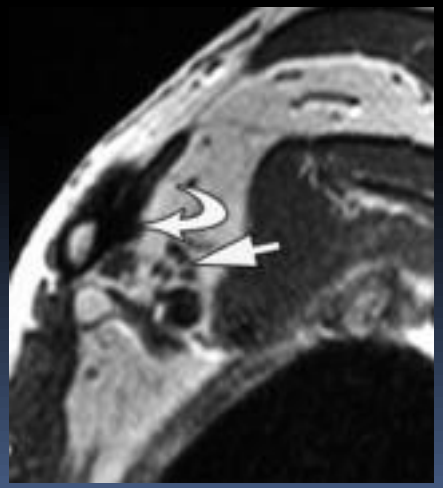
Bone Abnormalities

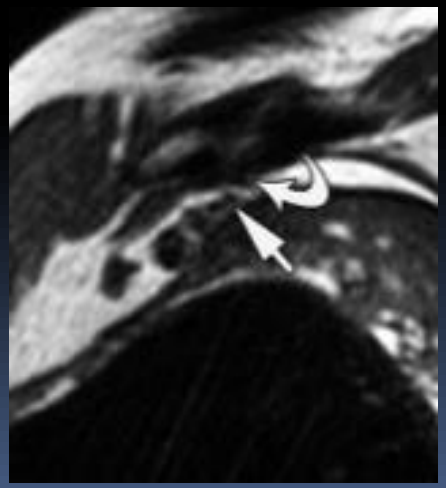
ABNORMAL FIRST RIB/CLAVICLE

- Jaws of the "costoclavicular pliers"
- Abnormal development/orientation of 1st rib and/or clavicle → vascular compression

Example (right)

- Excessive callus formation
- Exacerbates neurologic TOS with abduction





Demondion, et al. Radiographics. 2006 Nov-Dec;26(6):1735-50

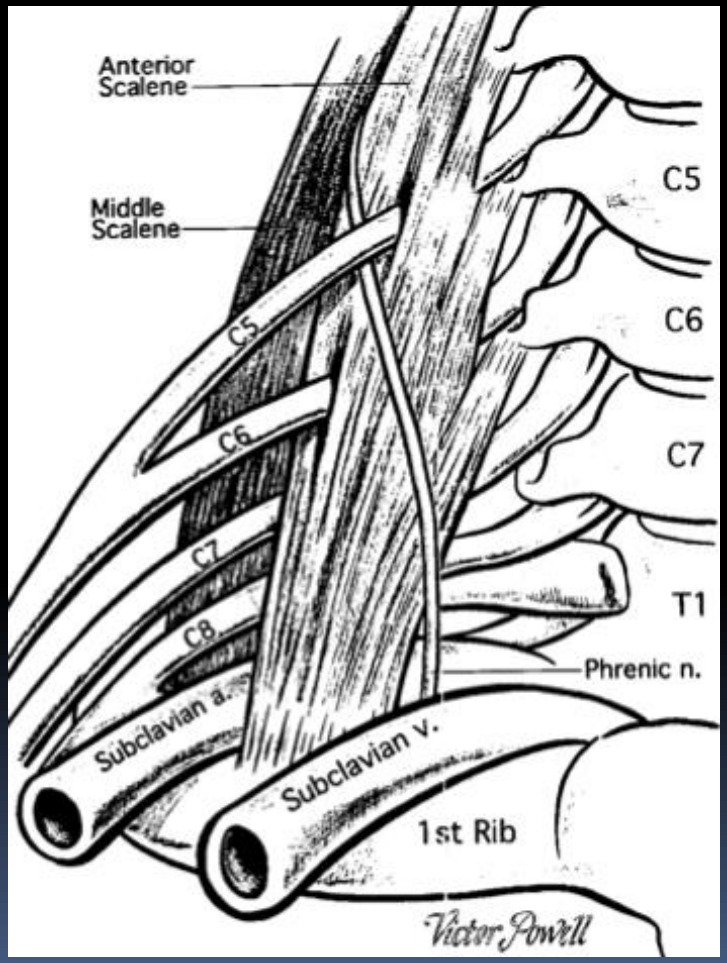
Soft-Tissue Abnormalities

- HYPERTROPHY of ANTERIOR SCALENE MUSCLE
  - Weight-lifting

Soft-Tissue Abnormalities

PASSAGE OF BP THROUGH ASM

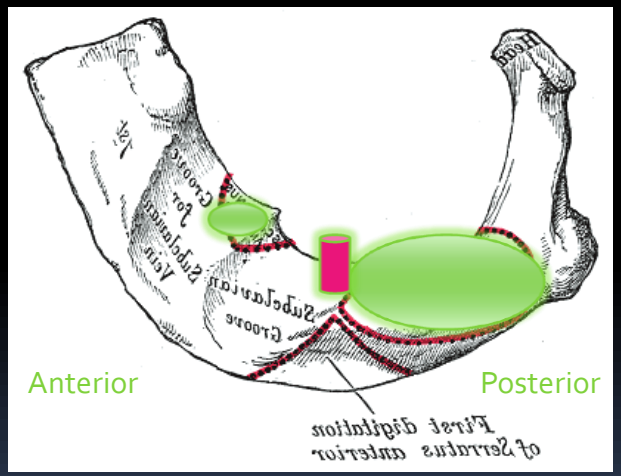
- 24% of cases from study of 51 bilateral cadaveric dissections
  - C5 and C6 pierce AS together – 15%
  - C5 pierce AS – 13%
  - C5 and C6 pierce AS separately – 6%

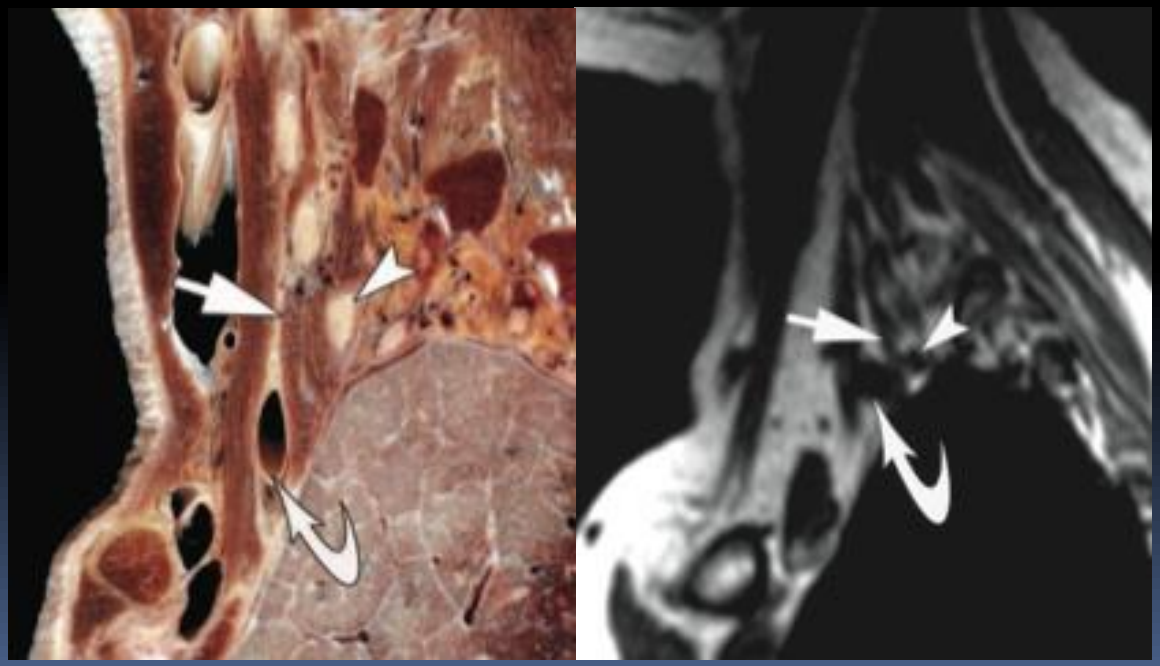


Soft-Tissue Abnormalities

SCALENUS MINIMUS

- Originates from C6 and C7 transverse processes to insert onto the first rib anterior to the middle scalene muscle, narrowing the interscalene triangle (similar to fibrous band).



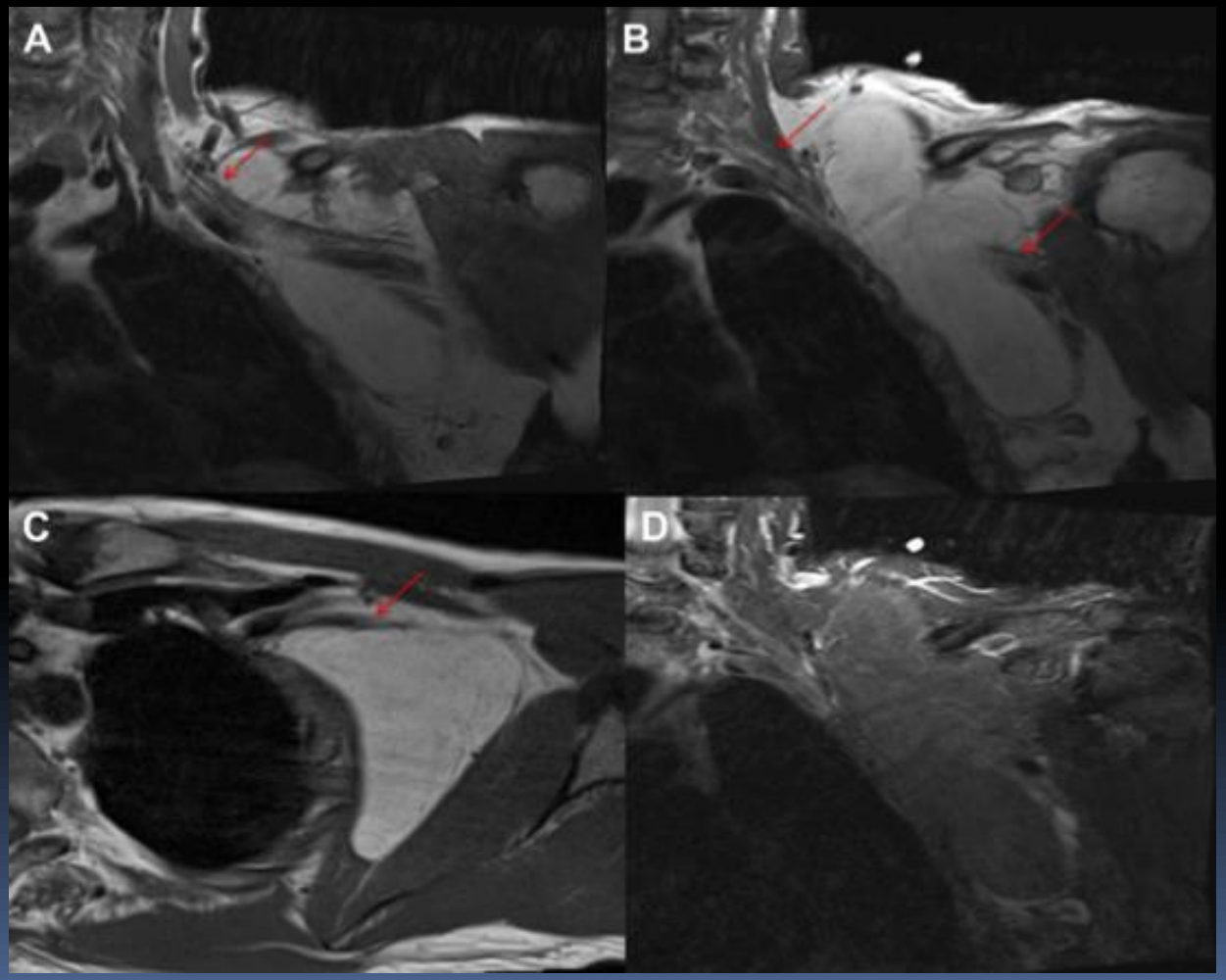


Demondion, et al. Radiographics. 2006 Nov-Dec;26(6):1735-50

Soft-Tissue Abnormalities

LIPOMA

- Large circumscribed axillary mass with imaging characteristics classic for lipoma.
- Displaces cords of the BP



Mikityansky, et al. Magn Reson Imaging Clin N Am. 2012 Nov;20(4):791-826

INFLAMMATORY PLEXOPATHIES

Radiation Plexopathy

- MC non-traumatic inflammatory cause of brachial plexopathy.
- Dose dependent; increased prevalence with higher total dose or dose per fraction
- 60Gy: 3.9% at 5 years, to 54% at 19 years
- Peak presentation 10-20 months after XRT.
- As early as 1.5 months late as 22y (23,25-30).

Castillo, AJR Am J Roentgenol. 2005 Dec;185(6 Suppl):S196-204.

Radiation Plexopathy

- Classification
  - Acute:
    - Within 6 months of starting XRT
    - Due to ischemia. Usually permanent
  - Chronic:
    - Manifests 6 months after termination of XRT
    - Due to fibrosis. Often reversible, however, usu. progressive without recovery
    - Risk increased by chemotx or overlapping fields.
    - MC due to breast or Lung CA treatment.
- Upper trunk more susceptible to radiation plexopathy because unprotected by clavicle

Castillo, AJR Am J Roentgenol. 2005 Dec;185(6 Suppl):S196-204.

Radiation Plexopathy

- Imaging Findings:
  - Diffuse thickening
  - Distortion of fibers
  - T2 SI, variable
  - Mild enhancement without focal mass
- Main Ddx:
  - Metastatic tumor recurrence
    - Tend to present as discrete masses
  - Viral neuritis
  - Allergic neuritis
  - Infection

Large FOV coronal FS T2W: Diffuse thickening, Increased SI, involving the trunks, divisions and cords

Castillo, AJR Am J Roentgenol. 2005 Dec;185(6 Suppl):S196-204.

Radiation Plexopathy

- Best imaging study to differentiate Radiation fibrosis from neoplastic recurrence is PET/CT
- Biopsy may be needed to provide definitive diagnosis

Brachial Plexitis

- Aka: Parsonnage-Turner syndrome
  - Inflammatory condition MC involving upper part of the plexus
  - Presentation
    - acute onset of severe burning shoulder pain night → subsequent sensory hypesthesias →
      delayed muscular weakness atrophy in shoulder girdle/chest
    - Resolution of pain symptoms prior to onset of muscular weakness/atrophy suggests against cervical radiculopathy
  - Causes
    - Vaccination-, immune-, and/or toxin-mediated
    - Atypical/Viral Infections
  - Diagnosis is mostly clinical, with radiography obtained to exclude other causes of shoulder girdle pain

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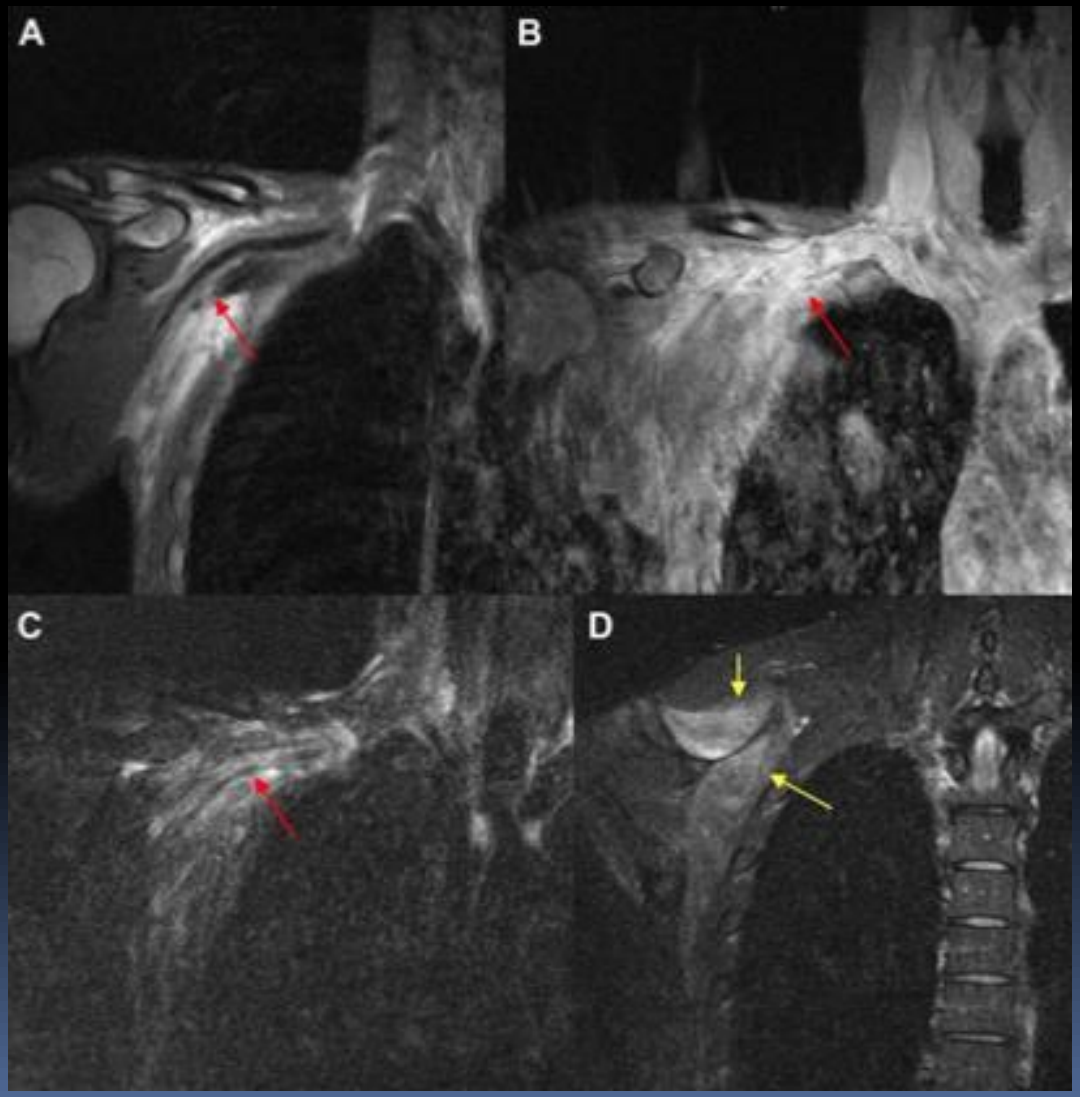
Brachial Plexitis

- 35 yo man
- acute onset of pain and delayed muscle weakness of RUE

MR FINDINGS

- T1 (a,b) and STIR (c,d) images: diffuse thickening, edema & enhancement of right BP, divisions and cords
- Denervation changes in shoulder girdle(d)



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Brachial Plexitis

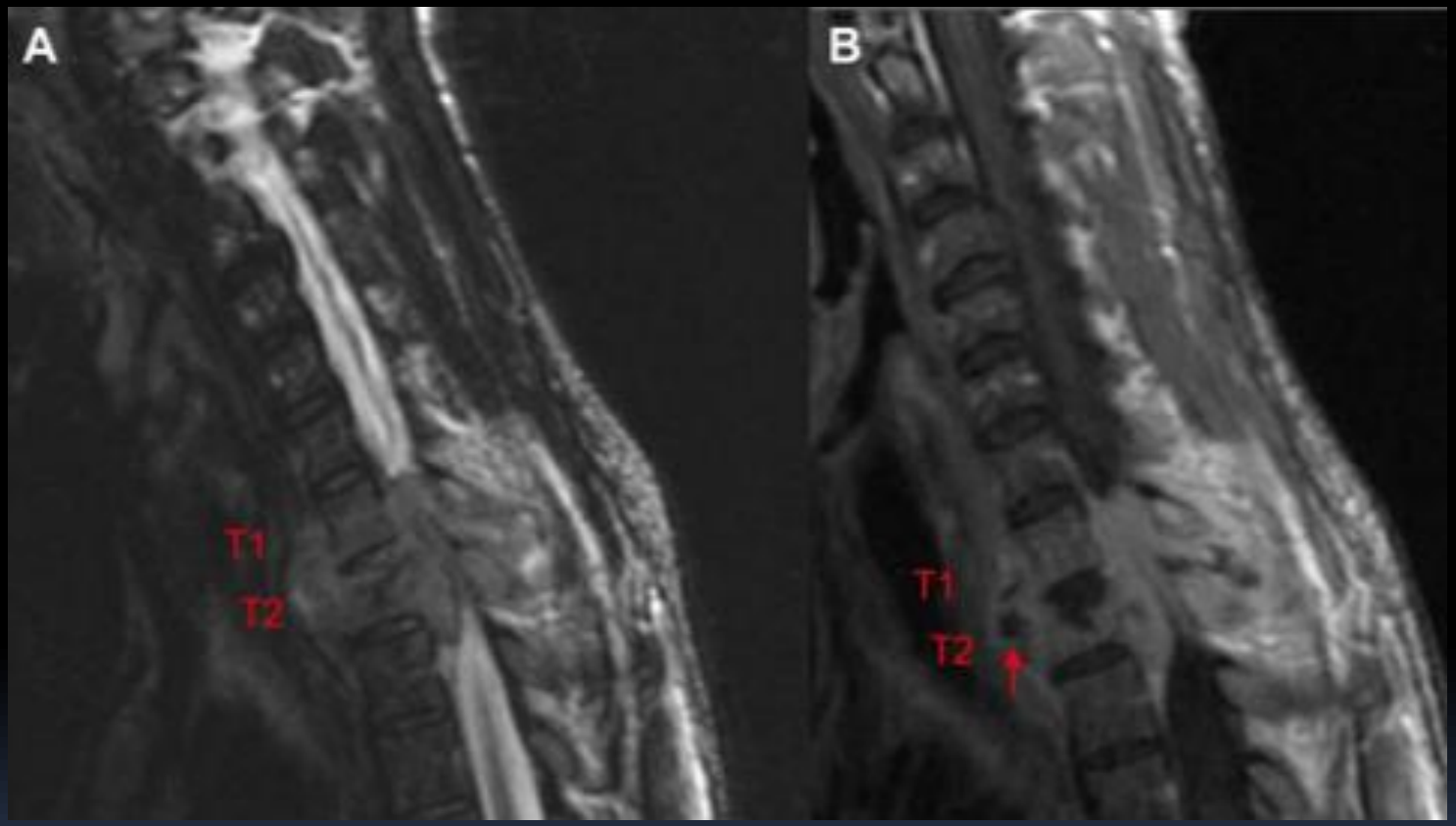
- Management of Brachial Plexitis is conservative
  - Analgesics/Narcotics
  - Immunomodulators
  - Steroids
  - Physical therapy

Infectious Plexopathy

Supparative involvement of the Brachial Plexus, due to contiguous spread of infection from adjacent location → 10 % mortality

- Possible primary sites of infection
  - Spine osteomyelitis = MC
  - Septic GH arthritis
  - Empyema
  - Infectious lung process
  - Open wound

Infectious Plexopathy



Sagittal T2W (a)expansile soft-tissue mass involving the T1 and T2 vertebral bodies, sparing the disc space. Suggestion of a small prevertebral fluid collection (

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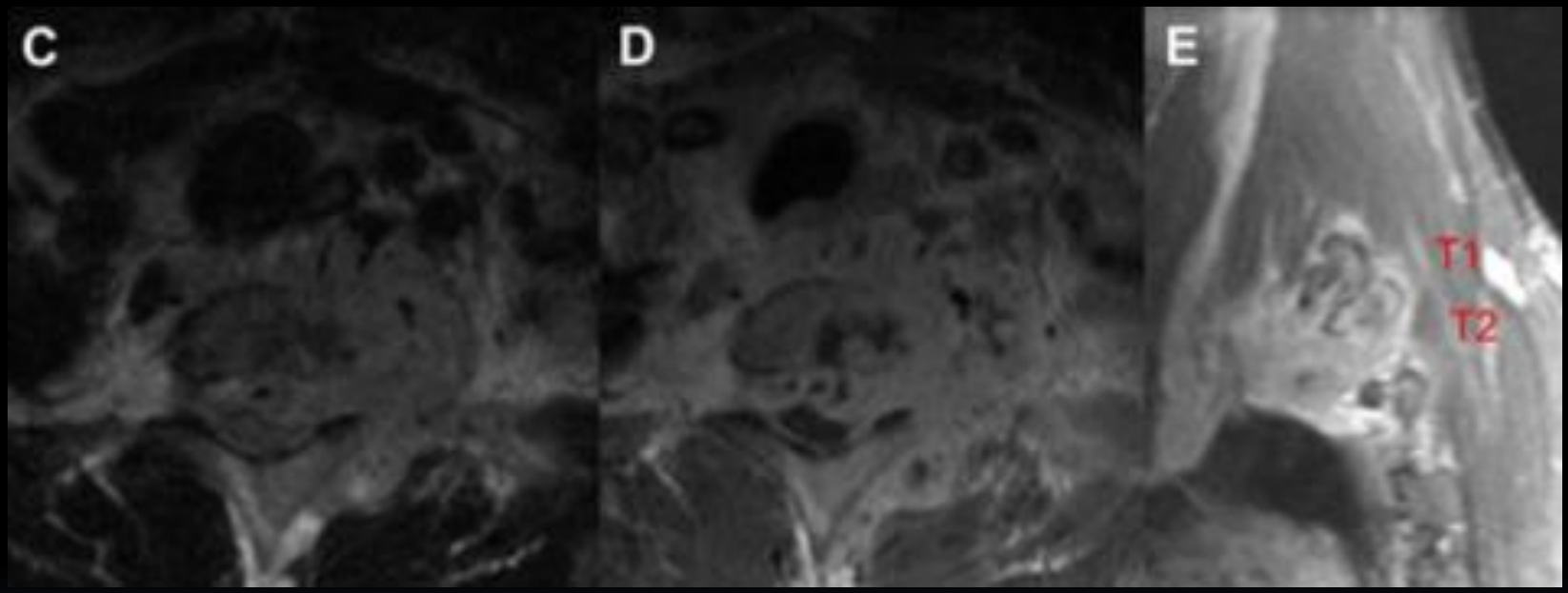
Infectious Plexopathy



Expansile mass extends into the central canal, left greater than right neuroforamina, left posterior elements, prevertebral soft tissues. Cord compression and obscuration of the left neuroforamen. This was a case of Pott disease.

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Infectious Plexopathy

- Management
  - Aspiration to determine the infectious agent and sensitivities
  - Drainage of visible fluid collections
  - Systemic antibiotic therapy

MASS LESIONS OF THE BRACHIAL PLEXUS

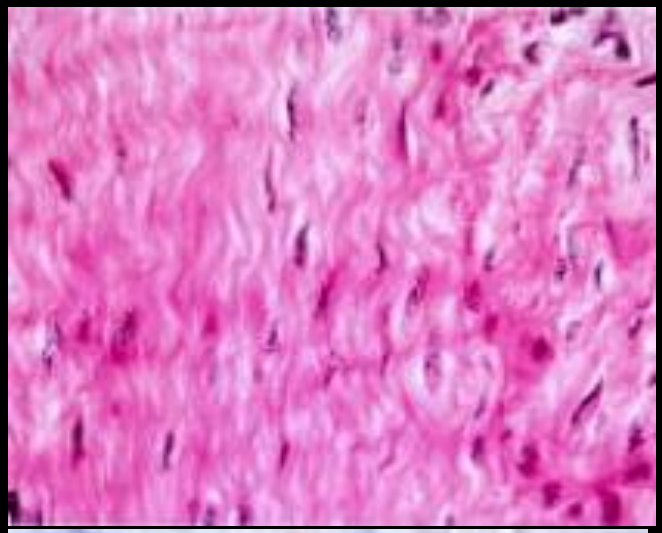
Desmoid-type Fibromatosis

- **MC** secondary mass lesion of benign cause affecting the brachial plexus
  - Entity first described in abdominal wall of pregnant/recently pregnant females
  - Head/neck region is most common extra-abdominal site (9 to 35%) of cases
  - Can be associated with Gardner's syndrome (an FAP)
- Clinical Features
  - Painless mass
  - Occasional neurologic dysfunction
  - Locally aggressive
  - Benign, without the potential to metastasize or degenerate

Desmoid-type Fibromatosis

Histologic Findings

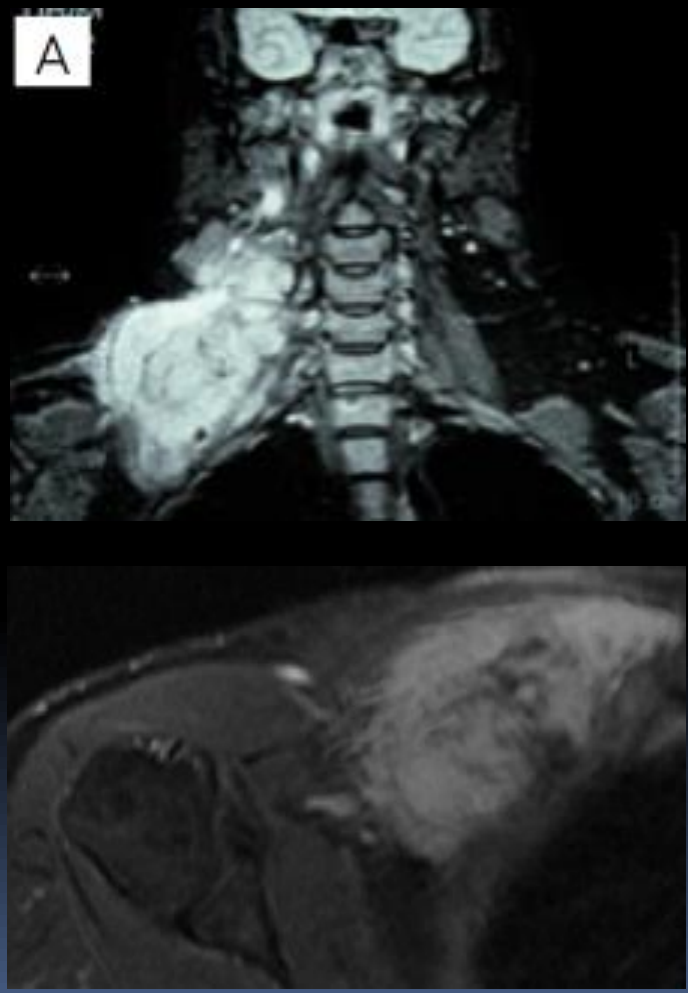
- Plump tapering fibroblast-like cells
- Collagen deposition
- No significant atypia/mitotic activity
- No significant necrosis.
- Nearly identical to neurofibromatosis, esp. when stained positive for S100 protein
  - Anatomic site of origin helps differentiate NF from DTF
  - Pathologist should be informed by the neurosurgeon of a musculoaponeurotic origin of the tumor



Seinfeld et al., Neurosurg Focus. 2007 Jun 15;22(6):E22

Desmoid-type Fibromatosis

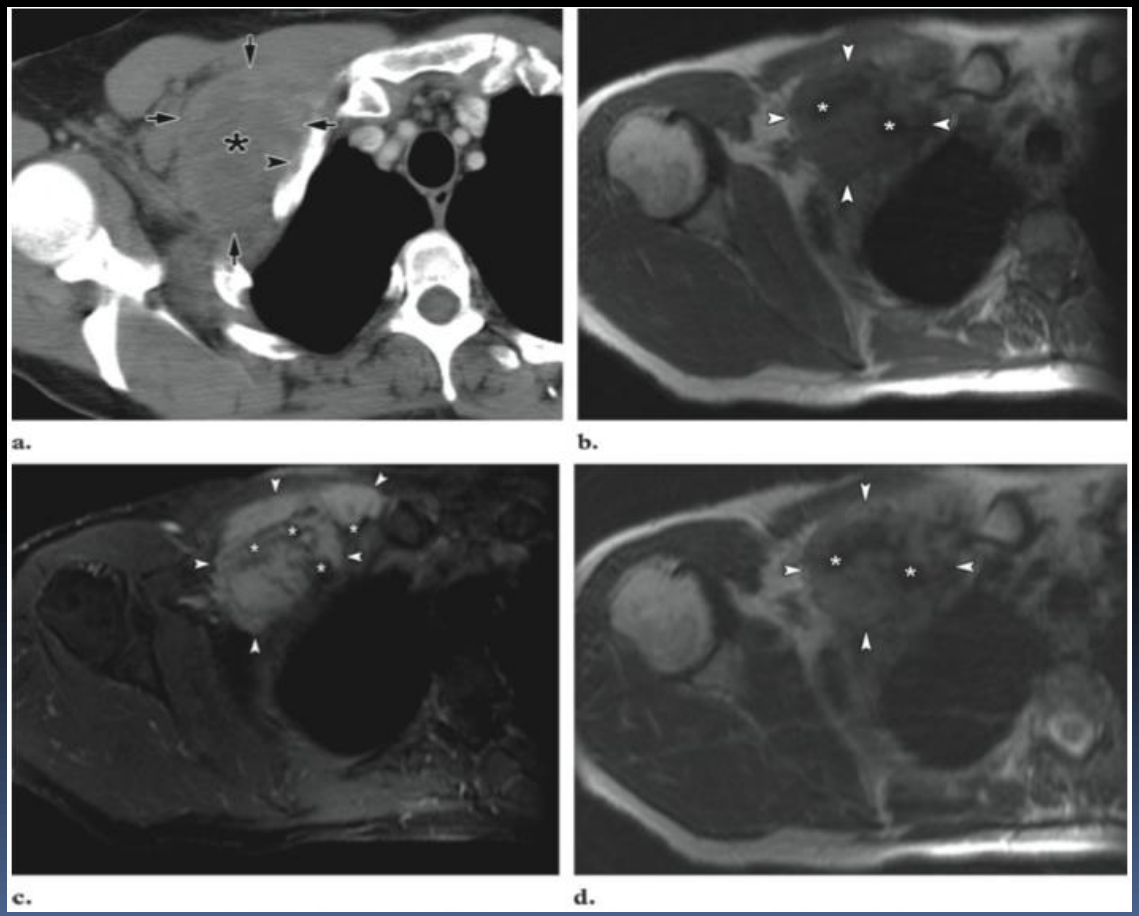
- MR Imaging Findings
  - Irregular/infiltrative margins
  - Signal intensity variable
    - Intermediate T1 & T2 SI: most common
    - High T2SI in early stage of lesion:
      - Hypercellularity
    - Band-like low T2SI in later stage of lesion:
      - hypocellularity
      - abundant collagen → bandlike regions of low T2 SI adds specificity
    - Avid contrast enhancement



Murphey, et al. Radiographics. 2009 Nov;29(7):2143-73.

Desmoid-type Fibromatosis

57 year-old F with discomfort and swelling in infraclavicular region for 5 months



CT

- nonspecific ST mass, with BP involvement and rib erosion

MRI

- Intermediate SI on T1 and T2 WI
- Diffuse enhancement
- Low-SI bands, best seen on post-contrast

Murphey, et al. Radiographics. 2009 Nov;29(7):2143-73.

Desmoid-type Fibromatosis

- Treatment
  - Gross total resection (GTR)
  - Fractionated XRT ~50Gy.
    - Empirically: most "in-vogue" strategy
    - Some reserve XRT for cases of tumor recurrence
- High recurrence rate
  - Up to 75% after initial resection

Seinfeld et al., Neurosurg Focus. 2007 Jun 15;22(6):E22.

Nerve Sheath Tumors (PNST)

- Most common primary neoplasm of BP
- 20% of all PNST occur in Brachial Plexus
  - Neurofibromas
    - 50-65% of all primary nerve sheath tumors of the BP
  - Schwannomas
  - Perineuromas
  - Malignant PNSTs
- 1/3 of all NS Tumors occur in pts with NF-1.

Nerve Sheath Tumors

- MR findings
  - most commonly in neuroforamina
  - Ovoid
  - T2 hyperintense
  - Malignant features
    - Larger lesions are more likely malignant
    - Irregular borders, (though many are well defined)
    - Rapid growth on interval imaging

Mikityansky, et al. Magn Reson Imaging Clin N Am. 2012 Nov;20(4):791-826

Nerve Sheath Tumors

Typical Demographic and Radiologic Features of Nerve Sheath Tumors

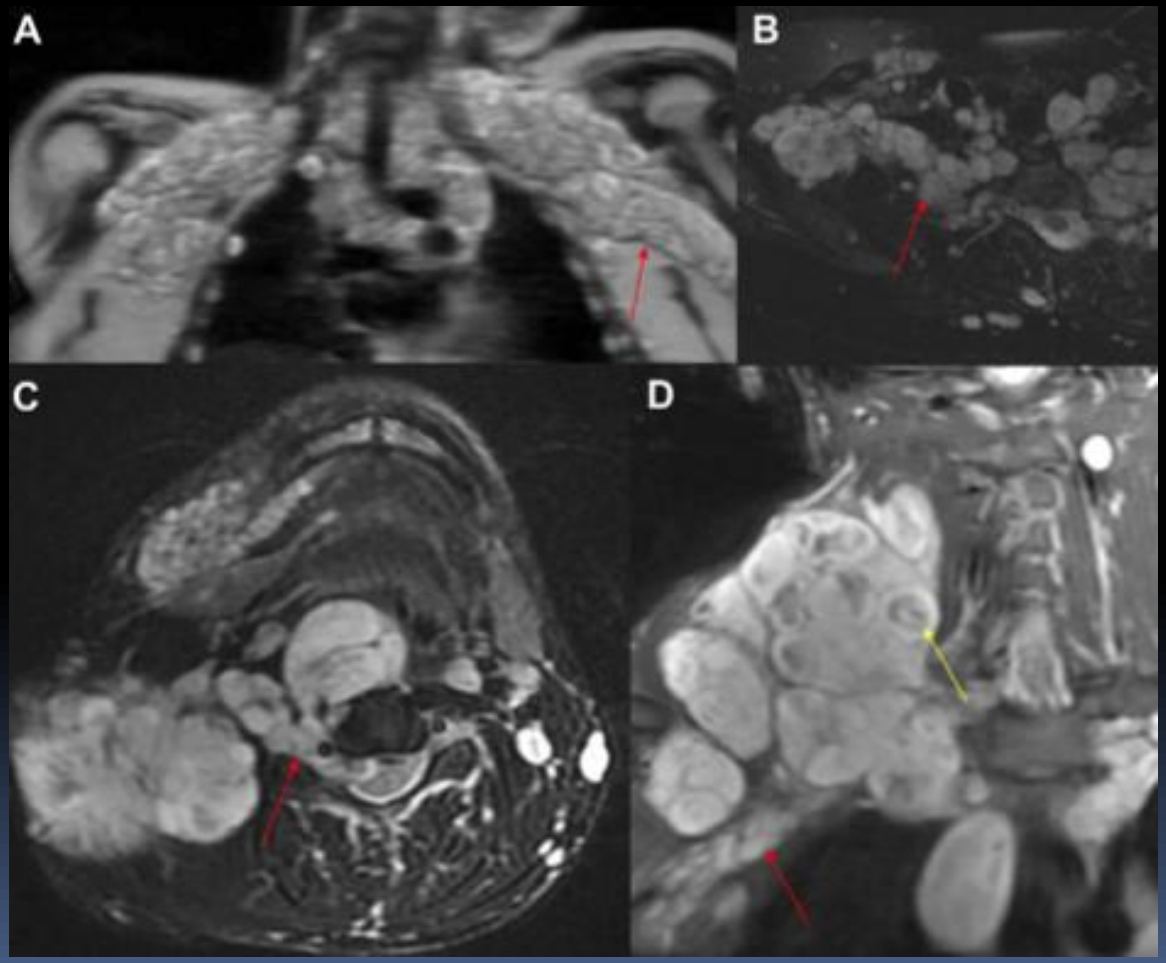
Feature	Tumor Type: Schwannoma	Tumor Type: Neurofibroma	Tumor Type: Malignant Peripheral Nerve Sheath Tumor
Demographic			
Prevalence	Constitutes 5% of all benign soft-tissue tumors	Constitutes 5% of all benign soft-tissue tumors	Constitutes 6% of all sarcomas
Affected patients			
Age (y)	25–65	20–55	20–65
Male-female ratio	~1.3:1	~1.2:1	~1:1
Multiplicity and association with neurofibromatosis 1	Rarely multiple; 5%–18% of patients with multiple lesions have neurofibromatosis 1	Typically solitary, but multiple when associated with neurofibromatosis 1	Solitary; about 50% occur in patients with neurofibromatosis 1
Malignant change	Extremely rare	Extremely rare except in neurofibromatosis 1	Seen in <5% of patients with neurofibromatosis 1 (range, 2%–29%)*
Lesion location	Most often seen in lower extremity, followed by torso, upper extremity, and retroperitoneum	Most often seen in head and neck, lower extremity, and torso, followed by upper extremity	Seen in major nerve trunks (commonly in proximal extremities and torso)
Radiologic			
Mass-nerve relationship	Mass eccentric relative to and inseparable from nerve	Mass central relative to nerve and intimately related to nerve	Mass central relative to nerve and infiltrates nerve
Capsule	70% of cases	30% of cases	Rare
Target sign	50% of cases	50%–70% of cases	Absent
Fascicular sign	Common	Common	Occasional, focal
Intratumoral cysts	Common	Rare	N/A†
Margins	Well circumscribed	Well circumscribed	More often well circumscribed than irregular

*Source.—Reference 1.
†*N/A* = not applicable.

Murphey et al, September 2004 RadioGraphics, 24, 1477-1481.

Neurofibromas

Patient with history of neurofibromatosis-1



MR Findings

- Multiple neurofibromas
- Plexiform neurofibromas along course of BP
- Target sign (yellow arrow)
  - Central hypointensity and peripheral hyperintensity on T2W imaging

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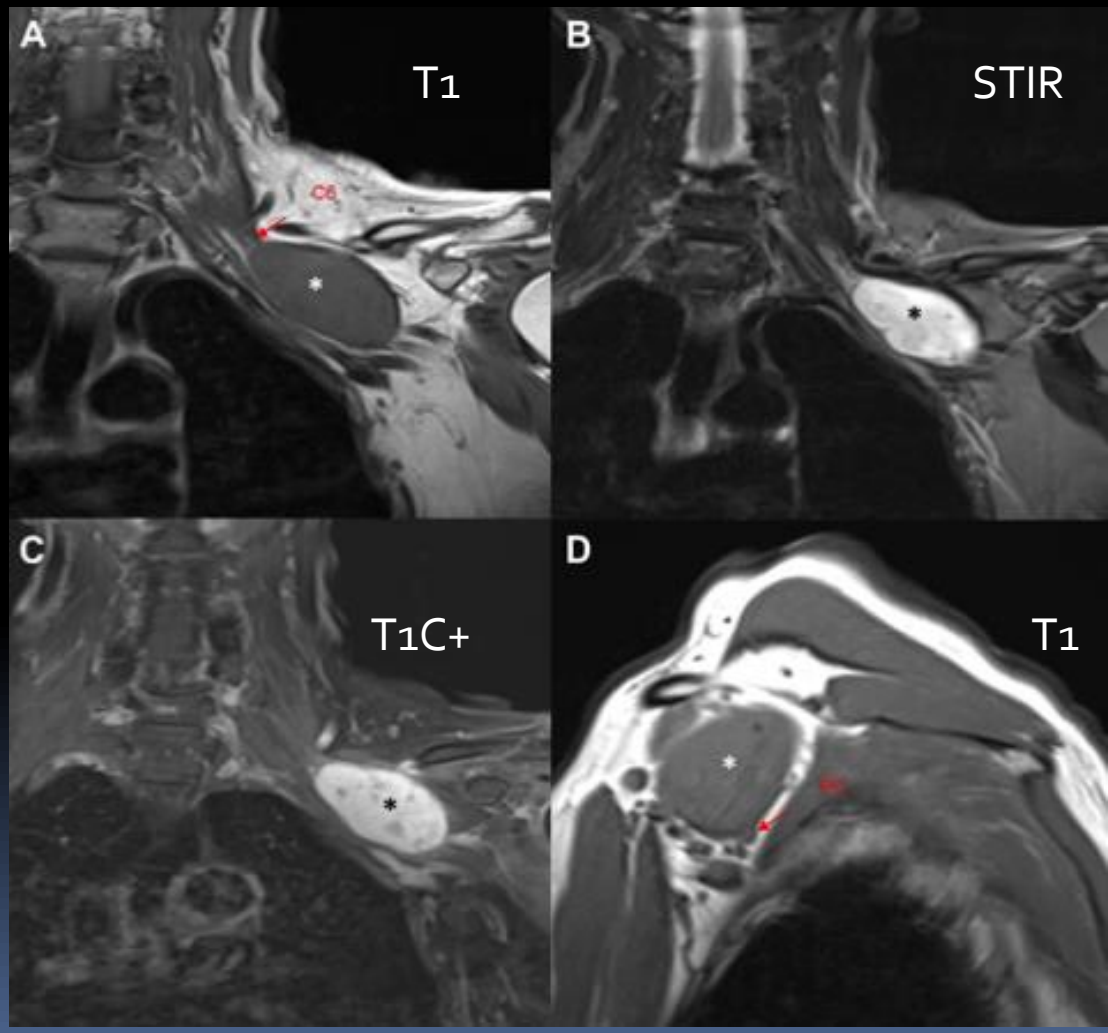
Schwannoma

MR Findings

- Circumscribed mass
- Eccentric growth, intimate with C6 nerve, upper trunk, and posterior cord
- Avid enhancement



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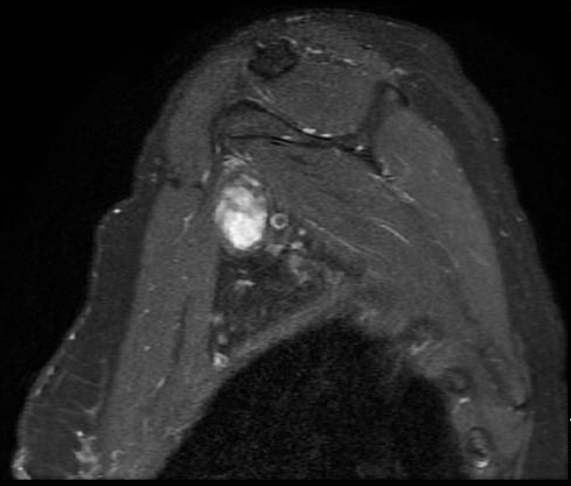
Schwannoma

- 42-year old female
- History of MISME
- New-onset of left upper extremity parasthesias

STIR

T1C+

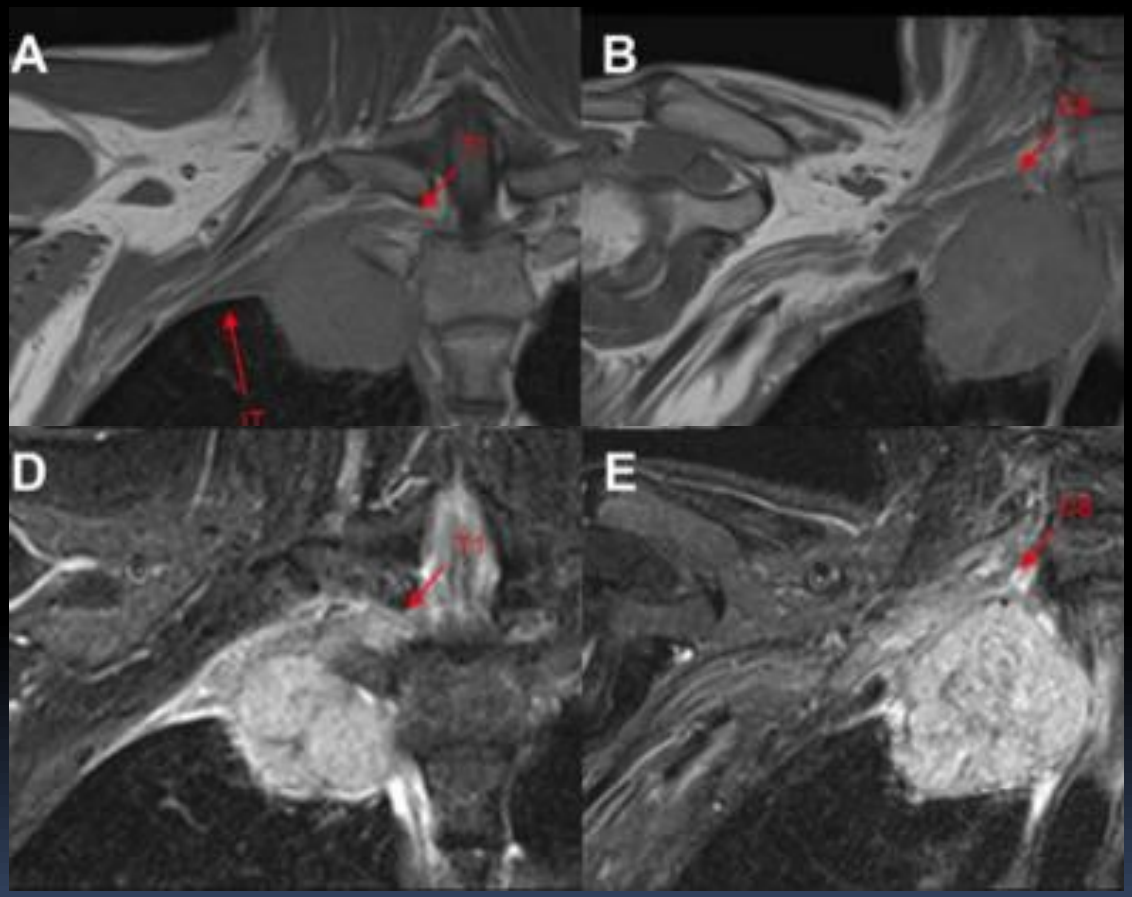


Report: Ovoid, T2-hyperintense, avidly-enhancing left axillary mass, left retropectoralis space, arising from the infraclavicular plexus, most likely representing a schwannoma given history of MISME.

Malignant Neoplasms

- Metastatic malignancy is most common non-inflammatory cause of plexopathy in middle-aged & older adults
  - Breast CA
    - MC by axillary lymphadenopathy compressing and/or invading the BP
    - LC by spinal metastases, with extension into the BP
  - Lung CA
    - MC by direct extension from the superior sulcus (Pancoast tumor)

Malignant Neoplasms: Lung CA



- Coronal T1 and STIR images demonstrate a superior sulcus tumor, extending into the region of the BP, involving the C8 and T1 roots, as well as the inferior trunk

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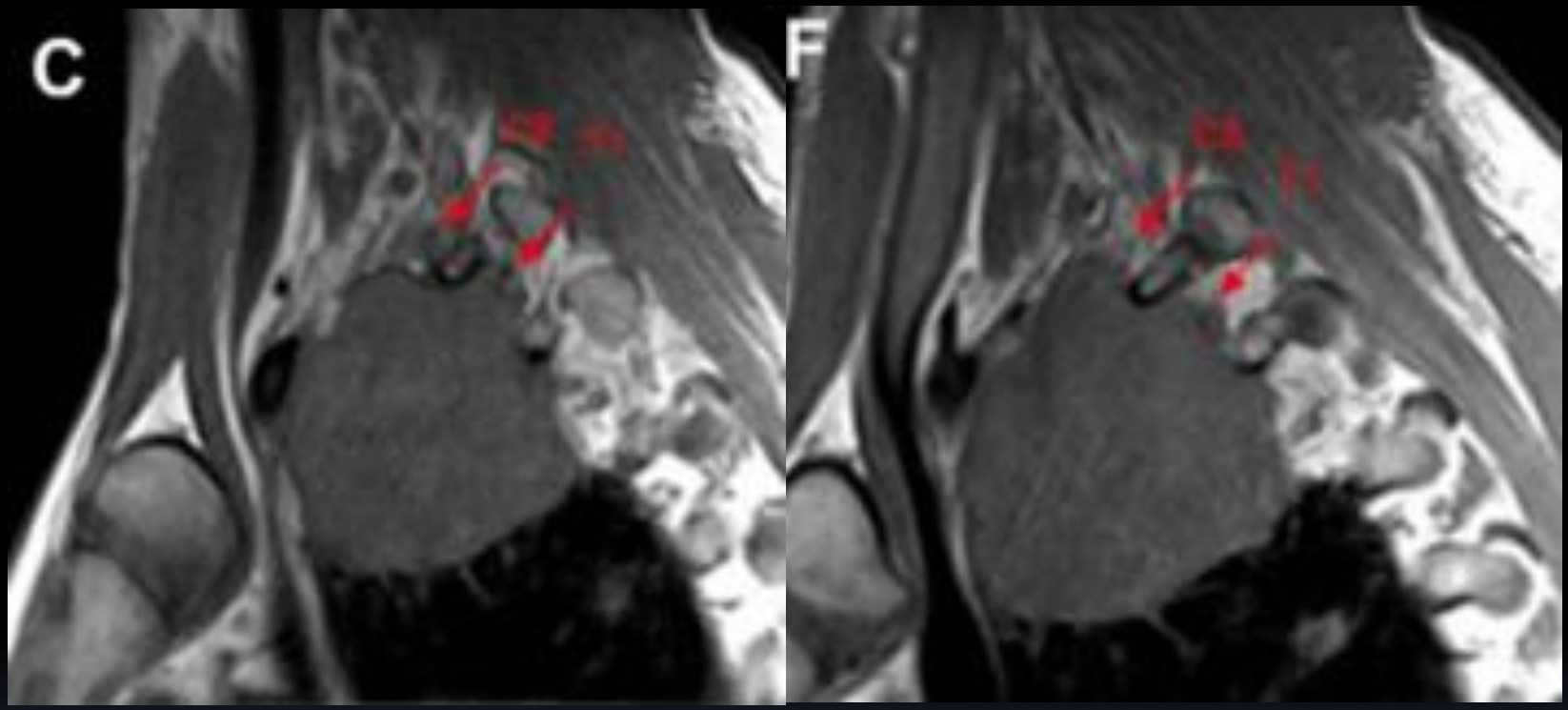
Malignant Neoplasms: Lung CA



- Sagittal T1 images demonstrate a superior sulcus tumor, extending into the region of the interscalene triangle, with intimate involvement of the C8 and T1 ventral roots

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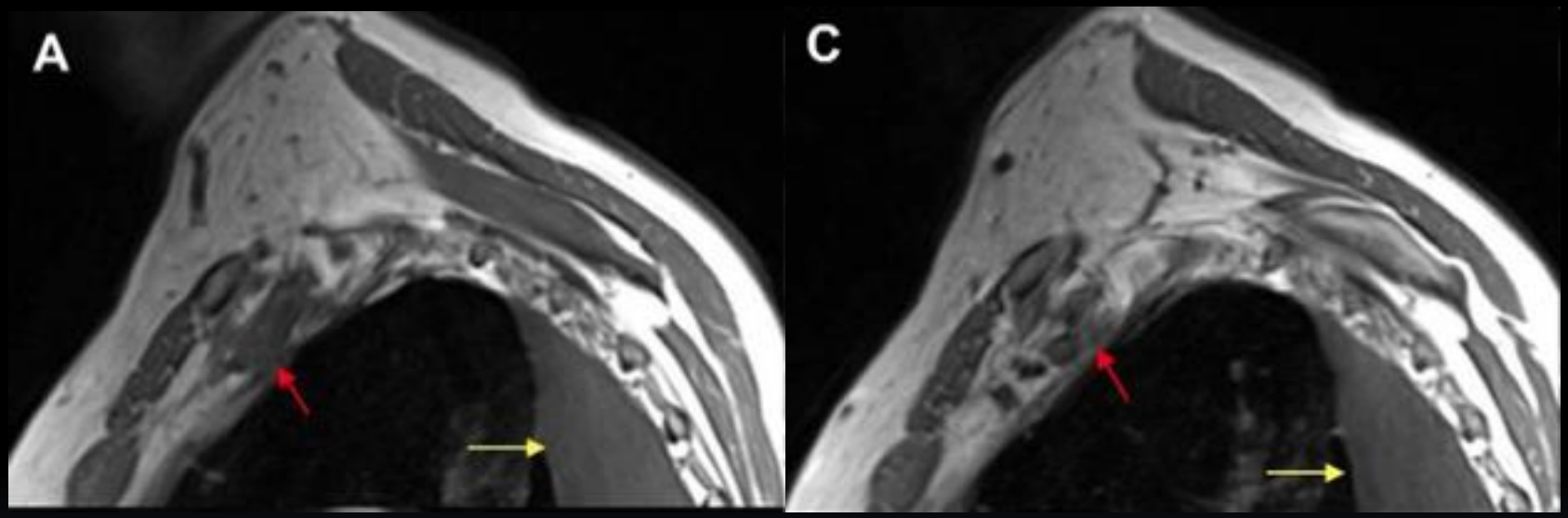
Malignant Neoplasms: Breast CA

54-year-old F, history of breast CA. New-onset LUE weakness, consistent with metastatic breast CA



Sagittal T1 weighted images, costoclavicular space. Ill-defined mass (red arrow) in lateral aspect of the costoclavicular space, surrounding causing indistinct appearance of the divisions, consistent with metastatic breast CA

Mikityansky, et al. Magn Reson Imaging Clin N Am. 2012 Nov;20(4):791-826

TRAUMA OF THE BRACHIAL PLEXUS

BP: Traumatic Injury

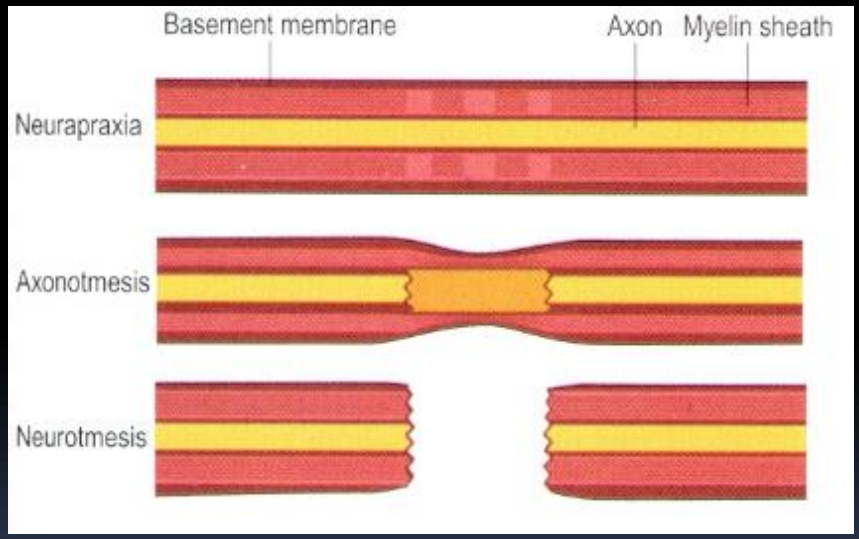
Overview

- Trauma is the MC cause of brachial plexopathy.
- Trauma = commonest indication for brachial plexus surgery
  - Stretch and/or Contusion (49%)
  - Laceration (7%)
  - Gunshot wounds (12%)
  - Tumors (16%)
  - Thoracic Outlet Syndrome (16%)

- Most cases of traumatic injury of the BP involve MVAs, specifically motorcycles and bicycles.
- Also seen at a high incidence in newborns and adolescents

BP: Traumatic Injury

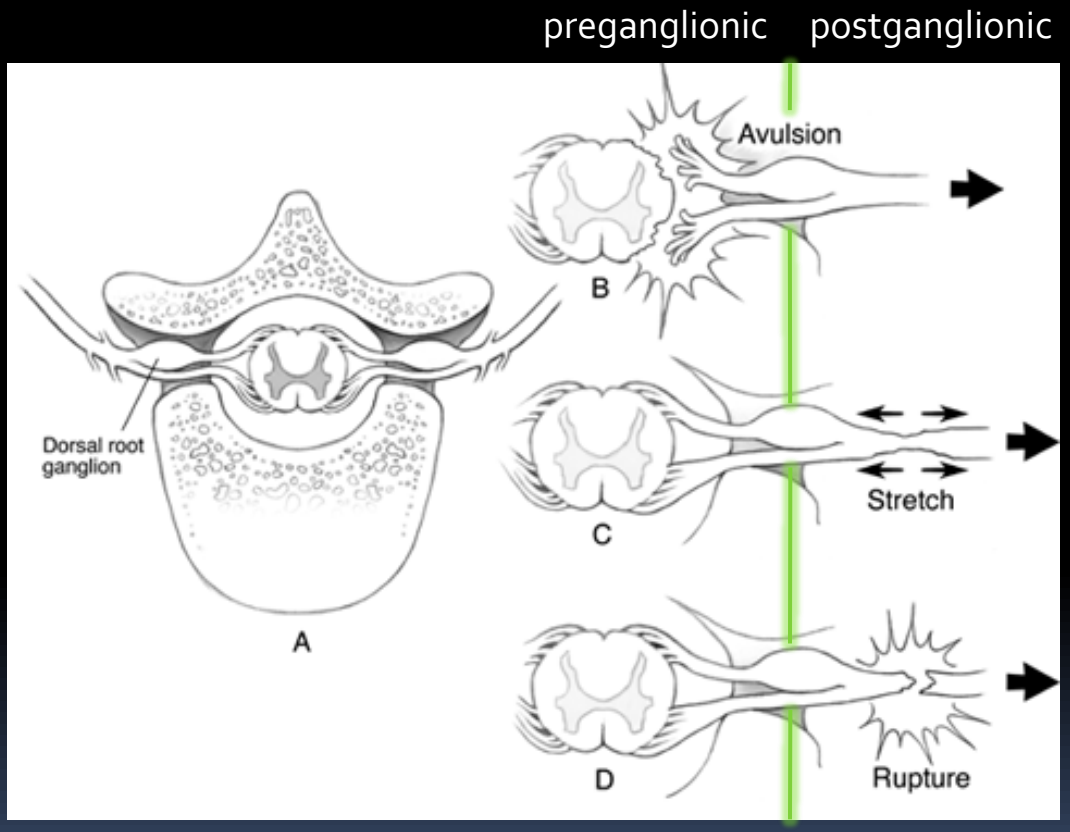
- Seldon Classification of Nerve Injury
  - Neurapraxia
    - Axons and myelin sheath intact
    - Spontaneous recovery of function in weeks
  - Axonotmesis
    - interruption of the axon
    - Intact Schwann sheath
    - Spontaneous recovery requires months to years if axonal regeneration is able to progress across injury zone (axons regenerate at 1mm/day).
  - Neurotmesis
    - Rupture of both axons and myelin sheaths.
    - Spontaneous recovery will not occur



Chung K, Yang LJ-S, McGillicuddy J, editors. Radiographic assessment of adult brachial plexus injuries. China: Elsevier Saunders; 2011.

BP: Traction Injury

- Classification of Traction Injuries
  - Preganglionic injury
    - Complete root avulsion
    - Partial root avulsion
  - Post-ganglionic
    - Stretch injury
      - Neurapraxia
      - Axonotmesis
    - Rupture (Neurotmesis)

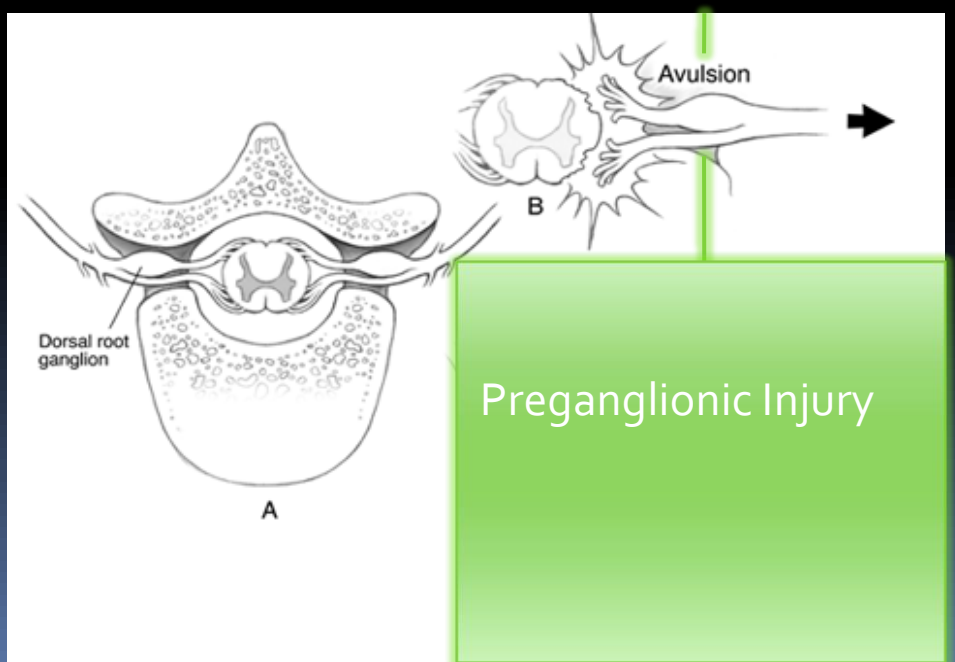


Chung K, Yang LJ-S, McGillicuddy J, editors. Radiographic assessment of adult brachial plexus injuries. China: Elsevier Saunders; 2011.

BP: Traction Injury

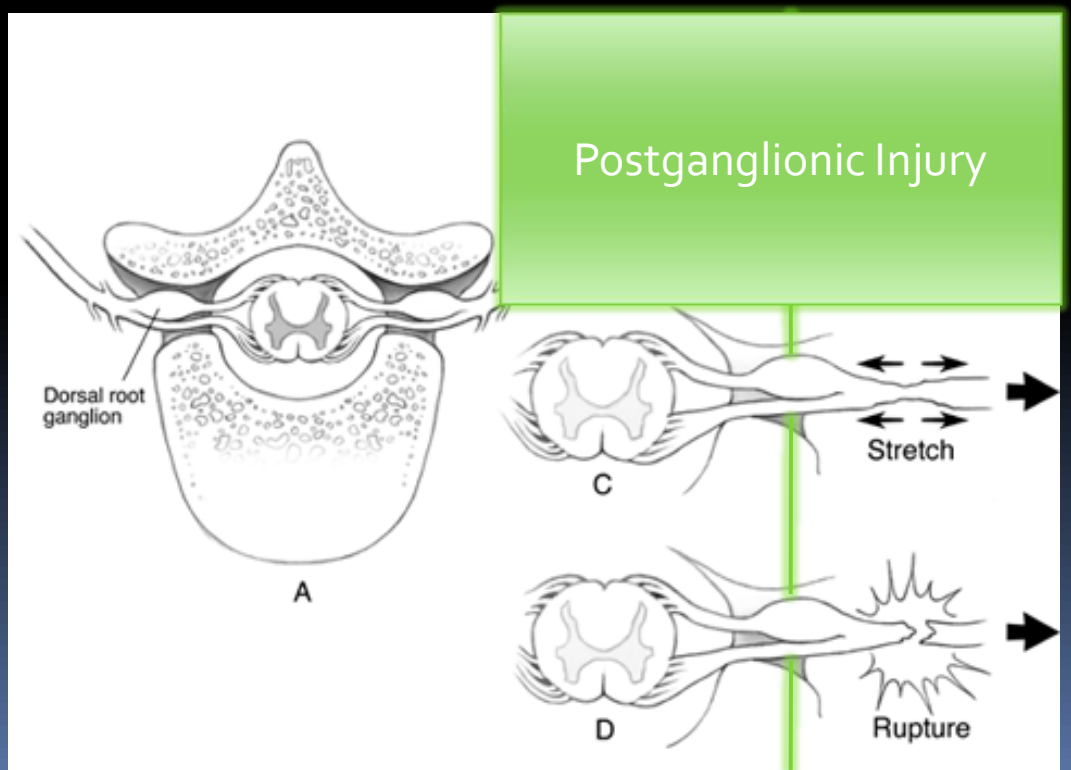
- Preganglionic lesions (figure b)
  - Complete avulsion: Both ventral and dorsal rootlets
  - Partial avulsion: Ventral or dorsal rootlet only

  - Mechanism:
    - Excessive traction → Nerve roots avulsed from the spinal cord → Nerve repair impossible & spontaneous regeneration unlikely
  - Outcome:
    - Permanent paralysis of the muscles innervated by the avulsed roots
    - Complete sensory loss of the corresponding dermatome



BP: Traction Injury

- Postganglionic lesions (Figures c,d)
  - Injury to the brachial plexus (axonal structure), with anatomic preservation of the cell body within the ventral horn of spinal cord
  - Thus nerve can be surgically repaired with the expectation of functional recovery
  - Axons may spontaneously regenerate in the case of axonotmesis (not so in the case of rupture/neurotmesis)



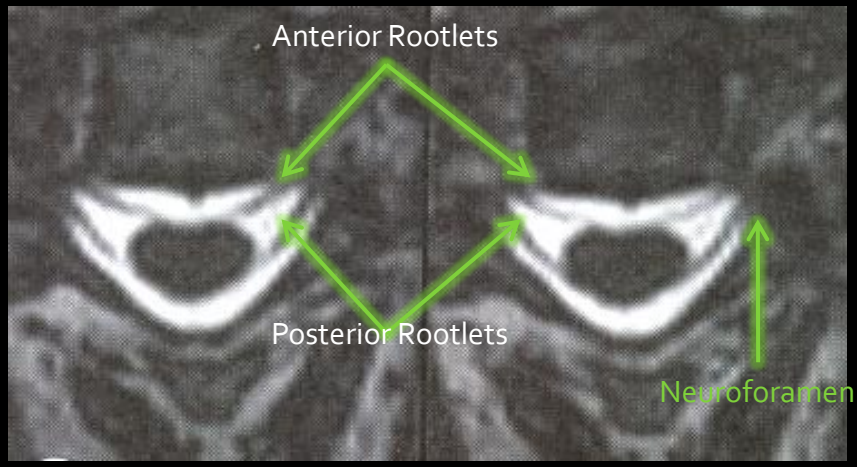
BP: Traction Injury

Normal preganglionic structures (above)

- At the neuroforamen,
- anterior & posterior rootlets

merge

Forms spinal nerve within the dural envelope.

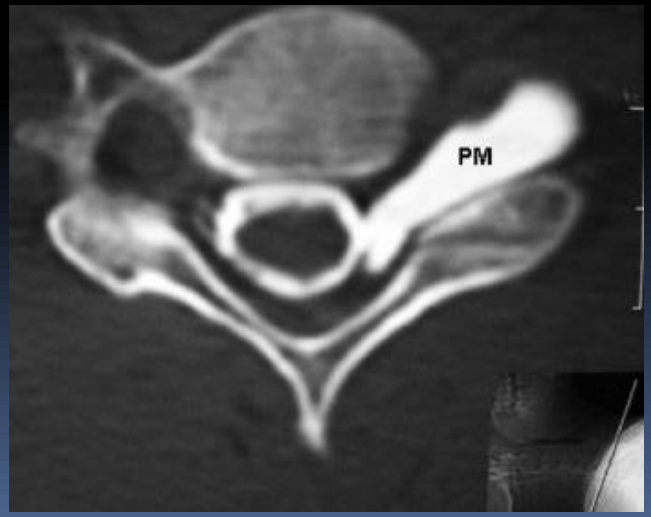


Normal

Traction Injury

- avulsion of ventral/dorsal rootlets from cord
- If an associated dural tear forms → bulging of arachnoid membrane → traumatic pseudomeningocele (below)

Traumatic pseudomeningocele- seen in vast majority (but not all) nerve root avulsions.



Traumatic pseudomeningocele

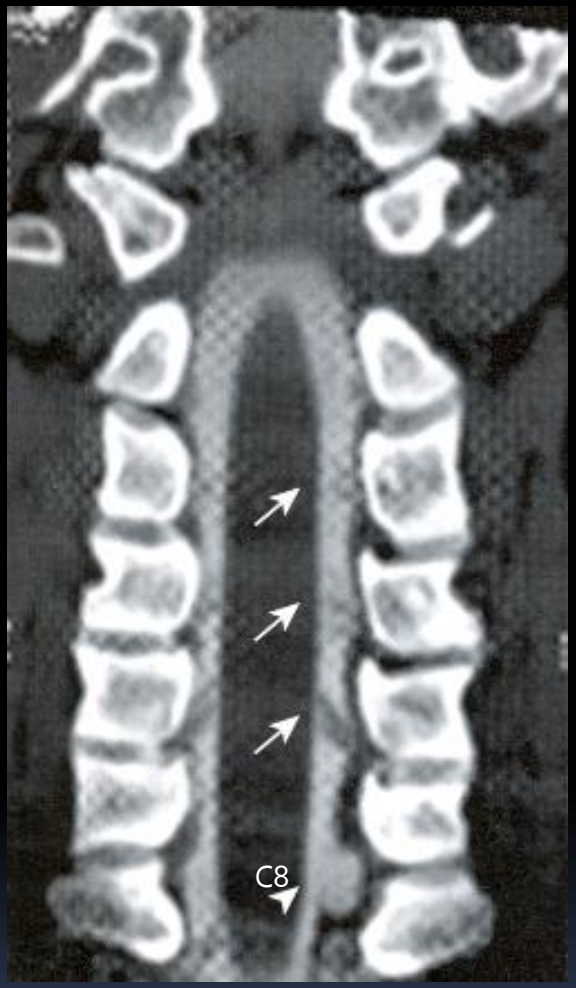
CT Myelography

- Standard examination in setting of trauma to BP
- Superior to X-ray myelography;

- Pros
  - High spatial resolution and accuracy
    - CT w/ isotropic 3D volume acquisition → ability to evaluate roots in any plane → ~100% sensitivity and 96% specificity in determining preganglionic injuries
  - Less intrathecal contrast than conventional myelography
  - Little motion artifact
- Cons
  - Invasive, LP required
  - Radiation to patient
  - Poor soft-tissue visualization of distal BP
  - Visualization of post-traumatic pseudomeningocele depends on contrast

CT Myelography

- Findings of preganglionic injury
  - Nerve root avulsion
    - Seen as absence within the perimedullary subarachnoid space from the cord to the neuroforamina
  - Post-traumatic pseudomeningocele
  - Dural tears and protrusion of nerve roots through a dural tear
  - Compression of nerve roots by penetrating bony fragments



Arrowhead depicts complete avulsion of the left C8 nerve root. A post-traumatic pseudomeningocele is seen as a mushroom-shaped bulge of the contrast beyond the confines of the dural sac

Chung K, Yang LJ-S, McGillicuddy J, editors. Radiographic assessment of adult brachial plexus injuries. China: Elsevier Saunders; 2011.

MR Myelography

- Historically, conventional myelography & CT myelography have been necessary to identify avulsed nerve roots.
- Now, MR myelography has same capability, but has the benefit of being noninvasive

MR Myelography: What is it?

- What is it?
  - 3-D technique used to generate myelogram-like images
  - Relies upon natural contrast between CSF and neural structures
  - Allows 0.7 axial oblique sections from the original 3-D data set
- Pros
  - High spatial resolution:
    - A single nerve rootlet is identifiable on several sections; can be compared with intact rootlets on opposite side → avoids false positives
  - Accuracy:
    - In some instances, shown to approach and/or supersede CT myelography in evaluation of adult BP injuries
  - Optimal visualization of post-traumatic pseudomeningoceles, which does not require contrast

MRM Findings of BP Trauma

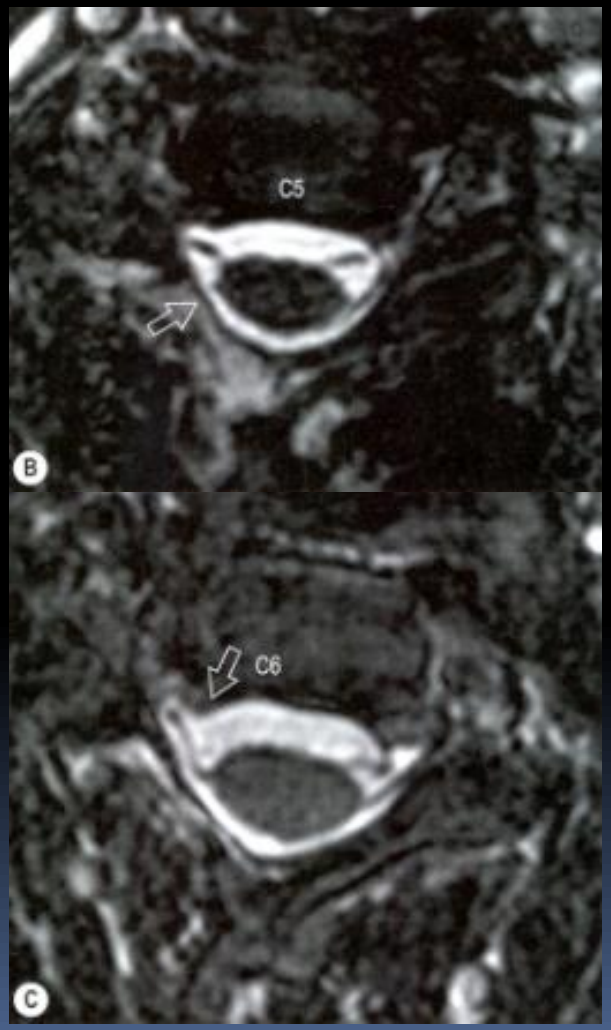
- Left-sided Complete nerve root avulsion
  - Left empty root sleeve with absence of both dorsal and ventral nerve rootlets within the perimedullary subarachnoid space from the cord to the neuroforamina
  - Intact right-sided dorsal and ventral nerve rootlets

Chung K, Yang LJ-S, McGillicuddy J, editors. Radiographic assessment of adult brachial plexus injuries. China: Elsevier Saunders; 2011.

MRM Findings of BP Trauma

- Partial nerve root avulsion
  - Characterized by absence ventral or dorsal rootlets on axial reformatted sections
  - small abnormalities of the root sleeves

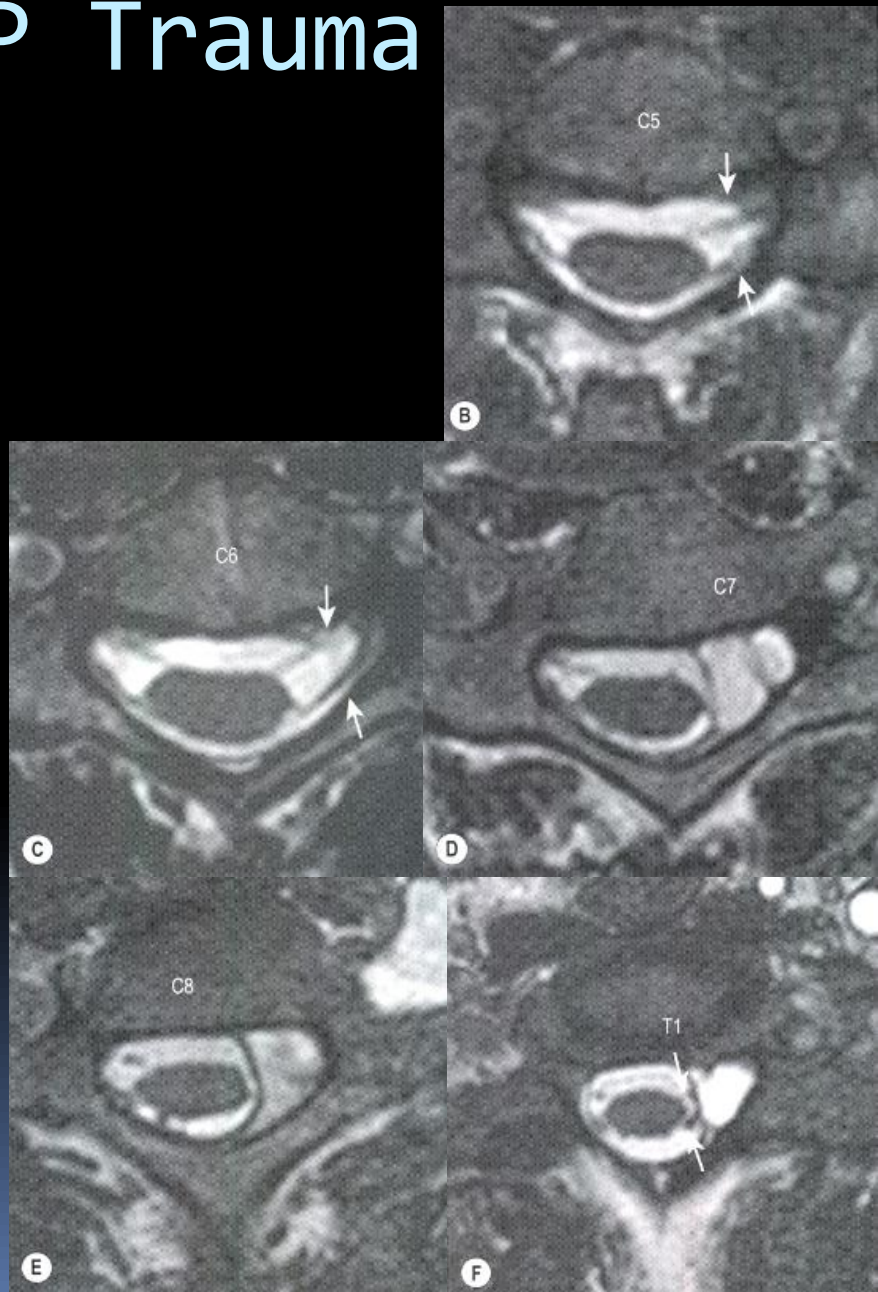
- (Right) 20-year old man with right-sided BP palsy
  - B. C5-Partial nerve root avulsion, with avulsed right dorsal rootlet
  - C. C-6 Partial root avulsion, with avulsed right ventral rootlet



Chung K, Yang LJ-S, McGillicuddy J, editors. Radiographic assessment of adult brachial plexus injuries. China: Elsevier Saunders; 2011.

MRM Findings of BP Trauma

- (Right) Traumatic pseudomeningoceles
  - B,C. Intact nerve roots and normal root sleeves
  - D,E. Traumatic pseudomeningocele with complete root avulsions
  - F. Traumatic pseudomeningocele with intact roots



Chung K, Yang LJ-S, McGillicuddy J, editors. Radiographic assessment of adult brachial plexus injuries. China: Elsevier Saunders; 2011.

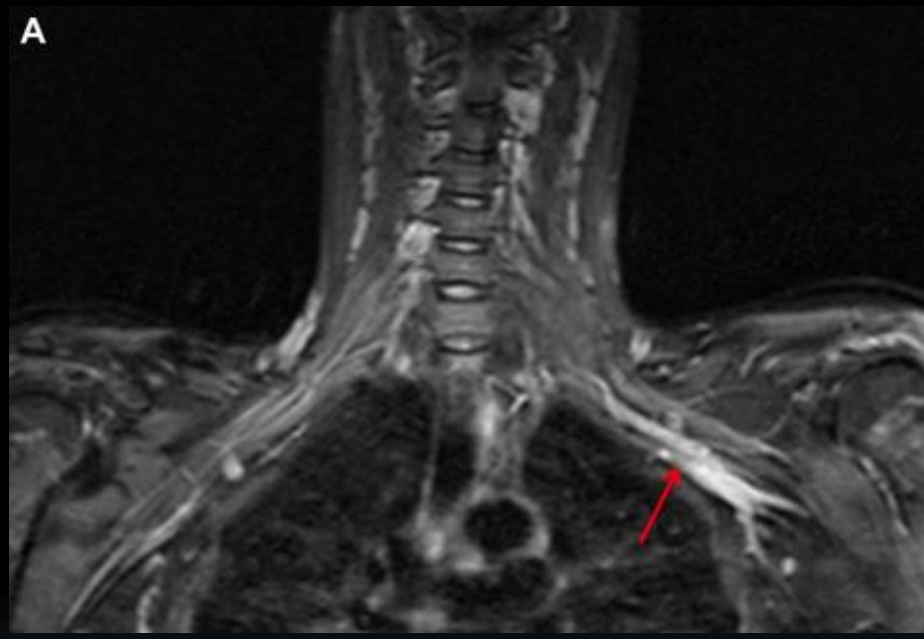
MR Neurography

- What is it?
  - high-resolution, fat-suppresed, heavily T2-weighted STIR sequences, oriented along peripheral nerves, distal to the neuroforamina
- Why useful?
  - Can evaluate nerve morphology
    - fascicular patterns
    - longitudinal variations in caliber
  - Signal intensity
  - Relationships to other nerves
- Recommended planes: coronal & sagittal planes to assess neural elements distal to neuroforamina

MR Neurography: Findings

Findings

- Intact nerves
  - slightly higher SI compared to muscle
- Injured Nerves
  - Marked increase SI on T2WI when compared to intact nerves
  - Signal hyperintensity begins at the level of axonal loss and continues distally
  - Enlarged size
  - Tortuosity of nerves
- Post-traumatic neuroma
  - Round resected margin of the distally retracted nerve



Above: Stretch Injury. Unilateral edem, thickening, and tortuosity of left divisions and cords (arrow) c/w stretch injury

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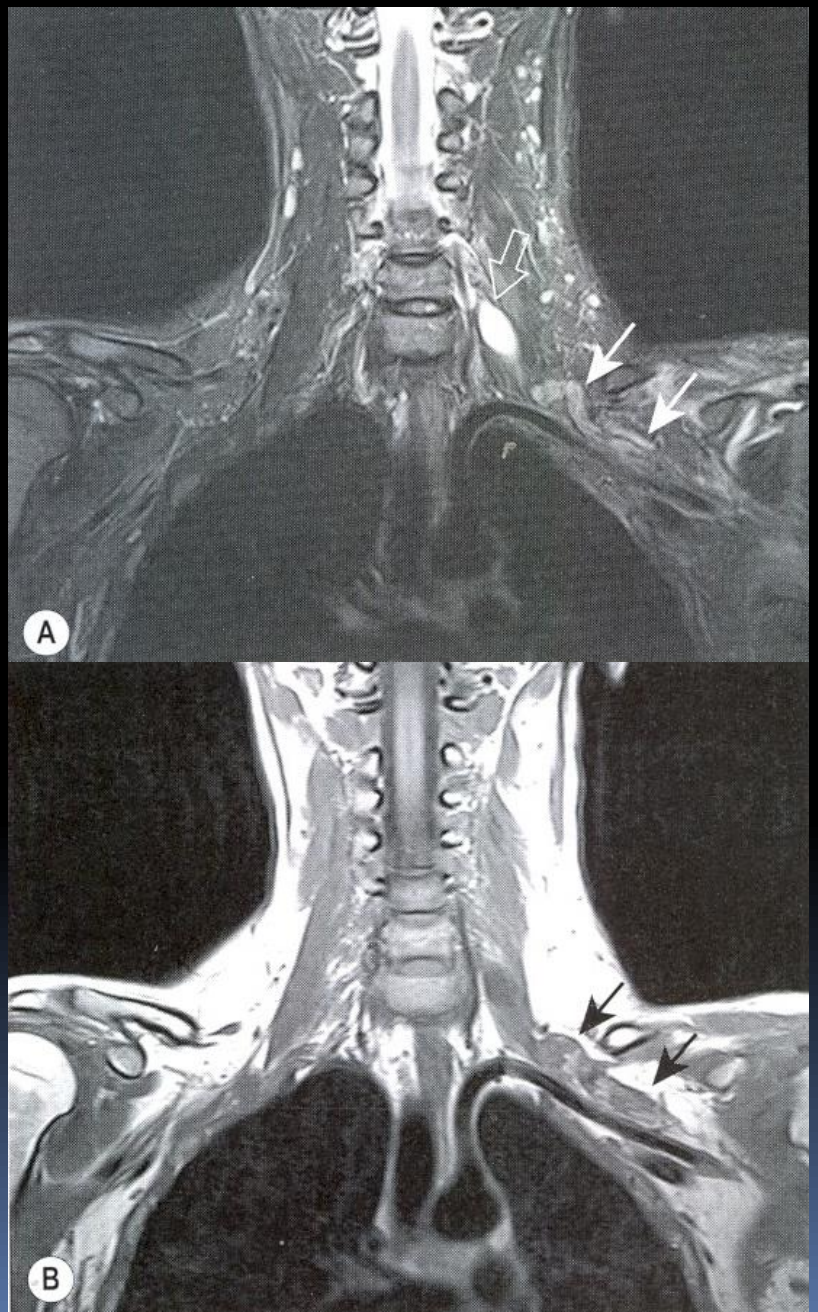
MR Neurography

- 40-year-old woman, 2 months after injury in motorcycle accident
  - MR Neurography
    - left C7-C8 pseudomeningocele
    - Swelling and increased signal intensity of plexus divisions & proximal cords due to severe stretch injury



Chung K, Yang LJ-S, McGillicuddy J, editors. Radiographic assessment of adult brachial plexus injuries. China: Elsevier Saunders; 2011.

Summary

In this talk, we have reviewed…

- Anatomy of the brachial plexus
- Relationship of BP to the thoracic inlet
- Compartments of the thoracic outlet
- NTOS
- Inflammatory/Infectious plexopathy
- Tumors of brachial plexus
  - Benign: desmoid-type fibromatosis, neurofibroma, schwannoma
  - Malignant: metastasis from breast or lung, MPNST
- Trauma and imaging of pre- and post-ganglionic injury

REFERENCES

Brantigan, C and Roos, D. Hand Clin 20 (2004) 17–22
Castillo, AJR Am J Roentgenol. 2005 Dec;185(6 Suppl):S196-204.
Christo, McGreevy. Curr Pain Headache Rep. 2011 Feb;15(1):14-21.
Chung K, Yang LJ-S, McGillicuddy J, editors. Radiographic assessment of adult brachial plexus injuries. China: Elsevier Saunders; 2011.
Demondion, et al. Radiographics. 2006 Nov-Dec;26(6):1735-50
Gasparotti, et al. AJNR Am J Neuroradiol 18:1733–1742, October 1997
Jeung, May 1999 RadioGraphics, 19, 617-637.
Linda, D. Radiographics. 2010 Sep;30(5):1373-400
Mikityansky, et al. Magn Reson Imaging Clin N Am. 2012 Nov;20(4):791-826
Murphey, et al. Radiographics. 2009 Nov;29(7):2143-73.
Murphey et al, September 2004 RadioGraphics, 24, 1477-1481.
Nagano, et al., Journal of Hand Surgery (British Volume, 1989) 14B : 59-64
Seinfeld et al., Neurosurg Focus. 2007 Jun 15;22(6):E22.
Sureka et al., Clinical Radiology (2009) 64, 208e218

Thank you

THE END