Imaging of Brachial Plexus Trauma with an Emphasis on MRI Neurography

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Financial Disclosure

• Nothing to disclose
Learning Objectives

1. Understand how each imaging modality can be used to assess for brachial plexus trauma and the strengths / weaknesses for each modality.

2. Become familiar with the normal and abnormal appearances of the brachial plexus with each imaging modality.
## Ultrasound

### Advantages:
- Probe closer to superficial nerves, allowing for better spatial resolution than MRI
- Fast
- Can assess for dynamic changes to the nerve (impingement or snapping)
- No ionizing radiation
- Can determine if structure is cystic
- Great for claustrophobic patients
- Can be used for diagnostic blocks to help confirm the nerve as a cause

### Disadvantages:
- Operator dependent
- Inability to "see" edema of nerve like on MRI
- Poor tissue contrast compared to MRI
- Cannot see deep nerves well
- Can be difficult to see edema in a muscle, may be able to see atrophy

## MRI

### Advantages:
- Better soft tissue contrast
- Can "see" edema of nerve (increased signal on fluid sensitive pulse sequences, decreased FA)
- No ionizing radiation
- MPR and MIP
- Sees deep nerves better than US
- Can see denervation changes in muscles to supplement EMG (see if muscles affected outside areas tested). Also, can help when patient cannot tolerate EMG / NCS.

### Disadvantages:
- Time consuming
- Less spatial resolution than US for superficial nerves
- Less dynamic capability
- In the absence of contrast, can be difficult to differentiate solid myxomatous masses from cysts

## CT Myelography

### Advantages:
- Spatial resolution

### Disadvantages:
- Radiation, invasive procedure
- Cannot see post-ganglionic injuries
CT Myelography

A-B. Axial CTM demonstrates normal appearance of dorsal and ventral rootlets (white arrows) as they extend from the spinal cord to toward the neural foramen. Note the normal termination of the nerve sleeve within the foramen.

C-E: 28-year-old male with C5-T1 (pan plexus) nerve avulsions related to work accident with resultant flail limb. The patient is five years out from a spinal accessory to suprascapular nerve transfer and intercostal (with sural graft) to musculocutaneous with some shoulder recovery, but no significant elbow flexion.

C: Conventional myelogram shows multiple left sided outpouchings of contrast at the level of the neural foramina (pseudomeningoceles) involving C5 – T1.

D-E: CTM shows pseudomeningoceles (red arrows) with normal rootlets above and on the right side (green arrows).
**HR Nerve Ultrasound**

- **Short axis:** cross section through nerve
  - Should look like a bunch of nearly uniform hypoechoic (dark) dots surrounded by hyperechoic fat
  - Likened to a cluster of grapes
  - Should demonstrate continuity along course of nerve

- **Long axis:** parallel to length of nerve
  - Should look like elongated uniform hypoechoic cables surrounded by hyperechoic fat
  - Likened to a cable
  - Fascicles are thicker than smaller tendon collagen bundles
Neurofibromatosis, type 1

Example of normal and abnormal fascicular architecture by US
Example of normal US images of the radial nerve with corresponding MRI from institutional teaching atlas
MR and US Neurography Overview

Normal fascicular architecture of the ulnar nerve at the cubital tunnel
**MR and US Neurography Overview**

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**MRI Neurography**

No different than ordering an MRI except we use different pulse sequences to optimize visualization of the nerve.

- No official definition at this time
- In general, usually makes use of a fluid sensitive fat suppressed pulse sequence with very thin slices (near isotropic) allowing for reconstructions in any plane.
- Usually also makes use of a non-fat suppressed T1 weighted pulse sequence for anatomic definition and to look for perineurial fibrosis.

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**STANDARD MRN PROTOCOL AT EMORY NOW:**

- STIR SPACE (3D FS fluid sensitive) +/- PSIF
- T1 SPACE (3D, no fat suppression)
- 2D in plane sagittal PDFS or STIR (1.5 mm thick slices)
- MR myelography: heavily T2 weighted 3D imaging of preganglionic rootlets

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**MR myography:**

- Thick slices STIR. Sampling tissue in various parts of affected limb looking for denervation change.
MR and US Neurography Overview

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MR and US Neurography Overview

- **IV Contrast:**
  - In general, not indicated for MRN (especially trauma).
  - The main indication is for suspected involvement of the nerves with tumor. A common indication would be recurrent tumor versus post-radiation change.
  - Currently, there is debate as to whether a neuroma in continuity enhances or not.
  - Also may be used for suspected thoracic outlet syndrome (MRA).
MR and US Neurography Overview

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<table>
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<th>Sunderland</th>
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<td>Thick, increased T2 signal</td>
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<tr>
<td>5th Degree</td>
<td>Neurotmesis</td>
<td>Complete transection</td>
<td>Denervation</td>
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Pitfall – Early Imaging

• Imaging too soon after the injury can mask injuries due to extensive edema/blood products in the region.

• May take weeks for denervation edema to become present on MRI.

• Scar tissue and blood in the foramina may make seeing a pseudomeningocele difficult.

• A proven protocol has not been established, but at Emory, we prefer to wait 4 weeks after the injury before imaging with MRN.
**MRI Neurography**

- **Secondary signs of brachial plexus injury**
  - Denervation in paraspinal muscle suggests preganglionic injury.
  - Cord edema or hemorrhage at site of trauma.
  - Blood products around area of avulsion or in neural foramen.
  - Pseudomenigoceles (20% of rootlet avulsions may not have pseudomenigoceles while 15% of pseudomenigoceles may not be associated with complete rootlet avulsions).

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**Case 1:** 76 year-old-male with pan plexus injury and flail limb.

A-B: Initial trauma routine MRI cervical spine. At the level of the C8 and T1 nerve roots, there is intermediate signal intensity filling the right foramina and there is cord edema (red arrow) with adjacent blood products (green arrow). No fluid is present at these levels initially.

C-D: One week later, also as part of a standard cervical spine MRI (2D T2 weighted axial images) there is developing fluid in these levels (blue arrows).

4 months later the foramen have filled in with fibrotic tissue and partial rootlet injuries are seen.

C8

T1

Case 1
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Case 1
Case 1: Post-ganglionic root transection with superimposed preganglionic C8 and T1 injury
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Case 2: Pre-ganglionic extended upper plexus injury (C5-C7)

32 YOM with traumatic brachial plexus injury.

A: Routine cervical spine MRI, demonstrates marked thickening of C6 (green arrow) and to a lesser extent C5 (white arrow). There is also edema in the anterior and middle scalene muscles around the plexus (compare to contralateral side).

B-D: The patient returned for MRN one month later.

B: 3D STIR MIP images demonstrate a pre-ganglionic injury at C5, C6 and C7 with pseudomeningoceles at C6 and C7.

C: There is now posterior paraspinal (multifidus) denervation (yellow arrow) as seen on the 2D axial PFDS images (may have been present previously in retrospect).

D: 2D PDFS sagittal images depict marked increased signal and fascicle thickening in the posterior and lateral cords sparing the medial cord which matched the patient’s symptoms.
Case 2: Pre-ganglionic extended upper plexus injury (C5-C7)

C5 Level

Blue arrows on left show intact ventral and dorsal rootlets. Single blue arrow on right at dorsal rootlet. Ventral rootlet torn.

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Case 2: Pre-ganglionic extended upper plexus injury (C5-C7)

Blue arrows on left show intact ventral and dorsal rootlets. The right dorsal and ventral rootlets are torn.

Right pseudomeningocele, red arrow.
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C7 Level
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Hyperintense and thickened radial, axillary, median and axillary nerves. Ulnar and medial cutaneous seem spared.
Case 2: Pre-ganglionic extended upper plexus injury (C5-C7)
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Case 3: Pre-ganglionic C8 Avulsion

C8 avulsion, empty nerve sleeve
(compare to contralateral side and above)
Case 3: Pre-ganglionic C8 Avulsion
Summary

1. Peripheral nerve imaging should ideally be tailored to the individual patient’s clinical story and the advantages of each imaging modality can be leveraged to provide as much information as possible.

2. MRN can help identify injuries to both the preganglionic and post-ganglionic brachial plexus better than any other imaging modality alone.
Thank you for your attention!

Questions or comments, please feel free to contact at:

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