Faculty Development Course
MSK-Lecture

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Objectives

• Review by case example management of BP injuries as an introduction to MS problems
• Differentiate between pre & post ganglionic injuries
• Understand the clinical significance between pre & post ganglionic injuries & total plexus involvement
• Understand some of the surgical options
A 21-year-old patient has a lesion of the upper trunk of the brachial plexus (Erb's–Duchenne's paralysis). Which of the following clinical findings is the most likely associated with this clinical entity?

A. Paralysis of the rhomboid major
B. Inability to elevate the arm above the horizontal
C. Arm tending to lie in medial rotation
D. Loss of sensation on the medial side of the arm.
E. Damage to nerve fibers from dorsal primary rami of C5 and C6
Presentation

- Partial or complete
- Bruising to tearing
- Erb's point
- Lower motor neuron synd
Anatomy – Brachial Plexus
"Most Alcoholics Must Really Urinate"

Musculocutaneous

Axillary

Radial

Median

Ulnar

C5

C7

T1

"Reach To Drink Cold Beer"

R = root
T = trunk
D = division
C = cords
B = branches

"3 Y’s" 
"2E’s"
& a connecting rod
## Important Nerves for Upper Brachial Plexus Injury & Reconstruction

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Muscles innervated</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Musculocutaneous</td>
<td>Biceps &amp; Brachialis</td>
<td>Elbow flexion</td>
</tr>
<tr>
<td>Axillary</td>
<td>Deltoid</td>
<td>Shoulder abduction</td>
</tr>
<tr>
<td>Suprascapular</td>
<td>Supraspinatus</td>
<td>Shoulder abduction and stability</td>
</tr>
<tr>
<td>Median</td>
<td>Wrist &amp; Finger Flexion, Radial Hand Sensation</td>
<td>Wrist &amp; Finger Flexion, Hand Sensation</td>
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<tr>
<td>Ulnar</td>
<td>Wrist &amp; Finger Flexion, Ulnar Hand Sensation</td>
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</tr>
</tbody>
</table>
• Traumatic brachial plexus injuries (BPIs) can involve any degree of injury at any level of the plexus
• More severe injury such as rupture of plexal segments or root avulsions are associated with higher energy trauma
Brachial Plexus Injuries (BPI’s) Include:

- Traumatic injury vs. obstetric brachial plexus injury  Erb's palsy (C5-C6)
- Klumpke palsy (C8-T1)
- Total Plexus (C5-T1)
- Burners and stingers
- Parsonage-Turner Synd
Epidemiology

- Supraclavicular injuries complete involvement of all roots is most common
  - 75%-80% of traumatic BPIs
- C5 and C6 upper trunk (Erb palsy)
  - 20%-25% of traumatic BPIs
- C8, T1 or lower (Klumpke palsy)
  - 0.6%-3.0% of traumatic BPIs
Mechanism

- High speed vehicular accidents (mostly motorcycle)
  - 83% of traumatic BPIs
- Caudally forced shoulder
  - predominantly affect upper brachial plexus
  - with high enough energy all roots can be affected
- Forced arm abduction (as in grabbing onto something while falling)
  - predominantly affects lower roots
Prognosis

• Recovery can take up to 3 years
• 1-1.5mm/day
• Infraclavicular plexus (post-ganglionic injuries) injuries have better prognosis than supraclavicular injuries
• Root avulsion (pre-ganglionic injuries) have worst prognosis not repairable
Preganglionic Lesions

- Avulsions proximal to dorsal root ganglion
  - involves CNS which does not regenerate – little potential recovery of motor function (poor prognosis)
Preganglionic Lesions (con’t)

- Lesions suggesting preganglionic injury:
  - Horner’s syndrome
    - disruption of sympathetic chain
  - winged scapula medially
    - loss of serratus anterior (long thoracic nerve) rhomboids (dorsal scapular nerve) leads to medial winging (inferior border goes medial)
  - presents with motor deficits (flail arm)
  - sensory deficits
  - absence of a Tinel sign or tenderness to percussion in the neck
  - normal histamine test (C8-T1 sympathetic ganglion)
    - intact triple response (redness, wheal, flare)
  - elevated hemidiaphragm (phrenic nerve)
  - rhomboid paralysis (dorsal scapular nerve)
  - supraspinatus/infraspinatus (suprascapular nerve)
  - latissimus dorsi (thoracodorsal)
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- Evaluation
  - EMG may show loss of innervation to cervical paraspinals
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Postganglionic

- Involve PNS, capable of regeneration (better prognosis)
- Presentation
  - presents with motor deficit (flail arm)
  - sensory deficits
- Evaluation
  - EMG shows maintained innervation to cervical paraspinals
  - abnormal histamine test
    - only redness and wheal, but NO flare
# Erb’s Palsy (C5-C6)

<table>
<thead>
<tr>
<th>General Comments</th>
<th>Physical Exam</th>
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<tbody>
<tr>
<td>Most common obstetric plexopathy</td>
<td>Clinically, arm will be adducted,</td>
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<tr>
<td></td>
<td>internally rotated at shoulder, pronated,</td>
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<td></td>
<td>extended at elbow (“waiter’s tip position”)</td>
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<tr>
<td>Results from excessive displacement of</td>
<td>C5 Deficiency</td>
</tr>
<tr>
<td>head to opposite side &amp; depression of shoulder on</td>
<td>- Axillary nerve def. (weakness in deltoide</td>
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<tr>
<td>same side producing traction on plexus</td>
<td>, teres minor)</td>
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<tr>
<td></td>
<td>- Suprascapular nerve def. (weakness in</td>
</tr>
<tr>
<td></td>
<td>supraspinatus, infraspinatus)</td>
</tr>
<tr>
<td></td>
<td>- Musculocutaneous nerve def. (to biceps and</td>
</tr>
<tr>
<td></td>
<td>brachialis)</td>
</tr>
<tr>
<td>Occurs during difficult delivery in infants or falls</td>
<td>C6 Deficiency</td>
</tr>
<tr>
<td>onto shoulder in adults</td>
<td>- Radial nerve def. (weakness in brachioradialis,</td>
</tr>
<tr>
<td></td>
<td>supinator)</td>
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<tr>
<td>Best prognosis</td>
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</table>
# Klumpke’s Palsy (C8-T1)

<table>
<thead>
<tr>
<th>General Comments</th>
<th>Physical Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rare in obstetric palsy</td>
<td>Deficit of all the small muscles of the hand (ulnar &amp; median nerves)</td>
</tr>
<tr>
<td>Usually avulsion injuries caused by excessive abduction (person falling from height clutching on object to save himself)</td>
<td>Clinically, presents as a “claw hand”</td>
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<tr>
<td>Other causes may include cervical rib, or lung mets in lower deep cervical lymph nodes</td>
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<tr>
<td>Frequently associated with a preganglionic injury &amp; Horner’s Synd.</td>
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<tr>
<td>Poor prognosis</td>
<td></td>
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<td></td>
<td>-wrist held in extreme extension because of the unopposed wrist extensors</td>
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<tr>
<td></td>
<td>-Hyperextension of MCP joints due to loss of hand intrinsics</td>
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<tr>
<td></td>
<td>Flexion of IP joints due to loss of hand intrinsics</td>
</tr>
</tbody>
</table>
## Total Plexus Palsy (C5-T1)

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<thead>
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<th>General Comments</th>
<th>Physical Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete involvement of the Brachial Plexus</td>
<td>Leads to a flaccid extremity</td>
</tr>
<tr>
<td>Worst Prognosis</td>
<td>Involves both motor &amp; sensory</td>
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</tbody>
</table>
Long Term Presentation

• Stunted growth
• Impaired muscular, nervous and circulatory development
• Weak
• Elbow contracture
Presentation

• History
  – high energy injury

• Physical exam
  – Horner's syndrome
    • features include
      – drooping of the left eyelid
      – pupillary constriction
      – anhidrosis
    • usually show up three days after injury
    • represents disruption of sympathetic chain via C8 and/or T1 root avulsions
  – severe pain in anesthetized limb
    • correlates with root avulsion
  – important muscles to test
    • serratus anterior (long thoracic nerve) and rhomboids (dorsal scapular nerve)
      – if they are functioning then it is more likely the C5 injury is postganglionic
  – pulses
    • check radial, ulnar and brachial pulses
      – arterial injuries common with complete BPIs
Imaging-Radiographs

• Chest radiograph
  – recommended views
    • PA and lateral
  – fractures to the first or second ribs suggest damage to the overlying brachial plexus
  – evidence of old rib fractures can be important in case intercostal nerve is needed for nerve transfer
  – inspiration and expiration can demonstrate a paralyzed diaphragm (indicates upper nerve root injury)

• Cervical spine series
  – recommended views
    • AP and lateral
  – transverse process fracture likely indicates a root avulsion
Imaging-Radiographs (con’t)

• Scapular and shoulder series
  – recommended views
    • at least AP and axillary (or equivalent)
  – scapulothoracic dissociation is associated with root avulsion and major vascular injury

• Clavicle
  – recommended views
    • orthogonal views
  – fracture may indicate brachial plexus injury
Imaging-CT myelography

• Indications
  – gold standard for defining level of nerve root injury
• avulsion of cervical root causes dural sheath to heal with meningocele
• scan should be done 3-4 weeks after injury
  – allows blood clot in the injured area to dissipate and meningocele to form
Imaging-MRI

- Indications suspect injury is distal to nerve roots
  - can visualize much of the brachial plexus
  - CT/myelogram demonstrates only nerve root injury
- Findings traumatic neuromas and edema
- Mass lesions in nontraumatic neuropathy of brachial plexus and its branches
- Consistent with injury include
  - Pseudomeningocele (T2 highlights water content present in a pseudomeningocele)
  - Empty nerve root sleeves (T1 images highlight fat content nerve roots and empty sleeves)
  - Cord shift away from midline (T1 highlights fat of cord)
Studies-Electromyography (EMG)

• Tests muscles at rest and during activity
• Fibrillation potentials (denervation changes)
  – as early as 10-14 days following injury in proximal muscles
  – as late as 3-6 weeks in distal muscles
• Can help distinguish preganglionic from postganglionic
  – examine proximally innervated muscles that are
    innervated by root level motor branches
    • rhomboids
    • serratus anterior
    • cervical paraspinals
Studies—Nerve conduction velocity (NCV)

- Performed along with EMG
- Measures sensory nerve action potentials (SNAPs)
  - distinguishes preganglionic from postganglionic
  - SNAPs preserved in lesions proximal to dorsal root ganglia
    - cell body found in dorsal root ganglia
  - if SNAP normal and patient insensate in ulnar nerve distribution
    - preganglionic injury to C8 and T1
  - if SNAP normal and patient insensate in median nerve distribution
    - preganglionic injury to C5 and C6
Innervation to the Paraspinal Muscles

Via the Dorsal ramus
Studies-Nerve action potential (NAPs)

- Often intraoperative
- Tests a nerve across a lesion
- If NAP positive across a lesion
  - preserved axons
  - or significant regeneration
- Can detect reinnervation months before EMG
  - NAP negative-neuropraxic lesion
  - NAP positive- axonotmetic lesion
Studies-Sensory and Motor Evoked Potential

• More sensitive than EMG and NCV at identifying continuity of roots with spinal cord (positive finding)
  – a negative finding cannot differentiate location of discontinuity (root avulsion vs. axonotmesis)

• Perform 4-6 weeks after injury to allow for Wallerian degeneration to occur

• Stimulation done at Erb's point and recording done over cortex with scalp electrodes (transcranial)
Treatment-Nonoperative

• Observation alone waiting for recovery indications
  – most managed with closed observation
  – guns shot wounds (in absence of major vascular damage can observe for three months)

• Signs of neurologic recovery
  – advancing Tinel sign is best clinical sign of effective nerve regeneration
Treatment-Operative

• “Immediate surgical exploration” (< 1 week)
• Indications
  – sharp penetrating trauma (excluding GSWs)
  – iatrogenic injuries
  – open injuries
  – progressive neurologic deficits
  – expanding hematoma or vascular injury
• Techniques
  – nerve repair
  – nerve grafting
  – neurotization
Treatment-Operative

• “Early surgical intervention” (3-6 weeks)
• Indicated for near total plexus involvement and with high mechanism of energy
Treatment-Operative

• “Delayed surgical intervention” (3-6 months)

• Indications
  – partial upper plexus involvement and low energy mechanism
  – plateau in neurologic recovery
  – best not to delay surgery beyond 6 months

• Techniques
  – usually involves tendon/muscle transfers to restore function
Surgical Techniques-Direct nerve Repair

• Rarely possible due to traction and usually only possible for acute and sharp penetration injuries
Surgical Techniques—Nerve graft

• Commonly used due to traction injuries (postganglionic)
• Preferable to graft lesions of upper and middle trunk
  – allows better chance of reinnervation of proximal muscles before irreversible changes at motor end plate
• Donor sites include sural nerve, medial brachial nerve, medial antebrachial cutaneous nerve
• Vascularized nerve graft includes ulnar nerve when there is a proven C8 and T1 avulsion (mobilized on superior ulnar collateral artery)
Surgical Techniques-Neurotization (Nerve Transfers)

- Transfer working but less important motor nerve to a nonfunctioning more important denervated muscle
- Use extraplexal source of axons
  - spinal accessory nerve (CN XI)
  - intercostal nerves
  - contralateral C7
  - hypoglossal nerve (CN XII)
- Intraplexal nerves
  - phrenic nerve
  - portion of median or ulnar nerves
  - pectoral nerve
  - Oberlin transfer
    - ulnar nerve used for upper trunk injury for biceps function
# Nerve Transfer Options (Upper Plexus)

<table>
<thead>
<tr>
<th>Injured Nerve</th>
<th>Nerve Transfer</th>
<th>Function Restored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Musculocutaneous</td>
<td>Median and Ulnar fascicles</td>
<td>Elbow flexion</td>
</tr>
<tr>
<td>Axillary</td>
<td>Radial fascicles</td>
<td>Shoulder Stability &amp; abduction</td>
</tr>
<tr>
<td>Suprascapular</td>
<td>Spinal accessory (XI) fascicles</td>
<td>Shoulder Stability &amp; abduction</td>
</tr>
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</table>


Muscle or Tendon Transfer-Indications

- Isolated C8-T1 injury in adult
- Reinervation unlikely due to distance between injury site & hand intrinsic muscles

Muscle or Tendon Transfer-Priorities of Repair/Reconstruction

- Elbow flexion (musculocutaneous nerve)
- Shoulder stability (suprascapular nerve)
- Brachial-thoracic pinch (pectoral nerve)
- C6-C7 sensory (lateral cord)
- Wrist extension / finger flexion (lateral and posterior cords)
- Wrist flexion / finger extension
- Intrinsic function
Shoulder Fusion
Muscle or Tendon Transfer-Technique

- Gracilis most common free muscle transfer
A 21-year-old patient has a lesion of the upper trunk of the brachial plexus (Erb's–Duchenne's paralysis). Which of the following clinical findings is the most likely associated with clinical entity?

A. Paralysis of the rhomboid major
B. Inability to elevate the arm above the horizontal
C. Arm tending to lie in medial rotation
D. Loss of sensation on the medial side of the arm.
E. Damage to nerve fibers from dorsal primary rami of C5 and C6
The answer is C. A lesion of the upper trunk of the brachial plexus results in a condition known as “waiter’s tip hand” in which the upper extremity tends to lie in internal rotation because of paralysis of the external rotators and the abductors of the shoulders. The long thoracic nerve, which arises from the root (C5-C7) of the brachial plexus, innervates the Serratus Anterior muscle that can elevate the arm above the horizontal. The medial side of the arm receives cutaneous innervation from the medial brachial cutaneous nerve of the medial cord. Nerve fibers from dorsal primary rami of C5 and C6 supply the deep muscles of the back.