Brachial plexus
Brachial Plexus

- Formed by ventral rami of spinal nerves C5-T1
- Five ventral rami form
  - three trunks that separate into
  - six divisions that then form
  - cords that give rise to nerves
- Major nerves
  - Axillary
  - Radial
  - Musculocutaneous
  - Ulnar
  - Median
M shape formed by
1. Musculocutaneous N.
2. Median Nerve
3. Ulnar N.
ERB’S PARALYSIS

- Erb’s point
- Causes Downward traction
- Nerve roots involved
- Muscles Paralysed
- Deformity
- Disability
- deltoid – supraspinatus – infraspinatus – biceps - brachialis
LEFT SIDE PARALYSIS

Erb’s palsy / Erb Duchenne Palsy
Klumpke’s paralysis -

Site of injury

Cause of injury

Nerve roots involved

Muscles paralysed

Deformity

Disability
CLAW HAND

HORNER SYNDROME
Brachial Plexus Injury: Adults

Brachial Plexus Mechanism of Injury
Injury Classification

Millesi classification*

- Supraganglionic
- Infraganglionic
- Trunk
- Cord

Anatomical Classification

- C5-6 waiters tip (Erbs palsy)
- C5-7 as above, elbow slightly flexed
- C5-T1 flail limb, claw hand, vasomotor changes, +/- Horner's syndrome
Preganglionic Injury

- Nerve root avulsion
  - dorsal & ventral rootlets
  - invested by pia mater / dural funnel

- etiology: traction (occasionally missile, knife)
  - Significant traction causes dural rupture / root vulnerability
  - ventral > dorsal root (esp C8-T1) at higher risk
  - POOR Prognosis!
Grades of Injury

- Grade 1 – Neuropraxia
  - Disruption in nerve function that produces numbness and tingling
  - Most common grade within athletics
  - Symptoms usually resolve within several minutes

- Grade 2 – Axonotmesis
  - Damage to the nerve’s axon
  - Symptoms = numbness, tingling, and affected function (may last several days)
  - Long nerves have a greater healing time than short nerves
  - Rare within athletics
  - Motor march, Tinel sign

- Grade 3 – Neurotmesis
  - Permanent nerve damage occurs
  - Very rare within athletics
  - “Occurs with high-energy trauma, fractures, and penetrating injuries”
How do you Rx the patient knocked off his motorcycle with clavicle # and flail arm?

- **Manage acute injury according to ATLS principles; look for concomitant injury ie c-spine.**

- **History**
  - Age, hand dominant, occupation, special skills
  - Cause of injury: arm hyperabducted vs neck laterally flexed
  - Immediate or delayed arm weakness
  - Concomitant injury
  - General health: PMH, DH, Smoker
Aim of examination

- Determine extent of injury

(Name by root value)

- Determine level/proximity of injury

- Donors

  - Nerve donors

  - Nerve source of neurotisation/grafts

- Muscle donors
Clinical Examination
General
  Observe how patient removes his shirt
  Altitude of UL – normally flail, IR, adducted
  Wasted UL with dry skin
  ? Scars/ bruises (Neck)
  ? Horner Syndrome
Inspection of UL
Comment on muscle bulk   
(behind -> front)   &   (proximal -> distal)
Deltoid (also ? sulcus sign; ? reducible)
Supra/ Infraspinatusko
Biceps/ Triceps
Forearm
Hand (Intrinsics)   ? clawing
Palpation
SCJ -> clavicle -> ACJ -> Shoulder   ->
spine of scapula
Over whole UL       ?deformity/ mi
Tinel’s sign over supraclavicular area
Suggestive of post ganglionic lesion
Quick screening for joint stiffness (passive
ROM)
Move
Back -> front; Proximal -> distal
? pre or post ganglionic lesion
Trapezius (spinal accessory n) – shrug shoulder
Rhomboids (dorsal scapular n) – shoulder retraction (may have contribution from C4)
Serratus anterior (long thoracic n) – winging of scapular

Shoulder
Abduction (Supraspinatus -> Suprascapular n ; Deltoid -> axillary n)
Flexion/ Abd/ Ext ( Deltoid – anterior, middle & posterior fibers)

Elbow
Flexion (Biceps -> musculocutaneous n)
Extension (Triceps -> radial n)
Remember to eliminate gravity
Wrist
   Extension
   Flexion

Hand/ Fingers
   Abduction
   Adduction
   Flexion
   Extension
**Sensation**
According to dermatomes
Pain or light touch

**Pulses**
Radial pulse (compare to normal side)

**Others**
Chest percussion (Phrenic n)
Any scar for previous chest tube (Intercostal n)
Lat dorsi ms (cough, feel for contraction)
Pectoralis ms (Shoulder adduction and extension)
Sural n (? Scar or sensation over lateral aspect of dorsum foot)
Upper plexus C5 C6 – unable to
Abduct shoulder (deltoid/ supraspinatus)
ER shoulder (infraspinatus/ teres minor)
Flex elbow (biceps/ brachialis/ brachioradialis)
Supinate forearm (supinator)

Sensory deficit over deltoid, lateral aspect of forearm & hand

Upper plexus C5 C6 C7 –
Same as C5 C6 palsy +
Unable to extend elbow +/- wrist

Lower plexus C8/T1
Weak intrinsic of hand
Paralysis of wrist & fingers flexors
Claw hand deformity

Sensory deficit over medial aspect of arm, forearm & hand

Complete BPI
With or without recovery
Pre ganglionic lesion

**Upper proximal**
Paralysis of rhomboids (dorsal scapular n), serratus anterior (long thoracic n) & diaphragm (phrenic n)

**Lower proximal**
Horner Syndrome (lower plexus root avulsion, damage of stellate ganglion at level of T1)

**Tinel’s sign**
Over supraclavicular region
Indicates nerve regeneration
Suggestive of Post ganglionic lesion
Intraplexus
Median n & Ulnar n – only in upper plexus injury

Extraplexus
Spinal accessory n (trapezius)
Intercostal n
Contralateral C7 (sensation over tip of middle finger)
Phrenic n (chest percussion)
Sural n (sensation over lateral aspect of foot) – as a cable graft

Trapezius (spinal accessory n)
Pect major (med & lat pectoral n)
Lat dorsi (long thoracic n)
Triceps (radial n)
<table>
<thead>
<tr>
<th>Region</th>
<th>Motor Deficits</th>
<th>Sensory Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5-C6</td>
<td>Shoulder abduction, shoulder flexion, elbow flexion, and wrist extension</td>
<td>Lateral arm, 1st digit, and 2nd digit</td>
</tr>
<tr>
<td>C7</td>
<td>Elbow extension weakness and wrist flexion</td>
<td>Pad of index finger</td>
</tr>
<tr>
<td>C8-T1 (very rare)</td>
<td>Finger abduction/adduction and thumb flexors/extensors</td>
<td>4th digit, 5th digit, medial forearm, and medial arm</td>
</tr>
<tr>
<td>C5-T1</td>
<td>Scapular motion and entire arm</td>
<td>Entire arm, forearm, and hand</td>
</tr>
</tbody>
</table>
Neurological Examination

<table>
<thead>
<tr>
<th>Dermatomes</th>
<th>Myotomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5 Lateral arm</td>
<td>Shoulder abduction</td>
</tr>
<tr>
<td>C6 Lateral forearm, thumb, index finger</td>
<td>Elbow flexion or wrist extension</td>
</tr>
<tr>
<td>C7 Posterior forearm, middle finger</td>
<td>Elbow extension or wrist flexion</td>
</tr>
<tr>
<td>C8 Medial forearm, ring and little finger</td>
<td>Grip strength, shake hands</td>
</tr>
<tr>
<td>T1 Medial arm</td>
<td>Interossei, spread fingers and resist finger adduction</td>
</tr>
</tbody>
</table>
DERMATOMES OF UPPER LIMB
Examine the Back

Wall test for serratus ant (winging scapula)

Note weak trapezius (asymmetric shrug)
Investigations

Imaging: Xray: AP chest (look for teeth and fractures), AP + lat views shoulder, C-Spine (AP, lat, odontoid peg), Fine-cut CT, MRI
Investigations

- Lung function test
- CT angio (if indicated)
- Nerve conduction test and EMG
Management

- Early treatment
  - physio: maintain supple joints with FROM
  - Brace / splinting
  - Pain control

- Surgical options:
  - nerve transfers
  - nerve grafting
  - muscle transfers
  - free muscle transfers
  - neurolysis of scar in incomplete lesions
  - Arthrodesis to stabilise joints
How to manage a BPI victim

- Open wounds
  - Sharp injury
  - Bullet injury

- Closed injuries
Sharp injury

Chest tube
Junction of trunk and cords

Clavicle osteotomy
Nerve repair and graft
- Closed injury, (tractional injuries)
Closed injury, (tractional injuries)

- Early exploration
- Underobservation
- Decision for the time of delay exploration
- Decision for the type of the treatment

- Late reconstruction

Straight on Brachial plexus
- Closed injury, (tractional injuries)
  - Early exploration
  - Underobservation
  - Decision for the time of delay exploration
  - Decision for the type of the treatment
  - Late reconstruction

Peripheral reconstruction
- Closed injury, (tractional injuries)
  - Early exploration
  - Underobservation

**First 3 months**
- Stabilization of the patient
- Stabilization of the injury
- Evaluation of the improvement

**After 3 months**
- No improvement: surgery
- Progressive improve; wait & watch

Based on severity
Closed injury, (tractional injuries)

- Early exploration
- Under observation
- Decision for the time of delay exploration
  - No recovery
    - After 3 months (based on the severity of the trauma)
  - Progressive improvement
    - Wait for further improvement
- Non-anatomic recovery
  - Exploration before 9-12 months
- Closed injury, (tractional injuries)
  - Early exploration
  - Under observation
  - Decision for the time of delay exploration
  - Decision for the type of the treatment
Treatment options’ indication

- Neurolysis
- Nerve graft
- Nerve transfer
- Tendon transfer
- Arthrodesis
- Functional muscle flaps

Straight on Brachial Plexus
Early exploration
Delay exploration

Peripheral reconstruction
Late reconstruction
Danger of more damage
Failure is obvious
After neurolysis from scar tissue
Treatment options’ indication

- Neurolysis
- Nerve repair...
- Nerve graft
- Nerve transfer
- Tendon transfer
- Arthrodesis
- Functional muscle flaps
Treatment options’ indication

- Neurolysis
- Nerve repair
- Nerve graft eg sural nerve
- Nerve transfer
- Tendon transfer
- Arthrodesis
- Functional muscle flaps
Treatment options’ indication

- Neurolysis
- Nerve repair
- Nerve graft
- Nerve transfer..neurotization

- Tendon transfer
- Arthrodesis

- Functional muscle flaps

- Accessory nerve
- Phrenic nerve
- Intercostal nerves
- Ulnar ECU nerve
- Crossed C7
- Hypoglossal nerve
Motor cycle accident open wound
Injured upper trunk
Superascapular nerve
Accessory
- Oberlin nerve transfer
Oberlin nerve transfer
Biceps m.
Ulnar n.
Anastamosis
Radial to axillary transfer
Treatment options’ indication

- Neurolysis
- Nerve repair
- Nerve graft
- Nerve transfer
- Tendon transfer
- Arthrodesis
- Functional muscle flaps
Latissimus dorsi m.
Latissimus dorsi transfer to flexion elbow and extension finger
Deltoid paralysis
- Trapez to Deltoid
Treatment options’ indication

- Neurolysis
- Nerve repair
- Nerve graft
- Nerve transfer
- Tendon transfer
- Arthrodesis
- Functional muscle flaps
Shoulder arthrodesis in BPI
Treatment options’ indication

- Neurolysis
- Nerve repair
- Nerve graft
- Nerve transfer
- Tendon transfer
- Arthrodesis
- Functional muscle flaps
Gracillis harvest

Accessory n.
First stage of Doi procedure
Partial ulnar n. as a donor nerve
Summary

Brachial plexus injury

- Open sharp injury (High energy)
  - Immediate exploration
- Shot gun (Low energy)
  - Exploration
    - Exploration in 12 months
      - Gradual improvement
    - Non-anatomic improvement
      - Peripheral reanimation > 12 months
- Tractional injury
  - Exploration
    - No improvement in 2-3 months
Anatomy of the median
Anatomy of the median
Anatomy of the median
Anatomy of the median

Superficial layer of muscles:
PT, FCR, PL FCU

Intermediate layer of muscles:
FDS

Deep layer of muscles:
PQ, FPL, FDP

Thener eminence muscles:
OP, ABPb, FPB
Clinical evaluation
Clinical evaluation
High median nerve palsy

Injury of the median nerve above the level of innervation of the forearm muscles with paralysis of PT, PQ, FCR, FDS, FDP (2nd -3rd), FPL, PL, Sensory loss, opposition loss
Low median nerve palsy

Injury of the median nerve below the level of innervation of the forearm muscles with only Sensory & opposition loss
Tendon transfer...

**Goals;** opposition, IP flexion of 1\textsuperscript{st} & 2\textsuperscript{nd} digits,
FDS opponensplasty (Bunnel type)
Opponensplasty
ADM use in Huber transfer.
Camitz Procedure
Side tenorrhaphy of FDP & brachioradialis to FPL transfer in high median nerve palsy
Radial Nerve Palsy
Background

- The radial nerve is the most frequently injured nerve in the upper extremity
  Barton, 1973

- Complete injury to the radial nerve results in the loss of
  - Finger extension
  - Thumb extension
  - Wrist extension
ANATOMY
Radial nerve (C5, 6, 7, 8, T1)
Posterior cord
Axillary n.
Radial n.

To lat. head, triceps
To long head, triceps
To med. head, triceps
To anconeus
To BR
To ECRL
Pathogenesis

- Orthopedic injury
- Tumor and inflammation
- Anatomic compression
- Open wounds
- Other causes
Radial nerve compression can occur as a result of either a benign or malignant neoplasm.

Benign lesions arising from the elbow or proximal radius can lead to PIN paralysis:
- Lipoma
- Fibroma
- Ganglion
CLINICAL EVALUATION
Sensory Examination

- Anesthesia on dorsum:
  - Thumb, index and long fingers
  - 1st and 2nd metacarpal webspaces

- Since deficit is not on a tactile surface, the loss is usually trivial

Barton, 1973
Motor Examination

DEFICIT
Triceps
Brachioradialis
ECRL

LEVEL
Brachial plexus
Humeral shaft
Proximal radial nerve

Extension of wrist & MP joints
Extension & abduction of thumb
Motor Examination

- Posterior interosseous nerve

- Radial deviation of wrist with extension

- Unable to extend fingers and thumb at MP joints

- No sensory deficit
MANAGEMENT
OPEN LESION

EXPLORE

NO INJURY

OBSERVE
(3 months)

IMPROVEMENT

DONE

INJURY

NO IMPROVEMENT

NERVE CONDUCTION STUDIES

SURGICAL RECONSTRUCTION

Lowe, Sen, Mackinnon, 2002
OPEN LESION

EXPLORE

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- SUSPECT TRANSECTION

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Lowe, Sen, Mackinnon, 2002
CLOSED LESION

OBSERVE (3 MONTHS)

IMPROVEMENT

DONE

NO IMPROVEMENT
NERVE CONDUCTION STUDIES

SUSPECT TRANSECTION

SURGICAL RECONSTRUCTION

Lowe, Sen, Mackinnon, 2002
Splinting

- During the observation and potentially nerve regeneration period, splinting becomes an important adjunct
  - Prevent joint contractures
  - Prevent over-stretching of the denervated extensor musculature
  - Maximizing hand function
Static Volar Wrist Cock-up Splint
Dynamic Tenodesis Suspension Splint
Dorsal Wrist Cock-up With Dynamic Finger Extension Splint
Tendon Transfers

- Goals in radial nerve palsy
  1) Wrist extension
  2) Finger (MP joint) extension
  3) Thumb extension and abduction
FCU Transfer

- PT to ECRB
- FCU to EDC
- PL rerouted to EPL
FCU Transfer

- EDC tendons identified proximal to the extensor retinaculum

- Fenestrate EDC tendons in slight oblique orientation from proximal ulnar to distal radial
FCU Transfer

- Transfer is set with FCU in maximum tension
- Wrist in slight extension
- MP joints fully extended
FCU Transfer

- PL to EPL dorsal to the 1st compartment
- Both PL and EPL placed under maximum tension
- Wrist neutral with thumb extended and radially abducted
FCR Transfer

- PT to ECRB
- FCR to EDC
- PL rerouted to EPL

Starr, 1922
Tsuge, 1969
Brand, 1975
FCR Transfer

- **Brand (1975)**
  - Divide EDC tendons to allow end-end sutures between FCR and EDC

- **Tsuge (1969)**
  - Pass FCR through interosseous membrane