Peripheral Nerve Surgery/DREZ Procedures with IONM

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Objectives

• Demonstrate Dorsal Root Entry Zone (DREZ)
• Quick Anatomy Review (Pictures)
• Go Over Related Vocabulary
• Indications for Surgery
• Case Review of Procedures
  – DREZ Lesioning (Cervical Avulsions)
  – Peroneal
  – Median Nerve
  – Thoracic Outlet Syndrome
  – Femoral
  – Piriformis Syndrome
  – Brachial Plexus
Gross Anatomy of Spinal Cord

(a) Spinal cord, posterior view

- Dorsal root
- Dorsal root ganglion
- Cervical spinal nerves
- Cervical enlargement
- Thoracic spinal nerves
- Posterior median sulcus
- Central canal
- Spinal nerve
- Ventral root
- Anterior median fissure

(d) Transverse sections of the spinal cord

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Gross Anatomy of Spinal Cord

(c) Cauda equina, posterior view

Conus medullaris of spinal cord
Cauda equina
Dura mater
Dorsal root ganglia of L2 and L3
1st sacral nerve root
Sacrum (cut)
Filum terminale
Sectional Anatomy of the Spinal Cord
Spinal Nerves: Peripheral Distribution of Sensory Fibers

**KEY**
- Somatic sensations
- Visceral sensations

**Diagram:**
- Dorsal ramus
- Ventral ramus
- Rami communicantes
- Dorsal root
- Ventral root
- Dorsal root ganglion
- Somatic sensory
- Visceral sensory
- From interoceptors of back
- From exteroceptors, proprioceptors of body wall, limbs
- From interoceptors of body wall, limbs
- From exteroceptors, proprioceptors of back
- From interoceptors of visceral organs
Posterior View of Sacral Plexus

- Superior gluteal nerve
- Inferior gluteal nerve
- Posterior femoral cutaneous nerve
- Sciatic nerve
- Pudendal nerve
- Common fibular nerve
- Medial sural cutaneous nerve
- Lateral sural cutaneous nerve
- Medial plantar nerve
- Sural nerve
- Lateral plantar nerve
(d) The sacral plexus, posterior view
Vocabulary

- TOS
- DREZ lesioning
- Radiofrequency thermocoagulation
- Deafferentation pain
- Thermocouple electrode
- Postherpetic neuralgia
Vocabulary

• Deafferentation
  – The elimination or interruption of afferent (sensory input) nerve impulses.

• Postherpetic Neuralgia
  – Complication of shingles, which is caused by the chickenpox (herpes zoster) virus
  – Postherpetic neuralgia affects your nerve fibers and skin
  – Burning pain associated can be severe
Thoracic Outlet (TO)

- Anatomically, TO bordered by vertebral column posteriorly, sternum and clavicle anteriorly and first rib laterally.
- Anterior and middle scalene muscles arise from cervical vertebral column/insert on first rib.
- Resultant triangle contains subclavian artery and brachial plexus.
- Entrapment of this neurovascular bundle may occur at 3 different sites:
  - Between anterior/middle scalene muscles and 1st rib.
  - Between 1st rib and clavicle.
  - Beneath the pectoralis minor muscle.
TOS

6.86. Compression of the neurovascular bundle in the axilla.

Thoracic Outlet

- Scalenus medius
- Scalenus anterior
- Brachial plexus
- Neurovascular bundle
- Coracoid process
- Subclavian artery
- Subclavian vein
- Pectoralis minor
Thoracic Outlet Syndrome (TOS)

• Heterogeneous group of disorders
  – Etiology based on symptoms and must be differentiated
    • Arterial, Venous or Neurological

• Diagnosed with clinical signs/symptoms and x-ray
  – Cervical Rib
  – Prominent C7 transverse process
  – EMG chronic axonal loss lower trunk of brachial
  – NCS low amplitude median and ulnar motor with low ulnar sensory and normal median sensory

• Not to be confused with entrapment neuropathy at elbow or hand
DREZ Lesioning
Lesioning Cervical and Conus
DREZ Lesion Indications

- Variety of indications:
  - Pain more than 6 months after injury
  - Nerve root avulsion
  - Spinal Cord Injuries (SCI)
    - SCI with diffuse pain is less responsive
  - Post herpetic neuralgia
  - Post amputation phantom limb pain
  - Deafferentation pain syndromes
    - Especially brachial and sacral plexus
- Presented case studies are on root avulsions

10/2/2014
DREZ Lesion Techniques

- Perform laminectomy over involved segments
  - Localization using fluoro

- Open Dura
  - Identify DREZ under microscope via intact rootlets above and/or below
    - It is possible to use contralateral rootlets

- Create ipsilateral lesions
  - Every 1-2mm for 20-60 lesions
  - Each lesion at 75° for ~15seconds
  - Lesioning needle angled at 30-45° (same as dorsal root)
  - Lesioning needle inserted 2-3mm
    - Usually caudal in a cephalad direction

(Greenberg, 2010)
Monitoring for DREZ (non-avulsed)

• Option to utilize somatosensory localization on intact leg in case of unilateral avulsion on conus or loss of leg
  – Recording electrodes placed on spinal cord
  – Stimulating over popliteal fossa (PT or Sciatic)
  – Recording on the conus gives S1 localization

• Site for dorsal root entry zone lesioning is determined by wave recorded when stimulating affected dermatome

(Starr, 2008)
DREZ Case #1

- 55 year old female - neuropathic pain with left brachial plexus avulsion following MVA 10 years previous
- Suffered combination of spinal cord and brachial plexus avulsion (C4-C6)
- She does not have use of LUE
  - Areflexic and atrophied
- Spinal cord stimulator placed
  - Has to be turned up so high to produce sensation in LUE that suffers spinal cord symptoms (i.e. ataxia)
  - Provides sensation to shoulder and upper arm and virtually never reaches the forearm or hand
DREZ Case #1

- Symptoms are very consistent with spinal cord injury
- However, surging and burning and other qualities are more consistent with brachial plexus avulsion
- Fact that stimulation could not reach hand and forearm where nerves are avulsed
- More rare to perform DREZ on patient with coexisting spinal cord injury
  - Efficacy of lesioning could be lower if problem resides primarily within spinal cord vs DREZ
DREZ Case #1 Operative

- Cervical laminectomy and dorsal root entry zone lesioning
  - (microsurgical technique with intraoperative microscope)
- Removal of percutaneously placed spinal cord stimulator and pulse generator
- Patient prone with head in Mayfield
- Cervical laminectomy including C5, C6, C7, and T1
DREZ Case #1 Operative

- Epidural space showed significant scarring
- Dura was opened in the midline and retracted back with stay sutures
- Spinal cord was dramatically atrophied and there was obviously injury to the left DREZ, including some cavitation in the C5 region
- DREZs on the right side appeared normal, although the overall spinal cord was quite small
DREZ Case #1 Operative

- Under microsurgical approach, a series of dorsal root entry zone lesions were made.
- Radiofrequency generator was used and the typical Nashold electrode was used.
- DREZ was penetrated at a 30 degree from vertical angle.
- Each lesion was made at 70 degrees for 15 seconds.
- Monitoring of somatosensory-evoked potential and motor-evoked potentials throughout.
Nashold Thermocouple DREZ Electrode
Surgeon walks lesion generator up to temperature (75 °) while RN or Resident watches clock for 15 second count.
Case #1 MEP and SSEP
Status Post DREZ Case #1

• Following Day
  – LUE plegic
  – Moves right side well
  – Weak on LLE (all stable compared to preop)
  – Still with LUE pain

• 2d S/P
  – Still having arm pain
  – Left leg weaker than pre-op
  – Slow to get up secondary to pain
Status Post DREZ Case #1

• 7d S/P
  – Neurostable
  – LLE improving with time
  – RHI has accepted pt
  – She was not sure if pain improving LUE

• Discharged to Rehabilitation Hospital of Indiana
DREZ Case #2

• 41 year old male with right brachial plexus avulsion injury

• Operated in Mayo clinic with nerve grafting transfers, nerve root muscle transfers
  – Intercostal to musculocutaneous nerve transfer
  – Can bend elbow with inspiration

• Hand is fixed in claw-like position to aid in holding objects

• Pain is severe burning and surging primarily in medial forearm, proximal hand, and near axilla
DREZ Case #2 Operative

- High-speed drill was used to perform a laminectomy of C5 through T1
- Dura was opened in the midline and tacked back with stay sutures
- Under the microscope, there were no dorsal roots throughout the C5 through T1 region on the right side
  - Left-sided dorsal roots were examined and were normal
  - The right T2 root was seen
  - C4 root could not be seen at the top of the laminectomy

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DREZ Case #2 Operative

- Series of DREZ lesions was made beginning at the T1 level and carried up to C5
- Electrode entered the dorsal root entry zone at a 30-degree angle from the true vertical
  - 75 degrees for 15 seconds
  - Lesions were made 1 mm apart
- After each group of 3 lesions, the neuromonitoring specialist was asked to repeat MEP and SSEP
  - these evaluations remained at baseline function
Case #2 MEP and SSEP
Status Post DREZ Case #2

• Patient says his pre-op pain is 90% improved
  – Some residual thumb burning
• Full strength in LUE and BLE
• RUE strength stable
  – able to flex his bicep with inspiration and extend the triceps with shoulder shrug
• Discharged after 3 days
PN Case #1 Femoral

• 43 year old female patient who underwent left anterior total hip arthroplasty 12/2011
  – Left hip dysplasia with severe osteoarthritis

• Follow up EMG in 2013 showing some reinnervation of Vastus Medialis

• On far branching aspect of femoral nerve, all that could be found was scar tissue
  – Assumption was that there was some injury from the prior hip operation, likely caused by retraction
PN Case #1 Femoral Operative

• Neuroplasty of the left femoral nerve
  – Looking to repair/restore nerve function

• Scar in the anterior thigh from a previous hip operation used for the incision site

• Femoral nerve very proximally had a mostly normal appearance

• Nerve was dissected more distally, the nerve became more discolored, and as it branched into its multiple sensory and motor branches, it became imbedded in more dense scar material
PN Case #1 Femoral Operative

- Surgeon placed sterile subdermal needle electrodes intraoperatively for recording from the VL and VM muscles.
- Small medial branch of the femoral nerve produced a visible muscle twitch with ball tipped probe.
  - Separately stimulated and recorded with small right angle hooked tip polar stimulating and recording electrodes.
  - Typical appearing Compound Nerve Action Potential (CNAP) was recorded from that nerve branch.
- Same type stimulus / recording procedure produced no response from the main trunk of femoral nerve.
- No repair was attempted based on the lack of distal nerve branches for repair.

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PN Case # 1 CNAP Recording

- Recording parameters
  - 50µV Gain
  - LFF 30Hz HFF 3000Hz
  - Sweep 1 ms/Div
  - Stim Rep Rate 05 – 1Hz
  - Pulse Width 50 µs
  - Intensity usually 2-20mA
PN Case #2 Peroneal

- 19 year old male wrestler with right knee injury 1 year prior
- Maintained full activity as wrestler and eventually diagnosed with severe ligamentous injury
- Endoscopic procedure and postoperatively could not dorsiflex ankle
- Two EMGs confirmed severe common peroneal nerve dysfunction w/ no evidence of recurrent function or reinnervation
- MRI showed evidence of ganglion cyst, not large
PN Case #2 Peroneal

• Patient had decreased sensation throughout common peroneal nerve distribution
• No masses palpable
• No function in peroneal innervated muscles including tibialis anterior, ankle evertors or extensor hallucis longus
• Complete peroneal nerve palsy
PN Case #2 Peroneal Operative

- Exploration of common peroneal nerve, excision of neuroma and repair of nerve using nerve tubule
- Patient turned into a left lateral decubitus position
- Incision was made along the expected course of the common peroneal nerve
- Nerve was identified just above the fibular head and traced back to its junction with the tibial nerve and into the anterior tibial compartment
Left Lateral Decubitus Position

- Refers to left side down, right side up lateral positioning
PN Case #2 Peroneal Operative

- Electrical stimulation of the nerve did not produce any EMG contraction of the appropriate muscles
- Low-voltage stimulation of the tibial nerve produced appropriate contraction of the gastrocnemius muscle
- Nerve hook electrodes were used to perform stimulation and recording across the common peroneal nerve
  - There was no evidence of a nerve action potential
- Nerve action potential could be recorded from the tibial nerve
PN Case #2 Peroneal Operative

• A series of impedance tests were done along the course of the nerve, and there was some variability of the testing

• 4 cm segment of nerve was then resected and sent to the pathologist for evaluation
  – Pathological diagnosis: Traumatic neuroma

• 2 cut ends of the peroneal nerve were placed into the 2 ends of the NeuraGen tube
  – Sutured in place
  – Tisseel was placed over the nerve graft site

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PN Case #2 Stim to Verify Anatomy
#2 CNAP to Verify Working Nerve

Tibial Nerve CNAP

Reusable Stimulating Probes
Peroneal Surgery Pictures
Peroneal Surgery Pictures
Peroneal Surgery Pictures

- Suture through tumor
- Microdisectors
PN Case #3 Median - EMG

- EMG by Dr. Kincaid for LUE pain
  - Sensory and motor conduction responses in the median, ulnar and radial nerves were normal
  - Needle exam revealed inability to activate anterior interosseous innervated muscles with abnormal rest activity seen in the pronator quadratus

- Evidence of a left anterior interosseous neuropathy

- No signs of beginning reinnervation are seen yet
PN Case #3 Median - EMG

• 42 day follow up EMG
  – left upper extremity to look for signs of beginning reinnervation in the anterior interosseus territory
  – continued evidence of neurogenic abnormalities in muscles supplied by the left anterior interosseous nerve
  – flexor digitorum profundus demonstrates signs of re-innervation
• 106 day follow up EMG
  – continued evidence of neurogenic abnormalities in the muscles supplied by the left anterior interosseous nerve
  – flexor digitorum profundus continues to demonstrate signs of reinnervation
  – no voluntary potentials are still present in the flexor pollicis longus or pronator quadratus
55 day follow up EMG
- results of this study continue to be abnormal
- no electrophysiologic signs of reinnervation of the pronator quadratus or flexor pollicus longus

EMG over about 11 months continue to show no improvement in nerve function

Patient elected to undergo decompressive surgery
PN Case #3 Median Operative

• Diagnosis: Left median nerve compression at the anterior interosseous nerve

• Operation: Left median nerve decompression (neurolysis) at the elbow and forearm (anterior interosseous nerve decompression)

• Left arm was extended on the side table

• Hand, forearm, and arm were prepared

• Incision was made across the elbow crease, began on the medial side of the biceps, and carried to the midline of the forearm
PN Case #3 Median Operative

• Stimulation of various components of the median nerve with EMG recordings in thenar muscles and flexor pollicis longus muscles

• Produced significant EMG electrical activity in these muscles, consistent with functioning nerve and good neuromuscular junction

• Main finding was compression of the main median nerve by fascial band above the pronator muscle and a tight canal for the anterior interosseous nerve

• Electrical stimulation continued to produce robust contraction of the appropriate muscles
Anterior Interosseous (Median Branch)

Flexor Pollicis Longus

Flexor Digitorum Profundus
#3 Stimulate to Verify Response

- Recording in the Abductor Pollicis Brevis with 0.5mA stimulation
#3 FPL Placed Sterile by Surgeon

AMBU Neuroline Inoject EMG Needle

3ms

0.2mA Stimulation
PN Case #4 TOS

• 16 year old patient with onset of symptoms with cheerleading
• Left shoulder pain, grinding in shoulder
• Episodes of numbness and tingling in forearm and hand
• Hand and forearm turn purple
• Perceived instability (not evidenced on x-ray)
• CT angiogram does not show vascular compression
• Patient does have bilateral cervical ribs
PN Case #4 TOS Operative

- Brachial plexus exploration, decompression neurolysis, and partial resection of the 1st rib
- Left supraclavicular region and superior chest wall were prepared
- Operation was done as a co-surgeon with vascular surgery and neurosurgery
- Electrical stimulation produced contraction of the diaphragm
  - Stimulation identified the phrenic nerve
- Electrical stimulation aided in identification of brachial plexus elements
PN Case #4 TOS Operative

- Dissection was carried back to the edge of the spine
- Decompression obtained with middle scalene
  - Muscle was coming up between C7/8 roots
- Overlying vessel coming across lower trunk of brachial plexus was clipped and divided
- First rib was resected
- T1 nerve root spared with intraoperative EMG
PN Case #5 Piriformis

- 42 year old male continues to have left buttock and thigh pain
  - Occasional numbness of left foot
- Pain is brought on by sitting or stair climbing
- Underwent piriformis injection, failed after 2 wk
- Physical therapy failed
Piriformis Muscle and Sciatic Nerve
PN Case #5 Piriformis Operative

- Decompression of left sciatic nerve
  - Diagnosis of Piriformis Syndrome
- Patient turned prone and incision in left buttocks
- Portion of the gluteus maximus elevated superiorly and medially
- Sciatic nerve was identified, both through direct observation and by electrical stimulation
  - Both components (common peroneal and tibial) were identified
- Main compressing site was artery and vein coming across the nerve, indenting and flattening it, and 1 vein that pierced the nerve and bisected the nerve into its 2 components
#5 Initial Stim with EMG

- Medial Gastrocnemius
- Tibialis Anterior
- Extensor Hallucis Longus
#5 Stim
PN Case #6 Brachial Plexus

- 49 year old female with benign schwannoma of right axilla
- Right arm numbness and tingling
- MRI showed enhancing mass consistent with nerve sheath tumor
- Normal sensation in arm
- Some pain noted with pressure to palpable area in pectoralis muscle radiating to proximal arm
PN Case #6 Brachial Plexus Operative

- Exploration of brachial plexus with resection of schwannoma
  - Right brachial plexus schwannoma (infraclavicular)
- Co-surgeon neurosurgery and orthopaedic
- Region around the clavicle was prepared and incised down through pectoralis major
- Cords of the brachial plexus were identified both anatomically and with electrical stimulation
PN Case #6 Brachial Plexus Operative

- Large mass was seen superior to the subclavian artery
- Medial cord of the brachial plexus was draped over the mass
- Posterior cord of brachial plexus intermittently attached to mass with electrical stimulation producing contraction of extensors of arm as well as the deltoid muscle
- Electrical stimulation showed an area that did not produce any motor contraction
  - One small fascicle entered the tumor
- Gross total resection of the lesion was obtained
- Electrical stimulation produced contraction of all muscles with a similar threshold
#6 Stimulate for Specificity

- Flexor Carpi Radialis
- Deltoid
#6 Stim for a Response
Status Post #6 Brachial Plexus

- One month status post tumor removal
  - Initial numbness and tingling in thumb and index resolved spontaneously
  - No numbness and minimal to no pain at surgical site with well-healed scar
  - Excellent range of motion in shoulder
DREZ and PN Conclusion

- Stimulate before and after interventions
References

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