EVALUATING THE PATIENT WITH SUSPECTED RADICULOPATHY

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Radiculopathies

- Pathophysiological processes affecting the nerve roots
- Very common reason for EDX referral
CAUSES OF RADICULOPATHY

- HNP
- Radiculitis
- Spinal Stenosis
- Spondylolisthesis
- Infection
- Tumor
- Facet Synovial Cyst
- Diseases: Diabetes, AIDP
MUSCULOSKELETAL DISORDERS : UPPER LIMB

- Shoulder Bursitis
- Lateral Epicondylitis
- Dequervains
- Trigger finger
- Fibrositis
- Fibromyalgia / regional pain syndrome
NEUROLOGICAL CONDITIONS MIMICKING CERVICAL RADICULOPATHY

- Entrapment/Compression neuropathies
  - Median, Radial, and Ulnar
- Brachial Neuritis
- Multifocal Motor Neuropathy
- Need Extensive EDX study to R/O other conditions
MUSCULOSKELETAL DISORDERS : LOWER LIMB

- Hip arthritis
- Trochanteric Bursitis
- Illiotibial Band Syndrome
- Patellofemoral Pain
- Pes Anserinus Bursitis
- Bakers Cyst
- Plantar Fasciitis
- Mortons Neuroma
Neurological conditions mimicking LSR

- Diabetic Amyotrophy
- Mononeuropathies
  - Femoral
  - Tibial
  - Common Peroneal
- Need Extensive EDX study
Anatomy
ANATOMY AND IMPLICATIONS

- Sensory (DRG) in the intervertebral foramen, spared with radiculopathies
- PLL; predisposes to posterolateral HNP
- Cauda Equina
  - Spinal cord ends at T11-L1
  - Nerve roots extending to intervertebral foramen
  - Lesion from T12 to Sacrum can produce same EMG findings
- Must know brachial and L-S plexus and muscle innervations
History and Physical Examination
PHYSICAL EXAM

**Focused Neuromuscular**
- Affected limb and contralateral
- If Neck symptoms-lower limbs to look for myelopathy
- Cranial nerves- ?CVA, MG, AIDP

**Reduced Reflexes with Acute Spinal Shock**
ALGORITHMIC APPROACH

- Symptoms
  - Generalized (2 or more limbs)
  - Focal (single limb)

- Signs
  - Sensory loss
  - Weakness
  - Reflexes

- Not perfect taxonomy: Radics and Entrapments
Patient Presentation
(Pain, Weakness, Gait disturbance, Sensory Symptoms, Paresthesias)

No sensory loss on Exam

Generalized Symptoms (With Weakness)
- Motor Neuron Disease
- Myopathy
- Neuromuscular Junction Disorder

Focal Symptoms
- MMN
- Radiculopathy
- Entrapment Neuropathy
- Mononeuropathy
- Musculoskeletal disorder
- Myofascial pain syndrome

Generalized Symptoms (No Weakness)
- Fibrositis
- Polymyalgia Rheumatica

Sensory loss on Exam

Generalized Symptoms
- Reduced Reflexes
  - Polyneuropathy
  - Bilateral CR
  - Bilateral LSR
  - Cauda equina Syndr.
- Increased Reflexes
  - Cervical Myelopathy
  - Thoracic Myelopathy
  - Multiple Sclerosis
  - Other Myelopathies

Focal Symptoms
- Entrapment
- Radiculopathy
- Plexopathy
- Mononeuropathy
Symptoms and EDX Study Outcome for Upper Limb and Lower Limb Studies
Lauder et al 2000 AJPMR

- Symptoms had low sensitivities
- Low specificities
- Non-significant Odds Ratios
Weakness, reflex change, or sensory loss in the leg

- 3-6 times the probability of having a positive study (Lauder et al, 2000 AJPMR)
- 3-14 times the probability of having an electrodiagnostically confirmed radiculopathy (Lauder et al, 2000 AJPMR)
PHYSICAL EXAM FINDINGS

- Weakness, reflex change, or sensory loss in the arm
  - 4-5 times the probability of having a positive study (Lauder et al, 2000 Arch PMR)
  - 2-9 times the probability of having an electrodiagnostically confirmed CR (Lauder et al, 2000 Arch PMR)
Electrodiagnosis
Electrodiagnostic Studies

- Nerve Conduction Studies
- SSEPs
- F waves and H reflexes
- EMG
Examine muscles representing all myotomes
PSM localize lesion to root level
One motor and one sensory NCS
ELECTRODIAGNOSTIC TESTING

- Perform the basic tests related to suspected condition
- Adjust and modify study as data are acquired
- May need serial studies
- Low threshold to study contralateral limb or upper (lower) limb
USEFULNESS OF ELECTRODIAGNOSIS

- Confirm clinical suspicion
- Raise other unsuspected diagnostic possibilities
- Exclude entities on the differential diagnosis
- Identify region to image
- Tailors other diagnostic testing
Nerve Conduction Studies

- Sensory NCS should be normal
- Motor NCS should be normal
  - Sometimes low amplitude with severe disease
F-WAVES

- Motor axons and axonal pool at spinal cord level
- Long pathways
- Different axons involved with each response
- Minimal latency, mean latency, dispersion
- Inconsistent morphology and latency
- Maximal stimulus response
- Not helpful for radiculopathy, good screen for polyneuropathy
H-REFLEXES

- Monosynaptic electrical Achilles reflex
- Long pathway
- Abnormal in sciatic n. plexopathy, S1 radic
- Submaximal stimulus response
- Consistent in latency and morphology
- Extinguishes with supramaximal stimulus
- Only 50% sensitive for S1 radiculopathy but high specificity 91%
- May help with L5 vs S1
- Better screen for polyneuropathy
Electromyography

- Most important test for suspected radiculopathy
- Good confirmatory test
- Helps clarify relevance of imaging findings
EDX CRITERIA FOR RADICULOPATHY

- Abnormalities in 2 or more muscles
  - Same nerve root
  - Different peripheral nerves
- Muscle innervated by adjacent nerve roots are normal
- Other conditions are excluded
EMG SENSITIVITIES FOR LUMBOSACRAL RADICULOPATHIES

- Varies widely
- Ranges from about 50% to 80%
- Various diagnostic standards
<table>
<thead>
<tr>
<th>Study</th>
<th>Sample Size</th>
<th>Gold Standard</th>
<th>EMG Sensitivity %</th>
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<tbody>
<tr>
<td>Lumbosacral radiculopathy</td>
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<td>Weber and Albert [55]</td>
<td>42</td>
<td>Clinical+imaging HNP</td>
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<td>49</td>
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<tr>
<td>Schoendinger [58]</td>
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<td>Surgically proven</td>
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<td>Knutsson [45]</td>
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<td>Young et al [3]</td>
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<td>Clinical an imaging</td>
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<td>Myelography and CT</td>
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</table>
EMG SENSITIVITY FOR CERVICAL RADICULOPATHIES

- Varies widely
- About 50% to 70%
- Usually clinical and/or myelographic
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<th>EMG sensitivity %</th>
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<tbody>
<tr>
<td>Lumbosacral spinal stenosis</td>
<td>68</td>
<td>Clinical+myelogram</td>
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<tr>
<td>Hall et al [46]</td>
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<td>Clinical+myelogram</td>
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<tr>
<td>Johnsson et al [59]</td>
<td></td>
<td></td>
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<tr>
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<tr>
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<td>18</td>
<td>Clinical</td>
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<td>Partanen et al [61]</td>
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<td>Intraoperative</td>
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<tr>
<td>So et al [62]</td>
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<td>Clinical</td>
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<tr>
<td>Yiannikas et al [18]</td>
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<td>Clinical/radiographic</td>
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<td>Tackman and Radu [15]</td>
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<td>Clinical</td>
<td>95</td>
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<tr>
<td>Hong et al [63]</td>
<td>108</td>
<td>Clinical</td>
<td>51</td>
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</table>
LUMBAR SPINAL STENOSIS

- EMG findings are less well studied than for single level radiculopathies
- Clinical entity with various clinical presentations
- Imaging is vital, but has gradations of severity
  - Dynamic aspects of spinal canal, narrow with extension
  - Boney spurs + facet hypertrophy + ligament hypertrophy + HNP
EMG in Lumbosacral Spinal Stenosis

- Hall and Colleagues (1985)
- 68 patients—myelographically proven/surgically confirmed Lumbar stenosis.
- Pseudoclaudication (94%)
- Numbness (63%)
- Weakness (43%)
- Bilateral symptoms (68%)
EMG in Lumbosacral Spinal Stenosis

Hall and colleagues (1985)-cont.

- EMG positive in 34 of 37 patients studied
  - 11 bilateral EMG findings with paraspinal fibrils
  - 17 bilateral EMG findings without paraspinal fibrillations
  - 6 showed single root EMG findings (bilateral in 3 cases)

Paraspinal findings often lacking on EMG

“EMG more helpful than physical exam”
SPINAL STENOSIS vs POLYNEUROPATHY


Difficult DDx

Three groups:

- 29 persons with imaging confirmed clinical mild lumbar spinal stenosis,
- 24 subjects had diabetic polyneuropathy,
- 25 healthy age-matched volunteers participated
SPINAL STENOSIS vs POLYNEUROPATHY

- Sural sensory amplitudes distinguished the diabetic polyneuropathy group
  - 4.2 microvolts or less was found in 47% of diabetic patients and only 17% of stenosis patients.

- Ulnar F wave was prolonged in polyneuropathy patients

- Radial SNAP was reduced in polyneuropathy patients.

- Sensory testing and F-wave testing in the involved extremity and an upper limb
Electrodiagnostic findings critical

**Sural sensory** and **peroneal motor nerve** conduction are the most sensitive for detecting a **distal symmetric polyneuropathy**

Will not exclude all polyneuropathies.
Case 1: Elderly patient with chronic low back pain, right leg pain and some numbness in both feet

<table>
<thead>
<tr>
<th>SIX MUSCLE SCREEN</th>
<th>RIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peroneus longus (L5-S1)</td>
<td>Normal</td>
</tr>
<tr>
<td>Vastus Med (L3-L4)</td>
<td>Normal</td>
</tr>
<tr>
<td>Anterior Tibialis (L4-L5)</td>
<td>Normal</td>
</tr>
<tr>
<td>TFL (L5-S1)</td>
<td>Normal</td>
</tr>
<tr>
<td>Medial gastroc (S1-S2)</td>
<td>2+ fibs</td>
</tr>
<tr>
<td>PSM (Multiple levels)</td>
<td>Normal</td>
</tr>
<tr>
<td>SIX MUSCLE SCREEN Plus</td>
<td>RIGHT</td>
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<tr>
<td>-----------------------</td>
<td>-------</td>
</tr>
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<td>Normal</td>
</tr>
<tr>
<td>Vastus Med (L3-L4)</td>
<td>Normal</td>
</tr>
<tr>
<td>Gluteus Maximus (L5-S1)</td>
<td>Normal</td>
</tr>
<tr>
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</tr>
<tr>
<td>Flexor Digitorum Brevis (S1-S2) Foot muscle</td>
<td>2+ fibs</td>
</tr>
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Case 1

- Suggestive of bilateral sciatic neuropathies, polyneuropathy, or bilateral S1 radiculopathies.
- Remember that PSM in lumbar Spinal stenosis may be normal
- What do you do to sort this out?
Case 1 Nerve conductions

- Sural sensory responses absent bilaterally.

In this case:

- **Polyneuropathy**
  - Bilateral sciatic neuropathies – unlikely
  - Bilateral lumbosacral plexopathies – unlikely
  - Bilateral S1 radiculopathies less likely.

What else?
Case 1 More NCS

- Peroneal motor studies low normal CMAP
- EMG of right FDI (in hand) was + for fibs
- Radial sensory was low in amplitude and slightly prolonged in latency
Case 1 Summary

Abnormal study:

Findings suggest:
- Motor and sensory primarily axonal polyneuropathy.
45 patients with imaging, EMG and surgically confirmed LSR

Little overlap between L2-L4, L5, and S1 Radiculopathies

- Tibialis anterior L5
- Gastrocnemius S1
- Biceps S1
IDENTIFICATION

- Different concept from Sensitivity
- Conditional probability
  - How much testing, given that EDX testing will identify a disorder
- If a disorder can be confirmed by EDX, how much testing is necessary to recognize this possibility
CAVEATS AND LIMITATIONS

- Needle EMG is not an effective screening test alone (Radiculopathy)
- MRI better screen for structural causes
- Better specificity - Diagnosis confirmation
- Motor Axonal loss necessary for fibs
RADICULOPATHIES

- Some cannot be confirmed by EMG
  - Sensory roots affected
  - No axonal loss

- No amount of muscles will help confirm

- Need to abbreviate study in this scenario

- Enough muscles to reach this conclusion

- When can a needle EMG be stopped with a confidence that there is a low probability of missing a confirmable radiculopathy
PROSPECTIVE LSR IDENTIFICATION

- Multicenter study
- 102 patients with EDX LSR
- Standard screen with 11 muscles
- Five muscles with PSM: 94-98%
- Six muscles with PSM: 98-100%
- Without PSM eight muscles; 90%
### Six-muscle screen identification of patients with lumbosacral radiculopathies

<table>
<thead>
<tr>
<th>Screen</th>
<th>Neuropathic (%)</th>
<th>Spontaneous Activity (%)</th>
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</thead>
<tbody>
<tr>
<td><strong>Six muscles without paraspinals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATIB, PTIB, MGAS, RFEM, SHBF, LGAS</td>
<td>89</td>
<td>78</td>
</tr>
<tr>
<td>VMED, TFL, LGAS, PTIB, ADD, MGAS</td>
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<td>70</td>
</tr>
<tr>
<td>VLAT, SHBF, LGAS, ADD, TFL, PTIB</td>
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<td>62</td>
</tr>
<tr>
<td>ADD, TFL, MGAS, PTIB, ATIB, LGAS</td>
<td>88</td>
<td>79</td>
</tr>
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<td></td>
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</tr>
<tr>
<td>ATIB, PTIB, MGAS, PSM, VMED, TFL</td>
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PROSPECTIVE CERVICAL RADICULOPATHY IDENTIFICATION

Dillingham, et.al, AmJPM&R, 2000
Multicenter-five institutions
Standard Screen
101 patients with EDX CR
six muscles with PSM: 94-99%
Seven muscles with PSM: 96-100%
Without PSM: eight muscles 92-95%
## Six-muscle screen identifications of patients with cervical radiculopathies

<table>
<thead>
<tr>
<th>Muscle screen</th>
<th>Neuropathic %</th>
<th>Spontaneous activity %</th>
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</thead>
<tbody>
<tr>
<td>Without paraspinals</td>
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<tr>
<td>Delt, APB, FCU, triceps, PT, FCR</td>
<td>93</td>
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<tr>
<td>Bic, tric, FCU, EDC, FCR, FDI</td>
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<td>Delt, tric, EDC, FDI, FCR, PT</td>
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<tr>
<td>Bic, tric, EDC, PT, APB, FCU</td>
<td>94</td>
<td>64</td>
</tr>
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<tr>
<td>Bic, FCR, APB, PT, PSM, tric</td>
<td>98</td>
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</tr>
</tbody>
</table>
“To minimize harm, six in the leg and six in the arm”
Suspected Radiculopathy

- Six muscles (with PSM)-lumbar screen
- Six muscles (with PSM)-cervical screen

If one muscle is positive, expand study

Determine if EMG reflects:
1) Radiculopathy (which level),
2) Entrapment neuropathy,
3) Generalized condition, or
4) Findings that are of uncertain relevance.

If all muscles negative, stop EMG exam in this limb

The patient will not have an electrodiagnostically confirmable radiculopathy.

They may:
1) not have radiculopathy, or
2) have a radiculopathy but you will not confirm this with EMG. Other diagnostic tests must be utilized such as MRI or SNRB.
Case 2 Person with sciatica for two months. Normal strength, reflexes, and sensation, +SLR.

<table>
<thead>
<tr>
<th>SIX MUSCLE SCREEN</th>
<th>FINDINGS</th>
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<tr>
<td>Vastus Medialis (L3-L4)</td>
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<tr>
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<tr>
<td>Medial Gastroc (S1-S2)</td>
<td>Normal</td>
</tr>
<tr>
<td>SH of Biceps Femoris (L5-S1)</td>
<td>Normal</td>
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<tr>
<td>Tensor Fascia Lata (L5-S1)</td>
<td>Normal</td>
</tr>
<tr>
<td>Lumbar PSM (Multiple roots)</td>
<td>1+ fibs</td>
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</table>
Case 2 Additional muscles after Six muscle screen.

<table>
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<th>SIX MUSCLES PLUS MORE</th>
<th>FINDINGS</th>
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<tbody>
<tr>
<td>Vastus Medialis (L3-L4)</td>
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<tr>
<td>Adductor Longus (L3-L4)</td>
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<tr>
<td>Tibialis Posterior (L5-S1)</td>
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<tr>
<td>Medial Gastroc (S1-S2)</td>
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<td>Lateral Gastroc (S1-S2)</td>
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<td>1+ fibs</td>
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</tbody>
</table>
Case 2 Conclusions

Abnormal Study

Finish it; {sural S. and peroneal M. NCS were normal}

Findings suggest:

– L5 lumbosacral radiculopathy with recent (acute) motor axonal loss.

Recommendations:

– Consider imaging the lumbar spine if not already pursued.
Case 3: 49 y/o with right arm pain, proximal weakness, and hand numbness for 3 months. 3/5 shoulder abduction and ER, otherwise normal strength, reflexes, sensation

<table>
<thead>
<tr>
<th>SIX MUSCLE SCREEN</th>
<th>Right side</th>
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<tbody>
<tr>
<td>Deltoid</td>
<td>3+ fibs, CRD</td>
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<tr>
<td>Triceps</td>
<td>Normal</td>
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<tr>
<td>EDC</td>
<td>Normal</td>
</tr>
<tr>
<td>FDI</td>
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<tr>
<td>APB</td>
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<tr>
<td>Cervical Paraspinals</td>
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<tr>
<td>SIX MUSCLE SCREEN</td>
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<tr>
<td>----------------------------</td>
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</tr>
<tr>
<td>Deltoid</td>
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<tr>
<td>Infraspinatus</td>
<td>2+ fibs</td>
</tr>
<tr>
<td>Biceps</td>
<td>2+ fibs, CRD</td>
</tr>
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<td>Triceps</td>
<td>Normal</td>
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<td>EDC</td>
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<td>APB</td>
<td>Normal</td>
</tr>
<tr>
<td>Cervical Paraspinals</td>
<td>Normal</td>
</tr>
</tbody>
</table>
## Case 3: More EMG

<table>
<thead>
<tr>
<th>SIX MUSCLE SCREEN</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deltoid</td>
<td></td>
<td>3+ fibs, CRD</td>
</tr>
<tr>
<td>Infraspinatus</td>
<td>normal</td>
<td>2+ fibs</td>
</tr>
<tr>
<td>Biceps</td>
<td>normal</td>
<td>2+ fibs, CRD</td>
</tr>
<tr>
<td>Triceps</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>EDC</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>FDI</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>APB</td>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td>Cervical Paraspinals</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>Anterior tibialis</td>
<td>Normal</td>
<td>Normal</td>
</tr>
</tbody>
</table>
Case 3

- NCS of Median and Ulnar Motor and Sensory were normal
- Radial sensory normal
- LAC normal
- Normal right median F-Wave
Case 3: Summary

Abnormal Study

Findings suggest:

- Right Upper Trunk Brachial Plexopathy OR Right C5-C6 Cervical Radiculopathy

- Suggest imaging of both the right brachial plexus and cervical spine
LUMBOSACRAL PSM EMG: PREVALENCE OF FIBRILLATIONS IN NORMALS

- Dumitru, Diaz, and King (2001)
- Prospective study 50 normals L4/L5 levels
- Monopolar needle, recorded potentials
- Examined firing rate and rhythm
- Fibrillation inclusion criteria; regular firing rate
- 4% false positive fibrillations in paraspinal muscles
CERVICAL PSM
(Date et al Muscle &Nerve 2006)

- Cervical PSM in asymptomatic persons
- C56 and C67 areas Bilaterally
- Four quadrants
- MUST BE REGULARLY firing for 1s or more
- Monopolar needle
- 12% in 66 showed PSWs none showed fibs
FALSE NEGATIVE (no fibs or PSW) ON EMG IN RADICULOPATHY

- Sensory root involvement only
- Motor root involvement without axonal loss
  - Demyelination, conduction block
- Motor axonal loss balanced with reinnervation
MUSCLE INJURY CAUSING FIBRILLATIONS
Partanen et al 1982 *Muscle & Nerve*

- Study of 43 patients with EMG before and after Muscle biopsy
- 50% had fibrillations 6-7 days after biopsy
- At 16 days 100% had fibrillations
- Fibrillations persisted up to 11 months post biopsy
Symptom Duration is not Related to Fibrillation Potentials

- Long held notion in the electrodiagnostic literature regarding radiculopathies
- Paraspinal (PSM) muscles denervate first, then more distal
- Reinnervation thought to occur first in PSM then distal
- No evidence to support this model
Four separate investigations
- Two retrospective (Cervical and Lumbosacral)
- Two prospective (Cervical and Lumbosacral)

Probability of finding fibrillations in a muscle (proximal or distal) was not related to symptom duration.

Simplistic model of symptom duration doesn’t explain the complex pathophysiology of radiculopathies and their EMG correlates.
Natural History of Radiculopathy
RADICULOPATHIES

- Cervical radiculopathy in absence of myelopathy - good outcomes with conservative care
- Lumbosacral radiculopathy, without cauda equina symptoms - good outcomes with conservative care
Saal, Saal, Yurth. Spine 1996
- 26 patients with Cervical HNP
- Tx: Pain meds, cervical traction, epidurals if poor pain control
- 24 of 26 achieved successful outcomes
66 patients with MRI mild cervical cord compression but no signs of myelopathy
Followed for 2 years
20% developed signs of myelopathy
Symptomatic cervical radiculopathy and EMG showing motor axonal loss in 2 myotomes predicted with 90% accuracy those who progressed to symptomatic myelopathy.

Odds ratio 12.5 (p<0.001) for EMG

Odds ratio 36.9 (p<0.001) for clinical radiculopathy (motor or sensory signs)
BACK SURGERY RATES IN THE UNITED STATES

- Cherkin et al, Spine 1994
- United States
  - 5 times that of England
  - Increased linearly with increasing number of surgeons
LUMBAR DISCECTOMY
PREDICTORS OF OUTCOMES

Spengler, et al, JBJS 1990
Developed scale for surgical candidate selection
100 points
- Neurological Signs (EMG) (25)
- Sciatic Tension Signs (25)
- MMPI (25)
- Lumbar Myelogram or CT (25)
Lumbar Discectomy Outcomes

Spengler et al JBJS 1990

- Preoperative assessment of probability of good outcomes
- Patients with < 50 points: No surgery
- Best outcomes are >80 points
NATURAL HISTORY OF SCIATICA

Bush et al, Spine 1992

165 patients with Sciatica
- 86% made satisfactory recovery
- 76% HNPs resolved on f/u MRI

Tx consisted of pain meds, epidurals
Conclusions

- Electrodiagnosis important adjunctive and confirmatory test
- Excludes confounding diagnoses
- Has important limitations you need to understand