I. Focal Radiculopathy

A. Definitions:
   1. Pathological process affecting dorsal (sensory) and/or ventral (motor) spinal roots
   2. Clinically includes roots, DRG (dorsal root ganglion) and spinal nerves.

B. Clinical Characteristics:
   1. Pain may be out of proportion to objective deficit.
   2. If chronic, radiculopathy can be asymptomatic.
   3. Features favoring radiculopathy vs plexopathy/mononeuropathy
      a. Proximal pain (neck, low back)
      b. Pain with movement (tilting neck, lumbar extension)
      c. Pain with cough, sneeze, Valsalva

C. Variables in localization:
   1. Nerve damage varies in severity
   2. Dermatomal and Myotomal distributions overlap:
      a. Masks objective deficits
      b. Enlarges positive phenomena (pain)
   3. Pain may also be referred.
   4. Involvement of multiple roots may confuse localization.
   5. Variable anatomy, especially motor
   4. If pain reproduced by palpation then higher suspicion for musculoskeletal disorder mimicking radiculopathy (see Table 1 and 2). However, pain to palpation does not exclude a radiculopathy or abnormal EDX test.
   5. 32% of patients referred for EMG lab for lumbosacral radiculopathy have a musculoskeletal disorder.
### Table 1

**Musculoskeletal conditions that commonly mimic cervical radiculopathy**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Clinical symptoms/signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibromyalgia syndrome</td>
<td>Pain all over, female predominance, often sleep problems, tender to palpation in multiple areas</td>
</tr>
<tr>
<td>Polymyalgia rheumatica</td>
<td>&gt;50 years old, pain and stiffness in neck, shoulder and hips, high erythrocyte sedimentation rate (ESR)</td>
</tr>
<tr>
<td>Sternoclavicular joint arthropathy</td>
<td>Pain in anterior chest pain with shoulder movement (adduction), pain on direct palpation</td>
</tr>
<tr>
<td>Acromioclavicular joint arthropathy</td>
<td>Pain in anterior chest, pain with shoulder movement (adduction), pain on direct palpation</td>
</tr>
<tr>
<td>Shoulder bursitis, impingement syndrome</td>
<td>Pain with palpation, positive impingement signs, pain in C5 distribution bicipital tendonitis</td>
</tr>
<tr>
<td>Lateral epicondylitis “tennis elbow”</td>
<td>Pain in lateral forearm, pain with palpation and resisted wrist extension</td>
</tr>
<tr>
<td>De Quervain’s tenosynovitis</td>
<td>Lateral wrist and forearm pain, tender at abductor pollicis longus or extensor pollicis brevis tendons, positive Finkelstein test</td>
</tr>
<tr>
<td>Trigger finger, stenosing tenosynovitis</td>
<td>Intermittent pain and locking of a digit in flexion of finger flexor tendons</td>
</tr>
</tbody>
</table>

### Table 2

**Common musculoskeletal disorders mimicking lumbosacral radiculopathy**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Clinical symptoms/signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibromyalgia syndrome and polymyalgia rheumatica</td>
<td>As in Table 1</td>
</tr>
<tr>
<td>Hip arthritis</td>
<td>Pain in groin, anterior thigh, pain with weight bearing, positive Patrick’s test</td>
</tr>
<tr>
<td>Trochanteric bursitis</td>
<td>Lateral hip pain, pain with palpation on lateral and posterior hip</td>
</tr>
<tr>
<td>Iliotibial band syndrome</td>
<td>Pain along outer thigh, pain with palpation</td>
</tr>
<tr>
<td>Knee arthritis</td>
<td>Pain with weight bearing</td>
</tr>
<tr>
<td>Patellofemoral pain</td>
<td>Anterior knee pain, worsen with prolonged sitting</td>
</tr>
<tr>
<td>Pes anserinus bursitis</td>
<td>Medial proximal tibia pain, tender to palpation</td>
</tr>
<tr>
<td>Hamstring tendinitis, chronic strain</td>
<td>Posterior knee and thigh pain, can mimic positive straight leg raise, common in runners</td>
</tr>
<tr>
<td>Baker’s cyst</td>
<td>Posterior knee pain and swelling</td>
</tr>
<tr>
<td>Plantar fascitis</td>
<td>Pain in sole of foot, worsened with weight bearing activities, tender to palpation</td>
</tr>
<tr>
<td>Gastrocnemius-soleus tendinitis</td>
<td>Calf pain, worsened with sports activities, usually limited range of motion compared to asymptomatic limb, chronic pain</td>
</tr>
</tbody>
</table>
D. Physical Examination:
   1. A focused neuromuscular exam should assess strength, reflexes, and sensation in the affected limb and contralateral limb.
   2. Lumbosacral Exam:
      a. Sensation = vibration and pin-prick
      b. Strength = include testing toe extension (EHL) - L5, calf raises (gastrocnemius) - S1, and hip flexors - L3/4
      c. Achilles and patellar reflexes, and plantar response (i.e. Babinski reflex)
      d. Straight-leg raise = abnormal if pain radiating below the knee
   3. 15-18% with normal exam will still have a lumbosacral radiculopathy by EMG
   4. One abnormal physical examination finding (sensation or strength or reflexes or straight-leg raise) associated with 1.5 - 2.5 times greater chance of lumbosacral radiculopathy by EMG (87% sensitivity, 35% specificity); two or more examination findings 2.0 - 4.5 times greater probability of lumbosacral radiculopathy.
   5. Abnormal Achilles reflex strongly associated with S1 radiculopathy [OR=8.44 95% CI (2.64 - 26.84) as well as gastrocsoleus weakness [OR=2.46 95% CI (1.31 - 4.64).]
   6. Abnormal patellar reflex [OR=14.33 95% CI (3.22-63.43) or Hip flexor weakness [OR=12.0 95% CI (5.64-25.28) strongly associated with a L3-4 radiculopathy.
   7. Weakness in any muscle associated with lumbosacral radiculopathy (Sensitivity 69%) [OR=2.46 95% CI (1.31 - 4.64) but not specific for diagnosis (Specificity 53%).
   8. Patient reported Symptoms are not associated with an abnormal EDX study or lumbosacral radiculopathy.

E. Pathology: most commonly partial axonal loss (excluding trauma).
F. Pathophysiology: EMG does not indicate the cause only that axonal loss is taking place.
   1. Herniated disc
      a. Abrupt, severe pain
      b. Onset with significant lifting/trauma or trivial maneuvers
      c. Age often younger, peak 45-54 yo
      d. Straight leg test more often abnormal
      e. Usually one nerve root involved
      f. Spontaneous, acute herniations more common in lumbar spine than cervical spine.
g. Cervical spine radiculopathies more often subacute in onset and worsen over days/weeks.

h. Cauda Equina syndrome:
   i. 2% of all disc herniations, usually L4/5 disc
   ii. Sacral roots closest to midline, therefore, get most severe damage
       1. Saddle sensory loss and sphincter dysfunction
       2. Weakness S1 and S2, loss anal wink and bulbocavernosus reflex
       3. Surgical emergency & requires urgent imaging

i. Management of acute disc herniation, excluding cauda equina syndrome
   i. Work cessation, analgesics, and rest
   ii. At 4 - 12 weeks 70 - 73% will have marked improvement and 60% able to return to work in 4 weeks, with only 2-19% undergoing surgery within a year of onset.

2. DJD-Spondylotic changes encroaching on nerve root foramen or nerve in lateral recess of spinal canal (see figures)
   a. Gradual onset of pain (unless superimposed disc herniation)
   b. Age >50, often long-standing back pain, may radiate down leg
   c. Gradual onset of sensory loss/weakness
   d. Often several nerve roots involved
      i. L4 =1%, L5 =31%, S1 =26%, both L5/S1= 25%, bilateral L5 or S1 =17% (mimic ALS)
      ii. C4-5 =2-14%, C5-6 =19-25%, C6-7 =56-70%, C7-T1 =4-10%

e. Management of Radiculopathy secondary to bony entrapment.
   i. Prospective randomized controlled study demonstrate outcome at 1y after lumbar spine surgery is superior but other controlled studies demonstrate after 7, 10 or 20 years equal outcomes in surgical and conservative treatments.
   ii. Prospective randomized controlled study in cervical radiculopathy demonstrates surgery patients have more improvement at 4 months but equal to conservative treatment at 12 months.
   iii. Even with bony root entrapment patients have spontaneous improvement and therefore conservative
management of analgesics & activities as tolerated remain first line.

iv. Limited data on Epidural and Transforaminal injections to recommend. However, Epidural injections may be effective in management of lumbar radiculopathy pain.

f. Lumbar Spinal Stenosis
   i. Neurogenic Claudication
      1. Low back, buttock, bilateral thigh pain brought on by walking or even standing and resolves with sitting for several minutes
      2. Walking flexed such as pushing a cart or walker enlarges spinal canal and may increase waking duration significantly.
      3. May have fixed weakness +/- distal muscle atrophy, and numbness or exam unremarkable
      4. Active lumbar extension may provoke symptoms, Straight-leg often normal
      5. L5/S1 most frequently involved
   6. Management:
      a. Natural history of disease demonstrates mild change/progression in symptoms over time.
      b. Some subjects will have improvement with conservative therapy.
      c. If intolerable symptoms interfere with walking and imaging demonstrates significant stenosis then surgery can be considered as 2 year outcome is favorable, but symptoms can reoccur.

3. Diabetes causing “radiculopathy”
4. Herpes Zoster
   a. pain, paresthesias & weakness with vesicles
   b. L2- S1 roots may be affected, and may have more than one root involved
   c. C2-5, may result in diaphragmatic paralysis
5. Trauma
   a. Disc herniation, vertebral fracture, epidural hematoma
6. Metastatic neoplasm, more often thoracic and lumbar spine, deposits to vertebrae-breast, prostate, lung, lymphoma
7. Early ALS may mimic radiculopathy
8. Benign nerve sheath tumor (Schwannomas or Neurofibromas more often cervical spine)
9. Paget’s disease
10. Congenital spinal stenosis
11. Synovial cysts
12. Inflammatory joint disease: Rheumatoid arthritis and Ankylosing spondylitis typically Cervical spine disease, more often spinal cord-myelopathy
13. Radiculomyelopathy
   a. Chronic spondylotic changes of Cervical Spine and Roots
   b. Usually mid-cervical involving bilateral C6-7 roots-characteristic loss of reflexes in biceps & brachioradialis with hyperreflexias triceps & lower limbs (easily confuse with ALS)
   c. Rheumatoid arthritis C3-6 lesion compressing anterior spinal artery severe C8/T1 weakness/wasting as watershed artery territory
   d. Syringomyelia- more frequently Cervical cord, differentiate from MS and spinal cord tumor

G. Nerve Conduction studies: Do not identify a radiculopathy but help exclude a polyneuropathy, plexopathy or mononeuropathy.
   1. Motor
      a. Acute (3-10 days) no change in CMAP
      b. In 2-3 weeks Wallerian degeneration causes decreased CMAP
      c. In 2-4 weeks sprouting causes increasing CMAP
d. If chronic/ongoing degeneration = sprouting then no change in CMAP
e. Preferential large fiber loss may result in reduced Conduction velocity by ~30%

2. Sensory
   a. Since most lesions proximal to DRG, Sensory nerve conduction normal (Exceptions: Schwannoma, arachnoid cyst)
   b. Paraesthesias:
      i. C6 = digits I & II (may confuse with carpal tunnel syndrome), with pain lateral forearm
      ii. C7 = digit III & dorsum hand, with pain mid-line forearm
      iii. C8 = digit IV & V (may confuse with ulnar neuropathy), with pain medial forearm

H. Proximal Conduction studies
   1. H-reflex: Monosynaptic reflex that is an S1 mediated response
      a. Limited in only assess one root level- S1
      b. Relatively low sensitivity 33-50% for lumbosacral radiculopathy
      c. Compare side-side difference >1.5-1.8 msec is significant, bilateral lesion less useful
      d. May be abnormal in polyneuropathy, tibial or sciatic mononeuropathy, plexopathy so superimposed lesions less useful
      e. Most useful in acute S1 lesion, when EMG changes not yet present
   2. F-waves: Response involving motor axons and motor neuronal pool at spinal cord level.
      a. Limited sensitivity 13-69% for radiculopathy
      b. As with H-reflex, limited to one root level and may be abnormal in polyneuropathy.
   3. Somatosensory and Motor evoked potentials (SEPS and MEPS)
      a. Inadequate evidence to recommend as routine test.
      b. SEP and MEP are found to be normal in subjects without imaging or physical exam findings of cord compression. Therefore, abnormal MEP or SEP likely represents true spinal cord compression/lesion.
      c. Little utility found in using dermatomal SEP in unilateral/unilevel L5/S1 radiculopathies.
I. Electromyography:
1. First (immediate) change is decreased recruitment of voluntary motor unit action potentials (MUAP)
2. Spontaneous activity:
   a. Fibrillation/P-waves seen 10-20 days after acute lesion, with earliest findings in proximal muscles. The proximal muscles affected first by Wallerian axonal degeneration and denervation from a root lesion, and observed earliest in paraspinal muscles.
   b. Fibrillation/P-waves may be scattered if only a few axons involved
   c. Fibrillations decrease with reinnervation; and disappear in paraspinal muscles first
3. Reinnervation (3 – 4 weeks) causes increased polyphasia and duration
   a. But cannot distinguish from oldish (8-12 weeks) from very old >6 months
   b. Distribution helpful: changes in proximal muscles earlier than in distal muscles.
   c. MUAP Amplitude increases with time.
4. Late findings:
   a. Fasciculations
   b. Complex repetitive discharges
   c. Cramp discharges
5. How many muscles to sample?
   a. Cervical Radiculopathy Screen: Without paraspinal muscles the identification of radiculopathy was lower.
      i. 5 muscle screen including paraspinal identified 90-98% and 5 muscles without paraspinal identified 84-92%
      ii. 6 muscle screen including paraspinal identified 94-99% and 6 muscles without paraspinal identified 87-94% of cervical radiculopathies
      iii. Common muscles sampled: Deltoid, Triceps, Biceps, EDC, PT, FCR, FCU, FDIH, APB (example: D, T, PT, EDC, APB & Paraspinals detected 99% of cervical radiculopathies)
   b. Lumbosacral Radiculopathy Screen: Without paraspinal muscles the identification of a radiculopathy was much lower
and required sampling 8 muscles to detect 90% of lumbosacral radiculopathies.

i. 4 muscles including paraspinal identified 88-97%

ii. 5 muscles including paraspinal identified 94-98%

iii. 6 muscles including paraspinal identified 98-100%

iv. Common muscles sampled: Anterior and Posterior Tibialis, Medial and Lateral gastrocnemius, Adductor longus, Vastus lateralis and medialis, Rectus femoris, Short head of biceps femoris, Tensor fascia lata (example: AT, PT, MGas, VMed, SHBF and paraspinal muscles detected 100%)

6. How many muscles should be abnormal to determine radiculopathy?
   a. When only fibrillations or p-waves used and present in two limb muscles, two limb muscles & paraspinal muscles, or one limb muscle and paraspinal muscle 100% specificity for lumbosacral radiculopathy.
   b. When use above plus at least 30% polyphasic in MUAP, specificity = 97%, 98%, and 87% respectively demonstrating EMG is very specific for lumbosacral radiculopathy.
   c. See Tables 4 and 5 for muscles typically found to be abnormal in both Cervical and Lumbosacral radiculopathies.
7. Errors, facts, tips
   a. Fibrillations seen in the first week, after onset of new symptom/root lesion, in distal muscles indicates a preexisting lesion
   b. Low sampling: Must evaluate 2 muscles in suspected root distribution, with multiple sites in the same muscle sampled.
   c. Time element: acute fibrillations are proximal; old fibrillations are distal
   d. MRI has high false positive rate for spine disease
      i. MRI lumbar spine: 27% normal subjects have disc protrusion
      ii. MRI cervical spine: 10% of normal subjects will have a disc bulge/herniation & 19% with any MRI abnormality
e. Sensitivity of EMG for radiculopathy is unimpressive 49-92%. However, while EMG may not be a sensitive test for radiculopathy, it is a very specific test.

i. EMG is a complementary test to MRI; as EMG more specific while MRI more sensitive (for lumbosacral radiculopathy).

ii. At least one study has demonstrated that patients with normal EMG testing before surgery for lumbosacral syndromes were more likely to have poor surgical outcomes.

iii. In a second study, patients with abnormal EMG findings that correlated to spinal imaging and were without psychological issues were more likely to have good surgical outcomes.

References:


2. Lauder et al. Effect of History and Exam in Predicting Electrodiagnostic Outcome Among patients with Suspected Lumbosacral Radiculopathy, Am J of PM&R, 79(1); 60-68:2000

Electromyographic and Nerve Conduction Study
Abnormalities Localizing the Lesion Site in Suspected Ulnar Neuropathy

<table>
<thead>
<tr>
<th>EMG Findings</th>
<th>UNW</th>
<th>UNE</th>
<th>Medial Cord</th>
<th>Lower Trunk</th>
<th>C8–T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>First dorsal interosseous</td>
<td>X</td>
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<tr>
<td>Abductor digiti minimi</td>
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</tr>
<tr>
<td>Flexor digitorum profundus (digits 4, 5)</td>
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<tr>
<td>Flexor carpi ulnaris</td>
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<td>Abductor pollicis brevis</td>
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<td>Flexor pollicis longus</td>
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<tr>
<td>Extensor indicis proprius</td>
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<tr>
<td>Cervical paraspinal muscles</td>
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</tbody>
</table>

**Nerve Conduction Study Findings**

- Low ulnar digit 5 SNAP (if axonal) | X   | X   | X           | X           |       |
- Low dorsal ulnar cutaneous SNAP (if axonal) | X   |     | X           | X           |       |
- Low medial antebrachial cutaneous SNAP (if axonal) | X   |     |             | X           |       |
- Low ulnar CMAP (if axonal) | X   | X   | X           | X           | X     |
- Low median CMAP (if axonal) | X   |     | X           | X           | X     |
- Conduction block/slowing of ulnar nerve across elbow (if demyelinating) | X   |     |             |             |       |

X = may be abnormal; UNW = ulnar neuropathy at the wrist; UNE = ulnar neuropathy at the elbow; SNAP = sensory nerve action potential; CMAP = compound muscle action potential.

Note: The table indicates classic patterns; other patterns may be seen (see text for details).
**Electromyographic and Nerve Conduction Abnormalities**

**Localizing the Lesion Site in Wristdrop**

<table>
<thead>
<tr>
<th>EMG findings</th>
<th>Posterior Interosseous Neuropathy</th>
<th>Radial Nerve: Spiral Groove</th>
<th>Radial Nerve: Axilla</th>
<th>Posterior Cord</th>
<th>C7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extensor indicis proprius</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
</tr>
<tr>
<td>Extensor digitorum communis</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Extensor carpi ulnaris</td>
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<tr>
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<tr>
<td>Brachioradialis</td>
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<tr>
<td>Supinator</td>
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<td>Triceps</td>
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<td>Latissimus dorsi</td>
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<tr>
<td>Flexor carpi radialis</td>
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<tr>
<td>Cervical paraspinal muscles</td>
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<td>X</td>
</tr>
</tbody>
</table>

**Nerve conduction study findings**

- Low radial SNAP (if axonal)  
- X  
- X  
- X  

- Low radial CMAP (if axonal)  
- X  
- X  
- X  
- X  

- Conduction block at spiral groove (if demyelinating)  
- X  

- Conduction block at elbow (if demyelinating)  
- X  

X = abnormalities may be present; SNAP = sensory nerve action potential; CMAP = compound muscle action potential.
<table>
<thead>
<tr>
<th>Electromyographic findings</th>
<th>Deep Peroneal Nerve</th>
<th>Common Peroneal Nerve</th>
<th>Sciatic Nerve</th>
<th>Lumbosacral Plexus</th>
<th>L5</th>
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<tbody>
<tr>
<td>Tibialis anterior</td>
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<td>Extensor hallucis longus</td>
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<td>Peroneus longus</td>
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<tr>
<td>Tibialis posterior</td>
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<td>Gluteus medius</td>
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<td>Tensor fascia latae</td>
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<tr>
<td>Paraspinal muscles</td>
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</table>

<table>
<thead>
<tr>
<th>Nerve conduction study findings</th>
<th>Deep Peroneal Nerve</th>
<th>Common Peroneal Nerve</th>
<th>Sciatic Nerve</th>
<th>Lumbosacral Plexus</th>
<th>L5</th>
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<tbody>
<tr>
<td>Abnormal peroneal SNAP (if axonal)</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Abnormal sural SNAP (if axonal)</td>
<td>X</td>
<td>X</td>
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</tr>
<tr>
<td>Low peroneal CMAP (if axonal)</td>
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<td>X</td>
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<td>X</td>
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</tr>
<tr>
<td>Low tibial CMAP (if axonal)</td>
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<td>X*</td>
<td>X*</td>
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<td>Abnormal H reflex</td>
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<tr>
<td>Conduction slowing/block at fibular neck (if demyelinating)</td>
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<td>X</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

X = abnormalities may be present; CMAP = compound muscle action potential; SNAP = sensory nerve action potential.

*May be abnormal if lesion involves S1 fibers as well.
<table>
<thead>
<tr>
<th>Clinical Differentiating Factors in Femoral Neuropathy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Femoral Neuropathy</strong> (Distal Lesion)</td>
</tr>
<tr>
<td>Weakness of knee extension</td>
</tr>
<tr>
<td>Weakness of hip flexion</td>
</tr>
<tr>
<td>Weakness of hip adduction</td>
</tr>
<tr>
<td>Weakness of ankle dorsiflexion</td>
</tr>
<tr>
<td>Reduced knee tendon reflex</td>
</tr>
<tr>
<td>Sensory loss in anterior medial thigh</td>
</tr>
<tr>
<td>Sensory loss in medial calf</td>
</tr>
<tr>
<td>Sensory loss in proximal medial thigh</td>
</tr>
<tr>
<td>Sensory loss in lateral thigh</td>
</tr>
</tbody>
</table>

X = may be present.