Electrodiagnosis of Cervical Radiculopathy

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KEYWORDS

• Cervical • Radiculopathy • Electrodiagnosis • Electromyography

KEY POINTS

- To properly diagnose cervical radiculopathy, a combination of clinical signs/symptoms, imaging, and electrodiagnostic studies should be used.
- Differential diagnosis must consider various causes of neuropathic and musculoskeletal pain, which may be affecting the extremity.
- Needle electromyography is the most useful electrodiagnostic technique and provides moderate sensitivity in the diagnosis of radiculopathies.
- Appropriate sampling of muscles must be done including paraspinals, if possible, to ensure a diagnostically accurate study.
- Electrodiagnostic findings can be particularly useful for patients with atypical symptoms, potential pain-mediated weakness, and nonfocal imaging findings.

INTRODUCTION

Cervical radiculopathy is a common disorder effecting people most often in the fourth and fifth decades of life. Symptoms of pain, numbness, and/or tingling may be mild, but in severe cases, cervical radiculopathy will be associated with motor weakness. Efficient diagnosis can minimize pain and disability and also minimize the direct and indirect costs of care. Treatment of cervical radiculopathy is based on a clear understanding of its natural history, clinical evaluation, diagnostic testing, and therapeutic options for this disorder. This article will provide an overview of the pathophysiology, pertinent anatomy, history/examination findings, and imaging options. It will focus on the electrodiagnosis of cervical radiculopathy. Electrodiagnosis is a critical part of the evaluation of patients presenting with signs and symptoms of neuropathic upper extremity dysfunction, especially when coexisting with neck pain. This article will review developing an appropriate differential diagnosis and

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choosing appropriate electrodiagnostic techniques with a focus on needle electromyography (EMG).

EPIDEMIOLOGY

An epidemiologic study of cervical radiculopathy was performed at the Mayo Clinic between 1976 and 1990.[1] Five hundred sixty-one cases were included in this study. This research revealed the following:

- Age ranged from 13 to 91 years (332 males, mean age 47.6 ± 13.1 years; 229 females, mean age 48.2 ± 13.8 years)
- History of trauma or exertion was found in only 14.8% of cases
- Previous history of lumbar radiculopathy was found in 41% of cases
- Median duration of symptoms before diagnosis was 15 days
- Monoradiculopathy involving nerve root C7 was most common, followed by nerve roots C6, C8, and then C5 in decreasing frequency
- Etiology included confirmed disc protrusion (21.9%) and spondylosis, disc, or both (68.4%)
- Recurrence over 4.9 years = 31.7%
- Surgery was performed in 26% of patients
- Ninety percent of patients were asymptomatic or only mildly incapacitated at last follow-up

A more recent study looked at the incidence of cervical radiculopathy in the US military from 2000 to 2009.[2] They found that age (40 years old and above) was the greatest risk factor for cervical radiculopathy, and that female sex, white race, senior military position, and service in the Army or Air Force were also risk factors.

ANATOMY

The cervical spine is comprised of 7 vertebrae. The first vertebra (C1, also called the atlas) is a ring-shaped bone without a spinous process. It serves as the point of attachment of the skull to the spine via the occipital condyles articulating with the superior aspect of the C1 vertebra. C1 articulates directly with C2 without the presence of an intervertebral disc. C2 has a bony superior process called the dens, which projects into the ring of the atlas and serves as the axis of rotation.

Facet Joints (Zygapophyseal Joints)

Vertebrae C3 through C7 have posteriorly placed facet joints that serve as points of articulation between the vertebrae. These are paired joints that arise at the junction of the pedicle and the lamina. The superior facets project upward to articulate with the inferior facets of the superior adjacent vertebra. The inferior facets project downward to articulate with the superior facets of the inferior adjacent vertebra. These joints are synovial with a surrounding capsule. The joints are innervated by the medial branch of the dorsal primary ramus of the exiting spinal nerve. The joints provide directional stability and prevent relative translation of 1 vertebra upon another. They lie posterior to the exiting spinal nerve root.

Uncovertebral Joints (Joints of Luschka)

Extending off the lateral surface of the cervical vertebral bodies are small bony projections called uncinate processes. The uncinate process makes contact with the disc and vertebral body above. The points of contact are called uncovertebral joints, and they are located anteromedial to the exiting nerve roots.

Intervertebral Disc

Between cervical vertebrae C2 through C7 is a supporting intervertebral disc. The disc is comprised of 2 layers; the outer layer is called the annulus fibrosis, which is made up of approximately 20 concentric lamellae of orthogonally oriented fibers. The inner layer is called the nucleus pulposis, comprised of 90% water, which desiccates with age. The anterior annulus is reinforced by the anterior longitudinal ligament (ALL), and posteriorly by the posterior longitudinal ligament (PLL). The PLL is not very broad, and accordingly there is greater chance of nucleus pulposis herniation laterally as opposed to centrally.

Spinal Canal

The spinal canal is made up of the consecutive vertebral foramen. In the intervertebral spaces, the canal is protected posteriorly by the ligamentum flavum and anteriorly by the PLL. The spinal canal has its greatest Anterior-Posterior (A-P) diameter in the upper cervical spine between C1 and C3. During maximal cervical spine extension, the canal narrows an additional 2 to 3 mm.

Spinal Motion

The specific motions of each cervical segment have been thoroughly described elsewhere. Broadly speaking, most rotational movement of the head occurs in the upper cervical spine, where flexion and extension occur predominantly in the lower cervical spine. Accordingly, spondylotic disease arises most commonly in the lower cervical spine.

Intervertebral Foramina

The foramina are bordered anteriorly by the vertebral body and disc, and posteriorly by the facet joint. The pedicles form the superior and inferior margins of the foramen. Additionally the uncinate processes are located at the anteromedial margin of the foramen.

Neural Elements

The spinal cord is located within the central canal. There is an enlargement of the cord diameter within the cervical spine from C3 through T2, and in the lumbar spine from L1 to S3. The spinal nerve is comprised of sensory fibers traveling through the dorsal root and motor fibers from the ventral root. The dorsal root ganglia (DRG) are located on the dorsal nerve roots, usually in the intervertebral foramen, just outside the spinal dural layer. The DRG of C4 and C5 are located closer to the spinal cord than the lower roots.[3] The dorsal and ventral roots fuse to form the spinal nerve in the intervertebral foramen. The spinal nerve continues for a few millimeters before it separates into the dorsal and ventral rami. The dorsal rami supply the cervical paraspinals (PSPs) and skin of the back of the neck. The ventral rami form the cervical and brachial plexuses.

The cervical nerve roots exit through the intervertebral foramen above the corresponding cervical vertebral body. For example, the C5 nerve root exits through the C4 to C5 intervertebral foramen. The C8 nerve root exits below the C7 vertebral body and above the T1 vertebral body. Subsequent nerve roots exit below the corresponding vertebral body.

Understanding the anatomy of the exiting spinal nerve with regards to both the innervation of the PSP musculature and position of the DRG is critical in understanding the results of the electrodiagnostic evaluation of cervical radiculopathy.

ETIOLOGY

Radiculopathy arises from a process that affects the nerve root. These processes can be divided into compressive and noncompressive causes. The compressive causes include cervical spondylosis and disc herniation.

Compressive Causes

Cervical spondylosis

As the nerve root enters the foramen medially, it lies at the level of the superior articular facet of the inferior vertebrae. Hypertrophy of either the uncovertebral joints or the facets joints may impinge mechanically on an exiting nerve root to cause radiculopathy. The process of degenerative change in these joints is called spondylosis. Degenerative change may also result in bone formation in these areas, producing an osteophyte or hard disc.

Disc herniation The anatomy of the intervertebral disc has been discussed previously. Circumferential tears in the annulus fibrosis begin to be present around the age of 20 and progress to fraying and splitting of collagen fibers. With the progression of degeneration, there is continued loss of the fluid properties of the nucleus pulposis, which undergoes replacement with fibrous tissue. The combination of intervertebral pressure and degenerative change of the disc can lead to tears in the annulus, which allow for disc bulging and/or prolapse of the nucleus pulposis. This often results in deformation of the DRG. The mechanical deformation (either compression or tension) causes release of substance P, phospholipase 2, and vasoactive intestinal peptide from the nucleus pulposis. This produces a chemical inflammation that is an additional insult to the nerve root on top of any mechanical pressure.

Noncompressive causes

Although less common, noncompressive causes should always be considered. These include demyelination, infection, tumor infiltration, root avulsion, and nerve root infarction. The dorsal and ventral roots may be affected (much more so than in compressive etiologies). Deficits of noncompressive radiculopathies may span multiple myotomes and dermatomes, and may be more complete or dense than are commonly seen in compressive etiologies.

KEY HISTORY FINDINGS

The patient's history is critical in evaluating a suspected radiculopathy, because there is an extensive differential diagnosis to be considered. Symptoms may develop acutely with an initial episode of neck pain followed by radiation in a dermatomal pattern or weakness in the affected extremity. A herniated disk more often causes acute radiculopathy, while spondylitic narrowing results in a more indolent course. Patients may complain of neck pain, arm pain, chest or shoulder pain, pain in the interscapular region, or pain in the face.[4]

Dermatomal paresthesia or numbness develops in 80% of patients. Subjective weakness is less common than paresthesia.[1] The patient may describe positions that alleviate symptoms, such as rotating the head away from the affected side, and the abducted shoulder sign, in which the patients describe pain relief with the affected shoulder abducted and the hand resting on top of the head.

Some patients may describe a recent history of physical exertion or trauma preceding symptom onset; however, most cases have no readily identifiable causative event.[4]

More concerning complaints that may suggest not only radiculopathy but also myelopathy or infection must also be sought. Lhermitte sign (shock-like paresthesias occurring with neck flexion), difficulty walking, or bowel and bladder symptoms are suggestive of myelopathy or intramedullary pathology. Any history of fever, chills, weight loss, or cancer should raise suspicion for tumor or infection.[5]

KEY PHYSICAL EXAMINATION FINDINGS

The initial physical examination includes observation of the patient, noting the position of the head and neck contours. Atrophy can be detected with more severe or long-standing lesions. Muscle wasting may suggest particular nerve root involvement:

C5 or C6: supra- or infrascapular fossae or deltoid
C7: triceps
C8: thenar eminence
T1: first dorsal interossei

Manual muscle testing has greater specificity than reflex or sensory abnormalities, and might need to be performed repetitively or with the muscle at a mechanical disadvantage to elicit subtle weakness.[6] Severe weakness (<3/5 on the Medical Research Council grade) is less consistent with a single root lesion and should prompt the examiner to search for multilevel pathology. Sensation to light touch, pinprick, and vibration should be assessed. Upper motor neuron signs should also be assessed including Hoffman sign and Babinski response.

Provocative maneuvers such as Spurling maneuver may be performed. This test is performed by extending and rotating the neck to the painful side followed by the application of downward pressure to the head.[7] The test is positive if it reproduces limb pain and/or paresthesia. Neck pain alone does not signify a positive test. The Spurling maneuver has a high specificity but moderate-to-low sensitivity for cervical radiculopathy.[8] A negative test does not rule out radicular pathology.

DIAGNOSTIC IMAGING

Plain Radiographs

Conventional radiographs are often obtained in the evaluation of neck pain, but their utility in establishing a diagnosis is somewhat limited. Radiographs have relatively low sensitivity in detecting tumor, infection, and disc herniation. Plain radiographs may be completely normal in patients with tumor or infection. Conversely, patients with compressive radiculopathy will likely have multilevel pathology identified on plain radiographs. Furthermore, there is limited value in the finding of cervical intervertebral narrowing in predicting nerve root compression.[9]

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is the imaging modality of choice when investigating cervical radiculopathy.[10] MRI generally provides superior evaluation of the soft tissues when compared with computed tomography (CT), although bony abnormalities may be underestimated, while stenosis is often overestimated.[11] T1 weighted images show bone spurs and disc herniations as hypointense, making it difficult to distinguish these structures from bone and ligament. T2 weighted images create a myelographic effect as fluid (both cerebrospinal fluid [CSF] and water within the nucleus pulposis) appears bright. Gadolinium enhanced images should be obtained if there is suspicion of metastatic disease, osteomyelitis, or other inflammatory

conditions. Radiographic abnormalities should always be interpreted within a clinical context.

Computed Tomography

CT myelography is considered the gold standard in evaluating foraminal compression. CT myelography is superior to MRI in distinguishing osteophyte from soft tissue material, although there is some evidence that CT myelography may be inadequate to assess developing osteophytes.[12] Due to the exposure to ionizing radiation, CT and CT myelography are usually reserved for patients who are claustrophobic or when MRI is contraindicated or nondiagnostic.

The clinician should always be cognizant of the fact that normal age-related changes may occur in the cervical spine in the absence of symptoms. Matsumoto and colleagues[13] recently reported a study of asymptomatic middle-aged patients (mean age 48 years) in which over 90% of patients had cervical degenerative changes on MRI – including posterior disc protrusion, anterior compression of the thecal sac, and decrease in disc height.

DIFFERENTIAL DIAGNOSIS OF POTENTIAL UPPER EXTREMITY RADICULAR SIGNS/SYMPTOMS

Patients with classical symptoms of neck pain and radicular type pain are often referred to the electrodiagnostic laboratory to be evaluated for cervical radiculopathy. However, often signs or symptoms will be more vague. The electromyographer following a thorough history and directed physical examination should also consider other diseases that may be mimicking a cervical radiculopathy and design an electrodiagnostic study to evaluate for these other possibilities as appropriate. Differential diagnoses are discussed in the following sections.

Peripheral Nerve Lesions

Median and ulnar neuropathies are very common and must always be considered a possibility in patients with neurologic finding in the upper extremity. Even if a patient has evidence of cervical radiculopathy, it is important to realize that peripheral nerve entrapments often occur concomitantly and should be documented. Questioning should include identification of numbness, paresthesias into the hand, repetitive motion history, and other potential risk factors for nerve entrapments.

Brachial Plexopathies

While brachial plexus lesions are less common then peripheral nerve entrapments, they must also be considered in the differential diagnoses. Traumas or mass lesions are common causes of plexopathies. When considering the possibility of a mass lesion, one should inquire about weight loss, fevers, night sweats, and smoking history. Idiopathic brachial neuritis (Parsonage-Turner syndrome) should also be considered, especially with a presentation of acute shoulder pain followed by muscle weakness.

Other Conditions

It is important also to consider other conditions such as myelopathy secondary to central spinal stenosis, which may present with more bilateral weakness, upper motor neuron signs, and possible bowel/bladder involvement. Motor neuron disease should be considered in a patient presenting with upper extremity weakness without radicular-type pain or sensation changes on examination. Neurogenic thoracic outlet

syndrome may also be considered but is a rare diagnosis to make in the electrodiagnostic laboratory. Non-neurologic causes of upper extremity pain should also be considered such as facet disease, subacromial bursitis rotator cuff pathology, and lateral/medial epicondylitis. Each of these processes may mimic radicular pain.

ROLE OF ELECTRODIAGNOSIS

Electrodiagnosis plays a critical role in the assessment of patients with symptoms and signs of cervical radiculopathy. Electrodiagnosis is often referred to as an extension of the neurologic examination, as it is able to provide physiologic evidence of nerve dysfunction. The electrodiagnostic study can aid in clarifying the presumed diagnosis of radiculopathy and is critical in identifying other possible nonroot-level causes of neurologic dysfunction. The electrodiagnostic information and history, physical, and imaging findings are combined to confirm the most likely diagnosis and to guide future treatment. Electrodiagnostic findings can be particularly useful for patients with atypical symptoms, potential pain-mediated weakness, and nonfocal imaging findings.

Various types of electrodiagnostic studies may be considered when evaluating a patient for cervical radiculopathy in the electrodiagnostic laboratory. Potential tests include EMG, motor and sensory nerve conduction studies, late responses, and somatosensory evoked potentials. These tests can all be considered based on the clinical scenario and will be discussed individually.

ELECTROMYOGRAPHY

EMG is the most useful test for evaluating for radiculopathy. The EMG portion of the examination can localize lesions to a particular root level and can provide information on acuity of the disease process. The goal of EMG is to find a pattern of spontaneous and/or chronic motor unit changes in a clear myotomal pattern. It is also important to note the limitations of EMG. EMG can only detect change in the motor nervous system; furthermore, it primarily detects damage to the axonal component of the nerve versus myelin. Many early radiculopathies may have a primary sensory and demyelinating component, and these types of radiculopathies would not be detected with needle sampling.

Diagnostic Criteria for Needle EMG

To diagnose radiculopathy electrodiagnostically, needle study of 2 muscles that receive innervation from the same nerve root, preferably via different peripheral nerves, should be abnormal. Adjacent nerve roots should be unaffected unless a multilevel radiculopathy is present. Since muscles receive innervation from multiple levels, the pattern of abnormalities should point to a nerve root level that is primarily affected. Various myotomal maps are available to assist the electromyographer in determining the root level affected (**Fig. 1**).

Sensitivity of Needle EMG

The utility of needle EMG in diagnosing cervical radiculopathy with regards to sensitivity was thoroughly reviewed in 1999 by the American Association for Electrodiagnostic Medicine (AAEM), now known as the American Association for Neuromuscular and Electrodiagnostic Medicine (AANEM), and published as a practice parameter.[14] Establishing the sensitivity of electrodiagnostic testing (as well as many radiological procedures) is difficult, because there is no gold standard by which one can definitively true presence of disease.

MUSCLE	C5	C6	C7	C8	T1
Proximal Nerves					
RHOMBOID (dorsal scapular nerve)					
SUPRASPINATUS/INFRASPINATUS (suprascapular nerve)					
DELTOID (axillary nerve)					
BICEPS (musculocutaneous nerve)					
Radial Nerve					
TRICEPS					
BRACHIORADIALIS					
EXTENSOR CARPI RADIALIS					
EXTENSOR POLLICIS BREVIS					
EXTENSOR INDICIS PROPIUS					
Median Nerve					
PRONATOR TERES					
FLEXOR CARPI RADIALIS					
FLEXOR POLLICIS LONGUS (anterior interosseous nerve)					
PRONATOR QUADRATUS (anterior interosseous nerve)					
ABDUCTOR POLLICIS BREVIS					
Ulnar Nerve					
FLEXOR CARPI ULNARIS					
FLEXOR DIGITORUM PROFUNDUS (medial part)					
ADDUCTOR POLLICIS					
FIRST DORSAL INTEROSSEOUS					

Fig. 1. Upper extremity myotomal chart showing major and significant nerve root innervation of upper extremity muscles. Boxes shaded in green represent a dominant contribution, while boxes shaded in yellow represent a significant contribution. Minor contributions are not shown.

The articles that were included in the AANEM review used a combination of clinical and radiological findings as a comparison. The 9 studies they cited in their final review revealed overall sensitivity of needle EMG in the diagnosis of cervical radiculopathy to be between 50% and 71%, which they described as having moderate diagnostic sensitivity. Studies that reported more motor deficits clinically had higher reported sensitivities in their review. Based on these reported sensitivities, it is important to understand that a negative EMG study for cervical radiculopathy does not rule out the presence of disease.

Appropriate EMG Study Design

Following the publication of the AANEM practice parameter, Dillingham and colleagues[15] published an article discussing the sensitivity of needle EMG screening in diagnosing cervical radiculopathies. The main question tackled in this study was how many muscles should be sampled to provide good sensitivity in detecting radiculopathy. Most electromyographers would agree sampling a few muscles is not sufficient to detect radiculopathy, but it is important to define the minimum number of muscles needed to ensure a quality examination. The study looked at 101 patients with cervical radiculopathy and tested 10 muscles in each patient. Analysis revealed that testing 6 muscles including the cervical PSPs achieved a sensitivity of 94% to 98% for the presence of radiculopathy. If PSPs were not tested, they recommend testing of 8 limb muscles to achieve a sensitivity of 92% to 95%.

PSP Findings

While the presence of fibrillations and positive sharp waves (PSWs) in the limb muscles of normal subjects is considered very unusual, the documentation of these

waveforms in the PSP muscles of normal subjects is more controversial. Two studies showed presence of PSWs in the cervical PSPs in normal subjects without neck pain or radicular arm pain. The first study found PSWs in 92% of PSPs in subjects older than 40 years old and fibrillations in 8% of subjects greater than 40 years old. They found no PSPs or fibrillations in patients under 40 years old.[16] The second study noted PSWs in 12% of the PSP muscles tested on asymptomatic subjects.[17] These studies illustrate some of the caveats of diagnosing radiculopathy based primarily on PSP findings, particularly in an older population.

However, such studies do not negate the importance of the PSP examination. As mentioned previously, Dillingham found that testing PSPs adds significant sensitivity to the needle examination for cervical radiculopathy. The presence of PSP abnormalities in combination with limb findings makes radiculopathy a more likely diagnosis. Lack of PSP findings may indicate a more distal lesion localized to the brachial plexus or peripheral nerve. The pattern of EMG abnormalities and nerve conduction study findings would help also to differentiate nerve root- from nonroot-level causes of upper extremity nerve dysfunction.

There are also other limitations to PSP muscle sampling. The proximity of the PSP to the nerve root means it may be the first abnormality detected in an early acute radiculopathy (as soon as 7 days), but also it may be the first muscle to return to normal. So based on the timing of the electrodiagnostic examination, a patient may have clear upper extremity myotomal EMG pattern with absent or subtle PSP abnormalities. It is also important to note that PSPs can also be positive in other diseases not related to nerve root compression. For example, patients with both motor neuron disease and inflammatory myopathies such as polymyositis may demonstrate PSWs in the PSP muscles. Finally, PSPs may exhibit both PSWs and fibrillations many years following any posterior approach spinal surgery. Some have also expressed concern of seeing some PSP abnormalities related to muscle trauma from repeated epidural steroid injections.

SPECIFICITY OF NEEDLE EMG

While sensitivity is a critical component in determining the utility of a test, a test must also have good specificity to ensure low false-positive results. Anecdotal evidence, clinical experience, and published studies involving normal subjects confirm high specificity of needle EMG in diagnosis of radiculopathy. A recent study looking at EMG patterns in the lower extremities showed no false-negative diagnoses of radiculopathy (ie, 100% specificity) when a pattern of acute changes was shown in 2 limbs and the PSP muscles.[18] Using less strict criteria of greater than 30% polyphasia in the same muscle groups, specificity was still excellent, at 87% to 97%.

NERVE CONDUCTION STUDIES

The primary role of nerve conduction studies in patients with symptoms of cervical radiculopathy is to determine if other neurologic processes exist as an explanation for a patient's clinical picture, or if another process coexists with a root level problem. The AANEM's 1999 practice parameter recommends performing at least 1 motor and sensory study when evaluating a patient for cervical radiculopathy. In pure radiculopathy, the sensory nerve studies should be normal. As described in detail previously, the pathologic lesion in radiculopathy typically occurs proximal to the DRG. Since the DRG houses the cell bodies for the sensory nerves, the sensory nerve studies should be normal. Marked abnormalities in sensory studies should prompt the electromyographer to look for disease processes that occur distal to the DRG, such as plexopathy, generalized peripheral neuropathy, or peripheral nerve entrapments. The

motor nerve conduction studies are also typically normal in cervical radiculopathy unless there is severe axon loss or multilevel disease.

The extent of the nerve conduction studies performed needs to be determined by the clinical scenario, and the differential diagnosis should be generated following the history and physical examination performed by the electromyographer. It is very common for patients who present with neck pain and radicular symptoms to also have symptoms that affect the hand, such as numbness. While neuropathic pain, numbness, and/or paresthesias could be related to cervical radiculopathy, in these cases, one must look more thoroughly for common nerve entrapments such as median neuropathy at the wrist or ulnar neuropathy at the elbow. If trauma has occurred or patients present with sudden shoulder pain followed by weakness, additional nerve conduction studies would also be considered to look for brachial plexus-level issues related to trauma or an idiopathic acute brachial neuritis.

Ulnar neuropathy can mimic symptoms of C8/T1 radiculopathy. Ulnar motor studies should be performed in patients presenting for evaluation of cervical radiculopathy who also have paresthesias or symptoms in typical ulnar innervated areas. In patients with predominantly median distribution symptoms or more diffuse sensory complaints, nerve conduction studies looking for carpal tunnel syndrome are indicated. Median motor studies and thorough sensory comparison evaluations such as the Robinson Index should be considered to ensure accurate diagnoses.[19]

Nerve conduction studies are also important for patients who may have symptoms of more generalized peripheral neuropathy. If the patient has symptoms of diffuse paresthesias (upper and lower extremities) or other neuropathic risk factors such as diabetes or alcohol use, the electromyographer may need to expand the electrodiagnostic study to include the contralateral limb, as well as potential nerve conduction studies in the lower extremity. In an appropriately designed study, the nerve conduction studies should be able to differentiate between peripheral nerve entrapment and a generalized process. The exception to this is when there is a severe peripheral neuropathy with many absent responses.

LATE RESPONSES

The utility of late responses such as F-waves and H-reflexes in diagnoses of cervical radiculopathy is debated. While H-reflexes can be useful in diagnosing S1 radiculopathies, there is less evidence to support use of late responses in the upper extremity. The 1999 AAEM practice parameter considers testing for F-waves and H-reflexes as optional studies when considering the diagnosis of cervical radiculopthy. F-waves are not sensitive in diagnosing radiculopathy and tend to be abnormal in severe disease. Like EMG, F-wave study only tests motor fibers. Furthermore, it is not useful to localize lesions. For example, F-waves recorded from the abductor pollicis brevis or abductor digiti minimi are evaluating both C8 and T1 pathways, so abnormalities do not single out a nerve root. Also, abnormalities of F-waves can be consistent with lesions in the peripheral nerve, plexus, or nerve root. A more recent study, published in 2007, suggested that various F-wave parameters may improve the diagnostic yield for cervical radiculopathy when combined with needle EMG. However, the study also noted that F-wave abnormalities could not localize a lesion to a specific cervical level.[20] It is also important to note that F-waves tend not to be well tolerated by patients, since they require supramaximal stimulation. This, combined with questionable diagnostic utility, contributes to the low use of these studies to diagnose cervical radiculopathy.

H-reflex study recording over the gastrocnemius or soleus muscle is commonly performed when considering an S1 radiculopathy. In the upper extremities, C6/C7 levels

can also be evaluated by stimulating the median nerve at the elbow to obtain an H-reflex to the flexor carpi radialis. It is reported that this response is obtainable in 90% of normal subjects but may require facilitation techniques.[21] Two more recent studies reported that the upper extremity H-reflex can add utility in the diagnosis of cervical radiculopathies, especially in cases when clinical symptoms are less clear and needle EMG is normal.[22,23]

SOMATOSENSORY EVOKED POTENTIALS

There is conflicting evidence on the utility of somatosensory evoked potentials (SEPs) in the diagnosis of cervical radiculopathy. Mixed nerve studies of the tibial, median, and ulnar nerves may be useful in assessing patients with cervical myelopathy or other central causes of neurologic symptoms (ie, multiple sclerosis). Dermatomal SEPs, in theory, should provide information on single-root sensory nerve root dysfunction for patients with cervical radiculopathy; however, review of clinical studies does not provide clear evidence to support routine use of SEPs in the diagnoses of cervical radiculopathy.[24]

SUMMARY

Referral for evaluation for cervical radiculopathy is a common request in electrodiagnostic laboratories. To properly diagnose cervical radiculopathy, a combination of clinical signs/symptoms, imaging, and electrodiagnostic studies should be used. It is crucial to generate a differential diagnosis to consider various causes of neuropathic and musculoskeletal pain that may be affect the upper extremity. Based on these findings, the provider can design an appropriate study based on the differential diagnoses.

It is also critical to understand the spinal anatomy of the cervical region, both with regards to the orientation of the spinal roots, as well as the location of the dorsal root ganglion. Needle EMG is the most useful electrodiagnostic technique, and it provides moderate sensitivity in the diagnosis of cervical radiculopathy. Appropriate sampling of muscle must be done including PSPs, if possible, to ensure a diagnostically accurate study. Nerve conduction studies are often needed to rule out peripheral nerve entrapments or atypical presentations for peripheral neuropathies.

Electrodiagnosis provides moderate sensitivity in diagnosing cervical radiculopathy. With good specificity, it is useful in confirming disease, excluding other diseases, and helping to localize lesions. It is critical to remember that a normal study does not rule out the presence of cervical radiculopathy. Electrodiagnostic findings can be particularly useful for patients with atypical symptoms, potentially pain-mediated weakness, and nonfocal imaging findings.

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