Electrodiagnosis of Lumbar Radiculopathy

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KEYWORDS

• Electrodiagnosis • EMG • Lumbar radiculopathy

KEY POINTS

- It can often be clinically challenging to diagnose lumbar radiculopathy. Electrodiagnostic studies are helpful in this diagnosis because the test is very specific and is therefore a good complement to lumbar magnetic resonance imaging, which is a very sensitive, but not specific, test for lumbar spine disease. In addition, it is the only test that gives information about the physiologic function of the nerve root, or if damage to a nerve root has occurred.
- A thoughtfully planned study can also help rule out competing diagnoses that cause pain or neurologic changes in the lower extremity as well as rule in the diagnosis of radiculopathy.
- The utility of electrodiagnostic studies in the diagnosis of radiculopathy depends on the expertise of the examining physician to plan, perform, and interpret the study appropriately.

INTRODUCTION

Lumbosacral radiculopathies were first described by Mixter and Barr in 1934, and electrodiagnosis has been part of the clinical evaluation of this condition for over 50 years.[1] The question of whether a lumbar radiculopathy is present is one of the most common referrals to the electrodiagnostic laboratory.[2] This review describes the value and limitations of electrodiagnostic studies in evaluating for this condition, as well as the technical aspects of planning the optimal electrodiagnostic study to evaluate for the presence of radiculopathy and to rule out competing diagnoses. There is also a discussion regarding the use of electromyography (EMG) to help determine the prognosis and treatment of radiculopathy.

It is not always easy to diagnose lumbar radiculopathy. There are many different medical conditions that cause low back and lower extremity pain, or patients may have more than one disorder. Some patients are vague historians, without a clear recall of their symptoms; sometimes the clinical picture is confounded by issues regarding compensation or blame. The physical examination relies on the patient's

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cooperation and may be difficult to interpret. Because of this, it is common for patients to undergo further testing to confirm or rule out this diagnosis. From an evidence-based medicine perspective, it can be difficult to assess the value of these tests, because there is no one gold standard for the diagnosis of lumbar radiculopathy. Therefore, in both research and the clinic, a combination of history, physical examination, imaging, and electrodiagnostic testing is used to come to a diagnosis.

MAGNETIC RESONANCE IMAGING VERSUS ELECTRODIAGNOSTIC STUDIES IN DIAGNOSING LUMBAR RADICULOPATHY

Most radiculopathies are caused by root compression, most commonly from intervertebral disk disease or other degenerative changes of the spinal column, such as ligamentous hypertrophy or the bony changes that accompany osteoarthritis. Other compressive lesions can less commonly cause radiculopathy, such as tumors and cysts. Magnetic resonance imaging (MRI) is exquisitely sensitive in detecting these anatomic changes. However, MRI often shows disk disease and other degeneration in asymptomatic people. Lumbar disk protrusions can be seen in as high as 67% of asymptomatic patients older than age 60, and more than 20% have lumbar central stenosis.[3] Therefore, MRI is very sensitive in detecting anatomic changes that could cause a radiculopathy but does not give any information about nerve function or whether these anatomic changes could be a source of symptoms.

There are other causes of radiculopathy besides nerve root compression, and MRI would not be helpful in the diagnosis of these types of radiculopathy. Motor radiculopathy can be seen in patients from varicella zoster virus, even in the absence of skin lesions.[4] Inflammatory mediator cytokines, perhaps from regional disk disease or other factors, can be a source of neuropathic pain and a "chemical radiculitis" without evidence of nerve root compression.[5,6]

STRENGTHS OF ELECTRODIAGNOSTIC TESTING FOR RADICULOPATHY

Studies have found that needle EMG is very specific in the diagnosis of lumbar radiculopathy when the appropriate electrodiagnostic criteria are used. For that reason clinically EMGs are commonly performed to rule in a radiculopathy, particularly in the following situations:

1. To determine if the structural changes seen on MRI are the common finding of an asymptomatic abnormality or are actually causing physiologic abnormalities in the nerve root
2. To determine the most likely affected level if clinical symptoms and imaging levels do not match
3. To look for physiologic evidence if noncompressive radiculopathies are suspected
4. To determine prognosis related to axonal loss
5. To search for other causes of neurologic symptoms
6. Electrodiagnostic studies for radiculopathy are rarely false positive: if an EMG shows evidence of a radiculopathy, the patient almost certainly has one. When the criteria used for diagnosis are the presence of positive sharp waves and fibrillation in 1-limb muscle plus lumbar paraspinal muscles at the corresponding level, or in 2-limb muscles innervated by the same nerve root, it is 100% specific, both in asymptomatic patients and in those patients with low back pain and sciatica. If evidence of either acute changes or chronic denervation (as demonstrated by more than 30% of motor units are polyphasic, have large amplitude, and have increased duration in a study that uses monopolar needles) is used as the

electrodiagnostic criteria, then specificity decreases, but still remains in the range of 81- nearly 100%, depending on the level tested.[7]

LIMITATIONS OF ELECTRODIAGNOSTIC STUDIES BECAUSE OF THE NATURE OF RADICULOPATHY

In contrast to the strength of very high specificity, one of the biggest limitations of electrodiagnostic testing for radiculopathy is that sensitivity is not that high. The exact sensitivity cannot be calculated, because of the lack of a gold standard, but it is often noted that a patient may clinically seem to have a radiculopathy that electrodiagnostic testing is unable to diagnose. It is also possible that an electrodiagnostician could determine that a radiculopathy is present, but be unable to ascertain the exact root level involved. Some reasons for this relative insensitivity follow.

WHY A PATIENT COULD HAVE A RADICULOPATHY AND STILL HAVE A NORMAL ELECTRODIAGNOSTIC STUDY

1. Inability to detect pure sensory radiculopathies: Clinically, most patients present with either purely sensory complaints (such as pain, parasthesias, or numbness) or primarily sensory complaints with some minimal complaints of weakness. However, because the site of nerve injury is proximal to the dorsal root ganglion in radiculopathies, sensory nerve conduction studies will be normal.[2] Therefore, there is no way for electrodiagnostic studies to evaluate these purely sensory nerve problems. Because there is no gold standard for the diagnosis of radiculopathy, it is unknown what percentage of radiculopathies is purely sensory.
2. Subtotal root involvement is the norm in lumbar radiculopathies: This root involvement may include demyelination, which would not cause most of the characteristic changes evaluated for on needle EMG, or limited axonal loss that goes undetected because only a few axons are involved. Therefore even in the presence of a motor radiculopathy, nerve fibers supplying much of the muscle are spared.[2]
3. If denervation is balanced with reinnervation, or the denervation is old, no fibrillations will be seen, and the denervation will be missed.[5]

WHY A PATIENT COULD HAVE A RADICULOPATHY, BUT THE LEVEL OF NERVE INJURY CANNOT BE DETERMINED

Imprecision of Myotomal Maps

Many myotomal maps have been published, but the primary root innervation of many muscles remains unclear. Besides a lack of consensus in this area, there is considerable individual variation in the innervation of individual muscles.[8] Because of this, if needle EMG changes are found in a muscle, the examining physician cannot say with 100% certainty what root level innervates that muscle; the examiner can only state what is thought to be the usual level for a typical patient.

Difficulty with Precise Localization of the Lesion in Patients with High Lumbar Radiculopathy

There are 2 issues that make this a difficult condition to diagnose precisely with electrodiagnostic testing. One issue is that lesions of L2, L3, and L4 radiculopathy have very extensive myotomal overlap, so it is often not possible to separate out which of these specific roots is the cause of the electrodiagnostic findings. The second issue is that it is often difficult to separate out plexopathy from radiculopathy at these levels. There are 2 main reasons for this. One is that, unlike brachial plexopathies, there are no good, reliable sensory nerve conduction studies for the nerves that arise for the

upper lumbar plexus. If there were, this would give evidence to the electrodiagnostician that the problem is the plexus rather than the nerve root. The second reason is the limitation of paraspinal muscles in separating plexopathy from radiculopathy. In theory, abnormal paraspinal muscles would be expected in radiculopathy and would not be present with plexopathy. However, in reality, sometimes the paraspinal muscles are normal, and a radiculopathy is present; sometimes the paraspinal muscles are abnormal for reasons unrelated to radiculopathy.

Difficulty with Precise Localization of the Lesion in Patients with Lower Lumbar and Sacral Radiculopathies

Because of the anatomy of this region, there are many locations where the nerve root may be injured by a ruptured disk or other compressive force. For example, a disk herniation between the L4 and L5 vertebral bodies (which is the most common level) can affect the L4 root if it is a far lateral herniation, the L5 root if it is a posterior lateral herniation, and the S1–S4 roots if it is a central herniation. Within the cauda equina, roots are packed closely together so it is common for bilateral, multiroot lesions to be found in lumbar central stenosis.[2]

ANOTHER STUDY LIMITATION: EXAMINER EXPERTISE

Although these studies may seem to be objective; in reality, just as in other diagnostic tests, the skill of the physician performing and interpreting the study is the biggest factor in obtaining accurate results. This issue was studied by Kendall and Werner by comparing the diagnostic impressions of 6 cases of lumbar radiculopathy of an unblinded electromyographer with the impressions of the recorded study by a blinded resident or faculty electromyographer.[9] They found that the overall diagnostic agreement was only 46.9%. Faculty was twice as likely to agree on the final diagnosis as residents, demonstrating that extensive training is necessary to perform these studies accurately. Another study that looked at interrater reliability of needle EMG findings in lumbar radiculopathy used only expert examiners and compared the results of unblinded with blinded electrodiagnosticians. This study found an outstanding overall diagnostic impression agreement of greater than 90% between the unblinded and blinded examiners.[10]

PLANNING THE ELECTRODIAGNOSTIC STUDY

As mentioned earlier, the usefulness of electrodiagnostic testing for radiculopathy depends directly on the skills of the physician performing the study, and this applies to study planning as well as study interpretation. In general, there are 2 purposes of the electrodiagnostic study: to determine whether there is electrodiagnostic evidence of a radiculopathy, and to rule in or out competing diagnoses for the patient's symptoms.

The first part of this section addresses study planning in general. The second part addresses using electrodiagnostic studies to help in sorting out competing clinical diagnoses.

NEEDLE ELECTRODE EXAMINATION

The most important part of the electrodiagnostic testing to diagnose a radiculopathy is needle EMG. Other components may be helpful, but they are used primarily to rule in or out competing diagnoses that could explain all or part of the patient's symptoms. The presence of positive sharp waves and fibrillations in a myotomal distribution is

the most reliable evidence of radiculopathy. Many electrodiagnosticians think there is a window of time when these acute changes are seen: They most likely first appear in the paraspinal muscles by about 7 days, but may not be seen in distal muscles for 5 or 6 weeks. Total myotomal involvement is rare—often many muscles within a myotome never show damage. If no further nerve damage occurs, these spontaneous changes generally disappear by about 9 months.[2] This limited duration of findings has also been shown in animal studies.[6] Other spontaneous activity, such as fasciculation potentials and complex repetitive discharges, are sometimes present and may help make the diagnosis. Abnormal motor unit action potential recruitment in a neurogenic pattern may be seen. Chronic neurogenic motor unit action potential changes are frequent in chronic radiculopathies, but if this alone is used for making the diagnosis, there is a significantly higher incidence of false positives, and many electrodiagnostic physicians think that this makes it unacceptable sole diagnostic criteria (**Fig. 1**).

WHAT MUSCLES TO CHOOSE TO STUDY FOR NEEDLE EMG

The best designed needle study is able to identify the level of radiculopathy, without causing unnecessary discomfort to the patient by testing unnecessary muscles. It also rules out another cause for an abnormal needle examination other than radiculopathy.

Principles of muscle selection include the following:

1. Several muscles with the same root innervations, but different peripheral nerves, should be tested.
2. Other muscles in the region and other muscles with the same peripheral nerve but different root levels should be tested, to rule out other causes of abnormal

MUSCLE	L2	L3	L4	L5	S1	S2
Proximal Nerves						
ILIOPSOAS (psoas from lumbar plexus and iliacus from femoral nerve)						
ADDUCTOR LONGUS (obturator nerve)						
VASTUS MEDIALIS/LATERALIS (femoral nerve)						
RECTUS FEMORIS (femoral nerve)						
TENSOR FASCIA LATA (superior gluteal nerve)						
GLUTEUS MEDIUS (superior gluteal nerve)						
GLUTEUS MAXIMUS (inferior gluteal nerve)						
Sciatic Nerve						
SEMITENDINOSUS/MEMBRANOSUS (tibial nerve)						
LONG HEAD BICEPS FEMORIS (tibial nerve)						
SHORT HEAD BICEPS FEMORIS (fibular nerve)						
Fibular nerve						
TIBIALIS ANTERIOR (deep fibular)						
EXTENSOR HALLUCIS LONGUS (deep fibular)						
PERONEUS LONGUS (superficial fibular)						
EXTENSOR DIGITORUM BREVIS (deep fibular)						
Tibial Nerve						
TIBIALIS POSTERIOR						
FLEXOR DIGITORUM LONGUS						
GASTROC LATERAL						
GASTROC MEDIAL						
SOLEUS						
ABDUCTOR HALLICUS (medial plantar nerve)						

Fig. 1. Lower extremity myotomal chart shows major and significant nerve root innervation of lower extremity muscles. Boxes shaded in green represent a dominant contribution, whereas boxes shaded in yellow represent a significant contribution. Minor contributions are not shown.

needle study, such as myopathy length-dependent peripheral neuropathy, or a mononeuropathy.

This framework for muscle selection still raises many questions: are some muscles more likely to be abnormal than others within a given root? Are there certain muscles that have less intersubject variation in root innervations, or more dominant root innervations, so that the examiner would be more confident that an abnormal muscle corresponded to a specific root?

One way of attempting to answer this question is to compare electrodiagnostic findings of patients with MRI evidence and surgically verified single-level spinal nerve root lesions as wasperformed by Tsao and colleagues.[11] In this study, 45 patients had positive electrodiagnostic studies, positive preoperative MRI, and surgically confirmed root lesions. Their findings are summarized below.

L2 and L3 Radiculopathy

There were very few patients in the study with L2 and L3 radiculopathies, and no particular pattern of muscle involvement was found that could distinguish one of these levels from another, most likely because of the marked overlap of muscle innervations in the anterior thigh. Both patients had abnormal iliacus, adductor longus, and paraspinal muscles as well as an abnormal quadriceps muscle.

L4 Radiculopathy

All patients had an abnormal adductor longus and, of those tested, an abnormal rectus femoris. They found no patients with L4 radiculopathies who had a positive anterior tibialis muscle, therefore concluding that this muscle is most likely highly L5 innervated. Most patients also had abnormal middle to upper paraspinal muscles.

L5 Radiculopathy

The muscles affected most commonly were the peroneus longus, tensor fascia lata, and posterior tibialis. Other commonly affected muscles were extensor digitorum brevis, anterior tibialis, and extensor hallucis longus. The biceps femoris short head was normal in all L5 patients in whom it was tested.

S1 Radiculopathy

The muscles affected most of the time included the long head of the biceps femoris, short head of the biceps femoris, the medial and lateral gastrocnemius, the abductor digiti quinti, and the gluteus maximus.

HOW MANY MUSCLES SHOULD BE INCLUDED IN A SCREENING EXAMINATION?

A second common question for the electromyographer to consider is how many muscles must be tested as an adequate screen before concluding that there is no electrodiagnostic evidence for a radiculopathy?

Dillingham and colleagues considered this question and performed a prospective study on patients referred for electrodiagnostic testing for suspected radiculopathy. For all patients, a standardized electrodiagnostic screen was performed that consisted of 11 muscles. Nonparaspinal muscles were considered abnormal if they had abnormal spontaneous activity, abnormal motor unit morphology consistent with nerve injury, or a neuropathic recruitment pattern (reduced recruitment). Paraspinals were considered abnormal if abnormal spontaneous activity was found. For the purpose of this study, they determined that if a patient had any abnormal muscle findings, they were considered to have an electrodiagnostically proven radiculopathy.

In this study, the paraspinal muscles were the most likely to be abnormal. The second most common muscle to show abnormalities was the medial gastrocnemius. They found that a 5-muscle screen that included parapinals identified 94% to 98% of radiculopathies that could be identified by needle EMG (which they defined as abnormality on an 11-muscle screen). A 6-muscle screen that included lumbar paraspinal muscles identified radiculopathy in 98% to 100% of the patients. Seven to 10 muscle screens that included parapinals did not identify a significant higher proportion of radiculopathies. If paraspinal muscles were not tested, a 5-muscle screen identified only 68% to 88% of radiculopathies, and to reach the level of 90% of radiculopathies identified, an 8-muscle screen was required.[5]

PARASPINAL MUSCLES AND THE ELECTRODIAGNOSIS OF RADICULOPATHY

Lumbar paraspinal muscles may be very helpful in the diagnosis of radiculopathy. It is thought that the lumbar paraspinal muscles are the first group of muscles to show spontaneous activity in acute radiculopathy, although this point has been disputed in the literature. Dillingham and colleagues performed a retrospective study of 139 patients with electrodiagnostically confirmed radiculopathy and found no evidence of correlation between abnormal paraspinal muscles and duration of symptoms.[12] They are also useful to prove that the lesion is located above the lumbar sacral plexus. One major drawback in their use in the diagnosis of radiculopathy is that, unlike most limb muscles, lumbar paraspinal muscles may show spontaneous activity in asymptomatic subjects. Date and colleagues found an overall prevalence of abnormal spontaneous activity in the lumbar paraspinal muscles of 14.5% of asymptomatic patients. This prevalence increased with age. They were very rare in patients under the age of 40 and were seen in 33% of those over the age of 60.[13] Another study found a prevalence of 42% had abnormal spontaneous activity in the paraspinal of asymptomatic patients. They characterized the activity as more commonly positive sharp waves than fibrillations, generally mild, and generally found in multiple locations.[14] This evidence has been disputed by others, who cite the close similarity in appearance of atypical-appearing endplate spikes with spontaneous activity. Dumitru and colleagues[15] reported a prevalence of 4% of true positive sharp waves or fibrillations in the paraspinal muscles of asymptomatic patients, but sited many examples of varied and atypical endplate spikes. At any rate, caution should be taken in making a diagnosis of radiculopathy in older patients when the only evidence is limited spontaneous changes in the paraspinal muscles.

NERVE CONDUCTION STUDIES AND RADICULOPATHY

Sensory nerve conduction studies are normal in radiculopathy, even if the physical examination reveals significant sensory loss, because the lesion occurs proximal to the dorsal root ganglion. Compound motor action potentials are usually normal unless severe damage has occurred, or if multiple root levels are involved, in which case there may be some diminished amplitude.

F WAVES

The evidence for the usefulness of F waves in the diagnosis of radiculopathy is limited. F waves are often normal in radiculopathy, most likely because the affected portion of the pathway is so small compared to the total pathway that the abnormality is not detected. If they are abnormal, the problem could be anywhere along the course of the nerve and cannot be localized to the root.[2] Some researchers have found that if multiple features of the F wave are taken into account (for example, considering the

minimum latency, the maximum latency, and the number of repeaters), they can be helpful in making the diagnosis.[16,17] Overall, they appear less sensitive than the needle study. For example, Weber found that in patients with radiculopathy discoveredon needle EMG, only 53% of L5 and 74% of S1 had abnormal F waves.[18] Aminoff and coworkers found similar results. Of 28 patients with unequivocal L5 or S1 radiculopathy, abnormal F waves were found in 14, and all of these patients also had abnormal needle EMG studies.[19]

H WAVES

H waves are helpful in the diagnosis of S1 radiculopathy. They have several strengths, including the ability to detect injury to sensory fibers, and they are not dependent on a window of opportunity to discover abnormalities as is the needle examination, because they become abnormal as soon as a compression occurs and the deficit can last indefinitely. Different waveform criteria are used to make the diagnosis by different examiners, such as side-to-side latency differences, side-to-side amplitude differences, or an absent response on one side and a present response on the other side. It is unclear which method is the best. Limitations of H waves include their inability to determine how acute or chronic the lesion is, and that they may be abnormal in other diseases, such as peripheral neuropathy. They also may be normal in radiculopathy if there is sparing of the fibers that relay the reflex.

SOMATOSENSORY-EVOKED POTENTIALS

Theoretically, somatosensory-evoked potentials (SEPs) should be helpful in the diagnosis of radiculopathy because they study the peripheral sensory pathway, including the sensory function of the proximal nerve root. Dermatomal SEPs should be particularly useful, because they assess the sensory fibers of a single root. However, the medical literature has not shown them to be useful in many cases.[2,20] Because of intersubject variations in SEP responses, only extreme changes can be interpreted as abnormal so more mild changes go unrecognized. Also, conduction in the normal fibers of the affected root may cause abnormalities to be missed.In addition, the small area of abnormality may be masked because of the long course of the pathway being tested.[19]

CONSIDERING A DIFFERENTIAL DIAGNOSIS FOR THOSE WITH BACK AND LOWER EXTREMITY PAIN

The differential of back pain with radiating leg pain is broad. Back pain affects most people at some point in their lifetime, and many structures in the back can cause referred pain into the thigh, such as facet joints, muscles, and the sacroiliac joint. Hip joint pain can cause buttock and thigh symptoms and therefore can be confused with radiculopathy. Other musculoskeletal conditions involving the hip can also cause symptoms in the thigh. A patient may have 2 conditions, such as back pain and plantar fasciitis, which could mimic radiculopathy. However, just because an examiner suspects the presence of a musculoskeletal disorder does not exclude the possibility of a radiculopathy being present. This theory was demonstrated in a study by Cannon and colleagues, in which 170 patients referred for electrodiagnostic testing were also examined for common musculoskeletal disorders.[21] They found a high prevalence of musculoskeletal disorders in this population, with an overall prevalence of 32%. Although there were a higher percentage of musculoskeletal disorders in those without electrodiagnostic evidence of radiculopathy (55%); musculoskeletal pain problems were a secondary diagnosis in 21% of those who did have electrodiagnostic evidence of a radiculopathy. The researchers concluded that the fairly high prevalence

in all groups of musculoskeletal disorders makes it difficult to predict the outcome of electrodiagnostic testing based on their presence or absence.

CONSIDERING A DIFFERENTIAL DIAGNOSIS FOR THOSE WITH LOWER EXTREMITY WEAKNESS OR NUMBNESS

Electrodiagnostic studies are particularly useful if evidence for neurologic disease is discovered in the lower extremity to assist in determining their cause. Some conditions commonly confused with radiculopathy are described below and the electrodiagnostic study planning that will help differentiate these conditions is outlined.

Lumbosacral Plexopathy versus Radiculopathy

There are many causes of lumbosacral plexopathy, including trauma, compression during surgery or labor, compression from tumors, radiation damage from the treatment of tumors, vasculitic and idiopathic causes, among others.[22] Electrodiagnostically, key features that would separate this diagnosis from lumbar radiculopathy include the presence of abnormalities in the paraspinal muscles, which suggests radiculopathy, and diminished amplitude or absent sensory studies in the leg, which suggests plexopathy. In practice, however, changes in the paraspinal muscles can be seen in older patients and diabetic patients, and these same patients may have absent sensory studies in the leg, which can make differentiating these 2 diagnoses difficult. However, a combination of the history and the extent of changes found on the physical examination and electrodiagnostically can often assist the examiner in determining the most likely diagnosis.

Sciatic Nerve Lesions versus L5 or S1 Radiculopathy

Lesions isolated to the sciatic nerve are rarer than radiculopathy but may occur. Because of an overlap of electrodiagnostic findings, sciatic neuropathy is often confused with radiculopathy. Causes include trauma, local compression from positioning, a tumor, an abscess or other compressive lesion, and an idiopathic condition, among others.[23,24] Electrodiagnostically, needle changes should be sought in muscles that are innervated by the L5 and S1 nerve roots that do not arise from the sciatic nerve, such as gluteus medius, gluteus maximus, and paraspinal muscles, so that a clear diagnosis can be made.

Fibular Neuropathy versus L5 Radiculopathy

For patients with weak dorsiflexors, a differential to consider is a common fibular neuropathy at the fibular head versus L5 radiculopathy. Nerve conduction studies to the extensor digitorum brevis and anterior tibialis may show the presence of conduction block at the fibular head in fibular neuropathy if there is a significant demyelinating component. If the lesion is primarily axonal at the fibular head, the superficial fibular nerve should be absent or low amplitude, and this would be normal in radiculopathy. The needle study is also very helpful in differentiating these 2 diagnoses, in that L5 muscles not innervated by the fibular nerve are often abnormal in an L5 radiculopathy, but should be normal in a fibular neuropathy.

Tibial Neuropathy versus S1 Radiculopathy

Another peripheral mononeuropathy that could be confused with radiculopathy is tibial mononeuropathy (particularly tarsal tunnel syndrome) versus S1 radiculopathy. Again, specific nerve conduction studies to the tibial nerve, particularly sensory/mixed

nerve studies, may be helpful, and the needle study of S1 innervated muscles above the ankle is helpful.

Lateral Femoral Cutaneous Neuropathy versus Radiculopathy

Lateral femoral cutaneous neuropathy (meralgia parasthetica) can cause numbness or parasthesias in the thigh that can be confused with radiculopathy. Specific testing of this nerve by either nerve conduction studies, or more sensitively by SEPs, can determine if this is the cause of thigh numbness.[25]

Polyperipheral Neuropathy versus Multilevel Radiculopathy

Often, a differential diagnosis of polyperipheral neuropathy versus multilevel radiculopathy is considered. Both of these conditions can cause bilateral numbness and weakness in the legs. The prevalence of both of these conditions increases with age, as does the prevalence of back pain from other causes, so it is not uncommon for a patient to have both back pain and peripheral neuropathy or both radiculopathy and peripheral neuropathy. Sometimes the history can be helpful in determining which of these is present: in general, the most common forms of polyperipheral neuropathy begin distally and symmetrically and progress slowly more proximally. In contrast, radiculopathy is often of a more acute onset with sensory and motor symptoms within a specific dermatome/myotome. However, with time, these dermatomes may overlap and appear to be distal and symmetric, and often the exact historical course of these changes is forgotten by the patient. Electrodiagnostic findings, particularly in patients older than 60 years of age, between the conditions may be similar. H waves are often unelicited in both conditions. Surals are commonly abnormal or absent in those with polyperipheral neuropathy but can be absent idiopathically in older patients, so their absence does not confirm one diagnosis as better than the other. What is helpful in differentiating these diagnoses is if proximal needle changes are seen, as this is unlikely to be due to a length-dependent peripheral neuropathy. Upper extremity nerve conduction studies, particularly sensory studies, may be abnormal in those with a typical length-dependent neuropathy severe enough to cause needle EMG changes in the leg, and this may help in the diagnosis of polyperipheral neuropathy rather than multilevel radiculopathy.

Early Motor Neuron Disease versus Radiculopathy

Sometimes motor neuron diseases, such as amyotrophic lateral sclerosis, may arise first in one or a few lumbosacral segments and therefore mimic radiculopathy. Features that suggest amyotrophic lateral sclerosis over radiculopathy include prominent, widespread fasciculation potentials, severe motor axonal loss in a patient without significant sensory complaints, and significant loss of axons in S1 distribution with an intact H reflex.[2] Additional needle EMG testing beyond one limb can be very helpful in determining this diagnosis.

EMG TO PREDICT PROGNOSIS

Several small studies have tried to determine if there is a clinical difference in patients who have EMG-positive radiculopathy, compared to those who have a presumed radiculopathy because of the history, physical examination, and imaging, but a normal EMG. One study compared 2 groups of patients who clinically met the diagnosis of radiculopathy, one group with positive EMG findings and the other group with normal EMGs. They found no difference between the groups in terms of pain scale ratings or Oswestry Disability Index scores.[26] Another study comparing the outcome of patients

treated surgically compared to those treated conservatively for radiculopathy found that the initial EMG had no prognostic ability to predict outcome at 5 years. The overall outcome was influenced most by psychosocial factors.[27] In contrast to the findings of acute radiculopathy, one study found that, in long-term follow-up of patients diagnosed with radiculopathy, some treated surgically and some treated conservatively, those patients with a normal EMG at 1- and 5-year follow-up had better outcomes than those with signs of a remote radiculopathy, such as large motor units and reduced interference pattern at 1- and 5-year follow-up.

EMG to Predict Outcome of Lumbar Epidural Steroid Injection

A few studies have been performed to determine if those with EMG-positive radiculopathy have a different response to treatment than those with EMG-negative radiculopathy. One study found that the EMG-positive group who received the lumbar epidural steroid injections had a statistically better improvement on the Oswestry disability index after the injection, compared to the EMG-negative group, who had the injections. Improvement in both groups was so small, however, that there was only a minimally clinically significant difference. A similar but larger and more recent study by other researchers found those patients with EMG-positive radiculopathy had better pain improvement and functional improvement as measured by the pain disability questionnaire after lumbar epidural steroid injections than the group who was clinically diagnosed with radiculopathy, but who had normal EMGs.[28]

EMG to Predict Outcome of Lumbar Discectomy

Very little research has been done on the value of EMG to predict the outcome of surgery for radiculopathy. Spengler and colleagues included positive needle EMG findings in a scoring system of objective evaluations to assess who would improve with elective discectomy and found that EMG in combination with other objective measures, such as neurologic examination and imaging, correlated with operative findings of a disk, but psychological scores were the best predictor of clinical outcomes.[29] Falck and colleagues found similar results in their study of patients with positive EMG findings and lumbar disk herniation, some of whom were treated operatively, and some who were treated conservatively.[27] In contrast, in a small study of patients with cervical radiculopathy, patients with positive preoperative EMGs had a better outcome after discectomy and cervical fusion than patients who had normal preoperative EMGs.[30]

EMG and Persistent Neuropathic Pain in Radiculopathy

Whether an EMG is positive for radiculopathy does not appear to be a good indicator for the persistence of nerve related pain. In a study using a rat model of lumbar disk herniation, evidence of neuropathic pain improved with time, but the neuropathic pain persisted beyond the timeframe when positive needle EMG findings of fibrillations and positive sharp waves had already resolved.[6] Similar studies have not been conducted in humans.

SUMMARY

Electrodiagnosis still plays a major role in the diagnosis of lumbosacral radiculopathy. It has a complementary role to spine imaging. In the hands of a skilled examiner, the test is specific and can assist in ruling out competing diagnoses that may cause neurologic symptoms in the legs. Preliminary research is promising for the role of EMG in determining prognosis for some treatment outcomes. However, its power comes

from the test's ability to determine physiologic function of the nerve root, not in detecting persistent neuropathic pain or predicting surgical outcomes.

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