



Electrodiagnostic challenges in the evaluation of lumbar spinal stenosis

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Lumbar spinal stenosis classically presents with the clinical syndrome known as neurogenic claudication or pseudoclaudication. Symptoms typically include leg pain, frequently with low back pain that is made worse with walking and better with sitting or walking in a forward flexed position. Physical examination is frequently normal including normal adverse dynamic neural tension signs. Sustained lumbar extension for 30 to 60 seconds may be the only physical examination maneuver that reproduces the patient's pain.

Electrodiagnostic examination at the stage when symptoms first begin is likewise frequently normal. As the condition progresses, electrophysiologic changes ensue, including conduction block, axon loss, and demyelination. Sensory nerve action potential (SNAP) studies are typically normal. Motor nerve studies remain normal until axonal loss progresses [1]. Needle electromyography may have abnormal spontaneous activity such as fibrillation potentials and positive sharp waves in two or more muscles sharing the same spinal nerve but different peripheral nerve innervations that would electrodiagnostically define a lumbosacral radiculopathy. Lumbosacral radiculopathies most frequently occur at L5 (48%), S1 (30%), L4 (17%), L3 (5%), S2 (4%), and L2 (3%) [2]. Confirming the diagnosis of lumbar spinal stenosis with electromyography and nerve-conduction studies can be difficult at times. Some say that these procedures do not help in making the diagnosis [3–5], and some say that it is helpful in selected patients [6–8].

What is the rationale behind performing electromyography in patients who may have lumbar spinal stenosis? Establishing a normal or abnormal test is helpful. If the test is abnormal, one can learn the onset, severity, and distribution of pathology. It can help discern between a neuropathy and a

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myopathy as well as assess whether the condition is improving or getting worse [9]. Electrodiagnostics may help rule out diagnoses with similar presentations such as peripheral neuropathy and motor neuron disease [10]. Electrodiagnostic testing can be helpful to evaluate real-time electrophysiologic function rather than an anatomic snapshot of the lumbar spine bones, discs, and nerves [6,11]. Because asymptomatic lumbar spine imaging can frequently be abnormal [12–18], electrodiagnosis can be “complementary, not exclusionary” [1]. The literature indicates abnormal electromyograms (EMGs) in 35% to 64% of patients with radicular leg pain and in 51% to 86% of those with abnormal neurologic examinations [19]. In evaluating radiculopathy, MR imaging provides high sensitivity for abnormalities in symptomatic subjects (53%–60%) [19] but has low specificity (50%). Electromyography gives good sensitivity (72%) and higher specificity (85%) in neurologically abnormal patients. Electrodiagnosis can therefore help maintain high diagnostic specificity. In Nardin’s study, the fact that MR imaging and EMG agreed on the diagnosis 60% of the time and disagreed 40% of the time indicates that the two tests truly evaluate different entities and should remain as complementary diagnostic choices [11,19]. Nerve-conduction studies and electromyography are justified in the assessment of patients with spinal stenosis (1) to exclude distal nerve entrapment, (2) to objectify subjective muscle weakness, and (3) to document preoperative muscle status (medicolegal aspects) [20].

Review of literature

The literature that pertains to lumbar spinal stenosis, electromyography, and routine nerve-conduction studies is outlined here. Somatosensory evoked potentials are discussed in Dr. Kraft’s article in this issue. Most of the studies published on electromyography and lumbar spinal stenosis were done in the 1980s and now are becoming somewhat antiquated. These studies reflect the standard diagnostic testing at the time, which was myelography. Few studies differentiate the findings of abnormal spontaneous muscle fiber activity (fibrillation potentials and positive sharp waves) and motor unit action potential characteristics.

In 1976, Jacobson retrospectively reviewed 97 patients who had undergone myelography, transverse axial tomograms, and bilateral concentric needle electromyography. A positive EMG was defined as any combination of fibrillation potentials or polyphasic potentials. Fifty-three patients were found to have stenotic conditions. Positive bilateral EMGs were found in 20 of the 30 patients with spondylosis with and without herniated nucleus pulposus, in 11 of 12 patients with spondylolisthesis, and in 10 of 11 patients with developmental stenosis. One third of the patients with stenotic canals had unilateral symptoms but positive bilateral EMG findings. None of the herniated disc patients had bilateral multiradicular EMG findings [21].

Seppalainen [22] studied 37 patients with a lumbar spinal stenosis diagnosis based on radiographs, myelography, and clinical symptoms. Central stenosis was found in 32 patients, and lateral recess stenosis was found in 5 patients. Abnormal fibrillation potentials or motor unit action potential morphology characteristics were found bilaterally in 36 patients, usually in several muscles. Fifteen patients had bilateral and 17 had unilateral paraspinal muscle abnormalities; L5 was the most frequent myotome involved. Twenty-five patients had higher-level stenosis causing EMG abnormalities in lower-level spinal nerves.

In 1985, Hall [8] studied electromyographic findings in 37 patients who had myelographically and surgically proven lumbar spinal stenosis. Thirty-four of the 37 patients had electromyographic abnormalities, although the article did not specify whether the term “abnormal” was used to signify abnormal spontaneous activity or abnormalities in motor unit morphology. Of these abnormal studies, 17 (50%) had normal paraspinal muscle examination. Multilevel radiculopathy, frequently bilateral with paraspinal muscle involvement, was found in 11 patients. There were six single-level nerve lesions, three of which were bilateral. These electromyographic abnormalities were frequently present when neurologic examination was normal.

Johnsson [23] investigated the results of myelography, nerve-conduction studies, and needle electromyography in 64 patients with clinical lumbar spinal stenosis. Sixteen had total occlusion, 24 had partial occlusion, and 24 had normal flow on myelography. Fibrillation potentials and positive sharp waves rarely occurred; most EMGs designated as abnormal were based on characteristics of motor unit action potential morphology. The most common finding, which is corroborated in other studies [22], was bilateral multi-segmental neurogenic motor unit action potentials found in the lower-limb muscles. Bilateral neurogenic changes were noted in the motor unit action potentials in 88% of the totally occluded, 81% of the partially occluded, and 29% of the normal myelography patients. All motor nerve-conduction studies were normal except in those patients who had total occlusion on myelography. Twenty-two percent of the patients had findings on nerve-conduction studies consistent with peripheral neuropathy. Eleven patients undergoing repeat electrodiagnostic testing after surgery showed no EMG changes compared with preoperative testing [23]. Petropoulos [6] reflected on 25 years of clinical experience during which he operated on 76 patients with lumbar spinal stenosis. Fifty-nine of the 76 patients (78%) had bilateral multiradicular positive electromyographic findings after a stress test, although it was not described how positive EMG tests and stress tests were defined. He felt that electromyographic testing provided “great accuracy in determining the proper localization and severity of root involvement especially after the patient is examined after stress test.”

These data from the studies discussed [6,8,21–23] should be interpreted with caution, because some electrodiagnosticians consider diagnosing radiculopathy on morphologic changes alone as inadequate [24]. Polyphasic

potentials are present in 12% to 35% of normal population [25], and morphology changes can be secondary to movement of the active E1 electrode [26]. Therefore, one can hazard a guess that some false-positive electrodiagnostic studies are probably included in the studies discussed here.

In a study, Rittenberg [40] evaluated 52 patients who had surgery for lumbar spinal stenosis confirmed on preoperative advanced diagnostic imaging. Before surgery, the cohort had an average age of 69.3 years, average visual analogue pain score of 8.1, and an average walking tolerance of less than 200 feet. On physical examination, pain with trunk extension was found in 56% of subjects. Electromyography and nerve-conduction studies were abnormal in 92% of the subjects, and 88% had at least one abnormal needle finding including motor unit morphology changes or fibrillation potentials/positive sharp waves in at least one muscle tested. Fibrillation potentials or positive sharp waves were present in the limbs in 61% of subjects, in lumbar paraspinal muscles in 65%, in limbs but not lumbar paraspinal muscles in 7.7%, and in lumbar paraspinal muscles but not limbs in 11.5%. More than 15% of motor unit action potentials were noted to be polyphasic in 42% of subjects. In 44% of subjects peroneal motor nerve studies showed compound muscle action potential (CMAP) amplitude of less than 3 mV. H-reflex (Hoffman reflex) was abnormal in 42%. Consistent with prior data, the most common electrodiagnostic diagnosis was bilateral multi-level lumbosacral radiculopathy.

The evaluation of the lumbar spinal stenosis patient in the electrodiagnostic laboratory

Nerve conduction studies

Sural or superficial peroneal nerve sensory studies, peroneal and tibial nerve motor studies with or without F-waves, and tibial H-reflexes are commonly performed in the evaluation of patients with lumbar spinal stenosis. Sensory studies are characteristically normal unless far-lateral osteophytes reach far enough to impinge on the dorsal root ganglia [1]. Decreased compound muscle action potential amplitudes elicited from the extensor digitorum brevis with peroneal motor studies may help diagnose axonal degeneration of an L5 radiculopathy [9]. F-waves that are absent or have poor penetrance may help identify an L5 radiculopathy [9]. F-wave testing performed after 3 minutes of standing can show increased chronodispersion [27]. In two patients with spinal stenosis, London reported that serial F-waves before and after ambulation may show absence or prolonged latency [28]. Manganotti [29] also showed evidence of these dynamic F-wave changes in 5 patients with lumbar spinal stenosis. Obviously, larger studies need to be performed to draw any conclusions regarding dynamic F-wave changes in lumbar spinal stenosis. F-waves, however, frequently are normal even in clear clinical radiculopathies and have low sensitivity [24]. H-reflex

amplitude asymmetry ($\geq 50\%$) [24], prolonged side-to-side latency (≥ 1.0 – 1.8 msec) [24], and its absence can be indicative of an S1 radiculopathy [9]. Sometimes H-reflex abnormalities can be the earliest abnormality in earlier stages of spinal stenosis [1].

Needle electromyography

Needle electromyographic examination is routinely performed in at least five to seven muscles of the lower limb including lumbosacral paraspinals. It is important to sample muscles that are innervated by different peripheral nerves and spinal root levels. Examination of clinically weak muscles is especially valuable. More information may be gleaned from careful assessment of the more symptomatic leg, although some have recommended routine examination of both legs [21].

Abnormal spontaneous muscle fiber activity including positive sharp waves and fibrillation potentials in a myotomal distribution is the hallmark of the electrodiagnostic evidence supporting lumbosacral radiculopathy. This muscle membrane instability can show the referring physician whether the process is acute or old. The severity can further be defined with assessment of gradation of positive sharp waves and fibrillation potentials and dropout of motor unit action potentials [9]. The size of the fibrillation potentials can suggest the approximate age of the lesion. Kraft showed that more acute nerve injuries show larger amplitude fibrillation potentials than older lesions. With a monopolar needle, no fibrillations potentials were over $100 \mu\text{V}$ in amplitude in lesions older than 1 year. He also showed that the fibrillation potential size correlates with the degree of Type I muscle fiber atrophy [30]. Motor unit action potential analysis can show reduced recruitment within the first month of nerve injury. Polyphasic potentials appear around 10 weeks, and long-duration, high-amplitude units appear well after 2 months after nerve injury [31]. Diagnosing radiculopathy solely based on motor unit action potential polyphasicity and recruitment requires considerable electrodiagnostic experience [24].

The extensor digitorum brevis muscle is a superficial intrinsic muscle of the foot that is innervated by L5 and S1 spinal nerves. Abnormal spontaneous activity in this muscle can be found that may not be related to a pathologic lesion. Histochemical [32] and physiologic [33] denervation of this muscle commonly occurs with aging. Endplate activity can frequently be confused with denervation potentials in lumbar paraspinal and foot muscles; however, close attention to discharge rate and rhythm is essential for correctly identifying pathologic potentials [34].

Patients presenting for electrodiagnostic examination to evaluate spinal stenosis are frequently older and may have had prior lumbar surgeries. Caution should be exercised when evaluating the lumbosacral paraspinal muscles in patients who have had prior lumbosacral surgery. Needle electromyography showed abnormal spontaneous activity at 1 and 3 cm

from midline in 17 of 20 patients who had prior laminectomy (85%) [35]. In the case of prior lumbar surgery, the work of Dillingham suggests that sampling of more lower limb muscles is necessary to detect the presence of acute radiculopathy. In a prospective analysis of patients who underwent a standard 11-muscle screen, 102 had electrodiagnostically confirmed radiculopathies by abnormal spontaneous activity. When paraspinal muscles could be sampled, a five-muscle screen consisting of the paraspinals, anterior tibialis, posterior tibialis, medial gastrocnemius, and vastus medialis showed 91% sensitivity. If prior surgery precluded examination of the paraspinals, sampling eight peripheral muscles (anterior tibialis, posterior tibialis, medial gastrocnemius, rectus femoris, short head biceps femoris, lateral gastrocnemius, adductor, and tensor fasciae latae) achieved 81% sensitivity [36].

Clinical conundrums

Case example 1

Consider a 76-year-old active male with a history of benign prostatic hypertrophy and knee osteoarthritis who has played tennis for the last 40 years. He complains of insidious onset of bilateral leg weakness that has progressed over the last 7 years. He notices it most after playing 2 hours of tennis. He admits to some mild numbness on the bottom of both of his feet. He denies any significant low back pain or radiating pain in the legs. Physical examination shows symmetric muscle stretch reflexes bilaterally and intact light-touch and pin prick sensation. He is referred by his treating physician for an electrodiagnostic examination to rule out peripheral neuropathy versus lumbar spinal stenosis. His motor nerve conductions are reported in Tables 1, 2, and 3.

Sural nerves were not obtained on initial examination with sensitivity of 20 μV per division (Fig. 1). Subsequently, the posterior calf and lateral ankle were scrubbed with abrasive skin cleanser. Electrodes were placed again assuring good skin contact. Sensory nerve action potential responses of the sural nerves were obtained with averaging at sensitivity of 5 μV per division (Fig. 2).

Interpretation of these data show slightly decreased compound motor action potential amplitudes, normal sural sensory studies, and abnormal needle electromyography of the tibialis anterior and lumbar paraspinal muscles. This example of an electrodiagnostic examination demonstrates the best one can hope for when referring such a patient for electromyography and nerve-conduction studies. The low CMAP amplitudes and small fibrillation potentials are consistent with a nonacute, indolent process reflecting an old left L4 or L5 radiculopathy that would be consistent with the diagnosis of lumbar spinal stenosis.

Table 1
Motor nerve conduction studies in case 1

Nerve and sites of stimulation	Recording	Distance (mm)	Distal latency (ms)	Amp (mV)	Lat Dif (ms)	CV (m/s)	Temperature (C)
Left peroneal nerve	EDB						
Ankle		80	5.2	1.8			33.7
Below fibular head		310	12.2	1.7	7.0	44	33.9
Above fibular head		80	14.0	1.6	1.8	44	34.1
Left tibial nerve	AH						
Ankle		80	4.2	4.2			34.0
Popliteal fossa		375	13.2	3.7	9.0	42	34.1
Right peroneal nerve	EDB						
Ankle		80	4.2	1.0			33.3
Below fibular head		310	11.7	0.9	7.5	41	33.4
Above fibular head		60	12.9	0.9	1.2	50	33.3
Right tibial nerve	AH						
Ankle		80	3.9	4.4			33.5
Popliteal fossa		380	12.4	3.6	8.5	45	33.5
Right median nerve	Thenar						
Wrist		80	4.0	6.4			33.5
Elbow		250	8.2	5.8	4.2	60	33.5
F-waves							
		Minimum Lat (ms)					
Left peroneal nerve at ankle	EDB	50.5					
Left tibial nerve at ankle	AH	52.2					
Left tibial nerve at ankle	AH	53.0					

Abbreviations: Lat, latency; Amp, amplitude; Dif, difference; CV, conduction velocity; EDB, extensor digitorum brevis; AH, abductor hallucis.

Table 2
Sensory nerve conduction

Nerve and sites of stimulation	Recording	Distance (mm)	Distal latency (ms)	Amp (μ V)	Temperature (C)
Left sural nerve	Ankle				
Calf		140	3.5	6	34.1
Right sural nerve	Ankle				
Calf		140	3.2	5	33.8
Right median nerve	Index finger				
Wrist		140	3.3	22	33.9

Abbreviations: Amp, amplitude.

Table 3
Needle electromyography

	Insertional activity			Spontaneous activity			Voluntary activity				Maximum recruitment	
	activity	Positive wave	Fibs	Fibs	Fasic	Amplitude	Duration	Polyphasic	Recruitment	Amplitude	Maximum effort	
Tibialis anterior	L Normal	1+	1+ <100 μ V amplitude	1+	1+	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Peroneus longus	L Normal	None	None	None	None	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Gastrocnemius, medial head	L Normal	None	None	None	None	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Vastus lateralis	L Normal	None	None	None	None	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Lumbar paraspinals	L Normal	1+	1+	None	None	Normal	Normal	Normal	Normal	Normal	Normal	Normal
First dorsal interosseus of hand	R Normal	None	None	None	None	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Tibialis anterior	R Normal	None	None	None	None	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Peroneus longus	R Normal	None	None	None	None	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Gastrocnemius, medial head	R Normal	None	None	None	None	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Vastus lateralis	R Normal	None	None	None	None	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Lumbar paraspinals	R Normal	None	None	None	None	Normal	Normal	Normal	Normal	Normal	Normal	Normal

Abbreviations: Fibs, fibrillation potentials; Fasic, fasciculations.

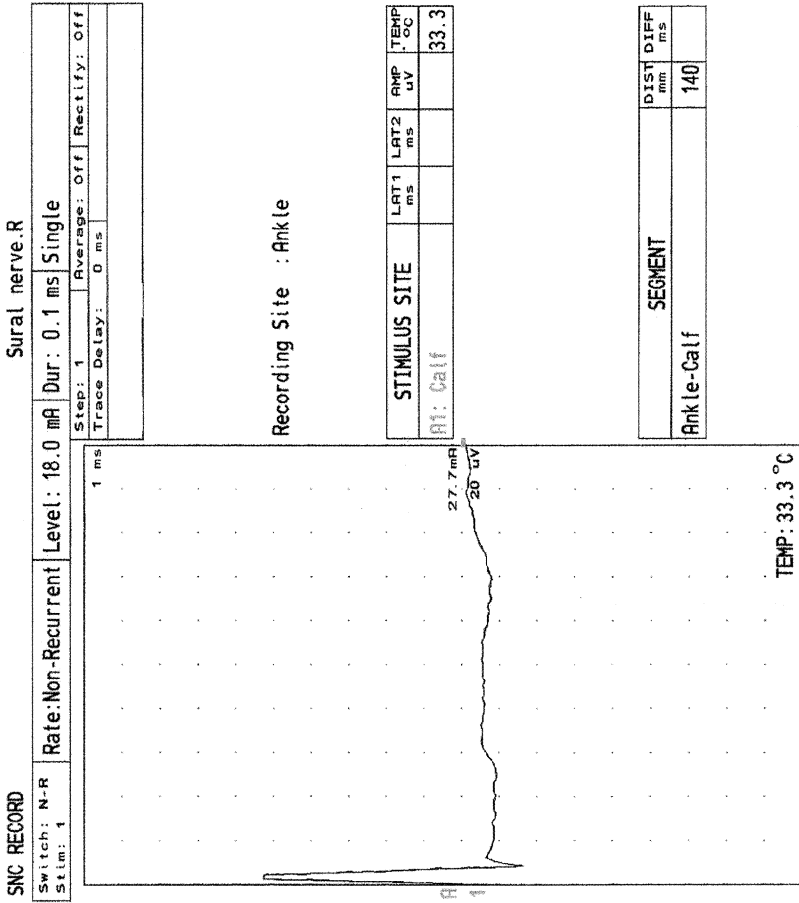


Fig. 1. Sural nerves were not obtained on initial examination.

Case example 2

The interpretation of these data becomes more clouded if the same patient had a medical history more representative of many 76-year-old persons referred to the electrodiagnostic laboratory. What if this patient had a 10-year history of diabetes, and the examiner did not persist to find the difficult-to-attain sural studies? In that case, it would seem that sural studies were absent, CMAP amplitudes were small, and a few fibrillation potentials were found in the tibialis anterior and lumbar paraspinal muscles. These findings may be more consistent with peripheral neuropathy common in those patients with diabetes mellitus affecting the legs more than arms.

Herein lies the quandary clinicians face when ordering and interpreting electromyography and nerve-conduction studies to evaluate lumbar spinal stenosis. Dry skin, swelling, or suboptimal technique can frequently hinder obtaining sural nerve sensory responses. Is a no-response sural study a true no-response that reflects presence of peripheral neuropathy, or is it just another sural nerve response that is difficult to attain? Sural studies can be hard to elicit in those over 60 years of age [24], the patient population in which lumbar spinal stenosis is most common.

Tibial H-reflexes may be abnormal in both spinal stenosis and peripheral neuropathy. Lower-limb nerve-conduction velocities may be mildly slowed or CMAP amplitudes can be decreased in long-standing lumbar spinal stenosis as well as peripheral neuropathy. Abnormal spontaneous muscle fiber activity on needle electromyography can be found in distal muscles both in peripheral neuropathy and in lumbar spinal stenosis with multi-level polyradiculopathy [24]; it can also be found in lumbar paraspinal muscles in isolation [31], especially in diabetic patients [37]. Fibrillation potentials and positive sharp waves can be found in lumbar paraspinals of 14.5% to 48% of asymptomatic people [38,39]. As mentioned before, however, these fibrillation potentials witnessed in asymptomatic lumbar paraspinal muscles may in reality represent endplate activity as proposed by Dumitru [34].

Summary

Taken together, the most common electromyographic finding in lumbar spinal stenosis is bilateral multilevel radiculopathy [6,8,21–24,40]. The sensitivity of electrodiagnostic testing for radiculopathy is difficult to quantify because there is no criterion standard. Differentiating peripheral neuropathy and lumbar spinal stenosis on electromyography and routine nerve-conduction studies can be clinically challenging, especially when the two entities may be present simultaneously in older patients.

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