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Differential diagnostics in patients with mild lumbar spinal stenosis: the contributions and limits of various tests

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Abstract Lumbar spinal stenosis (LSS) and diabetic polyneuropathy are common ailments of older age. Many people suffer from both at the same time. In such patients it may sometimes be difficult to separate signs and symptoms that could be attributed to either disease. This study evaluates the contributions and limits of various tests, especially the exercise treadmill test (ETT) and electrophysiological examination, in the diagnostics of patients with mild LSS. Twenty-nine patients with mild LSS documented by computed tomography (CT) participated in this study. Sixteen of the patients had neurogenic claudication (LSS NC+), and 13 patients did not (LSS NC–). Patients with LSS were compared with a group of 24 patients with diabetic polyneuropathy and 25 healthy volunteers. The distance covered, the time spent walking and the reasons for preliminary termination of the ETT were evaluated in all groups. Initial electrophysiological examination included electromyography (EMG) from the upper and lower extremities and motor evoked potentials (MEPs) to the lower extremities. LSS NC+ patients covered a significantly shorter distance and the time spent walking was significantly shorter than in LSS NC– patients and in the two control groups. The main reason for preliminary termination of the ETT was the development of NC

in 67% of the LSS NC+ patients. In contrast, no LSS NC– patient and none from the control groups revealed NC, but 31% of LSS NC– patients were not able to finish the ETT for other reasons (e.g. dyspnoea). Electrophysiological parameters evaluated from the upper extremities distinguished diabetic patients from LSS patients. The latencies of the tibial F-wave, soleus H-reflex and spinal MEP response reliably distinguished healthy volunteers from diabetic patients and LSS patients, and particularly LSS patients from diabetic patients. The chronodispersion of the tibial F-wave distinguished LSS NC+ patients from the other groups. The results of the study show that electrophysiological examination contributes to the differential diagnostics between mild lumbar spinal stenosis and diabetic polyneuropathy. The contribution of electrophysiological methods in verification of NC in LSS patients is limited (chronodispersion of the tibial F-wave only). The ETT is useful in confirmation of NC and walking capacity verification, but restriction of walking capacity should be carefully analysed.

Keywords Lumbar spinal stenosis · Neurogenic claudication · Exercise treadmill test · Diabetic polyneuropathy · Electrophysiological examination

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Introduction

Lumbar spinal stenosis (LSS) is defined as any type of narrowing of the spinal canal, nerve root canal, or intervertebral foramina [3]. In the pathogenesis of LSS, the degenerative process of the lumbar spine is the main component producing the compression of neural tissue in the spinal and/or nerve root canal [2]. The stenosis is classified as central or lateral, congenital or acquired; combinations are common.

The typical symptoms of LSS include neurogenic claudication (NC), back and leg pain and mixed symptoms [8]. NC limits walking in patients with LSS because, after walking a short distance, patients experience weakness, tiredness, or heaviness of the legs that gradually increases and causes them to stop. A suspected pathophysiological mechanism underlying NC is intermittent hypoxia of the cauda equina fibres that may lead to ischaemic nerve conduction failure and to transient clinical and electrophysiological changes after exercise [10]. The exercise treadmill test (ETT) is used to verify complaints experienced by patients while walking.

The diagnosis of LSS is based on the results of clinical examination and radiological documentation of narrowing of the lumbar spinal canal [7, 9, 13, 14]. The clinical differentiation between lumbosacral polyradicular disease (typical of LSS) and generalised peripheral neuropathies of the distal-axonal type (typical of diabetic patients) can sometimes be difficult. Bilateral, multiple lumbosacral radiculopathies (cauda equina lesion) are found in approximately half of patients with LSS [15]. Both diseases appear frequently in older age and may present with numbness and tingling of the feet, and helpful clinical clues such as back pain, proximal weakness, or radiating pain into the legs may be absent [4]. In such a situation, electrophysiological examination can be useful.

The purpose of the study was to evaluate the contributions and the limits of various tests (especially ETT and electrophysiological examination) in the diagnostics of patients with mild LSS, with respect to the presence of NC.

Materials and methods

Patients with LSS

Twenty-nine patients (16 men, 13 women) were recruited consecutively from a total of 132 patients with LSS treated and observed in the Department of Neurology, Faculty Hospital, Brno, between 1998 and 2001.

With respect to the presence or absence of NC in the history, they were divided into two subgroups – 16 patients with NC, 13 patients without NC.

Inclusion criteria for the selected patients with LSS

The following inclusion criteria were used for patients with LSS:

- Clinically symptomatic LSS (NC and/or low back pain)
- At least one-level central LSS documented by computed tomography (CT)
- A mild degree of LSS (no paresis, ability to walk without crutches, no opiates)
- Absence of hip and/or knee joint arthrosis limiting walking
- Absence of arteriosclerotic peripheral vascular disease of the lower extremities limiting walking
- Absence of diabetes mellitus
- No serious cardiac disease

Control groups

Two control groups were assessed: one was a group of patients with diabetic polyneuropathy, the other was a group of healthy volunteers. A random sample was initially recruited, and individuals were then selected from this pool on a “case-control” basis, in order to match the LSS patients with respect to age and height.

There were 24 patients in the control group with diabetic polyneuropathy (15 men, 9 women). The criteria for inclusion in this group were:

- Diabetes mellitus type I or II
- Signs of polyneuropathy (numbness and/or tingling of feet)
- No low back pain or NC
- Normal diameter of the lumbar spinal canal
- Absence of arteriosclerotic peripheral vascular disease of the lower extremities limiting walking
- No serious cardiac disease

The other control group comprised 25 healthy volunteers (8 men, 17 women) without low back pain or NC in their history, and without diabetes mellitus, no complaints, and normal clinical findings from the lower extremities.

Radiological examination

All patients were examined radiologically according to the following protocol:

1. A plain radiograph of the lumbar spine was taken in the LSS patients, with assessment of the presence of spondylarthrosis, scoliosis and degenerative or isthmic spondylolisthesis.
2. CT axial scans at three levels (L3–S1) were performed in LSS patients and in patients with diabetic polyneuropathy. The following standard parameters of the spinal canal were measured:
 - The anteroposterior (AP) diameter of the spinal canal at the level of the middle of the L3, L4, and L5 vertebrae (Fig. 1)
 - The transverse interarticular (IA) diameter (between ventral margins of facet joints) at the level of the upper margins of the L3/4, L4/5 and L5/S1 disc (Fig. 2)
 - The lateral recess diameter bilaterally at the same level as the transverse diameter

CT criteria of spinal stenosis were based on our own normal data [1]:

- *Central stenosis*: anteroposterior diameter <11.7 mm and/or transverse diameter <16.0 mm
- *Lateral stenosis*: lateral recess diameter <5.2 mm

The number of stenotic levels and the smallest anteroposterior and transverse diameter at L3–S1 levels were evaluated.

Exercise treadmill test

Quantified walking (speed for the first 3 min, 1.6 km/h; next 3 min, 2.4 km/h; following 3 min, 3.2 km/h; and final 3 min, 4.0 km/h) on

Fig.1 Axial computed tomography (CT) scan of lumbar spine of a patient with central anteroposterior (AP) stenosis at the level of the middle of the L4 vertebra (AP diameter = 9.3 mm)

Fig.2 Axial CT scan of lumbar spine of a patient with central transverse stenosis at the level of the upper margin of the L4/L5 disc (interarticular diameter = 8.0 mm)

a treadmill was performed in all groups. In the event of patient discomfort during walking (e.g. NC, dyspnoea, etc.), the exercise was aborted. The distance covered, the time spent walking and reasons for any premature termination of the test were evaluated in all groups.

Electrophysiological examination

In all groups the following parameters were examined:

- Soleus H-reflex (determination of latency and amplitude); sub-maximal stimuli with increasing voltage were delivered to provide the maximum H-reflex amplitude
- Tibial F-wave (determination of minimal latency, chronodispersion and persistence)
- Motor evoked potentials (MEPs) to abductor hallucis (AH) muscle (determination of spinal latency, cortical latency, central motor conduction time, amplitude of cortical response)

In patients with LSS and diabetic patients, electrophysiological examination was extended by recording motor and sensory conduction from the lower extremities, sensory action potential of radial nerve, ulnar F-wave, and needle electromyography from the lower extremities.

Clinical examination in LSS patients

Patients with LSS also underwent a clinical examination according to the following protocol:

- Walking test: evaluation of the ability and time needed to cover a distance of 10 m by walking without help, as quickly as possible
- Running test: evaluation of the ability and time needed to cover a distance of 10 m by running without help, as quickly as possible
- Evaluation of the presence of NC in the patient's history

Statistical methods

All the examined quantitative variables revealed normal, symmetric distribution as demonstrated by the Shapiro-Wilks test. The data were expressed by standard exploratory techniques and summed by common robust statistics (median and appropriate quantiles), in order to display real distribution patterns even within groups limited by sample size. Comparative analyses were based on non-parametric techniques, namely the Mann-Whitney U test and, in the event of more than two variants, the Kruskal-Wallis ANOVA test [12, 16].

Multiple comparisons of qualitative variables were based on multiple or two-sample binomial tests. However, the relative frequency profiles of many parameters nearly covered the whole spectrum of possible values (0–100%) and gave rise to substantial differences from normal distribution in the resulting binomial *P* estimate. This is why the comparison of the estimates was computed either by approximation to normal distribution or by F-distribution according to Brownlee [5] and Zar [16].

Results

All groups are fully comparable with respect to the age and height, the difference in gender structure has no impact on bias in the differential tests. As expected, patients with LSS revealed significantly smaller anteroposterior and transverse diameters of the lumbar spinal canal than the diabetic patients.

ETT in the diagnostics of patients with mild LSS with respect to the presence of NC

The LSS patients covered a shorter distance and the time spent walking was significantly shorter than in both con-

Table 1 Basic comparison of groups. Quantitative parameters are expressed as median estimates, with 10%–90% quantiles in parentheses (*AP* anteroposterior, *ETT* exercise treadmill test, *LSS* lumbar spinal stenosis)

Parameter	Healthy controls (n=25)	Diabetic patients (n=24)	LSS patients (n=29)
Age (years)	50 (30; 65)	49 (24; 67)	54 (42; 72)
Height (cm)	168 (158; 178)	174 (160; 183)	170 (160; 184)
Sex (%M/F)	32.0/68.0a	62.5/37.5b	54.8/45.2b
Radiological parameters			
Spinal canal diameter (mm)			
Smallest AP diameter		14.5 (13.0; 18.0)a	11.0 (6.7; 12.9)b
Smallest transverse diameter		23.5 (20.0; 27.0)a	15.4 (8.6; 17.2)b
Exercise treadmill test			
Distance covered (m)	380 (160; 610)a	370 (150; 570)a	236 (105; 530)a
Time spent walking (s)	540 (300; 720)a	540 (266; 720)a	380 (103; 590)b
Reason for premature termination of ETT (in %)			
No reason	40.0	33.3	38.7
Neurogenic claudication	0.0a	0.0a	41.9b
Other	60.0a	66.7a	19.4b

^{a,b} Letters indicate statistical significance within one row: groups marked with the same letter are not significantly different ($P>0.05$; Mann-Whitney test for quantitative parameters, binomial test for relative frequencies)

trol groups in the ETT (Table 1). There was no significant difference in radiological parameters between the two subgroups of patients with LSS (Table 2). On the other hand, there was a significant difference in the walking and running test and in the ETT with respect to the presence of NC in the history. The time to cover a distance of 10 m by

walking and running was significantly shorter in LSS NC– patients.

LSS NC+ patients covered a significantly shorter distance and the time spent walking was significantly shorter than in LSS NC– patients. NC was the main reason (67%) for premature termination of the ETT among LSS NC+ patients. In

Table 2 Characteristics of patients with LSS with regard to neurogenic claudication. Quantitative parameters are expressed as median estimates, with 10%–90% quantiles in parentheses

Parameter	Neurogenic claudication		Significance level
	No (n=13)	Yes (n=16)	
Age (years)	54 (33; 57)	56.5 (45; 75)	$P=0.105$
Height (cm)	172 (160; 184)	170 (163; 180)	$P=0.952$
Sex (%M/F)	38.3/61.7	43.2/56.8	$P=0.853$
Radiological parameters			
Spinal canal diameter (mm)			
Smallest AP diameter	10.6 (10.0; 11.2)	10.8 (10.4; 11.2)	$P=0.542$
Smallest transverse diameter	15.1 (13.7; 16.4)	13.8 (13.1; 15.4)	$P=0.276$
No. of stenotic levels =1	30.8	12.5	$P=0.192$
No. of stenotic levels >1	69.2	87.5	
Spondylarthrosis	76.9	94.4	$P=0.181$
Scoliosis	23.1	27.8	$P=0.775$
Degenerative spondylolisthesis	15.4	38.9	$P=0.174$
10-m walking test ^a			
Time (s)	7.3 (6.6; 9.0)	10.6 (8.8; 12.4)	$P=0.006$
10-m running test			
Ability (in % of cases)	100.0	83.3	$P=0.130$
Time (s)	3.7 (3.3; 4.2)	5.4 (4.8; 6.0)	$P<0.001$
Exercise treadmill test			
Distance covered (m)	434 (342; 539)	202 (110; 294)	$P<0.001$
Time spent walking (s)	492 (403; 554)	308 (217; 399)	$P=0.011$
Reason for premature termination of ETT (in %)			
No reason	69.2	16.7	$P=0.008$
Neurogenic claudication	0.0	66.7	$P=0.001$
Other	30.8	16.6	$P=0.374$

^aAll patients were able to perform the 10-m walking test

contrast, no LSS NC- patient and none from the control groups revealed NC, but 31% of LSS NC- patients were not able to finish ETT for other reasons (e.g. dyspnoea).

The contribution of electrophysiological examination in the diagnostics of patients with mild LSS with respect to the presence of NC

Electrophysiological parameters evaluated from the upper extremities – latency of the ulnar nerve F-wave and amplitude of the sensory nerve action potential (SNAP) of

the radial nerve – distinguished diabetic patients from LSS patients. The latencies of tibial nerve F-wave, soleus H-reflex and spinal MEP response reliably distinguished healthy volunteers from diabetic patients and LSS patients, and particularly LSS patients from diabetic patients (the latencies of these parameters increased in LSS patients and increasing latencies in diabetic patients were even more evident). The chronodispersion of the tibial F-wave distinguished LSS NC+ patients from the other groups (the value of chronodispersion in this subgroup was the highest).

Fig. 3A,B Healthy volunteers, diabetic patients and lumbar spinal stenosis patients are separated on the basis of the initial values for electrophysiological parameters. Letters indicate statistical significance: groups marked with the same letter are not significantly different (*HV* healthy volunteers, *DM* patients with diabetic polyneuropathy; *LSS* lumbar spinal stenosis patients, *NC*- without neurogenic claudication, *NC*+ with neurogenic claudication)

The amplitude of the soleus H-reflex, in particular, separated LSS NC- patients from diabetic patients and LSS NC+ patients. The amplitude of the cortical MEP response, central motor conduction time and persistence of tibial F-wave had no discriminating effect. The amplitude of SNAP of the sural nerve significantly contributed to distinguishing patients with LSS from diabetic patients (as did the amplitude of radial SNAP), but we cannot confirm a contribution of sural/radial amplitude ratio to differential diagnostics in this respect (Fig. 3).

Discussion

No study on differential diagnostics prospectively comparing patients with LSS, diabetic patients and healthy volunteers has been published to date, to the best of our knowledge.

It can sometimes be problematic to establish that the patient's complaints are caused by LSS. The utility of ETT in the diagnostics of LSS is described in the literature [6, 10]. ETT has good test-retest reproducibility and there is no learning phenomenon associated with the test procedure [6]. ETT is invaluable for measuring a patient's response to treatment. Porter reported that the impression from a patient's history could be completely different from an objective assessment of walking [10]. Our study confirms the clinical utility of ETT in the diagnostics of patients with mild LSS and the contribution of ETT to verifying walking capacity and NC, but any premature termination should be carefully analysed, avoiding false-positive results in older patients (dyspnoea, vascular claudication, joint complaints, etc.).

LSS NC+ patients covered a significantly shorter distance and the time spent walking was significantly shorter than in LSS NC- patients and also in the two control groups. The development of NC caused premature termination of ETT in 66.7% of the LSS NC+ patients, while no LSS NC- patient and none from the control groups revealed NC. The difference between LSS patients with and those without NC in the history was also clear in the walking and running test.

In this study we attempted to find electrophysiological parameters that can help to determine patients with LSS. The highest significance was associated with parameters obtained from the upper extremities, the latencies of tibial F-wave, soleus H-reflex and spinal response of MEPs to AH muscle, and amplitude of SNAP of the sural nerve.

Discrimination between diabetic patients and LSS patients by means of electrophysiological parameters from the upper extremities (latency of ulnar F-wave and amplitude of SNAP of the radial nerve) may be anticipated because diabetic polyneuropathy is a diffuse disorder that also affects the nerves of the upper extremities, while LSS affects only the nerves of the lower extremities.

Berger et al. [4] reported that tibial F-waves in patients with axonal polyneuropathy are characterised by prolongation of the minimal latency and have a lower persistence. In contrast, the most frequent F-response abnormality in radiculopathies was a prolonged chronodispersion rather than abnormalities of minimal latency or persistence. In our study, the latencies of the tibial F-wave and also the soleus H-reflex and spinal response of MEP to AH muscle were only slightly prolonged in LSS patients, but were considerably prolonged in patients with polyneuropathy. The persistence of the tibial F-wave showed no statistically significant difference in all the above-defined groups. In contrast to the paper by Berger and co-workers, we can confirm abnormal chronodispersion of the tibial F-wave only in the LSS NC+ patients.

We assume that the differences between the results in our paper and the results of Berger are based on differences in the selection process (inclusion criteria) for the study groups compared.

The amplitude of SNAP of the sural and radial nerves significantly contributed to distinguishing patients with LSS from diabetic patients. We tried to use the calculation by Rutkove and co-workers [11], known as the sural/radial amplitude ratio. They demonstrated that this ratio is more sensitive than the sural amplitude ($<6.0 \mu\text{V}$) alone.

Rutkove reported that a sural/radial amplitude ratio of less than 0.40 is a strong predictor of axonal polyneuropathy, with 90% sensitivity and 90% specificity. In our study, only 23% of patients with diabetic polyneuropathy exhibited a sural/radial amplitude ratio of less than 0.4, while this was also true of 10% of patients with LSS. An absolute sural amplitude of less than $4.2 \mu\text{V}$ (an abnormal value in our EMG lab) was found to be a feature of 47% of diabetic patients in contrast to 17% of LSS patients. The absolute value of the sural nerve amplitude seems therefore to be a better predictor of diabetic polyneuropathy than the sural/radial amplitude ratio in comparisons with LSS patients.

Conclusions

The following conclusions can be drawn from the results of our study:

- Electrophysiological examination contributes to the differential diagnostics between mild lumbar spinal stenosis and diabetic polyneuropathy. The highest significance has been associated with the parameters of ulnar F-wave, tibial F-wave, SNAP of the radial nerve and sural nerve, soleus H-reflex and MEPs to AH muscle.
- The contribution of electrophysiological methods in verification of NC in LSS patients is limited (chronodispersion of the tibial F-wave only).
- The exercise treadmill test is useful in confirmation of NC and walking capacity verification, but restriction of walking capacity should be carefully analysed.

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