Prediction of long-term clinical outcome in patients with lumbar spinal stenosis

B. Micankova Adamova · S. Vohanka ·
L. Dusek · J. Jarkovsky · J. Bednarik

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Abstract

Purpose The natural course of lumbar spinal stenosis (LSS) fluctuates and is not necessarily progressive. The aim of this study was to explore the predictors of clinical outcome in patients with LSS that might eventually help to optimise the therapeutic choices.

Methods A group of 56 patients (27 men, 29 women, median age 55; range 31–72 years) with clinically symptomatic mild-to-moderate LSS were re-examined after a median period of 88 months and their clinical outcomes classified as satisfactory (34 patients, 60.7 % with stable or improved clinical status) or unsatisfactory (22 patients, 39.3 % for whom clinical status deteriorated). A wide range of demographical, clinical, imaging and electrophysiological entry parameters were evaluated as possible predictors of clinical outcome.

Results Unlike the demographical, clinical and imaging variables, certain electrophysiological parameters were significantly associated with unsatisfactory outcomes. There was a significantly higher prevalence of pluriradicular involvement detected by EMG in patients with unsatisfactory outcome than those with satisfactory outcome (68.2 vs. 32.3 %; $p = 0.035$). Patients with unsatisfactory outcome

had more frequent bilateral abnormalities of the soleus H-reflex (50.0 vs. 14.7 %; $p = 0.015$) and lower mean H-reflex amplitude. Multivariate logistic regression proposed two variables as mutually independent predictors of unsatisfactory outcome: EMG signs of pluriradicular involvement (OR = 3.72) and averaged soleus H-reflex amplitude ≤ 2.8 mV (OR = 2.87).

Conclusions Satisfactory outcomes were disclosed in about 61 % of the patients with mild-to-moderate LSS in a 7-year follow-up. Electrophysiological abnormalities, namely the presence of pluriradicular involvement and abnormalities of the soleus H-reflex, were predictive of deterioration of clinical status in these patients.

Keywords Lumbar spinal stenosis · Electromyography · Outcome · Natural course · Prognosis

Abbreviations

LSS	Lumbar spinal stenosis
NC	Neurogenic claudication
ODI	Oswestry disability index
EMG	Electromyography
LL	Lower limb
NRS	Numerical rating scale
AP	Anteroposterior
CT	Computed tomography
MRI	Magnetic resonance imaging
ROC	Receiver operating characteristic

B. Micankova Adamova (✉) · S. Vohanka · J. Bednarik
Department of Neurology, Faculty Hospital and Masaryk
University Brno, Jihlavská 20, 62500 Brno, Czech Republic
e-mail: badamova@fnbrno.cz

B. Micankova Adamova · S. Vohanka · J. Bednarik
CEITEC, Central European Institute of Technology,
Masaryk University, Brno, Czech Republic

L. Dusek · J. Jarkovsky
Institute of Biostatistics and Analyses, Masaryk University,
Kamenice 3, 625 00 Brno, Czech Republic

Introduction

Lumbar spinal stenosis (LSS) is defined as any osteoligamentous narrowing of the spinal canal and/or nerve root

canals [1]. LSS can give rise to several clinical syndromes: neurogenic claudication (NC), radiculopathy, and chronic cauda equina syndrome. Low back pain is very frequent in patients with LSS but this complaint is not due to stenosis; in fact, it arises out of the degenerative changes in the lumbar spine that lead to the stenosis.

The frequency of degenerative LSS diagnosis has risen over time, a result of increasing life expectancy and demands for a better quality of life, awareness of the disease, and the availability of advanced imaging techniques [2]. LSS is now the most common diagnosis in individuals over the age of 65 years undergoing spinal surgery [3]. The choice of optimal treatment modality (i.e. conservative vs. surgical) remains a matter of debate. There are only a few long-term studies available that document the natural course of LSS, and most of them are retrospective, as well as methodologically flawed. Despite these problems, it is generally agreed that the long-term clinical stability is common in patients with LSS. A substantial proportion of patients do not deteriorate and may remain unchanged or they may even improve [2, 4]. The frequency of surgical treatment is increasing, but the effectiveness of surgery for LSS is still a matter of controversy. Surgery is also associated with more risk than conservative treatment, whilst mortality and operative complications increase with age and comorbidities [5]. The most recent trials have demonstrated that the surgical treatment of LSS provided better results than conservative methods of treatment but the efficacy of surgical treatment slowly declined within a few years of the operation [6–8]. Longer follow-up is needed to determine if the benefits of surgical treatment persist.

A sound knowledge of the natural course of the disease and the predictive factors influencing its course are therefore crucial [4]. Finding predictors of further clinical development may contribute to better decision making with regard to the whole question of surgical versus conservative treatment in patients with LSS.

Some studies have identified radiological [9, 10] or clinical [11, 12] predictors whilst one has not [13]. Electrophysiological examination is widely used in the diagnosis and differential diagnosis of LSS [12, 14–18], but our literature search found only one study that evaluated electrophysiological predictors of LSS outcome [12].

Nerve conduction studies and needle electromyography are the most useful electrophysiological examinations for the evaluation of suspected radiculopathies in patients with LSS [16]. EMG findings may vary in patients with LSS, bilateral multiple lumbosacral radiculopathy (cauda equina lesion) being the most frequent finding (in approximately 50 % of patients). Polyradicular lumbosacral lesions are often asymmetrical, and usually involve the lower lumbosacral roots, especially root S1 [19].

We therefore organised a prospective study to evaluate a wide range of variables (demographical, clinical, imaging and electrophysiological) as potential predictors of long-term outcome in patients with LSS.

Materials and methods

Patient population

The study group was recruited from a total of 151 patients with clinically symptomatic LSS diagnosed, treated and observed in the department of neurology of a university Hospital. The following criteria were used for inclusion into the prospective evaluation of outcome in patients with LSS:

- Clinically symptomatic LSS (NC and/or low back pain radiating to the lower limb)
- Central LSS (narrowing in the spinal canal) at one level at the least, documented by computed tomography (CT)
- Mild-to-moderate clinical symptoms suitable for conservative therapy at entry examination
- Age under 75 years at entry examination
- Absence of hip and/or knee joint arthrosis limiting walking
- Absence of arteriosclerotic peripheral vascular disease of the lower extremity limiting walking
- Absence of diabetes mellitus or other disease causing polyneuropathy (to eliminate the effects of polyneuropathy on electrophysiological and clinical neurological examination)
- Absence of any other serious comorbidity.

Most of the patients were given multimodal conservative treatment (analgesics, back exercises, physical therapy and the use of a lumbosacral corset), especially at the beginning of the study. Epidural steroid injections were administered only to a few patients. The conservative therapy was changed and adjusted with respect to the specific patient's condition and complaints during a 7-year follow-up, and most of these patients were observed at regular intervals between 3 and 6 months.

This study was reviewed and approved by the local research ethics committee.

Outcomes for the LSS patients included were evaluated at check-up and classified as satisfactory (with stable or improved clinical status) and unsatisfactory (deterioration in clinical status).

The criteria for unsatisfactory outcome were:

- New onset of neurogenic claudication becoming evident in the course of follow-up.
- Occurrence or progression of lower limb paresis.

- A minimum 15-point increase in the Oswestry disability index.
- Indication for surgical treatment based on deterioration of clinical status, severe pain and agreement of the patient for surgery.

For definition of unsatisfactory outcome at least one of these criteria had to be met.

Radiological examination at initial visit

The LSS patients were examined radiologically according to the following protocol:

- A plain radiograph of the lumbar spine was taken, with assessment of the presence of spondylarthrosis, scoliosis and degenerative spondylolisthesis.
- CT axial scans at three levels (L3-S1) were performed. 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.
- 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.

CT criteria for central LSS were based on our own normal data [20]: anteroposterior diameter <11.7 mm and/or transverse diameter <16.0 mm.

Any stenosis of the spinal canal was further evaluated by an experienced radiologist. If central stenosis was considered present on the basis of morphological evaluation (spondylosis, facet joint arthrosis and hypertrophy of the ligamenta compromising the nervous structures), a level was designated as the “stenotic level”. The shortest anteroposterior and transverse diameters at L3-S1 levels and the number of the stenotic levels were evaluated.

Electrophysiological examination at initial visit

The electrophysiological examination of the lower extremities included motor and sensory conduction studies, F-waves, soleus H-reflex and needle EMG from L4-S1 myotomes. A conventional EMG device was used to perform the nerve conduction studies from temperature-checked skin. Motor conduction studies of the peroneal nerve (muscle responses recorded via surface electrodes placed over the extensor digitorum brevis muscle) and the tibial nerve (muscle responses recorded via surface electrodes placed over the abductor hallucis muscle) were performed bilaterally. Sensory conduction studies of the sural and superficial peroneal nerves were carried out employing an antidromic surface technique. The F-wave responses of the tibial and peroneal nerves and H-reflex of

the soleus muscle were recorded bilaterally. Submaximal stimuli with increasing voltage were delivered, with facilitation to provide maximum H-reflex amplitude. We evaluated abnormal spontaneous activity and the analysis of action potentials of motor units in needle EMG.

The presence of radiculopathy in patients with LSS was investigated. The criteria for radiculopathy included abnormal spontaneous activity or signs of reinnervation found on quantitative analysis of the motor unit action potential in two or more muscles receiving innervation from the same root, preferably via different peripheral nerves. Isolated abnormality of soleus H-reflex amplitude (<0.5 mV, side-to-side difference in amplitude >50 %, or non-elicitable) was considered as sufficient sign of S1 radiculopathy in patients with clinical suspicion of S1 radiculopathy.

Clinical examination and history at initial examination and later check-up

All patients underwent detailed clinical neurological examination including full history, and the symptoms were confirmed by an experienced neurologist specialising in LSS.

We investigated the presence of hip and/or knee joint arthrosis, the presence of neurogenic claudication and rest pain (low back pain and/or leg pain), average daily pain score for low back and/or lower limb measured on an 11-point numerical rating scale (0–10), presence and severity of lower limb paresis, the positivity of straight leg raise test (Lasègue sign), deep tendon reflexes, tactile and vibratory sensation in the lower limb, disability measured in terms of the ODI, walking test (evaluation of a 10-m walk including time taken to walk the distance as quickly as possible without help), and running test (evaluation of a 10-m run including time taken to do the run as quickly as possible without help).

Statistical approaches

Standard robust summary statistics were used to describe primary data: relative and absolute frequencies, median, and 5th–95th percentile range. The ML- χ^2 test was employed to compare experimental variants in categorical variables and the non-parametric Mann–Whitney *U* test was used for comparison of variants on the basis of continuous variables.

The diagnostic power of potential predictors of unsatisfactory outcome of LSS was assessed by means of receiver operating characteristics (ROC) curves. These ROC analyses were based on the binormal assumption. MedCalc 11.1.0.0 (MedCalc Software 1993–2009) was used to estimate the sensitivity and specificity of potential

predictors in relation to unsatisfactory outcome of LSS. Sensitivity and specificity estimates were supplied with corresponding confidence intervals based on binomial distribution.

Univariate and multivariate logistic regression was applied to assess association of the predictive factors examined and the risk endpoint (i.e. binary coded unsatisfactory outcome of LSS). Odds ratios at 95 % confidence limits were calculated and tested in Wald χ^2 test. Parameters with predictive power (providing at least $p < 0.10$ in univariate logistic regression) were then examined for mutual correlation and interaction terms were coded and tested for significantly correlated pairs of variables. If used in the models, effective cut-off values of continuous variables were optimised on the basis of ROC analysis. The final set of potential predictive factors and interaction terms entered an objective stepwise selection algorithm in multivariate logistic regression (driven by maximum likelihood ratio test).

Results

Seventy-one patients fulfilled the inclusion criteria and were invited to undergo a neurological examination check-up. Fifty-six patients were examined, 15 patients did not take part (4 of them died, 2 changed address, 9 gave no reason for absence). The mean (median) period between entry and examination was 84 (88); range 56–104 months. The group comprised 29 women and 27 men, median age 55; range 31–72 years at initial examination.

Clinical outcome

The LSS patients were divided into two subgroups based on previously established criteria for unsatisfactory outcome. A satisfactory outcome (unchanged or better clinical status) was disclosed in 34 patients (60.7 %), and an unsatisfactory outcome (worse clinical status) in 22 patients (39.3 %). The basic characteristics of all the patients included and the two subgroups appear in Table 1. The subgroups with satisfactory and unsatisfactory outcome were comparable in characteristics such as duration of follow-up period, sex and age. Six patients (10.7 %) had symptoms of LSS so severe (conservative treatment failed) during the 7-year follow-up that they agreed to undergo surgery (decompression with addition of lumbar fusion in cases where it was indicated, with or without instrumentation); spinal cord stimulation was used in one patient. The mean time from initial visit to operation was 28 months (range 5–50 months). One patient was operated upon again 14 months after the first operation.

Clinical predictors

We evaluated the difference in initial clinical parameters between the two subgroups (with satisfactory and unsatisfactory outcome). We found no statistically significant difference in any of the potential clinical predictors evaluated (Table 1).

Radiological predictors

We evaluated the initial radiological parameters in the two subgroups and no statistically significant difference in imaging characteristics emerged (Table 1).

Electrophysiological predictors

The presence of a radicular involvement in EMG was established in 67.6 % of patients with a satisfactory outcome and in 86.4 % with an unsatisfactory outcome ($p = 0.104$).

Pluriradicular involvement was significantly more frequent than the monoradicular form in patients with unsatisfactory outcome (68.2 vs. 18.2 %) compared to the subgroup with satisfactory outcome (32.3 vs. 35.3 %) ($p = 0.035$). The parameters for the soleus H-reflex were more frequently normal in the subgroup with satisfactory outcome (61.8 % of patients) compared to the subgroup with unsatisfactory outcome (31.8 % of the patients). Unilateral abnormalities of the soleus H-reflex occurred in 23.5 % of the patients with satisfactory outcome and bilateral abnormalities in 14.7 % of them; patients with unsatisfactory outcome exhibited unilateral abnormalities of the soleus H-reflex in 18.2 % and bilateral abnormality in 50.0 % ($p = 0.015$).

Amongst the soleus H-reflex parameters, mean soleus H-reflex amplitude was significantly higher in patients with satisfactory outcome compared to those with unsatisfactory outcome (2.7 vs. 1.3 mV; $p = 0.023$).

ROC analysis of potential predictors of unsatisfactory outcome in patients with LSS disclosed mean soleus H-reflex amplitude as the only effective discriminating factor between the two subgroups of patients at a sensitivity of 81.3 % and specificity of 61.0 % ($p = 0.025$) when using an optimal discriminating cut-off point of 2.8 mV (Table 2; Fig. 1).

We also calculated the odds ratio (OR) of potential predictors for unsatisfactory outcome in patients with LSS (Table 3). Univariate analysis led to a statistically significant odds ratio (crude OR) for unsatisfactory outcome in the presence of pluriradicular involvement (OR = 4.48), of averaged soleus H-reflex amplitude 2.8 mV or less (OR = 3.92) and bilaterally abnormal soleus H-reflex (OR = 5.8). Multivariate logistic regression proposed two

Table 1 Initial characteristics of LSS patients

Parameters ¹	All patients (N = 56)	Outcome after 7-year follow-up		
		Satisfactory (N = 34)	Unsatisfactory (N = 22)	<i>p</i> ²
Follow-up (months)	88 (63, 98)	87 (63, 100)	89 (63, 95)	0.680
Patient characteristics				
Sex, Men	27 (48.2 %)	15 (44.1 %)	12 (54.5 %)	0.445
Age at entry (years)	55 (42, 71)	55 (41, 71)	55 (42, 66)	0.562
≤55 years	29 (51.8 %)	18 (52.9 %)	11 (50.0 %)	0.829
>55 years	27 (48.2 %)	16 (47.1 %)	11 (50.0 %)	
Clinical characteristics				
Coxarthrosis	11 (19.6 %)	7 (20.6 %)	4 (18.2 %)	0.824
Gonarthrosis	9 (16.1 %)	5 (14.7 %)	4 (18.2 %)	0.731
Coxarthrosis or gonarthrosis	17 (30.4 %)	11 (32.4 %)	6 (27.3 %)	0.772
Coxarthrosis and gonarthrosis	3 (5.4 %)	1 (2.9 %)	2 (9.1 %)	0.555
Neurogenic claudication at entry	31 (55.4 %)	19 (55.9 %)	12 (54.5 %)	0.921
Resting low back pain at entry	39 (69.6 %)	25 (73.5 %)	14 (63.6 %)	0.554
Lower limb paresis at entry	18 (32.1 %)	11 (32.4 %)	7 (31.8 %)	0.924
Positive Lasègue sign	20 (35.7 %)	14 (41.2 %)	6 (27.3 %)	0.394
Abnormal tactile sensation in LL	32 (57.1 %)	19 (55.9 %)	13 (59.1 %)	0.885
ODI at entry	38.0 (6.0, 71.0)	39.0 (0.0, 71.0)	38.0 (12.0, 68.0)	0.926
Pain at entry (NRS)	4.5 (1.0, 7.0)	5.0 (0.0, 7.0)	3.5 (2.0, 8.0)	0.714
Ability to perform walking test	46 (82.1 %)	27 (79.4 %)	19 (86.4 %)	0.724
Walking test (s)	9.3 (6.5, 21.8)	8.0 (6.5, 17.8)	9.4 (6.2, 36.6)	0.337
Ability to perform running test	31 (55.4 %)	19 (55.9 %)	12 (54.5 %)	0.918
Running test (s)	4.6 (3.0, 6.2)	4.6 (2.4, 7.2)	4.7 (3.0, 6.2)	0.919
Lumbar spine surgery before entry	7 (12.5 %)	3 (8.8 %)	4 (18.2 %)	0.415
Radiology				
Lowest AP diameter	11.0 (7.1, 13.7)	10.9 (7.1, 13.8)	11.0 (9.3, 13.3)	0.795
Lowest transverse diameter	13.4 (6.6, 19.6)	14.0 (6.6, 19.6)	12.9 (6.6, 16.0)	0.140
Number of stenotic levels				
1	12 (21.4 %)	8 (23.5 %)	4 (18.2 %)	0.390
2	27 (48.2 %)	18 (53.0 %)	9 (40.9 %)	
3	17 (30.4 %)	8 (23.5 %)	9 (40.9 %)	
Spondylarthrosis	50 (89.3 %)	30 (88.2 %)	20 (90.9 %)	0.999
Degenerative spondylolisthesis	17 (30.4 %)	9 (26.5 %)	8 (36.4 %)	0.554
Electrophysiology				
H-reflex-normal	28 (50.0 %)	21 (61.8 %)	7 (31.8 %)	0.015
H-reflex-unilateral abnormality	12 (21.4 %)	8 (23.5 %)	4 (18.2 %)	
H-reflex-bilateral abnormality	16 (28.6 %)	5 (14.7 %)	11 (50.0 %)	
H-reflex amplitude-mean	2.5 (0.5, 5.7)	2.7 (0.6, 5.7)	1.3 (0.3, 7.0)	0.023
H-reflex latency-mean	31.4 (28.0, 35.7)	31.2 (27.9, 33.9)	32.3 (28.0, 38.9)	0.393
Radiculopathy	42 (75.0 %)	23 (67.6 %)	19 (86.4 %)	0.104
Monoradicular involvement	16 (28.6 %)	12 (35.3 %)	4 (18.2 %)	0.035
Pluriradicular involvement	26 (46.4 %)	11 (32.3 %)	15 (68.2 %)	

¹ Categorical data are described by absolute number and percentage of patients in the given category, continuous variables are described by median and 5th–95th percentile

² Statistical significance of difference between subgroups is tested by ML- χ^2 test for categorical data and by Mann–Whitney *U* test for continuous parameters. Results significant at $\alpha = 0.05$ level appear in bold

Table 2 ROC analysis of potential predictors for unsatisfactory outcome of LSS

Variable	AUC (95 % CI) ^a	<i>p</i> ^a	Optimal cut-off ^b	Sensitivity ^c (%)	Specificity ^c (%)
Age at entry	0.45 (0.30, 0.61)	0.563	>55	59.1	47.1
Clinical characteristics					
ODI at entry	0.51 (0.35, 0.66)	0.926	>55	31.8	82.4
Pain at entry (NRS)	0.47 (0.31, 0.63)	0.718	>8	9.1	100.0
Walking test (s)	0.58 (0.41, 0.75)	0.337	>9	68.4	55.6
Running test (s)	0.49 (0.27, 0.71)	0.919	>5	50.0	57.9
Radiology					
Lowest AP diameter	0.48 (0.33, 0.63)	0.795	>9.2	95.5	23.5
Lowest transverse diameter	0.38 (0.23, 0.53)	0.140	>24	4.5	100.0
Electrophysiology					
H-reflex amplitude-mean	0.71 (0.54, 0.87)	0.025	≤2.8	81.3	61.0
H-reflex latency-mean	0.58 (0.38, 0.78)	0.393	>34	37.5	96.4

^a Area under the ROC curve with corresponding 95 % confidence interval and statistical significance

^b Optimal cut-off points for binary coding of parameters

^c Sensitivity and specificity for given cut-off point

Fig. 1 Mean soleus H-reflex amplitude as a predictor for unsatisfactory outcome after 7-year follow-up

variables as mutually independent predictors of unsatisfactory outcome: pluriradicular involvement (OR = 3.72) and averaged soleus H-reflex amplitude ≤ 2.8 mV (OR = 2.87).

Discussion

This is, to the best of our knowledge, the first prospective long-term study to evaluate a wide range of potential clinical, imaging and electrophysiological predictors of clinical outcome for patients with LSS, and it highlighted the usefulness of electrophysiological parameters.

In our prospective study, 22 patients (39 %) were categorised as having an unsatisfactory clinical outcome, a

slightly higher proportion compared to the 11–33 % reported in previous studies [9, 10, 13, 21]. A recent study by Haig et al. [12] showed that clinical spinal stenosis is a fluctuating and largely improving syndrome. The results of these studies are, however, difficult to compare, they are also dependent on definitions of endpoints (i.e. type of outcome or therapeutic success). In our study, unsatisfactory outcome was defined as worsened clinical status, whilst satisfactory outcome marked stable or improved clinical status. In contrast, a bad result (treatment failure) in the Amundsen study included unchanged or worse status for the patient, whilst a good result was defined as full or partial restitution with clear improvement [13]. The criteria for unsatisfactory outcome in our study were based on actual clinical status (occurrence of NC, occurrence or progression

Table 3 Potential predictors for unsatisfactory outcome of LSS in logistic regression

Parameters (categories)	% ^a	Crude OR ^b	<i>p</i> ^b	Multivariate-adjusted OR ^b	<i>p</i> ^c
Total	39.3				
Patient characteristics					
Sex, Men	44.4	1.52 (0.52, 4.47)	0.447		
Age at entry (years)	–	0.98 (0.93, 1.04)	0.581		
Age >55	40.7	1.13 (0.39, 3.29)	0.830		
Clinical characteristics					
Coxarthrosis	36.4	0.86 (0.22, 3.36)	0.825		
Gonarthrosis	44.4	1.29 (0.31, 5.44)	0.730		
Coxarthrosis or gonarthrosis	35.3	0.78 (0.24, 2.56)	0.687		
Coxarthrosis and gonarthrosis	66.7	3.30 (0.28, 38.78)	0.342		
Neurogenic claudication at entry	38.7	0.95 (0.32, 2.79)	0.922		
Resting low back pain at entry	35.9	0.63 (0.20, 2.00)	0.433		
Lower limb paresis at entry	38.9	0.97 (0.31, 3.08)	0.967		
Positive Lasègue sign	30.0	0.54 (0.17, 1.71)	0.292		
Abnormal tactile sensation in LL	40.6	1.14 (0.39, 3.38)	0.813		
ODI at entry	–	1.00 (0.97, 1.03)	0.873		
Pain at entry (NRS)	–	0.99 (0.75, 1.29)	0.918		
Ability to perform walking test	41.3	1.64 (0.38, 7.17)	0.510		
Walking test (s)	–	1.08 (0.96, 1.20)	0.207		
Ability to perform running test	38.7	0.95 (0.32, 2.79)	0.922		
Running test (s)	–	0.92 (0.48, 1.77)	0.807		
Lumbar spine surgery before entry	57.1	2.30 (0.46, 11.44)	0.310		
Radiology					
Lowest AP diameter	–	1.07 (0.78, 1.46)	0.687		
Lowest transverse diameter	–	0.92 (0.80, 1.05)	0.213		
Number of stenotic levels					
1	33.3	Basal category	–		
2	33.3	1.00 (0.24, 4.23)	0.999		
3	52.9	2.25 (0.49, 10.41)	0.300		
Spondylarthrosis	40.0	1.33 (0.22, 7.98)	0.753		
Degenerative spondylolisthesis	47.1	1.59 (0.50, 5.04)	0.433		
Electrophysiology					
H-reflex-normal	25.0	Basal category	–		
H-reflex-unilateral abnormality	33.3	1.50 (0.34, 6.55)	0.590		
H-reflex-bilateral abnormality	68.8	5.80 (1.59, 21.14)	0.007		
H-reflex amplitude-mean	–	0.70 (0.51, 0.95)	0.039		
H-ampl-mean ≤ 2.8 or not present	47.5	3.92 (1.07, 14.29)	0.032	2.87 (1.08, 7.69)	0.038
H-reflex latency-mean	–	1.17 (0.91, 1.50)	0.236		
Radiculopathy	45.2	3.03 (0.74, 12.45)	0.124		
Monoradicular involvement	25.0	0.41 (0.11, 1.53)	0.173		
Pluriradicular involvement	57.7	4.48 (1.38, 14.52)	0.011	3.72 (1.11, 12.49)	0.029

^a Percentage of worsened patients within category given by the predictor (only for categorised predictors)^b Odds ratio with 95 % confidence interval (in parentheses); statistical significance based on Wald's test^c Only statistically significant multivariate-adjusted ORs are displayed (variables selected by stepwise selection)

of LL paresis, a minimum 15-point increase in the ODI) and on history (deterioration that required surgical treatment). The minimal 15-point change of the ODI was derived from a US Food and Drug Administration recommendation [22].

Some studies used patient satisfaction as a primary outcome for treatment success. This could, however, be unreliable in view of the long duration of follow-up (some patients cannot clearly recall how they felt prior to

treatment, at the time of their initial visit) [9, 10, 13]. Another study used an assessment of pain intensity (usually conveyed by visual analogue scale), again something that could be influenced by many factors, including current use of analgesics [21].

The proportion of patients in our study who required surgical intervention due to failure of conservative treatment (10.7 %) was lower compared to those reported in the previous studies with mild-to-moderate LSS and ranged between 18 and 43 % [6, 10, 11, 13, 23].

A possible explanation is the fact that our patients might have been motivated to accept non-surgical therapy because their examining physician was not a surgeon but a neurologist.

The lack of clinical or imaging predictors of outcome in our study does not disagree with other published reports [12, 13]. We were not able to confirm the predictive value of severity of LSS [9] or the presence of scoliosis [10].

The Maine lumbar spine study identified some interesting predictive factors. Unilateral leg pain and less than a year since the first visit to a physician for any episode of the pain were predicted as a good outcome. In contrast, predominance of low back over leg pain and worse Roland scores (reflecting functional capacity) were associated with the worse outcomes. These variables predicted outcomes for both surgically and non-surgically treated patients [11].

Similarly, Haig et al. [12] noted that pain, functional disability, and difficulty with sleep predicted a worse outcome.

In our study, we established certain electrophysiological parameters as reliable predictors of clinical outcome in patients with LSS, namely soleus H-reflex figures as markers of S1 radiculopathy, and signs of radiculopathy on needle EMG. The absence of the soleus H-reflex or prolongation of its latency is commonly used to diagnose S1 radiculopathy and the diagnostic sensitivity of soleus H-reflex abnormalities in S1 radiculopathy varies from 50 to 100 % [24–26]. Reduction in H-wave amplitude has been considered the most useful H-wave abnormality for detecting S1 root lesions [19]. The soleus H-reflex is, however, often abnormal or non-elicitable bilaterally in patients with polyneuropathy. Patients with diabetes mellitus or other diseases causing polyneuropathy were excluded from this study (to avoid the influence of polyneuropathy on electrophysiological and clinical neurological examination).

We found the presence of pluriradicular involvement and an average soleus H-reflex amplitude of 2.8 mV or less to be independent predictors of unsatisfactory outcome in the current study. Only one study is available that deals with electrophysiological predictive factors in patients with LSS [12], and it found no correlation between severity of

EMG findings and future pain or disability. Its follow-up period was, however, considerably shorter than that of our study (18 vs. 88 months). It could be concluded that pluriradicular involvement revealed by EMG examination indicates a higher degree of impairment of nervous structures in the lumbar spine, something that probably predicts an unsatisfactory outcome.

One limitation of our study is the low number of patients analysed, recruited from a total of 151 patients with clinically symptomatic LSS (71 patients) and of those who completed follow-up (56 patients). The inclusion criteria were kept strict in order to eliminate factors (e.g. diabetes mellitus, serious comorbidity, higher age) that might influence outcome, whilst the drop-out (15 patients) is appropriate to the duration of follow-up. Another limitation of this study is the nature of the radiological examination at initial visit. We used CT scans at three levels (L3-S1), as CT was the standard evaluation for LSS at the time of entry radiological examination. In contrast to the MRI examination more usually used today, this approach could result in missing stenosis at higher levels of the lumbar spine. The anteroposterior (AP) diameter was measured at the middle level of the vertebra to detect the presence of congenital (developmental or primary) stenosis; we did not evaluate the AP diameter at the intervertebral segment because the severity of the canal narrowing can be underestimated in some cases through the influence of soft tissue. Evaluation of the central stenosis on the basis of morphological evaluation is somewhat subjective, with a degree of inter-rater variability, and is a further possible source of inaccuracy in the radiological data in the study. The effectiveness of CT could be improved using dural sac cross-sectional area.

The results of our study are also influenced by the selection of outcome measurements and the definition of satisfactory outcome. This study is based on objective parameters. Subjective assessment of status by the patient, used by other investigators, was not employed.

Conclusions

Satisfactory outcome (unchanged or better clinical status) appeared in 61 % of patients with mild-to-moderate LSS after 7-year follow-up. As electrophysiological parameters showed some prognostic value in patients for LSS, especially those of pluriradicular involvement and the parameters of soleus H-reflex, we recommend the use of needle EMG and conduction studies as a standard examination in patients with LSS.

Conflict of interest None.

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