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Comorbidity of Lumbar Spinal Stenosis and Polyneuropathy

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Abstract

Background: The aim of the present study was to determine for the first time the proportion of patients with or without symptomatic lumbar bilateral spinal stenosis who also have polyneuropathy. Furthermore, a simple test battery for the diagnosis of polyneuropathy in patients with symptomatic and proven central lumbar spinal stenosis should be developed.

Methods: In this study, 70 patients with and 57 patients without symptomatic and MRI-diagnosed lumbar spinal stenosis were clinically examined for polyneuropathy. Among other methods, analyses of variance, a matched-pair design, and stepwise regression analysis were used for evaluation of the results.

Results: Patients with such lumbar spinal stenosis were found to have a highly significant higher incidence of polyneuropathy than those without. A resulting test battery with which spinal stenosis patients could be adequately validated for detection of polyneuropathy in cases of concomitant lumbar central spinal stenosis and required only the following selected items: patellar tendon reflex, vibration sensation in the feet, and allodynia.

Conclusions: On the basis of the results and the sparse data available so far, it seems urgently necessary that controlled prospective studies be conducted as far as possible in order to shed further light on the therapeutic perspectives of the results in particular. Invasive validation of the results requires increased interdisciplinary collaboration.

Keywords: Comorbidity, Spinal Stenosis, Polyneuropathy.

Introduction

The diagnosis and treatment of lumbar spinal stenosis, like that of polyneuropathy, is an increasing challenge in the medical care of a continuously aging overall population [1]. Both diseases lead to similar (and quite confusable) complaints and deficits, which are usually addressed very differently. A clear differential diagnosis with simple means already in the run-up to specialized medical care and without high expenditure on equipment has so far neither been propagated in the relevant specialist literature nor in the health policy discussion, let alone assessed for its sense. However, it is a fact that early and targeted differentiation and therapy of both diseases could help to save enormous

follow-up costs for the health care system [2, 3]. However, there is little robust data on the costs of polyneuropathies. First, because their direct and indirect costs are apparently not recorded separately in analyses of the health economic impact of its main cause, diabetes mellitus, and second, because very many different forms of polyneuropathy are classified with various ICD-10 codes [4].

For the United States, direct and indirect costs of conservatively treated lumbar stenosis patients were estimated to be approximately $ 3,900 per year in 2014 [5], assuming a clinical prevalence of 17 % in the 40-90-year-old population [6].

Surgery for symptomatic lumbar spinal stenosis has become the most frequent procedure on the lumbar spine. It has now replaced nucleotomy as the most common surgical indication in the lumbar spine [7]. From clinical experience, it is known that comorbidities occur [8]. However, their frequency is unknown to date. To determine the magnitude of the joint prevalence of lumbar spinal stenosis and polyneuropathy constitutes the first part of the present study (prevalence study). Aim of this paper is to deliver clear diagnostic criteria for both diseases and to describe simple and valid clinical methods for referring physicians, which can facilitate the setting of the course for further diagnosis and treatment. The second part of the study compiles a feasible "test battery" for simple and reliable detection or exclusion of superimposed polyneuropathy in lumbar spinal stenosis based on statistical analysis. Thus, not every patient with back pain needs MRI [9] and not every diabetic patient needs an examination by a neurologic specialist [10]. But, for example, by overlooking concomitant polyneuropathy in spinal stenosis, the patient may be deprived of conservative therapeutic options that could also ultimately significantly increase the efficiency of the necessary treatment. Vice versa, a patient may be deprived of useful surgical options. Also, the "conditional reflex" of prescribing often lordotic physiotherapy in combination with heat applications and massages in post- proven symptomatic spinal stenosis under the idea of a necessary "strengthening of the back muscles" without at least considering invasive therapy measures is often due to ignorance of the underlying pathology and usually not very successful [11,12]. Such measures are even less helpful in the presence of additional polyneuropathy, because they do not address either of the two symptom and cause complexes. Gait training, occupational therapy, and fall prevention, on the other hand, have been shown to be useful, especially with instruction in self-activation [13] and could be combined in a more targeted manner for both symptom complexes and thus be used more effectively. Also, a renunciation of targeted drug therapy of an accompanying polyneuropathy under the assumption of a sole lumbar spinal canal stenosis weakens the treatment result. The mostly used medication of a spinal stenosis with non-steroidal anti-inflammatory drugs hardly reduces polyneuropathic complaints. This often leads to a causal therapeutic nihilism with frustration of patient and practitioner as well as escalating opiate prescription with its known side effects[14], especially in the elderly patient. The observations and considerations presented so far culminate in two focal points of this work.

Prevalence study:

- What is the prevalence of polyneuropathy in a patient population with clinically and MRI-diagnostically confirmed lumbar central spinal stenosis?
- What is the prevalence of polyneuropathy in a patient population with clinically and MRI-diagnostically excluded lumbar central spinal stenosis?

Test battery:

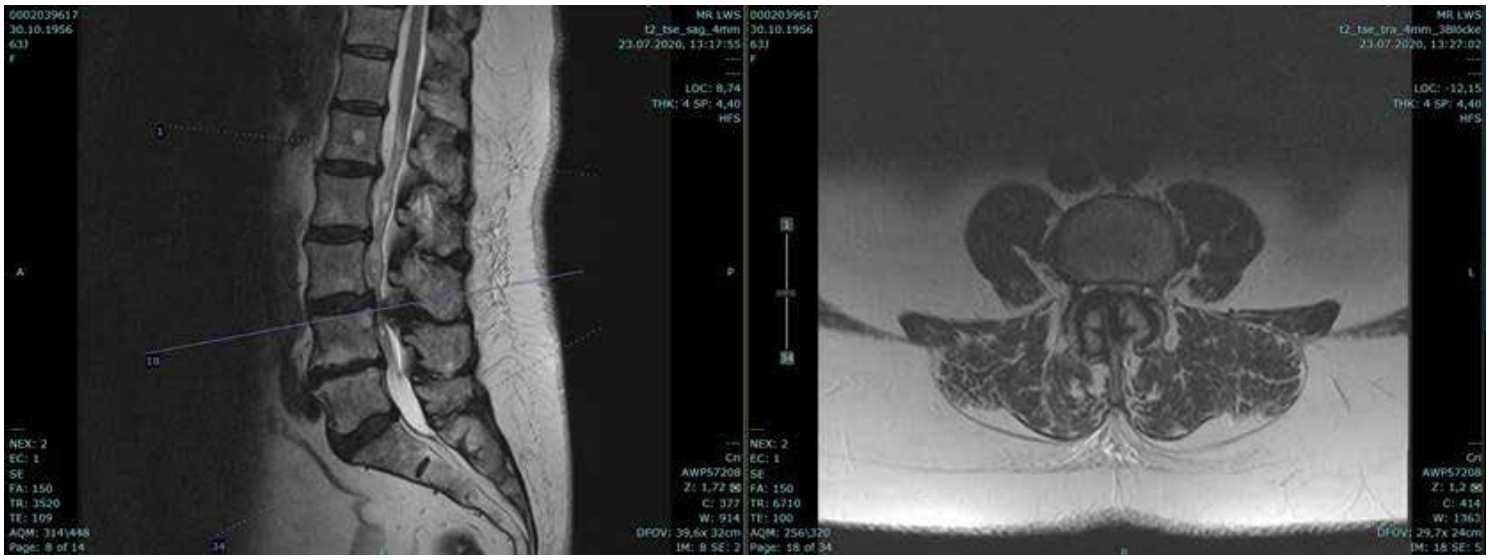
- Development of a simple feasible, reliable, and valid tool to detect or exclude polyneuropathy in patients with confirmed symptomatic lumbar central spinal stenosis.

Materials and methods

The study described below was submitted to the Ethics Committee of the Baden-Wuerttemberg Medical Association and approved under protocol number F-2021-018. No third-party funds were used for this purpose. There was no conflict of interest.

The subjects were recruited from the consultation hours of the Clinic for Spine Surgery at the Kreiskrankenhaus Loerrach, where they presented as patients. A total of 127 outpatients were included in the study. All study participants spoke German, were able to give consent, and gave their informed consent to participate in the study. For the study, consecutively and without exception, patients with statutory and private insurance were included from the outpatient consultation of the Clinic for Spinal Surgery at the Loerrach District Hospital. In this consultation, the patients were initially questioned and examined in the examination room alone by the personally authorized head

Figure 1: MRI of the lumbar spine, spinal canal stenosis type Schizas grade D at L3/4.



physician, as is also generally the case. In patients who showed a spinal stenosis of the lumbar spine type Schizas grade C or grade D on recent MRI imaging [15], thus a clear bilateral stenosis, and additionally reported claudication, the first examiner performed, among other tests, a test for forced reclination of the lower lumbar spine [16] the so-called hyperextension test.

This involved stopping the time until the moment patients noticed a pulling or tingling sensation in the buttocks or legs and asking about pain intensity on a Numeric Rating Scale (NRS) of 0 - 10 at the time of pain onset.

If these patients had no previous spinal surgery and the foot pulses were reliably palpable, thus peripheral arterial occlusive disease (PAOD) could be excluded, and there was no unilateral radiculopathy, these patients were assigned to the "study group", which was noted in the medical record, initially inaccessible to others. Patients with magnetic resonance imaging-proven spinal stenosis in whom the hyperextension test did not provoke bilateral pain in the buttocks or legs were not included in the study. Patients who were assigned to the "control group" were also not allowed to have had previous spinal surgery, had to have foot pulses that could be reliably palpated on both sides, and were likewise not allowed to experience bilateral or even unilateral radiculopathy. A recent MRI diagnosis also had to be available from these patients, but clearly without evidence of spinal stenosis in the lumbar spine. In contrast to the study group, the hyperextension test had to be negative in the subjects of the control group

Figure 2: Hyperextension test

and thus could not cause pain or discomfort in the legs of the patients. Negative supine MRI alone does not always exclude instability as a hidden cause of spinal stenosis [17]. To avoid this problem, only patients with unremarkable radiographs of the lumbar spine in reclination and inclination were included in the control group.

Inclusion criteria of the study group
1. Age ≥ 18 years
2. Not preoperated on the spine
3. Current MRI of the lumbar spine available
4. No known PAOD and palpable foot pulses on both sides
5. Bilateral radiculopathy
6. Spinal canal stenosis type Schizas grade C or D in MRI of the lumbar spine
7. Anamnestic spinal claudication
8. Hyperextension test positive within one minute

This resulted in 70 patients in the study group.
Inclusion criteria of the control group
1. Age ≥ 18 years
2. Not preoperated on the spine
3. Current MRI of the lumbar spine available
4. No known PAOD and palpable foot pulses on both sides
5. Exclusion of unilateral or bilateral radiculopathy
6. Exclusion of spinal stenosis on MRI of the lumbar spine
7. X-ray functional images of the lumbar spine in reclination and inclination stable
8. Hyperextension test negative

This resulted in 57 patients in the control group, predominantly with so-called "functional back pain", mostly in combination with degenerative changes of the small vertebral and/or sacroiliac joints. After the general examination and assignment of the patients to the appropriate group, the second examiner was called in. She performed further polyneuropathy diagnostics in the adjacent room: This examination included standardized, evidence-based noninvasive pain-free and low-pain examinations that did not exceed the level of a specialist neurological diagnostic test. The file remained with the head physician. Thus, during this examination and the subsequent interview, the second examiner did not know at any time to which group, (study or control group), the patients had been assigned. The examination findings were recorded in an examination protocol during the physical examination and were not changed thereafter. Only after the physical examination were the patients asked verbal questions about their medical history and the questions of the two questionnaires MNSI and LANSS. The results were then transferred by the second examiner to an Excel spreadsheet and finally the patient file. Sterile wooden medical cotton swabs of 15 cm length and 2 mm shaft diameter with a cotton head of 5 mm maximum diameter from Applimed SA, Châtel-St-Denis (Switzerland) were used to test mechanoreception and nociception (allodynia).

The monofilament, is a nylon filament that when pressed against the skin and flexes, acts on it with the mass of 10 g. The monofilament is on a TwinTip® test device (Twin-Tip GmbH & Co. KG, Heinsberg, Germany). This instrument is used in pressure perception testing in MDNS and MNSI (see below). For epicritic sensitivity testing, nickel-plated steel safety pins were used as described in the Utah Early Neuropathy Scales Research Report [18] and safely disposed of thereafter. These were from the Dritz Company (Spartanburg, USA) and were available in size 2. This instrument is used in testing mechanoreception and nociception (allodynia) in MDNS and UENS (see below). A Rydel-Seiffer tuning fork with a vibration frequency of 128 Hz and two 8/8-scaled reduction weights of 25 g each screwed to the ends and a resulting total frequency of 64 Hz was used to test vibration perception. This instrument is used to determine the vibration sensitivity in the MDNS, MNSI, and UENS (see below), which is determined by a "disappearance threshold" [19]. A Troemner reflex hammer according to with a weight of 161 g and a length of 24.5 cm was used to test the muscle reflexes. The examination took place in the supine position. This instrument is used to check muscle intrinsic reflexes in the MNSI, MDNS, and UENS (see below). To test the heat sensation of the patients, a commercially available latent heat pad from the company elasto form KG (Sulzbach-Rosenberg, Germany), among others, was used. This instrument is used for the verification of thermoreception.

A medical chloraethyl ice spray from Dr. Georg Friedrich Henning Chemische Fabrik Walldorf GmbH, Walldorf (Germany) was used to test cold sensation. This instrument is also used in the verification of thermoreception. A two-point discriminator (Greulich-Star) was used to test the ability to distinguish between two spatially

separated tactile stimuli. This instrument thus is used in mechanosensitivity testing.

The study should be based on clear diagnostic criteria for the presence of polyneuropathy, which in turn are based on easily practicable and valid clinical methods, primarily for primary care referral physicians. For this purpose, in a meta-analysis based on the criteria of Brink and Louw [20], publications from PubMed, Embase, and Cochrane, valid and reliable scores based on noninvasive clinical examinations and medical history were selected for the detection of polyneuropathy (MNSI, MDNS, UENS, LANSS). For complete description of these scores we refer to the original publications [21, 22, 18].

Results

A total of 127 patients from the spine consultation were studied; 70 were assigned to the study group and 57 to the control group.

Table 1: General information on patients

	Control group	Studies group	Total
Patients number	57	70	127
Age in years, Mean (range)	63,3 (27-88)	69,1 (29-86)	66,5 (27-88)
Male Number (%)	23 (40,4)	30 (42,9)	53 (41,7)
Female Number (%)	34 (59,6)	40 (57,1)	74 (58,3)
Size in centimeters, Mean	168	164	166
Weight in kilograms, Mean	77,9	83,7	81,1
BMI in kg/m², Mean (range)	27,6 (17,2-44,1)	30,8 (20,7-46,3)	29,4 (17,2-46,3)

The youngest patient examined in the study group was 29, in the control group 27 years old. The oldest patient examined in the study group was 86, the oldest patient in the control group 88 years old. The lowest BMI (Body mass index) was 17.2 kg/m² and the highest was 46.3 kg/m².

Figure 3: Age distribution of the groups

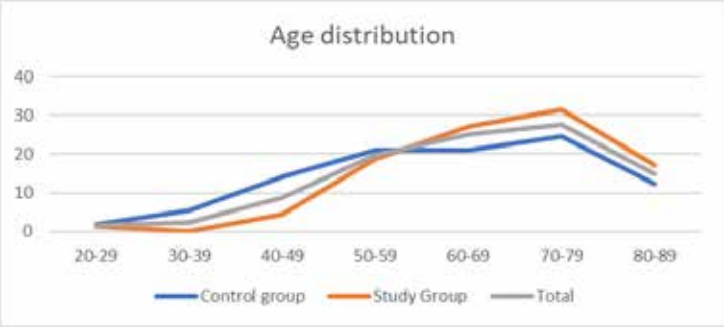


Table 2: Physical examinations and questionnaires

	Control group	Study group
Hyperextension test positive in seconds Mean value	negative	13,2
Leg pain score in hyperextension test NRS (0-10) Mean value	-	6,3
LANSS (0-24) Mean	5,1	8,7
MNSI questionnaire (0-13) Mean value	2,2	3,6
MNSI examination (0-10) Mean	0,9	3,2
MDNS (0-46) Mean	2,4	8,3
UENS (0-42) Mean	2,0	7,3

Prevalence Study

Condition 1 for this study was the validity and reliability of the operationalization of the term "polyneuropathy". The first step was to define the presence of polyneuropathy. For this purpose, a cutoff value was defined on the basis of the validated MNSI and MDNS scores, which had to be exceeded in at least one of the two tests in order to detect the presence of polyneuropathy (PNP). Subsequently, the corrected item-total correlation for each item of these two tests was calculated by computing Cronbach's alpha. From this, the essential items were extracted to generate "unused items" for the generation of predictors of polyneuropathy in a new test battery in the second part of the study. The rationale was that the same definition of "polyneuropathy" had to apply to both parts of the study and that these predictors had to be self-referent, i. e., not used to define "polyneuropathy" (avoiding the methodological error of self-reference).

It turned out that numerous items appeared in different scores, partly classified differently, but qualitatively redundant. Accordingly, the same was also evident from often highly significant intercorrelations. The aim was thus to produce a definition of polyneuropathy that was as "lean" as possible and allowed for a sufficient number of predictors to be tested. The usefulness of the reduction of definition criteria was validated by comparing the result before and after the reduction. A threshold value for the MNSI and MDNS given in the literature was adjusted on the basis of this comparison, since this reduction naturally had to result in lower maximum sums and thus threshold values.

This comparison showed that according to MNSI and MDNS, polyneuropathy was present in 44.1 % of all 127

patients. Based on testing of the ATR (Achilles tendon reflex), this was the case in 41.7 %. This difference was not significant. Overall, the results agreed 89.8 % and were strongly correlated ($r = 0.792$; $p < 0.001$). Thus, absent or attenuated ATR alone predicted polyneuropathy with high reliability in this patient population. Thus, all other items remained "unspent" for use in the second part of the study (development of a test battery).

Condition 2 was structural homogeneity of study and control groups. Yet, there was no structural homogeneity between the two groups with respect to the biometric totals of sex, age, and BMI.

Due to the structural inhomogeneities in the exact chi-square test (Fisher's exact test) chosen after examination of the application prerequisites, primarily an analysis of variance should neutralize any differences existing between both groups without loss of number of cases and as small an error of the second kind as possible. "Polyneuropathy" was the dependent variable and "spinal stenosis" was chosen as a factor. Age and BMI were included as covariates in the analysis. As a result, we obtained adjusted values for the proportions of polyneuropathy in the study and control groups.

Table3: Cell mean score variance for patients with polyneuropathy in control and study groups.

		Control group	Study Group	Total
Polyneuropathy (MNSI, MDNS)	Mean value	0,21	0,63	0,44
	Quantity	57	70	127

The difference in the means was 0.42. Thus, even when examined multivariately, the influences of age and BMI were highly significant ($p < 0.001$). As expected, gender did not play a role ($p = 0.062$).

Table 4: Multiple correspondence analysis with sex, age and BMI.

		Polyneuropathy (MNSI, MDNS)	
		Control group	Study Group
	Quantity	57	70
Predicted mean value	Unadjusted	0,21	0,63
	Adjusted for factors and covariates	0,28	0,57
Deviation	Unadjusted	-0,23	0,19
	Adjusted as above	-0,16	0,13

Unadjusted (without considering the covariates age and BMI), the PNP prevalence was
21 % in patients without spinal stenosis and
63 % in patients with spinal stenosis.

Adjusted (with consideration of the covariates age and BMI), the PNP prevalence was
28 % in patients without spinal stenosis and
57 % in patients with spinal stenosis.

The factor spinal stenosis was highly significantly effective on the relative incidence of polyneuropathy in this approach ($p = 0.001$).

Secondarily, a matched-pair procedure was now applied, in which a loss in the number of cases from $n = 127$ to $n = 100$ was accepted. In this procedure, there were neither significant differences in gender, age nor BMI. The matching of the pairs was done purely manually according to the criteria of sex, age and BMI. Simultaneous review and evaluation of the results of the search at did not take place. In the case of almost identical matching criteria, chance decided on inclusion or exclusion.

In the control group, the prevalence of polyneuropathy was 24 %. In the study group, the prevalence of polyneuropathy was 56 %. This difference was significant at $p = 0.002$.

Test battery

To develop a toolbox of easy-to-screen items that can reliably diagnose polyneuropathy in patients with spinal stenosis.

These items should be able to diagnose polyneuropathy just as reliably as MNSI, MDNS, or UENS, but the new test battery should be faster, easier to perform, and also less expensive.

The matched pairs were used as the patient base, that is, 50 patients with spinal stenosis, of whom 28 (56 %) had polyneuropathy, and 50 patients without spinal stenosis, of whom 12 (24 %) had polyneuropathy.

Potential predictors (independent variables) considered were:
- Feet appearance
- Ulcerations
- PTR (patellar tendon reflex)
- Degree of force toe spread

- Degree of force big toe extension
- Degree of force foot extension
- Vibration sensation („vibration“)
- Monofilament testing
- Pinprick testing
- Allodynia testing („Allodynia“)
- Proprioception testing
- Checking the sensation of warmth
- Checking the sensation of cold (“cold”)
- Two-point discrimination testing
- Gender
- Age
- BMI

The development of a logistic regression model with stepwise predictor selection began with the selection of the predictor that had the strongest influence (the highest explanatory value) on the dependent variable. The next step was to see if adding another predictor improved the explanatory value of the model. This process was continued as long as an improvement was still possible by adding further predictors. After the fourth step, the model-building process stopped because none of the remaining 13 predictors would have improved the model by more than p = 0.001 from a statistical point of view.

The model building process aimed to maximize the “proportion of variance explained” of the dependent variable. Ideally, the model should explain the dependent variable 100 %. In fact, of course, this is not to be expected in empirical reality, but the more variance a model “explains”, the more useful it is. For example, a model that “explains” only 2 % of the dependent variable is useless. The predictors of such a model would have practically nothing to do with the dependent variable.

The model which relied on vibration, PTR, and allodynia (“Step 3”) overall performed best at

Sensitivity: 78.6

Specificity: 86.4

Correct classification rate: 82.0 %.

Positive predictive value: 88.0

Negative predictive value: 76.0 %.

The model coefficients are shown in the following table:

Table 2: Variables to be used for model 3

		Regression coefficient B	Standard error	Forest statistic	DOF	p	Exp(B) (Odds Ratio)
Step 3	Vibration	**0,904**	0,319	8,045	1	0,005	2,470
	PTR	**0,843**	0,374	5,081	1	0,024	2,324
	Allodynia	**-2,554**	1,291	3,912	1	0,048	0,078
	Constant	**-1,088**	0,536	4,119	1	0,042	0,337

The vibration sensation at the big toe is examined on both feet. Thus, 0, 1 or 2 points with a maximum of 4 points according to the MNSI can be awarded for each foot. The PTR is then triggered by striking the patellar tendon with a reflex hammer. The patient should lie down during this process. No points are awarded for a (moderately) active PTR, 1 point for a weak reflex and 2 points for an extinguished reflex. Thus, 2 points can be awarded for each leg, and a maximum of 4 points for the entire item “PTR”. Allodynia can be tested with a with a cotton swab where 1 point can be awarded for each foot in case of hyposensitivity and a maximum of 2 points (hypersensitivity) for both feet.

The inputs to the model were the values for vibration, PTR, and allodynia.

From these measured values, the linear component (ZL_M3) of the model was calculated in the first step according to the following formula:

ZL_M3 =	- 1,088	
	+ 0,904	* Vibration
	+ 0,843	* PTR
	- 2,554	* Allodynia

In the second step, a non-linear transformation was performed, using the linear component calculated in the first step as input:

$$P\_PNP = 1 / (1 + e^{(-ZL\_M3)})$$

The result P_PNP obtained in this way is a number between 0 and 1, which corresponds to a probability between 0 % and 100 %. This is the individual probability that a spinal stenosis patient with exactly these values for vibration, PTR and allodynia has PNP. Values below 0.5 are interpreted as “no”, larger values as “yes”.

The corresponding numbers can now be entered into the above formula. The result is a value between 0 and 1. If the value is greater than 0.5, i. e. corresponding to a probability greater than 50 %, it can be assumed that patients with proven symptomatic lumbar central spinal stenosis have concomitant polyneuropathy.

Discussion

Generally, it is not recommended to rely on individual clinical orthopedic examinations for the diagnosis of spinal disorders, as their accuracy does not seem to be sufficiently scientifically validated. There is a lack of high-quality research on this [23]. Accordingly, clinical tests alone have not been relied upon in this study.

However, imaging in the lumbar spine also has diagnostic weaknesses. Only patients were included in the study whose imaging was performed in a closed MRI machine at rest and in the supine position, also under the safe assumption that functional spinal stenosis due to instabilities masked in the supine position may well escape MRI diagnostics. Therefore, it is important to note that in the patients included in the control group, instabilities had basically been excluded by functional radiographic examinations [17]. These images were not obtained specifically for the study, but only patients with such images were included. These recordings were performed in a standardized manner using the validated technique according to Pitkänen et al. [24]. It should be noted that the exclusion of patients with instability from the control group was based on the assumption that these patients have an increased likelihood of dynamic nerve compression. However, this occurs in only 75 % of cases and the degree of sliding is not correlated with the severity of spinal claudication [25]. In this respect, a less strict exclusion procedure would also have been debatable.

There are even more debatable points about the various questionnaire scores which would be too numerous to discuss here in detail. Consequently, in this work, an attempt was made to shift the focus away from questionnaire-based procedures to standardized tests, recording of unambiguous parameters and examinations. The lower suitability of questionnaires for the detection of polyneuropathy is also reflected in nonsignificant correlations of the questionnaire part of the MNSI with electrophysiological examinations [22]. The LANSS score has apparently not been validated electrophysiologically at all to date.

Since the initial descriptions of the tests used in some cases did not define cutoffs for polyneuropathy, these were taken from other publications. Also, the performance of the clinical tests was often described in varying detail. In contrast to validity as measured by the gold standard of electrophysiological examinations and the intercorrelation between scores [22, 18], for the scores only sparse and vague information on test-retest reliability and inter-observer error of individual items can be found in the literature. Thus, it is crucial that a consistent and as close as possible to the original text way of performing the clinical tests is chosen and that no examiner change takes place in order to keep the possible inter-observer error small (as was the case in our study). This applies mutatis mutandis to several other items. For example, the application of the two-item discriminator between different users is not highly reliable but has high test-retest reliability for one single examiner [26]. Surprisingly, such data could not be found in the literature for the other tests used in clinical practice, although they are widely established.

For nearly absolute certain identification of polyneuropathy, only nerve conduction velocity measurement[27] can be considered. However, the high correlation of most applied scores with electrophysiological examinations makes this objection recede significantly. Also, the developed tool can be matched with electrophysiologic examinations in a follow-up study.

In this non-invasive diagnostic primary study, on the one hand with the aim of health care research and additionally the design of a time and cost favorable diagnostic tool, this could furthermore not be provided without a high research budget.

The null hypothesis that there is no difference between the control and study groups with regard to the proportion of polyneuropathy patients could be rejected. Thus, the alternative hypothesis that there is a difference in the proportion of polyneuropathy patients between the control and study groups could be affirmed. Since polyneuropathy is significantly more common in patients with spinal stenosis than in patients in whom spinal stenosis has been excluded, it cannot be ruled out, at least, that the two conditions may be mutually influential:

Polyneuropathy is significantly more common in patients with spinal stenosis than in patients without

lumbar spinal stenosis. Consequently, this cannot be a coincidence. What does it mean? There could be a causal relationship between the two conditions, i. e., lumbar stenosis could be the cause of PNP. This hypothesis was similarly put forward by Bostelmann et al. but there, too, the need for further clarification in future studies was pointed out [28].

Similarly, diabetes mellitus also promotes bony spurs on vertebral bodies in the sense of Forestier's disease [29]. Metaplasia due to reduced perfusion in the end-stream area of the small vessels supplying the vertebral bodies in the sense of a microangiopathy is suspected, i. e. a mechanism similar to that affecting neural structures in the development of diabetic polyneuropathy.

The physical activity of patients with spinal stenosis is often reduced, not only by painful reduction of their walking ability, but also by reduction of overall functional capacities [30]. However, lack of physical training often leads to high blood glucose levels and vice versa. It is possible that this makes blood glucose levels (fasting blood glucose and HbA1c) in patients an important concomitant indicator of both spinal stenosis and polyneuropathy.

Can polyneuropathy promote spinal stenosis? Quite conceivably: Polyneuropathic patients have poor proprioception and thus poorer coordination. This favors non-physiological movement amplitudes and incorrect loading with stress concentrations at the lumbar spine during locomotion. All these considerations suggest that there must be multicausal relationships between spinal stenosis and polyneuropathy, all of which have not yet been adequately demonstrated.

Conclusion and outlook

For the first time, clear evidence of a possible association between lumbar spinal stenosis and polyneuropathy was found in the present work with the included data.

However, the present work raises many even previously unsuspected questions. It should be seen as a basis for follow-up studies to investigate the comorbidity of (not only lumbar) spinal stenosis and polyneuropathy.

Further validation remains necessary, preferably using more "invasive" electrophysiological testing for polyneuropathy. Furthermore, if possible, prospective randomized studies should be performed to investigate the effect of anti-polyneuropathic treatment on polyneuropathic patients with concomitant spinal stenosis, e. g., whether these patients might require later surgery or even no surgery at all due to reduced deficits and symptoms. Also, on the basis of clearly identified comorbidities, prospective studies should try to determine whether surgical measures in the case of such polyneuropathic comorbidities show different results than without them.

The paper provides preliminary theoretical considerations, a current literature review, and statistical and other methodological guidance for conducting such studies in a structured manner.

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