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ORIGINAL ARTICLE

Improvement of sensory function after sequestrectomy for lumbar disc herniation: a prospective clinical study using quantitative sensory testing

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Abstract
Background Previous studies have investigated sensory recovery in patients with lumbar disc herniation using rather subjective methods. There have been no reports on changes of sensory function in patients suffering from a preoperative sensory deficit using quantitative sensory testing (QST). The aims of this prospective study were (1) to assess the recovery of preoperative sensory dysfunction after lumbar sequestrectomy and (2) to quantify the strength of relationship between a sensory deficit and the patient's quality of life.
Methods We applied the QST protocol of the German Research Network on Neuropathic Pain (DFNS) in fifty-two patients with a single lumbar disc herniation confirmed on MRI treated by lumbar sequestrectomy. Further evaluation included a detailed medical history, a physical examination, numeric rating scale for leg, EQ-5D questionnaire, and thermometer.
Results Disc surgery resulted in a significant reduction of leg pain and a significant gain of quality of life. Thermal, mechanical, and vibration perception thresholds showed an obvious side-to-side difference preoperatively ($p < 0.005$). An early recovery of mechanical and vibration perception thresholds was detected, whereas cold perception needed more than 6 months to recover ($p < 0.05$). Quality of life was independent from perception thresholds, but correlated significantly with pain reduction.
Conclusion Our data clearly show that there is a subjective and quantifiable improvement in sensory dysfunction postoperatively. The current data suggest that a sensory dysfunction does not influence a patient's quality of life.

Keywords Lumbar sequestrectomy · Quantitative sensory testing · Lumbar disc herniation · Lumbar radiculopathy · Sensory deficit

Introduction

Lumbar intervertebral disc herniations compressing a nerve root are the most common cause of sciatica which may be accompanied by sensory or motor dysfunction [1]. In the subpopulation of patients, refractory to conservative treatment lumbar sequestrectomy is performed [2]. Even though half of the patients show a remarkable improvement in sensory perception, in a third of patients sensory and motor dysfunction still remain after operation [3]. Accurate detection and quantification of the severity of a sensory disturbance have been imprecise. Quantitative sensory testing (QST) offers the possibility to investigate a patient's somatosensory profile accurately [4].

QST gained popularity in clinical practice and research, especially to evaluate the time course of recovery in

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sensory dysfunction and its different sensory modalities [5]. Previous trials investigated pain perception after surgical decompression in lumbar radiculopathy by QST, but did not detect changes in sensory function, assessed a minority of QST outcome parameters or had a short follow-up [6–9]. In addition, whether or not a sensory dysfunction influences the patient's quality of life is controversial [10].

To the best of our knowledge, there have been no reports on the development of sensory function investigated by QST in patients suffering from a preoperative sensory deficit caused by a lumbar disc herniation one year after the operation. Thus, the aims of this prospective study were (1) to assess the recovery of preoperative sensory dysfunction after lumbar sequestrectomy and (2) to quantify the strength of relationship between a sensory deficit and quality of life in patients with a sensory dysfunction.

Materials and methods

Subjects

>The study was purely observational, and there were no recommendations for additional diagnostic measures or interventions. Pain management was not delayed or altered by participation in this study. All subjects gave their informed consent. The study was approved by the Local Ethics Committee of the Medical University of Innsbruck in accordance with the ethical principles originating from the Declaration of Helsinki and in compliance with Good Clinical Practice. Consecutive patients were considered for inclusion if they had a single-level disc herniation confirmed on magnetic resonance imaging (MRI) and a sensory dysfunction in the corresponding nerve root distribution of L3 to S1. All patients had an indication for sequestrectomy according to the guidelines of the German Society of Neurosurgery (DGNC) and the German Society of Orthopedics and Orthopedic Surgery (DGOOC). All participants were on the best medical pain treatment, but sufficient pain relief was not achieved. No previous back surgery had been performed in any of the patients. None of the included patients had a history of peripheral nervous system disorders. Neither metabolic nor toxic damage of the peripheral nerves was revealed. Prospectively planned evaluation included a detailed medical history and a physical examination. Preoperatively, patients were asked by a single investigator to characterize their subjective sensory disturbance. The numeric rating scale (NRS) for leg at rest, the EQ-5D, and EQ-5D thermometer was used to assess outcome and quality-adjusted health status [11]. Preoperative MRI of the lumbar spine was performed in a standardized fashion on a 3.0-T MRI scanner (Siemens, Verio). All the data were recorded by the day before surgery, within 1 week, and 6 and 12 months after surgery.

Quantitative sensory testing (QST)

The QST was performed pre- and postoperatively by a single investigator. Bilateral evaluation of the test (TS) and control side (CS) was conducted. Patients were not distracted during the testing and were given clear and identical instructions. An infra-red thermometer was used to assess skin temperature before the testing. The thermal tests were performed using a Sensory Analyzer TSA-II (Medoc, Israel). Cold and warm detection thresholds were measured first (CDT, WDT), then cold pain and heat pain thresholds (CPT and HPT). The mechanical detection threshold (MDT) was measured with a standardized set of modified von Frey hairs (Somedic, Sweden) that exert forces upon bending between 0.25 and 512 mN. The vibration detection threshold (VDT) was performed with a Rydel–Seifer tuning fork (64 Hz, 8/8 scale). The mechanical pain threshold (MPT) was measured by a custom made pinprick set with forces from 8 to 512 mN. Mechanical pain sensitivity (MPS) was assessed using the same pinprick stimuli to obtain a stimulus response function for pinprick evoked pain. Subjects were asked to give a pain rating for each stimulus on a 0–10 numerical rating scale (NRS; "0" indicating "no pain" and "10" indicating the "most intense pain imaginable"). A pressure gauge device (FDK 20, Wagner Instruments, USA) was used to measure the pressure pain threshold (PPT) [12, 13].

Surgical procedures

Surgery was performed after the induction of general endotracheal anesthesia and with the assistance of an operating microscope (Pentero, Carl Zeiss Co.), while the patient was in a prone position, by two surgeons in a standardized manner. The spinal canal harboring the sequestrated disc material was exposed by performing a minimal interlaminar fenestration in the cases of non-dislocated or caudally herniated discs. In the cases of cranially herniated discs, a translaminar approach was undertaken. Based on the results of previous trials, only the herniated material was removed and the herniated space was not entered if at all possible [14]. Intraoperative problems, such as surgery-related complications and postoperative complications, such as re-operations, recurrent disc herniations, infection, or bleeding, were recorded and these patients were excluded from further analyses.

Statistical analysis

Data generation at the study site was clearly separated from data storage, processing, and statistical analysis at the Department of Medical Statistics, Informatics, and Health Economics. The analyses followed the intention-to-treat principle. All patients with a complete examination were considered for inclusion into the intention-to-treat population. In this study with 39 patients, the power calculation was over 90 % on a two-sided level of significancy of 0.05. All values were expressed as mean ± SD. Kendall-Tau-b correlation was performed to assess the relation of quality of life on pain and QST variables. The Kolmogorov–Smirnov test was used for testing normal distribution. The unpaired Student's *t* test, Mann–Whitney *U* test, and Fisher's exact test were used to analyze differences in clinical and demographic characteristics and in clinical outcome variables. A p value <0.05 was considered statistically significant. All statistical evaluations were performed with SPSS Version 21.0 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0, NY: IBM Corp.). Figures were designed using GraphPad Prism (version 5.0 for Mac OS X, GraphPad Software, La Jolla California USA, www.graphpad.com).

Table 1 Demographic and clinical characteristics of 52 patients with a preoperative sensory deficit

Demographic characteristics	
Mean age, years (SD)	44.3 ± 10
Mean BMI (SD)	26.8 ± 3
Smoking, *n* (%)	29/52 (55.8)
Cigarettes per day (SD)	7.5 ± 9
Alcohol	
None, *n* (%)	13/52 (25)
Weekly, *n* (%)	2/52 (3.8)
Incidentally, *n* (%)	37/52 (71.2)
ASA score	
1, *n* (%)	31/52 (59.6)
2, *n* (%)	21/52 (40.4)
Physical activity	
None, *n* (%)	14/52 (26.9)
Daily, *n* (%)	15/52 (28.8)
Weekly, *n* (%)	11/52 (21.2)
Incidentally, *n* (%)	12/52 (23.1)
Mean duration of sensory deficit in days (SD)	126 ± 326
Dermatome	
L3, *n* (%)	4/52 (7.7)
L4, *n* (%)	5/52 (9.6)
L5, *n* (%)	20/52 (38.5)
S1, *n* (%)	23/52 (44.2)

ASA score American Society of Aesthesiology score, *BMI* body mass index, *n* number of patients, *SD* standard deviation

Results

The demographic details and preoperative characteristics of 52 included patients are presented in Table 1. The loss to postoperative 6 months follow-up was 15.2 % and to 12 months follow-up was 24.7 %. A recurrent disc herniation was the major cause for exclusion (17.1 %). The most commonly affected nerve root was S1. The mean duration of a sensory deficit was 126 days. The characteristics of sensory dysfunction and the subjective postoperative recovery are shown in Fig. 1.

The results of QST thresholds are presented in Figs. 2, 3, and Table 2. Thermal, mechanical, and vibration perception threshold showed an obvious side-to-side difference preoperatively: CDT 24.4 °C (±5) vs. 27.3 °C (±2), WDT 41.8 °C (±4) vs. 39.9 °C (±4), MDT 16.5 mN

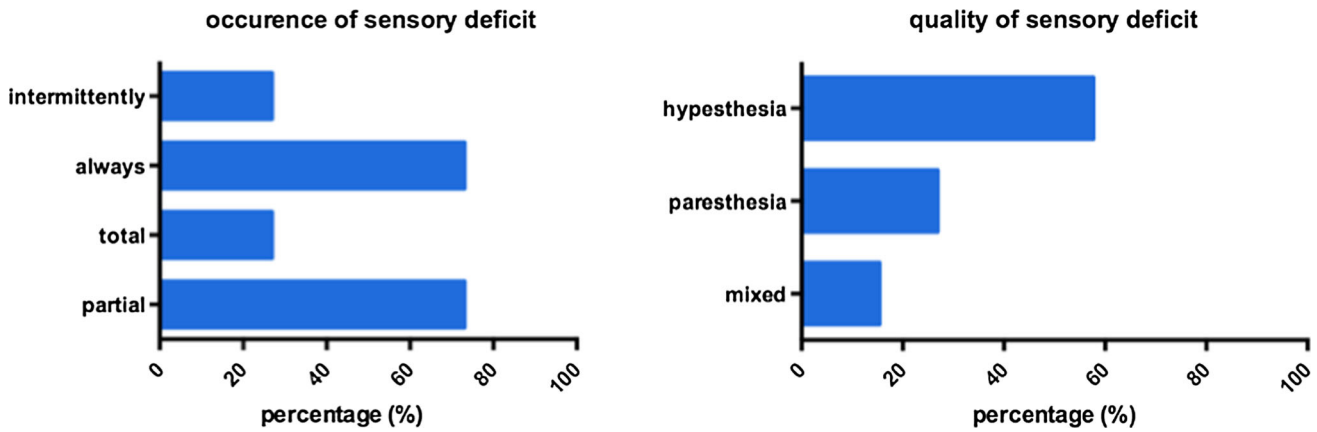

Fig. 1 Preoperative characteristics of sensory dysfunction. Most of the patients suffered from a permanent and partial sensory deficit. Hypesthesia was the most common type of sensory disturbance

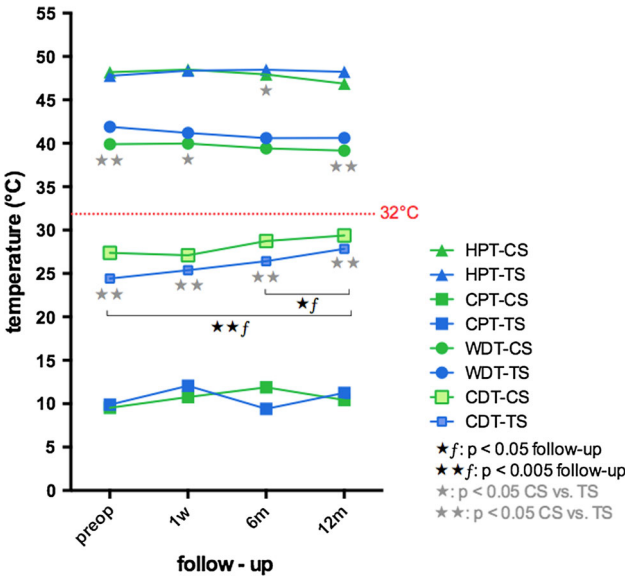

Fig. 2 Pre- and postoperative differences in vibration perception, mechanical perception, and pain thresholds. Data are presented as mean. *CS* controlside, *TS* test side, *p* significant difference between sides, *pf* significant difference between follow-up, *1w* 1 week, *6 m* 6 months, *12 m* 12 months

(±18) vs. 5.2 mN (±8), and VDT 5.5 Hz (±3) vs. 6.6 Hz (±1), respectively ($p < 0.005$). No difference was detected in pain perception thresholds, except PPT, 6.7 kg/cm2 (±2) vs. 7.7 kg/cm2 (±2) ($p < 0.005$). Skin temperature was lower on the affected side, 31.2 °C (±2) vs. 31.9 °C (±2) ($p < 0.005$).

MDT and VDT reached significant differences at 1 week follow-up: MDT preoperatively 16.5 mN (±18) vs. MDT postoperatively 11.1 mN (±15) and VDT preoperatively 5.5 Hz (±2) vs. VDT postoperatively 6.0 Hz (±1), respectively ($p < 0.005$). CDT differed significantly from baseline at 6 months postoperatively: 24.4 °C (±4) vs. 26.4 °C (±3) ($p < 0.05$). CDT [24.4 °C (±5) vs. 27.8 °C (±2)], MDT [16.5 mN (±18) vs. 9.2 mN (± 22)], VDT [5.5 Hz (±2) vs. 6.6 Hz (±1)], and PPT [6.7 kg/cm^2 (±2) vs. 8.1 kg/cm^2 (±2)] improved from baseline to 12 month follow-up ($p < 0.005$). Side difference remains. MPS differed 12 months postoperatively: 1.5 (±2) vs. 2.4 (±2).

EQ-5D index showed a remarkable increase in the quality of life 12 months after lumbar sequestrectomy: 0.83(±0) vs. 0.9 (±0) ($p < 0.005$). The improvements in EQ-5D thermometer and NRS for leg are presented in Fig. 4. There was a correlation between EQ-5D and pain

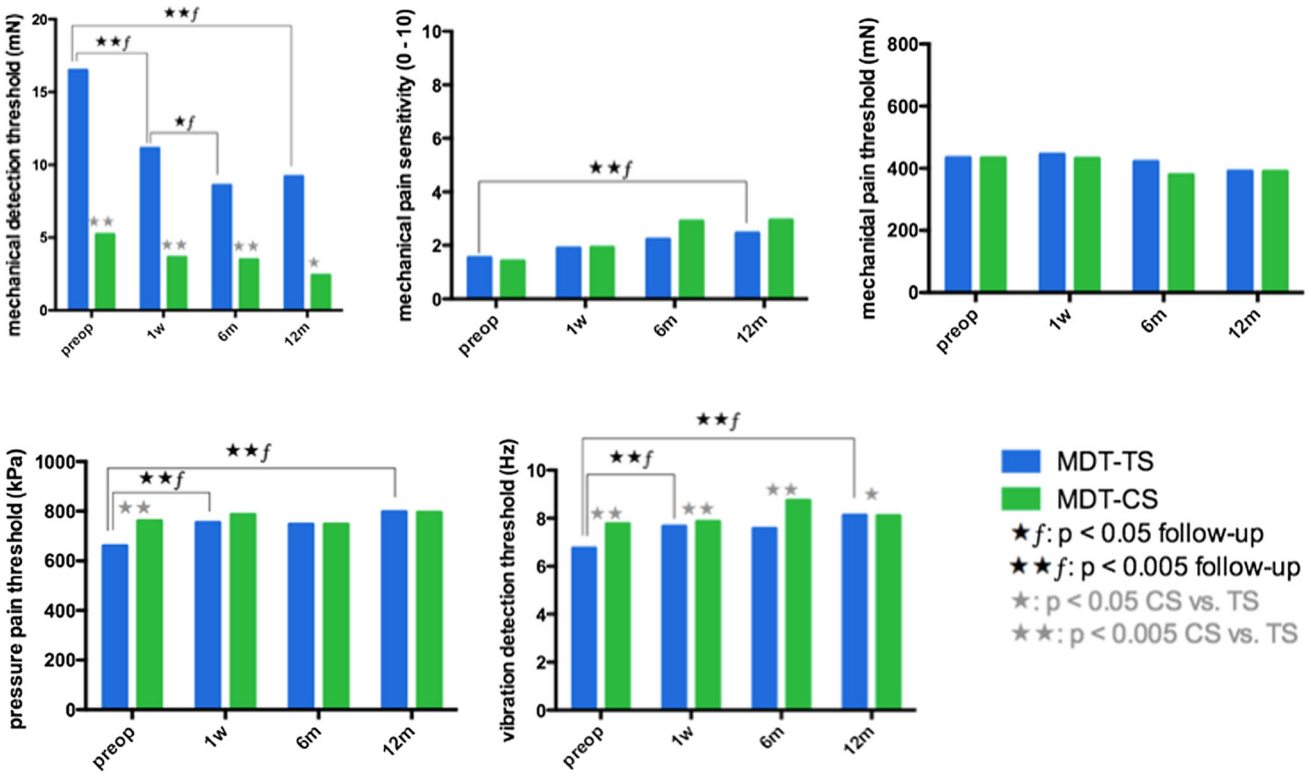

Fig. 3 Pre- and postoperative differences in thermal perception and pain thresholds. *CDT* cold detection threshold, *CPT* cold pain threshold, *HPT* heat pain threshold, *p* significant difference between sides, *pf* significant difference between follow-up, *WDT* warm detection threshold, *1w* 1 week, *6 m* 6 months, *12 m* 12 months

Table 2 Pre- and postoperative differences in thermal and mechanical perception thresholds

	Preop ($n = 52$)			Preop–1w pf	1w ($n = 52$)			1w–6m pf	6m ($n = 44$)			6–12m pf	12m ($n = 39$)			Preop-12m pf
	TS	CS	p		TS	CS	p		TS	CS	p		TS	CS	p	
CDT (°C)	24.4 ± 5	27.3 ± 2	**	NS	25.3 ± 5	27.1 ± 2	**	NS	26.4 ± 3	28.7 ± 2	**	*	27.8 ± 2	29.3 ± 1	**	**
WDT (°C)	41.8 ± 4	39.9 ± 4	**	NS	41.2 ± 4	39.9 ± 3	*	NS	40.6 ± 4	39.4 ± 3	NS	NS	40.6 ± 3	39.1 ± 3	**	NS
CPT (°C)	9.8 ± 9	9.5 ± 8	NS	NS	12.0 ± 9	10.7 ± 9	NS	NS	9.4 ± 9	11.8 ± 9	NS	NS	11.2 ± 9	10.4 ± 9	NS	NS
HPT (°C)	47.7 ± 5	48.2 ± 2	NS	NS	48.3 ± 2	48.4 ± 1	NS	NS	48.4 ± 2	47.9 ± 2	*	NS	48.2 ± 2	46.8 ± 7	NS	NS
MDT (mN)	16.5 ± 18	5.2 ± 8	**	**	11.1 ± 15	3.6 ± 5	**	*	8.5 ± 18	3.4 ± 6	**	NS	9.2 ± 22	2.4 ± 3	*	**
MPT (mN)	433.9 ± 150	433.2 ± 143	NS	NS	444.9 ± 136	431.3 ± 46	NS	NS	421.8 ± 136	378.9 ± 146	NS	NS	390.5 ± 152	389.7 ± 164	NS	NS
MPS	1.5 ± 2	1.4 ± 1	NS	NS	1.9 ± 2	1.9 ± 2	NS	NS	2.2 ± 2	2.9 ± 2	NS	NS	2.4 ± 2	2.9 ± 2	NS	**
VDT (Hz)	5.5 ± 2	6.6 ± 1	**	**	6.0 ± 1	6.6 ± 1	**	NS	6.4 ± 1	7.1 ± 0.9	**	NS	6.6 ± 1	7.1 ± 1	*	**
PPT (kPa)	660.5 ± 279	761.6 ± 225	**	**	754.92 ± 219	786.4 ± 216	NS	NS	746.8 ± 216	746.8 ± 212	NS	NS	797.3 ± 203	794.3 ± 196	NS	**

QST data are presented as mean ± SD

CDT cold detection threshold, *CPT* cold pain threshold, *CT* control side, *HPT* heat pain threshold, *MDT* mechanical detection threshold, *MPT* mechanical pain threshold, *MPS* mechanical pain sensitivity, *NS* not significant, *p* significant difference between sides, *pf* significant difference between follow-up, *PPT* pressure pain threshold, *TS* test side, *VDT* vibration detection threshold, *WDT* warm detection threshold, *1w* 1 week, *6 m* 6 months, *12 m* 12 months

* $p < 0.05$, ** $p < 0.005$

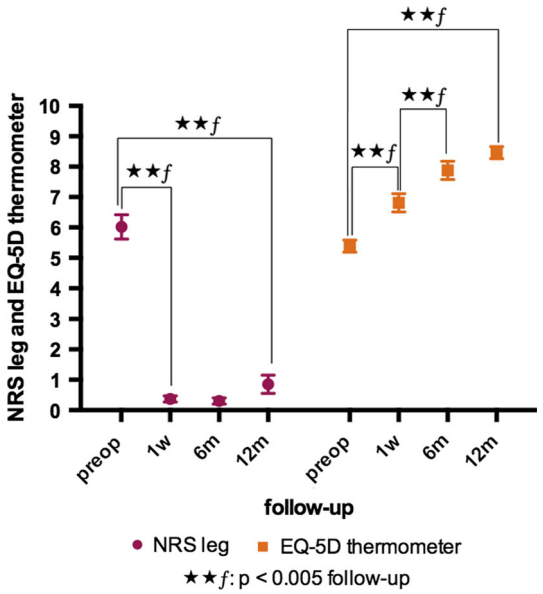

Fig. 4 Improvement in EQ-5D thermometer and NRS for leg. *pf* significant difference between follow-up, *1w* 1 week, *6 m* 6 months, *12 m* 12 months

pre- and postoperatively ($p < 0.05$), but the quality of life was independent of perception thresholds ($p > 0.05$).

Discussion

The authors present the results of the first prospective clinical trial investigating the recovery of sensory dysfunction caused by a lumbar disc herniation using QST. Disc surgery resulted in a significant reduction of leg pain and a significant gain in the quality of life. Thermal, mechanical, and vibration perception thresholds showed an obvious side-to-side difference preoperatively. While mechanical and vibration perception thresholds recovered early, cold perception needed more than 6 months to recover. The quality of life was independent from perception thresholds, but correlated significantly with pain reduction.

Mechanical, vibration, and cold perception thresholds reflect the myelinated A-fibers, whereas pain and warm detection thresholds reflect the unmyelinated C fibers [12]. Our findings correlate with a previous trial, which reported an early postoperative improvement of A-fiber function [9]. Further investigations showed that unmyelinated C fibers in the dermatome of the compressed and the adjacent root did not recover within 12 months following surgery [8, 9]. Whereas immediate pain release was observed in all patients of our study, C-fiber function did not recover early after sequestrectomy. Our data, therefore, suggest that immediate pain release after lumbar sequestrectomy is not associated with an improvement in pain perception values.

To date, the improvement of sensory function after lumbar spine surgery is discussed controversially. Experimental trials reported on the early and late recoveries of sensory function depending on the type of neuronal fibers [9], while clinical studies found an early regeneration of sensation after lumbar decompression [3, 15]. However, these discrepancies might be explained by the different methods and subjective tests used to quantify sensory function. QST allows a selective stimulation of nerve fibers in a standardized and established manner [13].

Overall, the improvement of pain and sensory function after lumbar spine surgery may be associated with various factors, such as the severity of preoperative leg pain [16] or gender [17]. Pain perception thresholds, for example, seem to be lower in women than in men [17]. The outcome after surgery may also be influenced by the surgical technique itself. Sequestrectomy as the standard technique used in this trial, previously demonstrated superior satisfactory rates and lower recurrent back pain compared with microdiscectomy in the short as well as long-term outcome [14, 18].

Skin temperature changes continuously according to blood circulation. It can be easily detected using an infrared thermometer. Many patients with lumbar disc herniation describe cold lower extremities. This phenomenon is probably due to the dysfunction of sympathetic fibers that regulate skin temperature by the vasoconstriction of skin vessels [19]. Experimental investigations could show side differences in skin temperature between the affected and contralateral extremity in patients with lumbar disc herniation. Some authors suggested that muscle atrophy in the lower limb might be the major cause [19, 20].

A limitation of our findings was the high loss to follow-up. Missing data were an important limitation in interpreting our study results. Furthermore, we did not include a control group and we preferred to use the symmetric healthy dermatome in the same patient as a reference value instead. In adherence to the guidelines of DGNC and DGOOC, surgery was preceded by at least 3 months of conservative treatment. Maybe earlier surgery with shorter duration of symptoms would have elucidated a better recovery.

In conclusion, our data demonstrate that there is an improvement in sensory dysfunction postoperatively. Our data suggest that a sensory disturbance does not seem to influence a patient́s quality of life. Therefore, based on the guidelines of DGNC and DGOOC, the authors do not recommend a lumbar sequestrectomy in patients suffering only from a sensory deficit without pain considering the potential intra- and postoperative complications, a patient may gain. Which predictive factors influence the improvement of sensory function is still an open question and requires further research.

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Compliance with ethical standards

Conflict of interest None of the authors has any conflict of interest in connection with the study.

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