L. Samuelsson
A. Lundin

Thermal quantitative sensory testing in lumbar disc herniation

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L. Samuelsson (✉) · A. Lundin
Department of Orthopaedics,
Örebro Medical Center Hospital,
70185 Örebro, Sweden
e-mail: lars.samuelsson@orebroll.se,
Tel.: +46-19-6025300,
Fax: +46-19-187201

Abstract The most frequent clinical presentation of sciatica suggests injury of sensor root fibers alone. To evaluate whether thermal quantitative sensory testing (QST) is applicable in the study of sensory dysfunction in lumbosacral disc herniations, 36 men and 30 women with L4/5 or L5/S1 disc herniations underwent thermal QST of the L4, L5, and S1 dermatomes. For both levels of disc herniation, there was a significant difference for all temperature modalities, i.e., cold, warmth and heat pain, between all dermatomes as well as between the side of the herniated disc and the corresponding asymptomatic side. However, the proportion of herniated discs classified correctly was only 48% in pa-

tients with disc herniations at the L4/5 level, while it was 71% at the L5/S1 level. We conclude that thermal QST measurements reflect and document sensory dysfunction in patients with lumbosacral disc herniation. The method offers a new means both to study the time course of a spontaneous recovery of sensory dysfunction and to evaluate the result of different treatment options. However, thermal QST seems to have the same poor predictive value for identifying the anatomic location of a herniated lumbar disc as conventional electrophysiologic methods.

Keywords Disc herniation · Nerve root · Dermatome · Quantitative sensory testing · Thermal threshold

Introduction

The most frequent clinical presentation of sciatica suggests injury of sensory root fibers alone. Pain in the absence of clinical signs is common and sensory symptoms and signs may often occur in isolation or earlier than motor deficit [6]. Clinical symptoms and radiologic results may be conflicting or inconclusive and warrant complementary electrophysiologic investigations for diagnostic and therapeutic decisions. Usually the neurophysiologic evaluation includes electromyography (EMG), motor conduction studies, and F-wave and H-response studies, which all involve motor nerve function [5, 6, 13, 18, 25]. Novel techniques in electrodiagnostic testing to quantify sensory dysfunction have evolved, but they have limitations [1, 6, 9, 17, 23, 24]. Thermal quantitative sensory

testing (QST) offers the possibility of evaluating the function of thinly myelinated A- δ nerve fibers conducting cold sensation and unmyelinated C-fibers conducting warmth and heat-pain sensation [7, 26]. Thermal QST has mostly been used in the assessment of metabolic and traumatic neuropathies, but the technique should also be applicable in the study of sensory dysfunction in disc herniations [12, 21]. To our knowledge, this method has only been used once before, but the results of this study are difficult to interpret [19]. As part of a pharmacological intervention study in patients with lumbosacral disc herniations, we obtained preoperative values for thermal thresholds of involved dermatomes, using Thermotest (Somedic AB, Stockholm, Sweden). Our aims were to document preoperative thermal sensory dysfunction and to study the predictive value of thermal thresholds with respect to the anatomic location of the lesion.

Materials and methods

Eighty consecutive patients with lumbosacral radiculopathy caused by disc herniation and referred to the Department of Orthopaedics, Örebro Medical Center Hospital, were included in the study. Due to thermode failure, ten patients could not be examined before operation and one patient refused to participate. Thus, the study group finally consisted of 36 men and 33 women. Their mean age was 41 years (range 26–59 years), with a mean duration of sciatica of 4.5 months (range 0–12 months). No previous back surgery had been performed in any of the patients. The diagnostic criterion of nerve root compression was pain distribution below the knee corresponding to the L3/4, L4/5, or L5/S1 lumbar nerve roots with or without clinical sensory or motor signs or symptoms. Lasègue's sign was positive in 91% of patients. The diagnosis of a single-level disc herniation had been performed by magnetic resonance imaging (MRI), and was later confirmed at surgery for the herniated disc. There were no lateral disc herniations and only one nerve root was affected in all patients. The location of the herniated disc was at L3/4 in 3 patients, at L4/5 in 23 patients and at L5/S1 in 43 patients. The three patients with L3/4 disc herniations were not included in the study.

Quantitative sensory testing

QST was performed for temperature and pain by determining perception thresholds for cold, warmth, and heat pain with a modified Marstock thermo-stimulator operating on the Peltier principle (Thermotest, Somedic AB, Stockholm, Sweden). The thermode, with a rectangular surface of 2.5×5 cm, can be heated or cooled at a rate of 1–2°C/s, with the stimulating temperature continuously measured by a thermocouple and recorded on a computer (Sense-lab version 2.21). When the stimulator is applied in good contact with the skin, patients are asked to press a switch as soon as they perceive the sensation of cold, warmth, and heat pain. The patient was introduced to the test technique by a trial test on the abdominal skin. Thermal thresholds were determined from the L4 and the L5 dermatomes half way between the knee joint and the ankle joint on the lower leg, and from the S1 dermatome on the dorsolateral aspect of the foot. The perception thresholds were calculated as the mean value of at least three consecutive registrations. Thermal

stimulation was given at random intervals (the pulse method), and a baseline adapting temperature of 32°C was used in all tests. The outer temperature limits were set at 10°C for cold and 50°C for heat, to avoid tissue damage. The registration from the same location on the contralateral nonaffected lower leg and foot was used as a control. All examinations were performed by the same person (A.L.) in a quiet room at 23°C the day before the operation of the herniated disc. As the perception and registration of the thermal thresholds are entirely dependent on the patient, the person performing QST was not blinded to the clinical information or MRI results.

Statistical analysis

For each level of intervertebral disc herniation (L4/5, L5/S1) the temperature thresholds for cold, warmth, and heat pain perception were analyzed with a three-way analysis of variance with the factors dermatome (L4, L5, S1), level of herniated intervertebral disc (L4/5, L5/S1), and status (side of herniated disc, asymptomatic side) and patient, where the latter was considered as a random factor, the others as fixed. A nerve root injury caused by a herniated intervertebral disc would, in this model, impact on the two-factor interaction between dermatome and status. All temperature threshold measurements were transformed to log values by the transformation $\ln(x - 32)$ before the statistical analysis, owing to data skewness. The value 32 represents the baseline skin temperature, and x the thermal detection threshold. To test the nerve root position factors representing the L4, L5, and S1 dermatomes, the Tukey test was used. The ability to predict the location of a herniated disc was studied by discriminant analysis, using all temperature thresholds.

Results

The results of the thermal threshold measurements are presented in Table 1 and Table 2 and in Fig. 1 and Fig. 2. The three-way analysis of variance showed that, for both levels of disc herniation (L4/5 and L5/S1), there was a

Table 1 Thermal perception thresholds in 23 patients with L4/5 disc herniation (in degrees centigrade)

Dermatome	Cold				Warmth				Heat Pain			
	Asymptomatic		Symptomatic		Asymptomatic		Symptomatic		Asymptomatic		Symptomatic	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
L4	31.0	1.91	29.7	1.48	35.5	1.25	36.0	1.69	40.9	3.5	41.6	3.6
L5	30.1	1.4	29.6	1.7	37.8	3.2	38.5	2.9	42.2	3.6	43.1	3.2
S1	29.3	1.5	28.6	2.1	37.0	2.5	37.5	2.7	41.6	3.3	42.8	3.4

Table 2 Thermal perception thresholds in 43 patients with L5/S1 disc herniation (in degrees centigrade)

Dermatome	Cold				Warmth				Heat Pain			
	Asymptomatic		Symptomatic		Asymptomatic		Symptomatic		Asymptomatic		Symptomatic	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
L4	30.1	0.9	29.5	1.3	36.3	2.0	37.2	2.5	41.8	3.0	42.4	3.2
L5	29.9	1.0	29.1	3.3	37.5	2.4	38.4	3.3	42.0	2.8	43.2	3.1
S1	29.2	1.8	27.7	3.6	37.4	2.7	37.9	2.6	42.3	2.5	43.0	2.8

A

A

B

B

C

C

Fig. 1A–C L4/5 disc herniations. Interaction plot between means for logarithmic values of thermal detection thresholds and dermatomes (L4, L5, S1) of the asymptomatic leg (1) and the sciatic leg (2). **A** Cold detection thresholds (lnCDT), **B** warmth detection thresholds (lnWDT), and **C** heat pain detection thresholds (lnHPDT)

Fig. 2A–C L5/S1 disc herniations. Interaction plot between means for logarithmic values of thermal detection thresholds and dermatomes (L4, L5, S1) of the asymptomatic leg (1) and the sciatic leg (2). **A** Cold detection thresholds (lnCDT), **B** warmth detection thresholds (lnWDT), and **C** heat pain detection thresholds (lnHPDT)

significant difference for all temperature modalities, i.e., cold, warmth and heat pain, between all dermatomes as well as between the side of the herniated disc and the corresponding asymptomatic side. The greatest *P*-value was 0.017, and no significant interaction was found.

The Tukey test showed that, for both levels of disc herniation, the threshold for cold was significantly different between the L4 and S1 dermatomes as well as the L5 and S1 dermatomes, and the threshold for warmth was significantly different between the L4 and L5 dermatomes as well as the L4 and S1 dermatomes. However, the threshold for heat pain was significantly different between the L4 and S1 dermatomes, but also for disc herniations at the L4/5 nerve root between the L4 and L5 dermatomes. All significances were at the 1% level, except for the heat pain threshold for L5/S1 disc herniations, where it was at the 5% level. The discriminant analysis showed that the proportion of herniated discs classified correctly was 48% in patients with disc herniations at the L4/5 level and 71% at the L5/S1 level.

Discussion

Our main finding was that there was a significant difference in thermal thresholds between all dermatomes representing different nerve root levels as well as between the side of the herniated disc and the corresponding asymptomatic side. This result shows that thermal QST reflects sensory dysfunction in patients with disc herniation, which is not consistent with the recent report by Nygaard and Mellgren [19]. In their study of the function of sensory nerve root fibers in lumbar L4/5 and L5/S1 radiculopathy, they did not find any significant difference for any thermal threshold between the dermatome of the compressed nerve roots and the ipsilateral or contralateral neighboring dermatomes in the feet. Furthermore, comparing their patients to a matched control group, they only found significant differences between the cold detection thresholds. For warmth and heat pain there were no significant differences except for the warmth threshold in the dermatome of the compressed nerve root. We used the unaffected contralateral side as a control, and were careful to standardize the testing procedure, as data on thermal thresholds in healthy control subjects are limited, and comparisons with previously published data may be hampered by possible differences in the testing procedure and the type of patients tested. The lack of significant threshold differences may in part be explained by sample size, the thermode size, and the anatomic location of the measurements. A small thermode covers fewer temperature receptors, which also may differ in number and distribution in the foot compared to the leg. Chronic pain may also affect thermal thresholds by central modulation [10, 22]; as the mean duration of sciatic pain in their study was 17 months compared to 4 months in our patients, this may account for the discrepancy in results [8, 11]. Finally, root

compression may also vary in different cases, and the state of reinnervation differs [2, 27], which may contribute to inconclusive or contradictory findings.

Our finding that all thermal thresholds recorded from the dermatomes supplied by the L3/4 and L5/S1 nerve roots differed significantly for both levels of disc herniation probably reflects the distance of the pathway from the different nerve roots to the central nervous system. The lack of significant threshold differences between some neighboring dermatomes is probably due to their multi-segmental innervation or to anomalous innervation patterns, which are reported to occur in 14% of the population [16, 17].

According to Olmarker, pain in sciatica is associated with both mechanical compression of the nerve root as well as inflammatory mediators released from the injured disc [20]. The suggestion by Nygaard and Mellgren [19] that their findings may reflect a generalized effect of inflammatory mediators released from the disc and affecting neighboring dermatomes as well can not be excluded. However, the change in thermal thresholds representing the L3/4, L4/5, and L5/S1 nerve roots in our study was not related to their distance from the herniated disc, and we therefore believe that the nerve root level, the multisegmental innervation of the dermatomes, and the side of the herniated disc are the most important factors for the threshold differences.

The discriminant analysis confirms the poor localizing value of sensory threshold tests as regards herniated discs [3, 4, 6, 15]. Similar findings were also reported by Weise et al. [27] – the side of disc herniation being identified in 90% of patients, but the correct spinal level only in 50% – and also by Jensen [14], who found involvement of the ipsilateral neighboring dermatomes in 50% of patients.

Longitudinal clinical studies validating test results as related to clinical status, imaging studies and operative findings are sparse [2], and there are also many questions related to the predictive value of a particular test [5, 19, 24]. However, in patients with incomplete correspondence between imaging and clinical findings, the diagnostic capacity to identify spinal root lesions is enhanced if a number of tests are used [23, 25].

Conclusion

The value of conventional electrophysiological examinations for the localization of herniated lumbar discs as a complement to the clinical sensory examination and various imaging techniques has not been promising. Thermal QST seem to have a similarly poor predictive value for identifying the anatomic location of a herniated lumbar disc. However, thermal QST is a useful method for documenting sensory dysfunction in patients with disc herniation, in our opinion. Thermal QST also offers a new means of studying both the time course of a spontaneous recovery of sensory function and the evaluation of treat-

ments, including their effect on both the inflammatory and the mechanical component of a herniated disc. Further studies, which are in progress, will show whether preoperative sensory dysfunction quantified by thermal QST may serve as a predictor of outcome of different treatment options of a herniated lumbar disc.

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