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CHAPTER 2

MEASUREMENT OF HEAT FLUX DENSITY AS A NEW METHOD OF DIAGNOSING NEUROLOGICAL DISORDERS IN DEGENERATIVE-DYSTROPHIC DISEASES OF THE SPINE

ABSTRACT

Osteochondrosis of the lumbar spine and its neurological manifestations is one of the most common diseases, which leads to impaired working capacity and disability of people mainly at a young age. The issue of tactics for choosing a treatment method (conservative or surgical) remains debatable.

The chapter presents the results of the development of a thermoelectric device for diagnosing inflammatory processes and pain syndrome in degenerative-dystrophic diseases of the Lumboischialgia. Such a device makes it possible to save, process and visualize measurement results on the display of the device and on a personal computer in real time.

It was established that moderate indicators of temperature and heat flux density (HFD) in the paravertebral zone were recorded in the control group. In patients with lumboschialgia without signs of instability, there was a parallel fluctuation of temperature and HFD on the side of pain and low values on the intact side. In the case of lumboischialgia against the background of vertebral instability, the symptom of "scissors" on the side of pain and an increase in both thermal indicators on the intact side were positive.

With stenosis of the spinal canal, temperature and HFD decreased on both sides, but more intensively on the side of pain.

The results of clinical studies of thermometric indicators in the lumbosacral region of the spine in persons with chronic pain syndrome against the background of degenerative-dystrophic pathology of the spine in the presence of hernias and protrusions of intervertebral discs are also presented.

The effectiveness of the proposed thermoelectric device in medical practice has been confirmed.

KEYWORDS

Heat flux density, temperature, thermometric indicators, inflammatory processes of the human body, osteochondrosis of the spine, thermoelectric device.

Degenerative-dystrophic changes in the spine are one of the most common pathologies of the musculoskeletal system. Such changes can be of different nature: it can be osteochondrosis, spondyloarthrosis, spondylosis, etc.

According to statistical studies, more than 80 % of the world's population in one way or another face pathological changes in the spine. The situation is aggravated by the modern way of life: poor ecology, sedentary lifestyle, bad habits, improper nutrition, chronic stress [1].

Since practicing doctors in their activities most often face with osteochondrosis of the spine and its neurological manifestations, we found it necessary to pay more attention to this problem.

Osteochondrosis of the spine and its neurological manifestations are one of the urgent problems of modern medicine. This is due to the widespread prevalence of the pathology in the active working age, the frequent tendency of the disease to a persistent, protracted course of the process with frequent relapses; relentless progression of the number of such patients with age. A prominent place in this series is occupied by neurological manifestations of osteochondrosis of the lumbar spine, which make up 60–70 % of all diseases of the peripheral nervous system and are the cause of more than 70 % of cases of temporary disability. The prevalence of this pathology in Ukraine, according to statistical data of the current pre-war period, is currently 10,044.7 per 100,000 population. Among able-bodied persons, these indicators are the highest in Dnipropetrovsk (11,560.6) and Volyn (11,440.3) regions [1]. And although the fact that osteochondrosis of the spine is a multifactorial, multimorphic disease is undeniable, many aspects of the pathogenesis and clinical manifestations of this pathology have not been studied until now.

We found [2] that determining the pathophysiological mechanisms of back pain based on of clinical and paraclinical methods of examination of the patient is the main step towards prescribing the most effective and safe therapy and predicting the course of the disease. The most common cause of lower back pain is a herniated disc – a disease of the musculoskeletal system that occurs as a result of the rupture of the fibrous ring of the intervertebral disc (the upper shell of the disc) and the pushing out of the part of the annulus pulposus (the inner part of the disc). The main clinical neurological signs of intervertebral disc herniation can be manifested separately or in combination with the following syndromes: local pain (lumbargia), reflected pain (lumboischialgia), radicular syndrome (radiculopathy), spinal cord injury syndrome (myelopathy).

When examining patients, first of all, it is necessary to exclude serious pathology that requires immediate special medical interventions (spine fracture, tumour, infection, diseases of internal organs and other) [3]. After the survey, the patient is examined, which includes the following tests [2]:

1) examination of the patient (walking problems, antalgic postures, symmetry of body parts);

2) palpation (pain in the back, especially in the places where the pain is localized, pain in the Valleix and Gara points);

3) examination of the degree of paravertebral muscle tension (muscle-tonic syndrome);

4) examination of the mobility of the lower back (static-dynamic disorders);

5) examination of skin sensitivity (if there is a violation, determine by which type – central, segmental or non-aural);

6) assessment of muscle strength in the limbs (if there is a violation – determine in which group of muscles, to which myotome belongs);

7) assessment of tendon reflexes (live, increased, decreased, prolapsed);

8) assessment of nerve root tension symptoms (Neri, Lasegue, Dejerine, Wasserman, Sicard, Seletsky, Mackevich, Turin);

9) assessment of vasomotor, trophic and secretory symptoms.

In clinical practice, the investigation of the symptoms of tension of the roots of the lumbar spine, most of which are based on reflex myofixation of the affected motor segment of the spine due to irritation of the receptors of its deformed tissues, is carried out with the help of such symptoms as Neri, Lhermitte, Lasegue and others [4]. A thorough clinical examination allows the practitioner to choose the further tactics of treating the patient – conservative treatment or directing him to surgical treatment.

Since in our clinical practice we most often examine patients who are referred for surgical treatment, we consider it appropriate to highlight the features of neurological disorders in this category of patients.

2.1 SOME FEATURES OF NEUROLOGICAL DISORDERS IN PATIENTS WITH DEGENERATIVE-DYSTROPHIC SPINE PATHOLOGY WHO UNDERWENT SURGICAL TREATMENT OF THIS PATHOLOGY

With long-term pain syndrome, the presence of symptoms of "falling out" in clinical practice, surgical methods of treating herniations between the vertebral discs in the lumbar spine are quite often used. There are a number of modern methods of treatment of such pathology.

Microdiscectomy is a minimally invasive operation during which a herniated disc is removed through a small incision on the back.

The word "micro" is used in connection with performing an operation under an operating microscope with special microsurgical instruments. This technology has come a long way in its development, starting with the technique proposed by the American orthopedist and neurosurgeon William J. Mixter and Joseph S. Barr in 1934 [5]. In those days, removal of hernias was carried out by a wide laminectomy, possibly even transdurally. With the introduction of microsurgical technology, this operation has become truly minimally invasive. As a standard, resection of part of the arch (most often the lower edge of the upper arch) is used during the operation, sometimes resection of the medial part of the intervertebral joint is performed in the case of paramedian or mediolateral disc herniation. The use of microsurgical equipment with a magnification of 6–8–10 times allows you to clearly visualize the nerve root, hernia, and, if necessary, perform coagulation of the epidural veins [6].

One of the ways to prevent the development of postoperative fibrosis is the intraoperative use of special gels. The works of domestic and foreign authors [6] indicate the promising development of this direction, but note that the problem is far from a final solution [6, 7].

Methods of surgical treatment of hernias between the vertebral discs of the lumbar spine are progressively changing each other. And although the "gold standard" of surgical treatment of hernias between the vertebral discs is open microdiscectomy, recently numerous techniques have appeared, the authors of which seek to minimize the trauma of the surgical approach without reducing the radicality of the operation.

With the advent of surgical endoscopes, an opinion was constantly being expressed that the magnification obtained with the use of a microscope could be used for the microendoscopic technique. The advantage of the microendoscopic technique was even greater minimization of access. However, endoscopic technique requires specific tools, specific work skills and increases the duration of surgical intervention [8].

The technique of microendoscopic discectomy was described by Kevin T. Foley and Maurice M. Smith in 1997 [9]. The technique combines the principles of standard microdiscectomy with the use of endoscopic imaging. Indications for microendoscopic discectomy are the same as for microdiscectomy. Modern microendoscopic discectomy is a highly effective method of treating herniated intervertebral discs of the lumbar spine. This method should be used in case of paramedian, mediolateral hernias of the intervertebral discs.

The technique is positioned as less traumatic for soft tissues, which allows for faster occupational rehabilitation of patients. According to the reports of various authors, patients after microendoscopic discectomy are able to return to work 2–4 weeks after the operation [8].

Complications encountered with microendoscopic discectomy are similar to those with microdiscectomy. Suppuration of the surgical wound with the first technique occurs with a frequency of up to 1 %, with the second – up to 5 %; discitis – 1 and 1 %, respectively; dural sac damage – 10 and 5 %, respectively; hernia recurrences – 5 and 7 %, respectively [7, 8].

One of the disadvantages of microendoscopic discectomy is the need for a certain amount of time for surgeons to master the endoscopic technique. However, with the advent of modern endoscopic systems for the removal of lumbar hernias, this drawback has been partially eliminated. Traditionally, paramedian, mediolateral herniations of the intervertebral discs, stenosis of the lateral recess were considered indications for the technique. However, recently this technique is used for decompression of the lateral recess and installation of interbody cages in cases of spondylolisthesis of small degrees. This technique is also used with a high degree of effectiveness in recurrent herniation of intervertebral discs.

The nature of neurological manifestations in osteochondrosis of the Lumboischialgia during various types of surgical intervention to remove hernias between the vertebral discs at this level has not been studied. This was the aim of our research.

The object of our study were 87 young, middle-aged and elderly patients (47 men and 40 women). Of them, microdiscectomy was performed on 49 people (24 men and 25 women). 33 young people, 12 middle-aged people, and 4 elderly people were operated on. Monoportal endoscopic discectomy was performed on 11 patients (6 men and 5 women): 6 young, 4 middle-aged, and 1 elderly. Biportal endoscopic discectomy was performed in 27 people (17 men and 10 women). Young people

predominated in that group (12 people). There were 9 middle-aged patients and 6 elderly patients. The time of exacerbation of the process was from several weeks to one year. Hernias between the vertebral discs in the Lumboischialgia were most often of medial and paramedian localization. In one case, the patient underwent surgery at the same level.

Anamnestic, subjective and objective data were studied in the studied patients during hospitalization and in the dynamics of the treatment. When collecting the anamnesis and objective examination of the patient, the following other factors were taken into account formation: sex and age of the patient; duration of the disease and age since the onset of the disease; duration and nature of the last exacerbation; provoking factors that increased or decreased back and leg pain; clinical characteristics of the first exacerbation; constitutional type of the patient; type of vertebral deformation; nature of surgical treatment, its scope. All patients underwent a detailed clinical and neurological examination.

All examined patients showed an antalgic position of the body with an angle of inclination in the direction of pain distribution. The position of patients in bed was forced due to persistent pain syndrome. Lameness was found in 69 % of people. In 28 % of the examined, dysfunction of the pelvic organs was detected. Kernig's symptom was positive in 18 % of patients, which indicated the involvement of the spinal meninges in the process. Foot paresis was present in 12 % of subject patients.

In young patients who underwent microdiscectomy, hernias between the vertebral discs were most often localized at the $L_5 - S_1$ level (31 out of 33: 19 men and 12 women). Pain and sensitive disorders were observed in 34 % of people along the course of the S_1 root. The intensity of the pain syndrome according to the VASH scale was 59 ± 1.2 mm. The angle of inclination when determining the Lasegue symptom was 40–45°. Most often, paravertebral muscle tension was II degree according to Yakov Popelianskii [10]. The strength of these muscles in 66 % of the examined patients was within three points. The venous pattern on the legs was strengthened in 9 % of the examined.

In middle-aged patients of this thematic group, in 47 % of cases, hernias were localized at the level between the vertebral disc $L_4 - L_5$, in 29 % – higher localization ($L_2 - L_3$, $L_3 - L_4$). Sequestered hernias, instability of the I–II age vertebrae were observed more often. VAS was within 53 ± 2.4 mm. Lasegue symptom was 40–45° in 70 % of patients, 30–40° in 22 %, and more than 45° in 8 %. The tension of the paravertebral muscles was mostly II degree, and the strength of the paravertebral muscles in 79 % of people was 3 points, in the rest – within 4–5 points. Twisting of the body and limping were characteristic. Enhancement of the venous pattern on the legs was not characteristic.

For the elderly in this thematic group, the presence of instability in the Lumboischialgia, the presence of a sequestered hernia, the appearance of meningo-radicular symptoms, more often at the $L_5 - S_1$ level of the radicle, were characteristic; paresis of the foot on the side of pain. VAS varied within 51 ± 2.8 mm. Tension of paravertebral muscles is mostly II degree, and muscle strength is 2–3 points. In one patient, the angle of inclination when measuring the Lasegue symptom

was 25°, in others it was 40–45°. Enhancement of the venous pattern in the lower back and legs was not characteristic.

The results of the neurological examination of persons who underwent mono- or biportal endoscopic diskectomy were combined into one clinical group. 48 % of young people, 33 % of middle-aged and 19 % of elderly people were examined. Antalgic posture was characteristic of all patients, limping was almost absent. Spinal canal stenosis was present in 10 % of the examinees, foraminal stenosis in 23 % of the examinees. The strength of the paravertebral muscles in one patient was 3 points, in the other 37 people – 5 points. Tension of paravertebral muscles in one patient was II degree, in all others – III degree. In 92 % of the examined, an increase in the venous pattern on the legs, in the paravertebral area was characteristic, and in one patient, the "symptom of the breech" appeared. The dysfunction of the pelvic organs was not characteristic.

In young people, the intervertebral disc herniation was located at the level of $L_5 – S_1$. Pain in 75 % of patients of this age group radiated along the root of S_1, more often to the left or to both sides. Disorders of superficial types of sensitivity were not characteristic. One patient had stenosis of the spinal canal. VAS indicators were 74 ± 3.9 mm. In 80 % of patients, the angle of inclination of the Lasegue symptom was 30–35°, in others it was more than 45°.

In middle-aged people, 61 % of spinal disc herniation (SDH) hernias occurred at the $L_4 – L_5$ level. The pain most often radiated along the root of L_5 to the right. VASH indicators were within 66 ± 3.8 mm. Lasegue symptom was 25–30° in 29 % of the examined, 30–35° in 37 %, 40–45° in 26 %, more than 45° in others. In one patient, the process occurred against the background of spondylolisthesis of the L_4 vertebra.

In the elderly, endoscopic discectomy was mainly performed in women (62 %). SDH hernias at this age in 90 % of cases were localized at the $L_5 – S_1$ level and most often occurred according to the type of lumbago. VAS in this age group was equal to 68 ± 1.5 mm. The Lasegue symptom in the vast majority of operated patients was 25–30°.

Thus, the presence of weakly or moderately pronounced ischemic neuropathy of the corresponding spinal root is characteristic of persons who underwent microdiscectomy against the background of severe pain syndrome. The process primarily involved the short branches of this root, the spinal cord. The presence of reflex changes in the corresponding segment of the spine, damage to nociceptive receptors at this level, and the presence of chronic venous insufficiency in the lower back and legs are characteristic of persons who underwent endoscopic discectomy. Identified neurological signs can contribute to improving the treatment of this category of patients.

At the next stage of our research, we studied the indicators of fatigue in a decreed group of patients.

It is known that fatigue is a complex, multidimensional, mostly subjective phenomenon, which is described by different terms: "subjective feeling of lack of physical and (or) mental energy, which prevents normal daily activities and purposeful activity" [6], "sensation early exhaustion during physical and (or) mental activity, avoidance of loads" [4], "a feeling of exhaustion or fatigue that differs from a feeling of sadness or lethargy" [2].

From a biological point of view, fatigue is one of the oldest adaptive physiological processes. Physiological (normal) fatigue is a common phenomenon and is a signal for rest after a certain amount of activity in order to restore energy balance and prevent injuries [4].

From an anatomical point of view, fatigue is conventionally divided into fatigue of central origin (with changes in the central nervous system) and fatigue of peripheral origin (with changes in the metabolism of skeletal muscles, neuromuscular transmission, cardiovascular system) [4, 6].

According to the qualitative characteristics, fatigue is a multifaceted phenomenon consisting of various components: physical, cognitive/mental, motivational, somatic, and others [4, 6]. Physical fatigue occurs with muscle exhaustion and is manifested in the inability to maintain a constant level of effort or pace of performance when performing a certain activity. Mental fatigue is described as a feeling of exhaustion, lack of energy and reduced initiative in mental activity, which does not allow the patient to maintain a certain level of the latter for a normal period of time. Motivational (psychological) fatigue – a decrease in interest and lack of motivation when performing any activity. Somatic fatigue is a manifestation of the pathology of internal organs. As a rule, the patient simultaneously has different types of fatigue in different ratios [4, 6].

According to the duration, fatigue is conditionally divided into acute (lasts up to six weeks) and chronic (present more than 50 % of the time during the last six weeks or longer).

The phenomenon of fatigue consists of both subjective (own feeling of fatigue) and objective (quantitative characteristics of fatigue when performing certain activities) components [11]. External techniques cannot measure the feeling of fatigue, and it is a purely subjective feeling of exhaustion. Instead, fatigue, both in general and its individual components (physical, mental, and others) can be objectified with the involvement of physical, cognitive and other tests [8, 11].

Today, the most accessible method of assessing fatigue remains the patient survey. Until now, there is no specific diagnostic tool for the diagnosis of somatic pathology. All the questionnaires and scales that we used to assess degenerative-dystrophic spine pathology were originally intended to investigate fatigue of other origins.

In our studies, we determined fatigue indicators using standardized scales MFIS-20, FAS and FSS.

At this stage of the research, the object of our study were 71 patients with neurological manifestations of osteochondrosis of the spine in the lumbosacral section caused by herniations and protrusions of the intervertebral discs at this level. 50 patients underwent surgical interventions: 25 – open microdiscectomy and 25 – bipolar microendoscopic discectomy. 21 people made up the control group, which underwent conservative treatment for lumbago and lumboischialgia in the stage of exacerbation of the process. The duration of the pain syndrome in all patients was more than six months.

Fatigue diagnosis and determination of its characteristics were performed using the MFIS-20, FAS, and FSS fatigue scales.

The MFIS-20 scale consists of 20 questions, each of which has 5 possible answers.

MFI-20 includes 5 subscales (with four questions each):

– subscale for assessing global (general) fatigue (questions № 1, 5, 12, 16);

– subscales for assessing individual components of fatigue – physical (questions № 2, 8, 14, 20), mental (questions № 7, 11, 13, 19), motivational (questions № 4, 9, 15, 18) and reduced activity (questions № 3, 6, 10, 17) [11]. **General fatigue** describes a general feeling of tiredness and reduced activity, combines physical and psychological aspects. **Physical fatigue** encompasses the physical aspects of feeling tired. **Mental fatigue** refers to cognitive functioning, including impaired concentration. **Motivational fatigue** reflects a decrease in the level of motivation to perform a certain activity. Reduced activity implies a negative effect of fatigue on the patient's activity level. The value of each of the MFI-20 subscales ranges from 4 to 20 points; higher values indicate a higher level of the corresponding component of fatigue. A global fatigue subscale value of 12 or more points out of a possible 20 is considered a marker of chronic fatigue [6, 11].

The FAS scale consists of 10 questions: 5 questions about the mental component of fatigue and 5 questions about the physical component of fatigue. There are 5 possible answers to each question. The value of the questionnaire ranges from 10 to 50 points. A scale indicator of 22 points and above indicates the presence of fatigue in the patient [11].

The FSS scale consists of 9 questions, each of which is rated from 1 to 7 points. The scale indicator is calculated as the arithmetic mean of the sum of points. The critical value is 4 points and above, indicating the presence of fatigue in the patient. The scale assesses the impact of fatigue on the patient's quality of life (questions № 1–4, 6) and on his motor and cognitive functions (questions № 5, 7–9) [11].

All patients were asked to rate the presence and nature of fatigue, if it was observed during the last four weeks before hospitalization.

The research was carried out in compliance with the main provisions of the "Rules of Ethical Principles of Scientific Medical Research with Human Participation" approved by the Declaration of Helsinki (1964–2013), ICH GCP (1996), EU Directive № 609 (from November 24, 1986), orders of the Ministry of Health of Ukraine № 690 dated 23.09.2009, № 944 dated 14.12.2009, № 616 dated 03.08.2012. Each patient signed an informed consent to participate in the study, all measures were taken to ensure patient anonymity.

We found that open microdiscectomy was performed in 69 % of young men and 56 % of middle-aged women. In old age, men and women were operated on almost equally often: 19 % of men and 22 % of women. Men in middle age and women in young age were less often operated (12 %). The side of the lesion in men and women differed slightly among themselves: in men, in 44 % of cases, the operation was performed on the left, in 38 % – on the right, and in 18 % – there was a bilateral injury; in women, the left and right sides were equally damaged (22 % of cases each), and bilateral damage was most common – 56 %.

The following indicators were found in patients who were operated on by the method of microscopic endoscopic bipolar discectomy. This treatment method was preferred by young people (73 % of men and 44 % of women). In middle and old age, women underwent surgery equally often: 28 % in each age group. Among men in these age groups, the distribution was as follows: 18 % of middle-aged people and 9 % of elderly people.

Regarding the side of the injury in this type of operation, the following was found. In 18 % of men, damage was observed on the left, in 45 % – on the right, in 37 % – a bilateral process. In women, 64 % of cases had a left-sided process, 21 % – right-sided, 15 % – bilateral.

There were almost equal numbers of people in the control group: 11 men and 10 women. The age groups were almost equally distributed: approximately 33 % in each age group. The side of the injury in 9 % of men was on the left, in 45 % – on the right, in 36 % of cases there were bilateral symptoms. In women, left-sided symptoms were observed in 60 % of cases, right-sided in 30 %, and a bilateral process in 10 % of cases. Such differences in the course of the process can be explained by the specifics of the physical load on the Lumboischialgia, which is not equally loaded by men and women. The results of studying the nature of fatigue are given in **Table 2.1**.

Table 2.1 Characteristics of fatigue in people with various types of discectomy for localization of hernias in the Lumboischialgia

Type of operation	MFIS-20	FAS	FSS
Open microdiscectomy	3.57 ± 0.15**	2.18 ± 0.49**	2.00 ± 0.81*
Bipolar microendodiscectomy	1.80 ± 0.54*	1.22 ± 0.65**	0.63 ± 0.02
Control group	0.36 ± 0.08	0.33 ± 0.03	1.6 ± 0.14*

*Note: * – $p < 0.5$; ** – $p < 0.05$*

The conducted studies showed that all the examined patients had no signs of chronic fatigue, since according to the data of the MFIS scale out of 20 possible points, all the examined indicators were below 12 points (from 12 to 20 points – markers of chronic fatigue).

We found differences in the assessment of fatigue indicators between two groups of patients who underwent surgical interventions.

When examined using the MFIS-20 scale, the following complaints were found in the first clinical group (open microdiscectomy). In 53 % of cases, patients complained about their physical abilities: their movements were clumsy and uncoordinated; they felt weakness in the leg muscles, there were problems with prolonged physical activity; they did not move much during physical activity. The average score in this subscale reached 34 ± 1.5. When analyzing statements related to cognitive issues, such as memory, concentration of attention and decision-making, patients of this group in 47 % of cases complained of their forgetfulness, concentration of attention, it was difficult for them to make decisions; had trouble performing tasks that require thinking. The average score was 27 ± 0.9. Regarding the psychosocial aspects of their health, they were less motivated to participate in social activities; they were limited in their ability to do things outside the home. The subscale range in the psychosocial subscale was 5 ± 0.4 points.

The FAS and FSS scales also determined the presence of physical and mental fatigue in them, which in 68 % and 61 % of cases were of a mild degree, but in 32 % and 39 % of cases, respectively, approached a moderate degree.

With regard to the individuals of the second clinical group (individuals who underwent bipolar microscopic endoscopic discectomy), in a significant number of patients (47 %) the presence of global fatigue of a mild degree was also detected, but with lower indicators, which can be seen from **Table 2.1**.

Some differences were also found in the survey on the MFIS-20 subscales. In the physical subscale, the range in 41 % of respondents was from 11 to 29 points. Patients complained mainly about problems even with minor physical exertion; they were often clumsy and uncoordinated, sedentary. In the subscale of cognitive functions, 31 % of respondents had problems with concentration of attention, sometimes they had forgetfulness. Their average score on this scale reached 18 ± 2.1. In the psychosocial subscale, the average score was 2 ± 0.4 points.

The values of the FAS and FSS scales ranged within the limits of the mild degree, but they were lower than those of the first clinical group.

In the subjects of the control group, the values of the subscales of physical fatigue, mental fatigue, motivational fatigue, and reduced activity did not have any significant differences between individual observations of patients of this clinical group and approached indicators close to normal values.

Therefore, the determination of fatigue indicators using the standardized scales MFIS-20, FAS and FSS helps to improve the selection of patients for one or another type of surgical microsurgery on the Lumboischialgia for herniated intervertebral discs at this level and to improve the development of individual rehabilitation programs for patients in postoperative period.

For many years, issues of assessing the degree of neurological disorders have been developed as a criterion for selecting patients for conservative or operative intervention in this pathology. Therefore, in our research, we paid special attention to the assessment of the quality of life in the decreed group of patients using the SF-36 questionnaire.

At this stage, the object of our research was 63 patients aged 20 to 74 years. All patients were divided into three clinical groups, which were comparable in terms of age, gender, and duration of the disease. 21 individuals were examined in each clinical group: *group I* – patients who underwent biportal endoscopic discectomy; *group II* – patients who underwent open microdiscectomy; *group III* is a comparison group that underwent conservative treatment with the use of acupuncture reflexology.

The control group also consisted of 21 practically healthy individuals, comparable in age and sex, with X-ray signs of osteochondrosis of the spine, but without neurological manifestations of this pathology. There were 24 men (38 %), 39 women (62 %). Herniated intervertebral discs at the level of L_{IV}–L_V vertebrae were present in 23 % of men and 60 % of women; at the level of L_V–S_I – vertebrae – in 31 % of men and in 20 % of women; 38 % of men and 20 % of women had two to three hernias in the lumbar spine; a combination of herniated intervertebral discs at the lumbar level with protrusions of intervertebral discs was present in 8 % of men. Hernias were in the range of 4.5–7 mm and were mainly posterolateral. All patients underwent a detailed clinical and neurological examination.

In order to assess the quality of life of patients and practically healthy persons at work, we used the general questionnaire SF-36 (Heals Status Survey). The SF-36 [12] is intended for use in clinical practice and scientific research to assess the general health of the population and health care tactics and is designed for patients aged 14 years and older. It contains 36 questions covering 8 main characteristics of health.

Measurement within the SF-36 has three levels:

1) points (questions);

2) 8 scales, each of which combines from 2 to 10 points;

3) 2 generalized indicators that combine scales together.

8 scales form 2 different highly ordered groups (total assessments of psychological and physical health). The scales are grouped into two generalized indicators as follows:

1. *Physical Component Summary* (PCS), which includes physical functioning (PF), role physical functioning (RP), and pain (BP) scales that measure physical health.

2. *Mental Component Summary* (MCS), includes scales of mental health (MH), role-emotional functioning (RF), and social functioning (SF) that correlate most closely with the psychological component of health and measure it.

When assessing the quality of life using the SF-36 scale before starting treatment (operative or conservative), the following was found (**Table 2.2**).

● **Table 2.2** Indicators of life quality in patients with herniated intervertebral discs in the Lumboischialgia, to whom various treatment methods were applied (data from the SF-16 questionnaire)

Groups of patients	Indicators of the SF-36 scales (M ± m)								Generalized indicators (M ± m)	
	PF	RP	BR	GH	VT	SF	RE	MH	PCS	MCS
Group I (n = 21)	45.4 ± 9.1	52.1 ± 6.4	61.9 ± 16.4	45.6 ± 21.2	50.3 ± 7.1	53.4 ± 24.1	58.1 ± 25.2	61.1 ± 19.3	43.1 ± 13.7	47.8 ± 12.5
Group II (n = 21)	41.7 ± 11.0*	33.5 ± 7.3**	49.2 ± 18.6**	39.7 ± 29.3	39.5 ± 6.9**	47.3 ± 18.6*	54.2 ± 23.1	59.3 ± 17.4	32.2 ± 16.8*	38.7 ± 11.5
Comparison group (n = 21)	56.3 ± 11.3	51.3 ± 13.4	69.7 ± 28.6	52.2 ± 19.8	50.3 ± 19.1	62.4 ± 23.0	68.4 ± 23.7	70.0 ± 17.6	49.7 ± 9.9	45.9 ± 9.3
Control group (n = 21)	85.7 ± 16.9	76.8 ± 23.8	83.2 ± 21.4	72.4 ± 19.0	70.11 ± 18.7	82.7 ± 25.3	86.0 ± 23.3	83.5 ± 24.1	68.2 ± 21.1	73.5 ± 17.6

*Note: the level of significance of differences in quality of life in patients with SDH hernias compared to controls: *p < 0.05; ** p < 0.01*

As a result of calculating quality of life indicators in patients with herniated intervertebral discs in the Lumboischialgia, who underwent operative or conservative treatment, compared to the control group, quality of life indicators were significantly lower both on individual scales and due to generalized indicators. The most significant was the difference on the scales of RP (role physical functioning), VT (scale of vital activity), BP (pain scale). Generalized indicators of quality of life also differed in I and II clinical patients: PCS (physical component of health) and MCS (psychological component of health).

As can be seen from the obtained data, in the II group of patients, where a significantly higher index of pain intensity is noted ($p < 0.05$), there is a significant prevalence of asthenic, depressive and cognitive disorders ($p < 0.05$; $p < 0.01$; $p < 0.05$, respectively), significantly lower indicators of quality of life were registered on several scales and generalized indicators.

In the process of conducting a comparative analysis of the quality of life in all three clinical groups, depending on the gender, the form of the course, the duration of the disease, the degree of severity of the process, we obtained a heterogeneous picture of the patients' perception of their disease. It turned out that the quality of life of men is lower than that of women. The difference on the RP scale is especially large: 27.4 and 46.3, respectively.

The quality of life of patients with a remitting form of the course of the disease is higher than with a progressive form. Thus, in patients with a remitting form of the disease, the indicators of the Pf scale are not grossly reduced compared to the control group, while in the case of a progressive form of the course, the severity of physical symptoms increases.

Therefore, the use of the SF-36 questionnaire contributes to a better understanding of the pathogenesis of the development of neurological complications in the case of herniated intervertebral discs in the lumbar region, both at the peripheral level and in case of damage to brain structures. Assessment of the quality of life and determination of the intensity of pain in the preoperative period in patients with herniated intervertebral discs in the Lumboischialgia allows for a more differentiated selection of the method of surgical intervention in this pathology.

At the next stage of our research, we drew attention to the fact that there are a number of neurological manifestations of degenerative-dystrophic pathology of the spine, which do not fit into the already described neurological phenomena of this pathology. Therefore, we grouped them into a separate group.

2.2 CLINICAL MANIFESTATIONS OF A NUMBER OF UNKNOWN AND LITTLE-KNOWN NEUROLOGICAL SIGNS OF DEGENERATIVE-DYSTROPHIC PATHOLOGY OF THE SPINE

Osteochondrosis of the spine and its neurological manifestations are among the most urgent problems of our time. This pathology affects the most able-bodied part of the population in young and middle age. The specific weight of clinical neurological manifestations of osteochondrosis among diseases of the peripheral nervous system is 67–95 %. According to data from an epidemiological study

by the International Association for the Study of Pain (IASP), 56 % of the population experience back pain up to 10 days a year and about 9 % – from 10 to 100 days. During life, back pain is diagnosed in 80 % of the population. Dorsalgia is one of the most frequent reasons for seeking medical help.

The issues of etiology, pathogenesis and treatment of this disease remain controversial. Existing classifications of neurological manifestations of this disease do not fully reproduce the variety of their clinical signs.

The nature of rehabilitation measures for vertebrae-neurological manifestations of degenerative-dystrophic lesions of the spine is determined primarily by clinical manifestations, the stage of the disease, and the presence of concomitant pathology both on the part of the spine and the body as a whole. An undifferentiated approach is unacceptable, as it can lead to the breakdown of compensatory processes.

The aim of our research was to identify an atypical clinical course of this process, which was not reflected in any of the existing classifications of neurological manifestations of spinal osteochondrosis.

The work is based on the results of long-term clinical observations of more than 2,000 thousand patients with neurological manifestations of osteochondrosis of the spine during the exacerbation of the process, who were examined and treated in the clinics of our institute. In addition to the usual neurological examination of patients, additional research methods were used: magnetic resonance imaging of the spine, brain and spinal cord structures; inspection and functional X-rays of the spine; electroneuromyography, various ultrasound research methods; electroencephalography; if necessary – study of cognitive functions and psycho-emotional disorders.

The result of our research was the identification of the following atypical manifestations of neurological complications of spinal osteochondrosis [2]:

1. Pseudotrigeminal syndrome (or syndrome of abnormal development of the IV ventricle of the brain). It was observed in 5 patients (4 men and 1 woman). It was characterized by paroxysmal facial pain that mimicked the picture of unilateral trigeminal neuralgia. The pain had a dull, diffuse character; provoked by a cold factor, neuroinfectious process, hypertensive crisis, etc. During the examination of the patients, the exit points of the trigeminal nerve were intact. Local hypo- or hyperesthesia in Zelder's zone on the side of the facial pain, irritation of the cervical sympathetic nodes on the side of the pain, and phenomena of sensitive ataxia on the same side were revealed. On the opposite side – light pyramidal signs, increased tendon and periosteal reflexes according to the hemi type, sclerotome hyperesthesia of the cervical spine. The patients were withdrawn, introverted. The clinical picture of pseudotrigeminal was combined with anterior spondylolisthesis of the II–IV cervical vertebrae and the presence of an hourglass-type abnormality in the development of the IV ventricle of the brain and moderate CSF hypertension syndrome.

2. Epileptiform-irritative syndrome. Diagnosed in 4 middle-aged people (2 men and 2 women) against the background of exacerbation of osteochondrosis, mainly in the thoracic spine. In three patients, the picture of pseudo-angina was simulated, and in one patient – pseudo-bronchial dyspnoea. Phenomena of pseudo-angina or pseudo-hypocardia were paroxysmal, more often in the evening or at night. The attack was preceded by a dull, diffuse, aching pain along the course of

the 3rd–4th or 5th–6th intercostal nerves (more often on the left) for 1–2 hours. Taking analgesic, sedative, vasodilator or bronchospastic drugs in usual therapeutic doses did not relieve pain. At the height of the pain, the patients had loss of consciousness, mild clonic-tonic convulsions of the limbs.

During the examination of the patients, sclerotome tenderness was detected at the level of the upper or middle thoracic spine; to one degree or another, the presence of hyperesthesia or hyperpathia along the course of the 3rd–4th intercostal nerves. Sometimes the tendon reflexes on the pain side increased slightly. Inconstant and vague symptoms of Babinski, Rossolimo, Chaddock, Pusepp were determined on the limbs on the homolateral side. The sharp general pallor of the skin could instantly change to redness or cyanosis. General tenderness of the cervical sympathetic ganglia was noted. The patients were quite pedantic, could talk about their feelings in detail, and often kept a diary of their illness. During X-ray and MRI studies, degenerative changes in the anterior parts of the vertebral bodies, and lateral or posterior disc herniations at the thoracic level were most often found. The electroencephalogram showed convulsive activity of the brain, most often in the parietal, central or occipital region. The condition of the patients improved after adding to the treatment complex chondroprotective and anticonvulsant drugs.

3. "Additional vertebra" syndrome. It was observed in three young and middle-aged patients who presented with long-term radicular pain in the lower back, sacrum and coccyx. The patients had hysteroid traits. Their actions had a somewhat theatrical character. Tasting and showing off to a certain extent, they talked about constant unbearable pain in the area of the lower back, sacrum or coccyx. The story was supplemented with active movements in all sections of the spine, showing the doctor their painful areas.

An X-ray examination revealed a developmental anomaly in one patient – the VI lumbar vertebra and a vestige of the VII lumbar vertebra. Three coccygeal vertebrae were found in another patient, and an additional XIII thoracic vertebra was found in the third patient. In all three patients, an EEG was diagnosed with a sharp decrease in the bioelectric activity of the brain in the frontal and parietal regions.

The behaviour of the patients can be explained to some extent by the fact that in the process of embryogenesis, a representation for 32 segments of the spinal cord was established in their cerebral cortex, while in fact impulses came here from 33 segments of the spinal cord. Therefore, a violation of higher nervous activity was observed.

4. Herpetic ganglionitis syndrome. It was found in 19 middle-aged and older patients. Pain and herpetic rashes were most often of the monoradicular type and were localized at the upper thoracic or lower thoracic levels or along the course of the 1st lumbar vertebra. Herpetic rashes were isolated, small. The development of the disease was preceded by excessive physical overload of the spine. During the neurological examination, reflex-muscle-tonic syndrome and local sclerotome tenderness of the spinous and lumbar processes of the vertebra were revealed; in MRI examination – a lateral disc herniation at the same level or one segment higher, which blocked the intervertebral foramen. The addition of dehydration therapy and light manual correction significantly accelerated the recovery of patients.

5. Paget-Schroetter pseudosyndrome. It was observed by us in two elderly patients with osteochondrosis of the cervical spine who were operated on for the cervical ribs of the C_{VI}–C_{VII} vertebrae. In the postoperative period, there developed pain and swelling in the area of the shoulder girdle of the upper limb on the side of the surgical intervention. The skin was pale, shiny. The pain spread mainly along the C_8 root. Weakness, paresthesias, and a feeling of heaviness in the damaged segment were also noted. At the height of the intensity of the pain component, signs of involvement of the C_6, C_7, T_1 roots were added to the process. There was no dilatation of subcutaneous veins and cyanosis of the skin. In one patient, this syndrome was also combined with Horner's triad, decreased visual acuity and mild hemiatrophy of the face on the side of the injury. No signs of thrombosis of the subclavian veins were detected during the ultrasound examination of the deep veins on the side of the injury. Spontaneous blood flow in all segments was preserved, retrograde blood flow was not determined. Coagulogram corresponded to age characteristics.

The origin of this syndrome can be explained by the fact that in the preoperative period,an additional cervical rib squeezed the root of C_7, and this led to the development of degenerative and dystrophic changes in it. In the postoperative period, after decompression of the root, it developed degenerative-dystrophic processes with a hyperpathic component. Against the background of neurodystrophically altered adjacent tissues and vertebrae, closely spaced segments of the spinal cord and cervical sympathetic formations were involved in the process. The use of nootropic drugs and sympathicotonic substances contributed to the improvement of the general condition of the patients.

6. Phantom limb defect syndrome. It was diagnosed in 12 patients with amputated lower limb who constantly used prostheses. This syndrome was formed no earlier than a year after the amputation of the lower limb. It was characterized by a certain increase in tendon and periosteal reflexes on the side of the limb defect, a slight decrease in superficial types of sensitivity on the same side. The electroencephalogram on the heterolateral side of the limb defect revealed zonal activity in all brain structures. On the homolateral side, the amount of brain biocurrent corresponded to the physiological norm. On X-rays at the segmental level of the amputated limb, the phenomena of osteochondrosis were observed on the convex side of the spine, and the phenomena of spondylosis were observed on the concave side. A significant improvement in the well-being of patients occurred when this group of patients used in the treatment nootropic and vascular drugs, chondroprotectors.

7. We have allocated **neuroosteoarthropathy syndrome** to a separate clinical group, since in our daily work we meet with this nosology quite often, and it is not mentioned at all in ICD-10 and in the well-known classification of 1982–1985, which was used in the territory of the former Soviet Union about this type of neurotrophic disorders of the musculoskeletal system.

Our studies in this regard mainly concerned neurotrophic changes in the hip joints. We grouped all these disorders into three clinical groups.

In patients of the first clinical group (69 people), we studied neuroorthopedic changes in Hip-Spine syndrome. Patients complained of pain in the hip joint, which quite often radiated to the knee

joint and the lumbosacral region of the spine; for burning pain on the outer surface of the thigh. The pain increased with physical exertion and decreased at rest.

During the clinical examination, point tenderness was detected in the place of attachment of the piriformis muscle, the middle and small gluteal muscles (area of projection of the greater acetabulum) on the side of the damaged hip joint; restriction of internal rotation of the hip; palpable tenderness of the outer surface of the thigh in the area of projection of the external femoral nerve. The angle between the bispinal line and the hip axis was 90–95°. Normally, this angle is 87°. With long-term irritation of the piriformis muscle, patients developed an abductor, external rotation contracture of the hip.

In the neurological status, there was a slight decrease in surface sensitivity on the outer surface of the thigh on the side of the painful hip joint (90 % of cases). In all patients of this clinical group, knee and Achilles reflexes were normal or slightly reduced on the injured side. Pain in the paravertebral points at the L_2–S_1 level on both sides (more clearly on the affected side) was also diagnosed – 87 % of cases. Lasegue's sign was negative in all patients. Muscle strength on the lower limbs was normal in 100 % of cases and amounted to 5 points.

During X-ray examination of the hip joint, patients of this group were diagnosed with increased subchondral sclerosis of the acetabulum, slight hyperostosis of the medial surface of the femoral neck. Patients gradually developed a bone-like remodeling of the femoral head and its subsidence. Pathology in the hip joint developed against the background of a decrease in the height of the intervertebral discs L_3–S_1, hernias, protrusions of the intervertebral discs, stenosis of the spinal canal at the same level.

The second clinical group included 30 young and middle-aged patients (18 women and 12 men) with coxarthrosis in the I–II stages of the disease. During X-ray examination of the hip joint in patients of this group, signs of subchondral sclerosis of the acetabulum, marked hyperostosis of the medial surface of the femoral neck, and cystic remodeling of the femoral head were also diagnosed. The pathological process developed against the background of long-term pain syndrome in the lumbosacral region of the spine, caused by herniated intervertebral discs, stenosis of the spinal canal at this level. During the clinical and neurological examination of patients, we identified 3 types of the course of the disease:

1) benign (14 people);

2) permanent-progressive (11 people);

3) malignant (5 people).

With a *benign type of course*, the disease occurred 1–6 months after the clinical manifestations of vertebrogenic lumboischialgia or radiculoneuropathy at the same level. It occurred more often in women aged 30–60. There was almost no pain during passive rotation of the joint. The starting pain was not typical. The pain most often occurred during the day, worsened during walking, prolonged standing on the feet or external rotation, when going down the stairs. Nocturnal pain was not typical. An increase in knee and Achilles reflexes was observed in the first weeks of the disease, which gradually changed to their decrease on the side of the injury. Hypotonia and hypotrophy of gluteal muscles above the damaged joint were diagnosed; there was an asymmetry

of the gluteal folds on the affected side, a thickening of the lower edge of the middle gluteal muscle. There were changes in the skin of the segmental level on the side of the damaged joint.

The clinical signs of the *permanently progressive course* of neurogenic coxarthrosis were as follows. Osteoarthritis was most often observed in persons who were operated on for herniation of L_{III}–L_V intervertebral discs and had signs of spinal arachnoiditis and epiduritis. The time of onset of neurogenic coxarthrosis is 1–5 years after the surgical intervention. There were signs of moderate thickening of the skin over the damaged joint, pronounced hypotonia and muscle hypotrophy at the segmental level. The disease continued for a long time, over many years, with periodic exacerbations of the process. Short-term starting pain was combined with pain in the joint and spine while walking. Morning stiffness in the damaged joint and spine, restriction of movement in the damaged joint during the exacerbation period was characteristic; crepitation in the joint.

The malignant course of neurogenic coxarthrosis was characterized by the fact that the time from the first clinical manifestations of damage to structures at the lumbosacral level to the rapid development of grade III–IV neurogenic coxarthrosis took only 1–4 years. Clinically, it did not differ from ordinary coxarthrosis. During the neurological examination, there were signs of myeloradiculoneuropathy of the L_4–S_1 roots. Patients with a malignant course of the process needed endoprosthetics of the hip joint, because conservative treatment of the process was not effective for them.

Magnetic resonance spectroscopy of brain structures revealed unilateral stenosis or occlusion of the internal carotid artery or middle cerebral artery in our patients without signs of cerebral infarction. However, insufficiency of blood perfusion in the areas of the border zones of the brain, a decrease in the indicators of the main cerebral metabolites, especially in the area of the hippocampus, was found in them. Patients with the debut of coxarthrosis of metabolic dystrophic origin did not have such specific magnetic resonance spectroscopic signs. All this prompted us to conduct a study of cognitive functions in our patients.

All examined patients, compared to healthy individuals, especially patients of the third group, had significantly lower indicators characterizing the following mental functions: short-term verbal memory, attention, speed of sensorimotor reactions, mental capacity, volume of active attention, short-term and long-term visual and auditory memory, the ability to think logically, as well as distraction and generalization, understanding the meaning of words and the logical connection between concepts. Long-term use of nootropic and vascular drugs against the background of basic therapy made it possible to significantly improve cognitive functions in such patients and improve metabolic processes in the cartilage tissue of damaged joints.

The third clinical group included 12 patients with signs of aseptic necrosis of the femoral head. During MRI and clinical examination, signs of compression radiculoischemia, reactive epiduritis, slowly progressing chronic myeloischemia in the basin of the Adamkiewicz artery (AKA) artery against the background of herniated intervertebral discs of the L_1–L_V vertebrae were revealed. Quite often, the removal of a herniated intervertebral disc did not contribute to the improvement of clinical symptoms, and in four cases it led to hip joint replacement.

8. Elongated limb syndrome. Over the course of several years, we observed a woman with chronic pain in the lumbosacral region of the spine, which radiated to the left lower limb. At the age of 54, she was diagnosed with a 6.5 mm paramedian hernia at the level of L_{IV}–L_V vertebrae. Gradually, for no apparent reason, the patient's left lower limb lengthened evenly in all segments. At the age of 58, the difference between the left and right limbs reached 5 cm. The patient had to compensate for the static scoliosis due to the elevating insole on the right leg. During the in-depth examination, no signs of pathology of the brain structures, neuroendocrine disorders and malformations of the blood vessels of the legs, which would cause such pathology, were found. On examination, the left limb was slightly swollen, with a marble shade. Left knee and left Achilles reflexes were decreased. Lasegue's symptom on the left was moderate. Sclerotome and paravertebral pain in the Lumboischialgia were determined.

9. The "pepper knife" syndrome. We observed a 56-year-old woman who had pain in the lower chest and lumbosacral region of the spine, weakness and numbness of the left leg. The patient moved with difficulty, leaning on a cane. The body was rapidly tilted to the left. When asked to stand on her left leg without additional support, her body rapidly bent down to the left and folded like a penknife. At the same time, she could stand straight and for a long time on her right leg, without using a stick. During the examination, there was smoothing of the lumbar lordosis, moderate paravertebral tenderness at the level of Th_{11}–S_I vertebrae on the left; moderate increase of periosteal and tendon reflexes on the left; Babinski's and Lasegue's symptoms on the left were moderate. An MRI study revealed a 5 mm herniation at the Th_{12}–L_1 level of the intervertebral disc, ante-spondylolisthesis of the body of the L_5 vertebra; initial signs of dyscirculatory encephalopathy were found in the structures of the brain. Electroneuromyography showed signs of moderate pyramidal insufficiency at the level of lumbar thickening of the spinal cord.

10. Syndrome of damage to the arcuate joints. Predominance of reflex neurological signs over organic (especially radicular) neurological manifestations in patients with osteochondrosis of the spine allowed us to establish that in 83 patients they were caused by pathology of the arcuate joints. The clinical picture of damage to these joints has some specific features.

As is known, the posterior arcuate joints are true synovial connections between the upper and lower articular processes of adjacent vertebrae. With sudden movements, especially with excessive extension, each capsule can stretch or tear, after which the formation of a subluxation becomes possible. Contributing factors leading to injury are the patient's excess body weight, acute lumbosacral angle, degenerative changes, damage to the intervertebral disc, chronic occupational stress and excessive vertical displacement of joint surfaces. Repeated damage to the arcuate joints leads to degenerative changes and a significant tendency to recurrent exacerbations. The return of pain to the lower extremities is not characteristic, but they can radiate along the spine in the buttock. With significant subluxations or progressive changes, pinching of the root may occur.

In the anamnesis, patients, as a rule, note the presence of acute pain in the back, which is caused by excessive extension. Often, patients complain of a number of previous similar attacks. The pain increases when sneezing, coughing, slightly bending the spine or when sleeping on the stomach.

During the examination, the patient often stands in a position slightly bent in the hip joints. His movements are limited in all directions. Pain in the lumbosacral region of the spine is especially significant, which is often accompanied by a reflex muscle-tonic syndrome. If there is no tonic tension of the muscles, then quite often it is possible to palpate the arcuate joints of the spine on both sides between the adjacent spinous processes and near them (approximately one finger to the side). Local tenderness over the joints, increasing pain during excessive extension and the absence of organic neurological disorders convincingly indicate an acute syndrome of damage to the arcuate joints. The straight leg raise test can be positive for two reasons. With maximum lifting, the joint capsule is stretched, which causes local soreness. This test also becomes positive when the nerve is pinched. It is necessary to measure the length of the legs, since asymmetry can increase the load on the arcuate joints.

X-ray examination of the spine in the acute period in the lateral projection may be without deviations from the norm. When the process is chronic, degenerative changes in the arcuate joints are visible in the lateral projection. Radiography in an oblique projection better reveals subluxation of the articular process with displacement of the upper fragment to the back and slight narrowing of the posterior part of the intervertebral disc. At the same time, narrowing of the intervertebral foramen can also be observed.

Along with the above little-known clinical signs of damage to the arcuate joints, we managed to identify their new clinical manifestations. In particular, in 83 patients with reflex manifestations of osteochondrosis of different parts of the spine, we drew attention to the fact that when we asked the patient to draw on the surface of his skin the zones of sensitivity disorder (so-called "stripes"), they somewhat did not coincide with the well-known schemes of the radicular innervation on the surface of the skin.

Such patients complained that sensitive disturbances were manifested in the form of signs of hyperesthesia, sometimes with some hyperpathic sensation; the presence of a pinching painful sensation of a constant breath of light breeze or a feeling of slight swelling of the skin in one or another area.

During the objective examination, we found some thickening of the skin in the place of the painful sensation, an increase in skin turgor, and a change in its elasticity. During an acupuncture session, a specific cracking of the skin was often felt in this place, somewhat reminiscent of the sound of cutting frozen meat with a knife. In some patients, it was difficult to insert the needle into the skin due to its increased elasticity, up to the presence of "gutta-percha skin" syndrome.

Based on the above signs, we hypothesized that in the initial stages of osteochondrosis of the spine, when there is displacement of the intervertebral joints, partial narrowing of the intervertebral opening, root disorders may be preceded by the stage of dermatomal damage to the root branch, which is characterized by the above signs. Later, our assumptions were confirmed by a number of paraclinical studies. This allowed us to create our scheme of dermatome innervation of the surface of the human skin, which is somewhat different from the generally known literature data.

Thus, according to its clinical signs, osteochondrosis is quite multifaceted and sometimes does not fit into the framework of its known typical clinical manifestations. This requires constant clinical study and generalization of unknown and little-known cases of this process.

2.3 COMPREHENSIVE ASSESSMENT OF THE RESULTS OF A NUMBER OF PARACLINICAL STUDIES OF PAIN SYNDROME IN DEGENERATIVE-DYSTROPHIC SPINE PATHOLOGY

The next stage of our research was the study of some causal processes in the occurrence and development of osteochondrosis of the spine and its neurological pain syndromes. We used a comprehensive approach to solving the problem.

At the first stage, a whole series of specific morphological, including neuromorphological and histochemical studies was carried out. Simultaneous changes in the spinal cord and discs and vertebrae in 41 suddenly deceased young, middle-aged and elderly persons without concomitant signs of severe systemic organic diseases of the internal organs and nervous system at the level of the mid-thoracic spine as the least loaded were compared. The reliability of the obtained results was confirmed by X-ray studies of the section material.

Studies have shown that dystrophic changes occur first in the spinal cord, especially in its posterior and lateral horns. These changes precede pathomorphological changes in the vertebrae and discs. At a young age, the phenomena of dyscirculatory or metabolic dystrophic myelopathy gradually develop at the segmental level.

Moreover, if we compare the activity of the somatic and autonomic nervous systems during this period, then the autonomic nervous system is the first to react, which was proven by the example of histochemical studies of biogenic amines (their accumulation, especially norepinephrine, in the lateral and posterior horns of the spinal cord begins to decrease). The process from the rear and lateral horns is gradually transferred to the front horns of the grey matter of the spinal cord. Over time, degeneration of the nerve fibres of the white matter of the spinal cord develops. The membranes of the spinal cord are gradually involved in the process. Around the age of 30, degenerative-dystrophic changes also begin to appear in the vertebrae and discs, which are so thoroughly described in the literature.

According to our data, in middle age, degenerative-dystrophic changes in the spinal cord and in the vertebrae and discs proceed almost in parallel, but in the spinal cord they acquire a more widespread character and go beyond the limits of one segment.

Degenerative-dystrophic processes in all structures of the spinal cord continue to progress in the elderly, metabolic processes are suppressed (in particular, the production of biogenic amines slows down). Gradually, the spinal cord begins to lose its corrective and regulatory influence on metabolic processes in the vertebrae and intervertebral discs. This is manifested by the fact that degenerative-dystrophic changes in the vertebrae and discs begin to lag behind those in the spinal cord and may even become somewhat reversed.

Thus, in the series of studies we conducted, we found confirmation of the statement of Yurii Golovchenko [13] that the nervous system begins to age first in the ontogenesis of an individual, followed by all other organs and systems, including vertebrae and intervertebral discs.

To confirm our opinion that the nervous system plays a leading role in the formation of clinical and pathogenetic signs of osteochondrosis of the spine, a number of paraclinical studies were conducted.

The leading role of the cortical analyzer in the formation of neurological manifestations of spinal osteochondrosis was judged by electroencephalography data. So, in particular, when examining the bioelectric activity of the brain in 146 patients with neurological manifestations of spinal osteochondrosis, it was established that the greatest changes occur in the frontal, temporal, and central regions of the brain, where, according to Heorhii Yankovsky [14], there is a cortical representation of the bone analyzer, in particular the bones of the spine. These changes are most clearly recorded in patients with radicular and radicular vertebrogenic disorders. Changes in the deep structures of the brain, which take part in the formation of suprasegmental vegetative-trophic mechanisms, were also revealed. These changes were most pronounced in patients with reflex neurodystrophic symptoms. The phenomenon of hypoxia of the cerebral cortex was detected at the height of the pain component and in patients with hypokinesia.

Clinical examinations of 2,093 patients with neurological complications of spinal osteochondrosis showed that 66.5 % of them had an imbalance of autonomic reactions. Therefore, an in-depth study of the state of the autonomic nervous system was conducted using modern functional cardiovascular tests, as the most simple, reproductive, non-invasive, reliable and accurate methods of diagnosing autonomic disorders. As the conducted studies have shown, all patients with neurological manifestations of osteochondrosis of the spine have gross violations of the autonomic nervous system at the subclinical stage of the type of systemic degenerative process. They affect not only the autonomic structures of the disc or vertebra itself, but also segmental spinal centers, peripheral departments of the autonomic nervous system, and suprasegmental formations. Moreover, a sharp increase in the activity of the autonomic nervous system was observed in patients with autonomic vascular disorders, and its greatest suppression was observed in radicular vascular pathology.

These provisions were confirmed by a number of other paraclinical studies. In particular, with the help of the method of non-contact thermal imaging thermodiagnostics, the nature of vegetative-vascular disorders that occur with neurological manifestations of spinal osteochondrosis was established. Thus, in patients with reflex neurological signs, these manifestations did not depend on the variety of clinical symptoms, but on the nature of the vegetative direction of these vascular reactions at the segmental level and were most significant when the process was localized in the lumbosacral region in women with a parasympathetic tonic orientation, and in men with sympathotonic in the stage of subcompensation.

The reaction of the microcirculatory channel to a painful stimulus was judged by the data of television capillaroscopy during the examination of 77 patients. It was established that regardless of where the primary pain point was (on the arm or on the leg), the capillaries of the hand on the homolateral side always reacted first. The prevailing importance in the formation of reflex neuro-

logical syndromes in osteochondrosis of the vagus nerve spine was revealed. At the same time, with vertebrogenic reflex vegetative-vascular manifestations, trunk baroreflex mechanisms also suffer, and with vertebrogenic reflex muscle-tonic and neurodystrophic – changes occur in baroreflex mechanisms at the segmental level. Simultaneous activation of suprasegmental sympathetic and segmental parasympathetic reactions was detected in root neurological disorders. Capillaroscopic changes obtained in patients with radiculovascular syndrome showed that in this pathology, inhibition of both parasympathetic and sympathetic reactions develops, but the latter are more severe and intense.

The examination of the content of catecholamines in biologically active fluids (blood plasma and urine) in 104 patients with neurological manifestations of osteochondrosis of the spine showed a significant decrease in the content of noradrenaline in the urine and an increase in its indicators in the blood plasma in vertebral radicular, reflex muscle-tonic, autonomic vascular and, to a lesser extent, with neurodystrophic syndromes. This serves as proof that with these neurological signs of osteochondrosis of the spine, degeneration of peripheral autonomic nerve endings develops, the compensatory baroreflex mechanism decreases, and there is no normal reabsorption of this mediator from the blood plasma and its inclusion in further processes of exchange in the body and its excretion with urine. An increase in the ratio of noradrenaline to adrenaline in the urine of patients with vertebrogenic radiculovascular syndrome was also established, which could indicate the activation of mediator exchange processes in this pathology.

The genetic predisposition of the body to certain neurological syndromes of spinal osteochondrosis was established based on the results of studying HLA-immunogenetic markers in 116 patients with the aforementioned pathology. It was established that the largest number of histocompatibility antigens (125) was characteristic of patients with radicular syndrome. The smallest number of HLA antigens (51) was typed in reflex neurodystrophic syndrome and this suggests homozygosity of phenotypes in this syndrome. As you know, homozygosity for any genetic trait significantly reduces the body's ability to adapt and recover. And it is the manifestation of clinical symptoms of a neurodystrophic nature that has a progressive direction, is poorly amenable to treatment, prone to relapses and chronicling of the pathological process. "Indicator antigens" in this pathology have also been identified. Thus, in reflex muscle-tonic and neurodystrophic syndromes, antigen B27 was detected most often. With vertebrogenic root-vascular syndrome – A10, B40; with widespread osteochondrosis of the spine – B13 and B16. Detection of the HLA-Aw32 antigen in radicular syndrome indicated a certain frequency of development of systemic primary autonomic neuropathy in this pathology. Representatives of the HLA-C locus were completely absent in patients with reflex vegetative-vascular syndrome. With the progression of clinical signs of osteochondrosis of the spine, a high frequency of antigens A1, A2, A9, B5, B8, B12 was detected.

Thus, summarizing the results of the conducted research, it is possible to suggest that the primary basis for the occurrence of osteochondrosis of the spine and its neurological manifestations is the dysfunction of segmental nerve reactions at the level of the spinal cord, and not the intervertebral disc, as expressed by most authors. This dysfunction is due to the peculiarities of

the biomechanical properties of the spine, which arise primarily in its "key" zones as a result of unbalanced, excessive load on the spine. It can also be supported by frequent microtraumas of the spine, endocrine-humoral or vascular disorders, the effect of hereditary, infectious and intoxication agents, etc. An afferent impulse arises in the posterior and lateral horns of the spinal cord, and then in its anterior horns and lateral spines. This process is aggravated by the fact that the lateral horns and lateral spines in each specific segment are at the junction of the blood supply of the anterior and posterior spinal arteries. This leads to the emergence of a pathological action potential at the level of the spinal cord segment, primarily in its vegetative nerve formations.

Suprasegmental nerve structures are also included in the process, the so-called transsynaptic degeneration of the central genesis develops, which we proved, in particular, on the example of patients with the syndrome of the defect of the lost limb. This leads to an even greater imbalance at the level of the segmental spinal centers. Dyscirculatory or metabolic dystrophic myelopathy occurs. Systemic degeneration of peripheral vegetative fibers and, in particular, the sinuvertebral nerve (or Luschka nerve) is gradually formed. And only after that, vegetative-trophic disorders begin at the level of the intervertebral disc. The formation of systemic peripheral polyneuropathy leads to the fact that the process gradually covers the adjacent musculoskeletal segments, intervertebral discs; on this background, various neurotrophic disorders begin to form in the muscles, connective tissue, and internal organs. Therefore, in our opinion, changes in the spine such as osteochondrosis are only a "facade", behind the walls of which the main changes in the nervous system are played out, which are hidden from the researcher's view.

Therefore, the final solution to the issue of the pathogenesis of osteochondrosis of the spine and its neurological manifestations is not yet complete and needs to be resolved in time precisely from the point of view of its neurological concept.

The application of high-quality modern tools of functional methods of research of this pathology plays a significant role in solving many controversial issues. It was established that measuring the heat flow density of the human body is a new promising method of diagnosing neurological disorders in degenerative-dystrophic diseases of the spine. The study of changes in thermometric indicators of the skin in the lumbosacral region of the spine is a new highly informative diagnostic method. To confirm this hypothesis, a unique thermoelectric device was developed and manufactured for measuring the heat flow density from the surface of the human body, the design, technical characteristics and results of experimental medical research are given in the following sections of this work.

2.4 CONSTRUCTION AND TECHNICAL CHARACTERISTICS OF THE DEVICE FOR MEASURING THE HEAT FLOW DENSITY FROM THE SURFACE OF THE HUMAN BODY

The development of modern diagnostic methods, such as magnetic resonance and computer tomography, allows to determine the level and localization of a hernia or protrusion of the intervertebral disc. Today, there are already many works [2–6] in which it was shown that there is no direct

relationship between the presence or degree of severity of degenerative-dystrophic changes in the spine and the presence or intensity of back pain syndrome. That is, there is an urgent problem of studying other peripheral mechanisms that cause back pain. The mechanisms of the occurrence of back pain in the first hours/days of its occurrence in degenerative-dystrophic pathology of the spine, especially in its lumbosacral region, which is most often encountered in the clinical practice of neurologists and orthopedists, have not been fully studied. Medical practice also requires the introduction of new highly informative, portable devices for functional diagnostics, which would make it possible to reveal the nature of neurological damage in degenerative-dystrophic spine pathology in the first hours/days and to assess the degree of pain in this pathology [4–7].

Semiconductor thermoelectric heat flow sensors [15, 16], which combine miniaturization, high sensitivity, stability of parameters in a wide range of operating temperatures, and are compatible with modern recording equipment [17–28] are promising for the study of local human heat emissions. The use of such sensors makes it possible to achieve high locality and accuracy of thermometric measurements. This, in turn, makes it possible to obtain information about the characteristics of the objects under study and to analyze them in detail in order to detect inflammatory processes in the human body in the early stages.

Therefore, the aim of this work is to study thermometric indicators in patients with a number of neurological manifestations of degenerative-dystrophic pathology, in particular osteochondrosis, in the Lumboischialgia.

At the Institute of Thermoelectricity of the National Academy of Sciences and the Ministry of Education and Science of Ukraine, a thermoelectric device was developed for the diagnosis of inflammatory processes and pain syndrome in degenerative-dystrophic diseases of the lumbar-sacral spine [21] (**Fig. 2.1**). Technical characteristics of the device are given in **Table 2.3**.

The device includes a control unit 1 and thermoelectric temperature and heat flow sensors 2. Temperature and heat flow density are measured simultaneously by 2 thermoelectric sensors with measurement results recorded on a MicroSD memory card and computer display on a PC (with Windows 7–10 operating system). Data is recorded in "Comma-separated values" (CSV) format, which allows you to open measurement result recording files without any additional conversion in most programs for working with electronic spreadsheets, such as "Microsoft Excel", "Open office", as well as in the specialized program of the "TermoMonitor" device for plotting graphs of measurements.

The principle of operation of the device consists in converting the heat flow and temperature of the human body with the help of two thermoelectric sensors of heat flow density and temperature into electrical signals equivalent in magnitude, which are displayed on the digital display of the control unit in units of heat flow density (mW/cm^2) and temperature (°C).

Two connectors for connecting thermoelectric temperature and heat flow sensors and a power button are mounted on the upper wall of the device. On the right-side wall there is a connector for a micro-SD memory card and a mini-USB connector for connecting the device to a personal computer. The battery of the device is also powered through the mini-USB connector.

Fig. 2.1 Thermoelectric device for diagnosing inflammatory processes and pain syndrome in degenerative-dystrophic diseases of the Lumboischialgia:
1 – control unit; 2 – thermoelectric temperature and heat flow sensor

Table 2.3 Technical characteristics of the device

№	Technical characteristics of the device	Parameter values
1	The operating temperature range of the thermoelectric sensor	(0 ÷ 50) °C
2	Accuracy of temperature measurement	± 0.1 °C
3	The range of heat flow density measurement	(1 ÷ 100) mW/cm^2
4	The maximum error of heat flow density measurement	5 %
5	Number of thermoelectric sensors	2
6	Overall dimensions of the thermoelectric sensor	(14×14×3) mm
7	Overall dimensions of the control unit	(90×55×25) mm
8	The weight of the thermoelectric sensor	20 g
9	The weight of the device	150 g
10	Possible time of continuous operation of the device	48 h

A liquid crystal display is mounted on the front wall of the case, which shows the values of the density of heat flows of the corresponding areas of the human body and the temperature values in the form of graphs. Thus, the obtained measurement results can be analyzed directly from the graphs displayed on the display. The simultaneous presence of two thermoelectric sensors in the device makes it possible to compare the results of measurements of the diseased and healthy areas of the human body surface.

In addition, there are 6 buttons for controlling the operation of the device on the front wall of the device – "LEFT", "RIGHT", "UP", "DOWN", "OK", "MENU". The purpose of the "MENU" items of the device is as follows:

– "START RECORDING" / "STOP RECORDING" – the device starts recording measurement results in a new file, stops the corresponding recording and saves the information to the memory card;

– "MODE SELECTION" – calls up a sub-menu for choosing one of 9 modes of displaying information in the form of graphs in real time;

– "RECORDING PERIOD" – designed to select the time period during which the measurement results will be saved to a file on the memory card and displayed on the device display;

– "TIME/DATE" – switching to time and date setting mode;

– "ACCUMULATOR" – displays the voltage on the device's power supply battery;

– "INFORMATION" – displays information about the device.

The structural diagram of the device (**Fig. 2.2**) consists of the following functional units: a thermoelectric heat flow sensor with a built-in temperature sensor, an analogue-to-digital converter (ADC) for converting the analogue signals of the sensor into digital ones, a multiplexer for switching digital signals from the ADC and alternately transmitting them to microcontroller, which is used to process digital signals, save them to a memory card, and display information graphically on display and a personal computer.

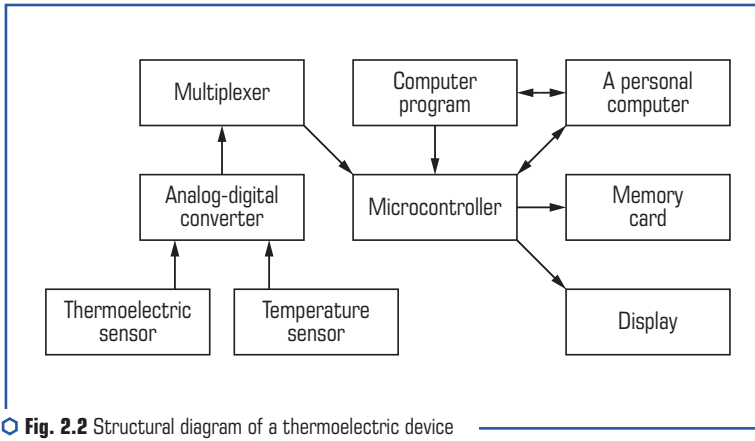

Fig. 2.2 Structural diagram of a thermoelectric device

The main functional piece of the control unit is a microcontroller that operates at a frequency of up to 20 MHz and provides a high speed of processing signals of the thermoelectric sensor of temperature and heat flow. With the help of a personal computer, programming of the microcontroller is carried out, which, in turn, controls the operation of other functional units of the device.

The device contains its own power source in order to ensure the possibility of its use in autonomous mode together with the patient. This, in turn, allows you to expand the functionality of the device. The device is powered by a lithium-ion battery with a capacity of 1200 mAh, which provides 48 hours of continuous device operation.

The computer program of the device (**Fig. 2.3**) is written in the Delphi programming language. The program allows you to exchange data with the control unit via the USB interface. Data exchange is carried out using the HID protocol (Human Device Interface), which makes it possible to connect the device to a personal computer without the need to install additional drivers.

When the "REFRESH DATA" checkbox is selected in the computer program, a cycle is started that sends data transfer requests from the control unit. In response to such requests, the control unit sends a packet of data on the temperature and heat flow of thermoelectric sensors with a specified time interval. The received data package is processed, after which the information is displayed on a personal computer in the form of tables and graphs.

When you click the "SAVE" button, all data from the table are converted into "string" values (plain text), separated by a dot and a comma and written into a file with the extension "CSV" that can be opened by any program for working with electronic spreadsheets (Microsoft Excel, for example). When the file is opened by such a program, the "CSV" format is decoded into a floating-point data package, which allows you to display the information in the form of a table and corresponding graphs on a personal computer.

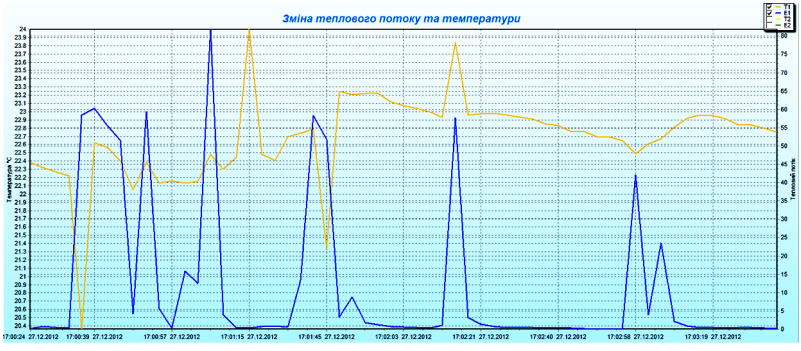

Fig. 2.3 The interface of the computer program "TermoMonitor" for processing the results of measurements, their accumulation and reproduction in a specified form on a personal computer (the change in temperature T_1 and heat flux E_1 of the 1st thermoelectric sensor is displayed)

2.5 THE RESULTS OF HEAT FLOW DENSITY MEASUREMENT IN A NUMBER OF NEUROLOGICAL DISORDERS IN DEGENERATIVE-DYSTROPHIC PATHOLOGY OF THE LUMBOISCHIALGIA

To study the effectiveness and feasibility of measuring heat flow density in patients with neurological pathology in degenerative-dystrophic diseases of the Lumboischialgia, these indicators were studied in a number of pathological conditions of this pathology [21, 24, 28].

In particular, we examined 71 patients aged from 39 to 69 years: 20 with signs of lumbosciatica on the background of herniated intervertebral discs, 20 with lumbosciatic pain on the background of herniated intervertebral discs in combination with instability of the vertebrae in this area, 11 patients with stenosis of the spinal canal and 20 people of the control group. Women predominated – 64 % of those examined. All patients underwent a detailed orthopedic and neurological examination. Heat flux density and body surface temperature of patients with neurological manifestations of spinal osteochondrosis were measured using a device designed at the Institute of Thermoelectricity of the National Academy of Sciences and the Ministry of Health of Ukraine.

In the room where the examination took place, the temperature was constantly maintained within the range of 20–25 °C, and the relative humidity was 50–60 %. There were no sources of infrared radiation. On the eve of the examination, all physiotherapeutic and warming procedures were cancelled for the patients; they also cancelled anti-inflammatory, antipyretic, vasodilator or vasoconstrictor medications. Patients had to stop smoking cigarettes 3–4 hours before the examination. 2–3 hours before the start of the examination, various ointment applications were removed from the patients, and the skin surface was degreased with a mixture of 40 % ethyl alcohol and ether (in a ratio of 4:1). Immediately before the examination, the patients underwent temperature adaptation for 15–20 minutes. At this time, they were at rest, without static or dynamic muscle tension. Measurement of thermometric parameters from the surface of the patient's skin was carried out in real-time within 3 minutes. We paid attention to the time of thermal adaptation (in seconds) – t (how much time passed from the moment the survey began to the output of the main indicators for thermal "saturation"), the temperature and heat flow density at the height of this "plateau", the appearance of the curves themselves. Sensors are applied symmetrically on both sides paravertebrally at the level of the spinous processes of the L4 – L5 vertebrae.

As the conducted studies showed, in the subjects of the control group (**Fig. 2.4**), the fluctuation of the main thermometric indicators in the paravertebral areas was symmetrical and practically did not differ according to the "left/right" test. Heat and thermal adaptation of the skin in contact with the surface of the thermoelectric sensors took place simultaneously and had the appearance of a smooth curve with the presence of clearly visible saturation. At the same time, all individuals of the control group maintained a full range of motion in the Lumboischialgia, there were no pain sensations of spinous processes and paravertebral areas in the lumbosacral area, there were no signs of sensitivity disorders, reflexes in the affected areas. In the control group, the time to thermal "saturation" was 45.3 ± 0.3 seconds. The temperature of the skin in the paravertebral areas was within 34.6 ± 0.5 °C, and the heat flow density was 17.1 ± 0.1 mW/cm^2.

During the clinical examination of patients with signs of lumboischialgia (**Fig. 2.5**), the cause of which was the presence of hernias or protrusions in the Lumboischialgia, we found the following. Patients complained of heartburn and pain in the lower back, lower limbs, trophic disorders. Their backs were fixed in a bent position. Unilateral tension symptoms were positive, and 20 % of patients had crossed Lasegue symptoms. There was a decrease in the range of motion in the lumbar region of the spine, tension in the muscles of the lumbar region, pain during palpation and percussion of paravertebral points, and a sharp limitation of tilting in the direction of the lesion. In the position of lying on the back and with the lower limbs bent, the pain in the hip joints decreased. The pain had a pulling character, was accompanied by chills, numbness and tingles in the lower limbs. The skin was pale, cold to the touch, dry (especially in the lower leg and foot) with signs of hyperkeratosis. White dermographism was noted. They had a parallel fluctuation of temperature and HFD on the pain side, (which can be seen in **Fig. 2.5**, in the extreme upper right corner, when the yellow and blue colours reached "thermal saturation") and low indicators on the intact side (**Fig. 2.4, 2.5**). The skin temperature indicators on the pain side were within 34.8 ± 0.5 °C, and the HFD was 101.6 ± 0.3 mW/cm^2, and on the intact side they were within 30.6 ± 0.7 °C and HFD = 71.8 ± 0.4 mW/cm^2. The time of reaching thermal "saturation" was 40.1 ± 0.2 seconds.

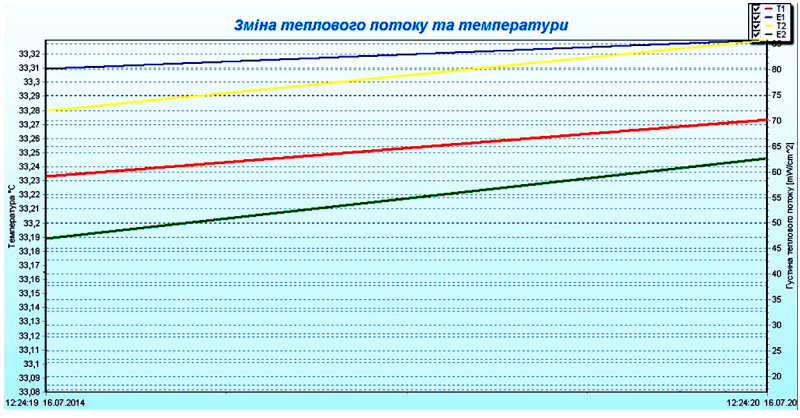

Fig. 2.4 Graphic representation of temperature and heat flow density indicators in the control group (patient Ch., 41 years old, medical history № 526475): T_1, T_2 – temperature values of the 1st and 2nd thermoelectric sensors; E_1, E_2 – density values heat flow of the 1st and 2nd thermoelectric sensor, respectively

In persons with signs of lumboschialgia, which arose against the background of hernias and protrusions between the vertebral discs in combination with instability in the lumbosacral spine (**Fig. 2.6**), the pain was bilateral, increased when bending or extending the spine and pro-

longed sitting, and decreased at rest. Movements in the lumbar spine were not limited, but painful, especially when bending. With the symptom of tension, there was bilateral pain in the lower back. Pallor of the skin, a feeling of burning, distension, asymmetry of white and red dermographism in the lower extremities were noted. Cyanosis, "marbling" of the skin was noted, mainly in the feet. Concomitant diseases were detected: varicose veins of the lower extremities and hemorrhoidal veins, which indicated a systemic weakness of the venous apparatus.

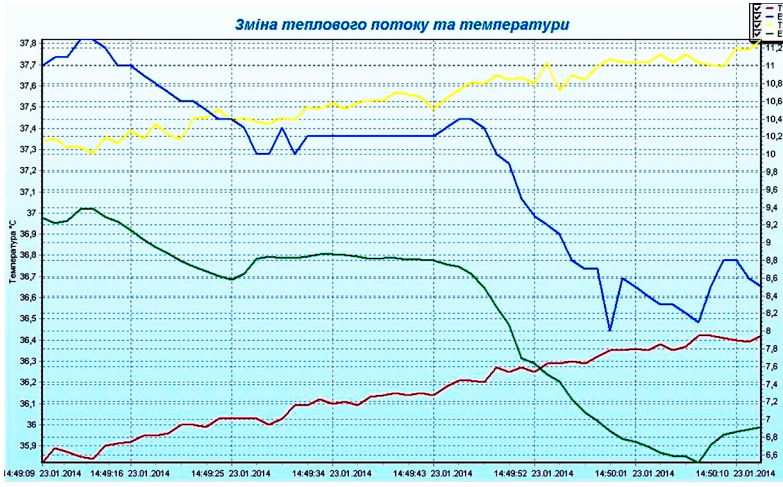

Fig. 2.5 Graphic representation of temperature and HFD indicators in patients with signs of lumboischialgia with hernias and protrusions between the vertebral discs without signs of instability in the Lumboischialgia (patient S., 36 years old, case history № 563818)

When thermometric studies were conducted in this group of patients, a tendency to the "scissors" symptom on the side of pain was observed (**Fig. 2.6** shows the intersection of the yellow and blue lines): a sharp rise in the heat flux density to 85.4 ± 0.6 mW/cm^2 with an almost unchanged skin temperature indicator on the side of pain (34.7 ± 0.2 °C); the time of reaching thermal "saturation" was reduced to 39.8 ± 0.8 sec. On the opposite side, in the paravertebral zone, there were slight fluctuations in thermometric indicators that did not go beyond the physiological norm (**Fig. 2.6**).

Patients whose pain syndrome arose against the background of stenosis of the spinal canal in the lumbosacral region of the spine noted that the pain syndrome lasted for more than two to three months and was not relieved by conventional painkillers and muscle relaxants. Only epidural adhesiolysis brought relief. During the focused examination, a decrease in HFD indicators was found in them on both sides, but more intensively on the dominant side of the pain (**Fig. 2.7**).

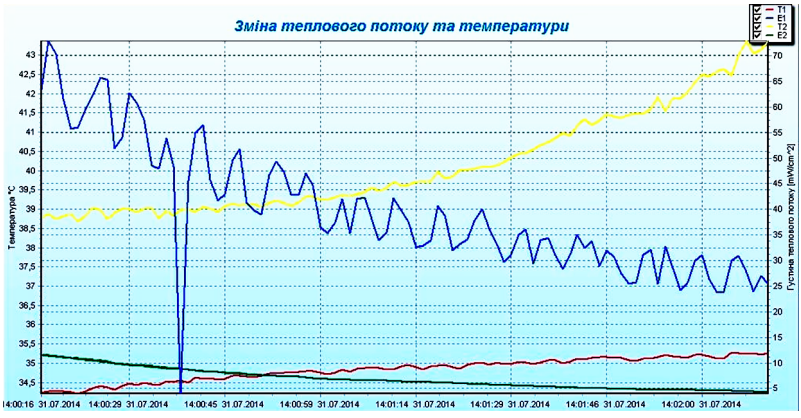

Fig. 2.6 Graphical representation of temperature and HFD indicators in patients with signs of lumboischialgia with hernias and protrusions between the vertebral discs in combination with instability in the Lumboischialgia (patient L., 50 years old, case history № 563009)

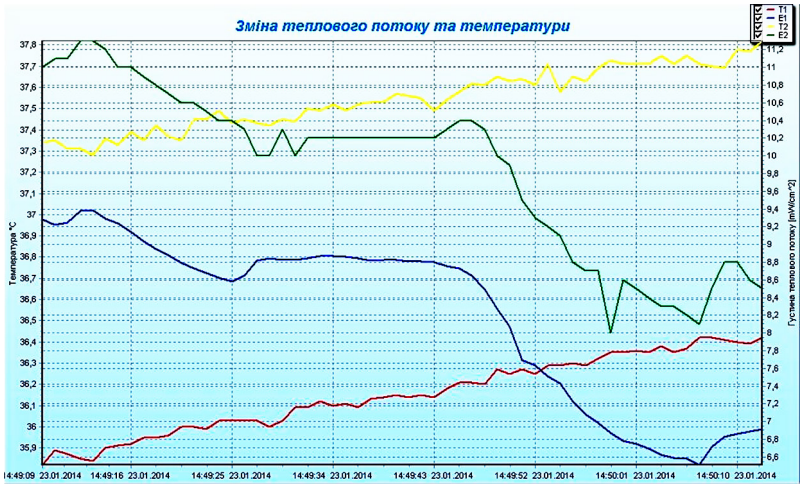

Fig. 2.7 Graphic representation of temperature indicators and HFD in patients with pain syndrome against the background of stenosis of the spinal canal at the lumbosacral level (patient A., 41 years old, medical history № 578193)

The object of this study was also 55 patients with chronic pain in the lumbosacral region of the spine. The pain was constant, radiated to one of the lower limbs, significantly limited their daily

activities, and worsened at night. Along with the use of nonsteroidal anti-inflammatory drugs, patients had to use anticonvulsants and antidepressants. The duration of the disease was 1–5 years. Age of patients: 49 ± 3.5 years. All patients were divided into two clinical groups.

The 1st clinical group included 39 people with unilateral lumboschialgia in the presence of hernias and protrusions of the intervertebral discs with signs of linear instability of the Lumboischialgia, who were subject to conservative treatment (main group).

The 2nd clinical group included 16 patients with unilateral lumboschialgia in the presence of hernias and protrusions of intervertebral discs without signs of linear instability of the Lumboischialgia, who were also subject to conservative treatment (comparison group).

The control group consisted of 10 people with no pain syndrome, in the presence of hernias and protrusions of the intervertebral discs, without signs of linear instability of the Lumboischialgia.

In all patients, the level of pain intensity was assessed using the verbal analogue scale (VAS). A scale of 100 mm length with millimeter divisions was used, which additionally every 20 mm contains words characterizing the intensity of pain: 0 – means no pain (initial point of the line), 20 mm – corresponds to the descriptor "weak", 40 mm – "moderate", 60 mm – "strong", 80 mm – "extremely strong", 100 mm – "unbearable" (endpoint of the line). Pain intensity was estimated in millimeters [3].

Thermoelectric sensors, in this case, were applied in the region of the spine symmetrically on both sides paravertebrally at the level of the spinous processes of the L_4–L_5 vertebrae. In addition to measuring thermometric indicators, heart rate variability was also determined, since both of these indicators are regulated by the autonomic nervous system, and the main centers of regulation of heat exchange and vascular tone are located nearby in the brain stem.

Spectral analysis of the heart rhythm made it possible to distinguish high-frequency respiratory waves (HF – high frequency), which reflect the tone of the parasympathetic nervous system, low-frequency waves (LF – low frequency), which reflect the state of the segmental baroreflex regulatory sympathetic mechanisms, and very low-frequency slow waves (VLF), which reflect the degree of activation of cerebral ergotropic systems. In addition, time characteristics were also analyzed: for the parasympathetic nervous system (RMSSD and Pnn 50 %), the sympathetic nervous system (SDNN), fluctuations of cerebral metabolic processes (SDANN), and the ratio of vegetative balance was determined by the formula of this ratio LF/HF. The obtained results were processed using the STATISTIKA 6.0 computer program package.

As research has shown, patients of the I clinical group complained of heartburn and pain in the lower back, lower limbs, and trophic disorders. Their backs were fixed in a bent position. Unilateral tension symptoms were positive, and 23 % of patients had crossed Lasegue symptoms. There was also a decrease in the range of motion in the lumbar region of the spine, tension in the muscles of the lumbar region, pain during palpation and percussion of paravertebral points, and a sharp limitation of inclinations in the direction of the lesion. In the position of lying on the back and with the lower limbs bent, the pain in the hip joints decreased. The pain had a pulling character, was accompanied by numbness and tingling in the lower limbs. The skin was pale, cold to the touch,

dry with signs of hyperkeratosis. White dermographism was noted. The intensity of the pain syndrome according to the VAS scale was 76.2 ± 4.1 mm.

In persons of the II clinical group, the pain was also unilateral, sometimes at night it tended to be bilateral, increased when bending or extending the spine and sitting for a long time, decreased at rest. Movements in the lumbar spine were not limited, but painful, especially when bending. With the symptom of tension, there was pain in the lower back. Pallor of the skin, a feeling of burning, distension, asymmetry of white and red dermographism in the lower extremities were noted. Cyanosis, "marbling" of the skin was noted, mainly in the feet. Concomitant diseases were detected: varicose veins of the lower extremities and hemorrhoidal veins, which indicated a systemic weakness of the venous apparatus. The intensity of the pain syndrome according to the VAS scale was 49.4 ± 3.9 mm.

The control group (10 people) had uniform temperature and heat flux density indicators on both sides within the limits: $T_0 = 33.2 \pm 0.5$ °C, $E_0 = 171.3 \pm 0.6$ mW/cm^2.

People of the main I group (39 people) had a symptom of "scissors" on the side of pain (temperature and heat flow density intersect on the side of pain), with a significant decrease in the values of heat flow density and a moderate increase in temperature on the injured side. The temperature indicators in the paravertebral area on the side of the pain were $T_1 = 34.2 \pm 1.7$ °C, and the heat flux density $E_1 = 26.8 \pm 4.9$ mW/cm^2 (**Table 2.4**). In our opinion, the occurrence of the symptom of "scissors" in the examined persons can be explained based on the well-known experimental studies of Viktor Veselovskyi [29], who found that when a peripheral nerve fiber is damaged, cold receptors are the first to suffer, which are 2–2.5 times more, than thermal ones.

In the II comparison group (16 people), a moderate decrease in heat flow density and a slight increase in temperature on the side of pain were found. The main thermometric parameters are as follows: $T_2 = 39.8 \pm 6.3$ °C, $E_2 = 120.6 \pm 99.2$ mW/cm^2 (**Table 2.5**).

As the analysis of the obtained results showed, in persons of the main I clinical group, the severity of the long-term chronic pain process is caused by a high degree of activity of metabolic processes both at the cellular level and at the level of cerebral ergotropic systems; there is a relative activation of both the sympathetic and parasympathetic autonomic nervous systems. Along with this, a weighted combination of drugs contributed to the maintenance of a weighted autonomic balance between the sympathetic and parasympathetic departments of the nervous system.

As the correlation analysis showed, in patients of the I clinical group, a high degree of correlation was recorded with indicators of skin temperature fluctuations in the superficial paravertebral areas in the lumbar region. A high degree of correlation was also observed when measuring the heat flux density. But these correlational changes indicated that the patients had more significant changes in the deep nervous processes with a tendency to form a predominance of the activity of the parasympathetic part of the nervous system, and this was indicated by the ratio of the LF/HF ratio, when a high correlation between this indicator was found and heat flow density indicator; reliability was $p < 0.05$.

In the comparison group (II clinical group), all negative weak correlations between heat flow density and heart rate variability were found, except for the HFn indicator, which also indicated the

role of parasympathetic reactions in the formation of heat flow density indicators in patients with signs of lumboschialgia according to absence of linear instability in the lumbar spine.

Table 2.4 Parameters of spectral and time characteristics of HRV in the I group

N = 39	**M ± m**	**T_1 = 34.2 ± 1.7 °C**	**E_1 = 26.8 ± 4.9 mW/cm²**
		Correlation coefficient, r	
Indicators (spectral characteristics):			
VLF, ms²	13,768.07 ± 7,361.08	0.65	0.28
LF, ms²	23,417.68 ± 14,962.65	0.76	0.37
HF, ms²	32,919.18 ± 21,321.92	0.84	0.44
LF/HF, c. u.	2.01 ± 0.55	–0.15	0
LFn, %	54.86 ± 4.37	–0.2	–0.3
HFn, %	45.14 ± 4.37	0.2	0.3
Indicators (time characteristics):			
SDNN, ms	156.11 ± 61.38	0.76	0.41
Pnn50, %	18.35 ± 7.01	0.65	0.57
RMSSD, ms	186.58 ± 86.67	0.81	0.46

Table 2.5 Parameters of spectral and time characteristics of HRV in the II group

N = 16	**M ± m**	**T_2 = 39.8 ± 6.3 °C**	**E_2 = 120.6 ± 99.2 mW/cm²**
		Correlation coefficient, r	
Indicators (spectral characteristics):			
VLF, ms²	21,608.2 ± 11,315.41	–0.09	–0.10
LF, ms²	60,093.9 ± 31,361.08	–0.06	–0.11
HF, ms²	114,969.2 ± 60,523.87	–0.07	–0.10
LF/HF, c. u.	1.0 ± 0.37	–0.13	–0.14
LFn, %	37.4 ± 3.57	–0.17	–0.28
HFn, %	60.5 ± 3.72	0.21	0.30
Indicators (time characteristics):			
SDNN, ms	287.5 ± 108.02	–0.02	–0.06
Pnn50, %	54.0 ± 22.07	0.08	–0.08
RMSSD, ms	383.7 ± 153.47	–0.02	–0.04

Therefore, the conducted preliminary clinical studies make it possible to diagnose inflammatory processes, in particular in the case of neurological manifestations of osteochondrosis of the spine, and to monitor the effectiveness of conservative treatment in degenerative-dystrophic diseases of the Lumboischialgia. Thus, the statistical set of clinical material will allow to improve the method of automatic processing of the obtained results, which in the future will allow to implement the proposed thermoelectric device in the primary medical care at the level of the family doctor's office and to automatically establish a diagnosis of persons with neurological vertebral disorders without the use of expensive radiation diagnostic devices.

CONCLUSIONS

1. It has been established that measuring the heat flow density of the human body is a new effective method of diagnosing neurological disorders in degenerative-dystrophic diseases of the spine. The study of changes in thermometric indicators of the skin in the lumbosacral region of the spine is a highly informative method of diagnosis and allows you to truthfully and effectively study these changes depending on the age and gender of the patient and to identify the main trends in the change in their condition over a certain period of time.

2. A thermoelectric device for measuring temperature and density of heat flows was developed and manufactured at the Institute of Thermoelectricity of the National Academy of Sciences of Ukraine and the Ministry of Education and Science of Ukraine. It was established that the simultaneous measurement of the temperature of the skin and the density of the heat flow with such a device allows to establish the nature of neurological complications in osteochondrosis of the human spine already in the early stages.

3. Determination of thermometric indicators in the lumbosacral region of the spine in persons with chronic pain syndrome against the background of degenerative-dystrophic pathology of the spine in the presence of hernias and protrusions of intervertebral discs allows to improve the diagnosis of neurological manifestations of this pathology, predict the course of this disease and choose an effective method of treatment.

4. It has been established that patients who undergo modern methods of spinal surgery for spinal disc herniation (SDH) require a balanced comprehensive examination by a neurologist to choose effective treatment tactics. Assessing the quality of life and determining the intensity of pain in the preoperative period in patients with SDH hernias in the Lumboischialgia allows for a more differentiated selection of the surgical intervention method for this pathology. Conducted studies have shown that individuals with neurological manifestations of osteochondrosis of the Lumboischialgia due to SDH herniations have hidden signs of fatigue, which can be detected by conducting studies using standardized fatigue scales.

5. The effectiveness of the application of the proposed thermoelectric device in medical practice has been confirmed, which in the future at the level of the family doctor's office will allow automatic

diagnosis of persons with neurological vertebral disorders without the use of expensive radiodiagnostic devices. The proposed device is promising for monitoring the temperature and thermal state of a person in real time, which makes it possible to detect inflammatory processes, various diseases in the early stages and carry out express diagnostics during a mass examination of patients.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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