ON THE EXTENT OF PREOPERATIVE RADIOLOGICAL AND CT EXAMINATION OF PATIENTS WITH DEGENERATIVE DISEASES OF THE LUMBAR SPINE

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Objective. To specify the extent of preoperative examination of patients with lumbar degenerative diseases and to study the effect of examination results on the tactics of surgical treatment.
Material and Methods. The study included retrospective analysis of 1340 patients with lumbar degenerative diseases treated in the Neurosurgical Department No. 2 of Novosibirsk RITO n.a. Ya.L. Tsivyan during 2017.
Results. The average height of the intervertebral disc as evaluated with MRI was 7.4 ± 1.8 mm, and that evaluated with MSCT — 4.9 ± 1.5 mm, with a statistically significant difference between them ($p < 0.05$). Immediate preoperative examination of patients with lumbar disc herniation showed reduction or lysis of the hernia fragment in some of them. Reduction of the leg pain and hernia size (by more than 50 %) and lysis of the herniated disc fragment evidenced by MRI were observed in 21 (3.2 %) patients. Comparison of the preplanned and actually performed extent of decompression and stabilization interventions showed that tactics and/or extent of surgical treatment changed in 37.6 % of cases.
Conclusion. The complex of instrumental radiological and neuroimaging studies, as well as methods of provocative procedure in the lumbar spine performed immediately before the planned surgical treatment allow choosing the proper treatment tactics, specifying or correcting the volume of surgical treatment, and to prognosing its outcome in lumbar degenerative diseases.
Key Words: preoperative examination, lumbar degenerative disease, planning of surgical intervention.

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Currently, spinal neurosurgery is one of the actively developing medical disciplines. The results of surgical treatment are obviously superior to those of conservative therapy in patients with degenerative spinal pathology [6, 15, 16, 20]. However, there is also a critical viewpoint regarding the effectiveness of surgical treatment. According to the literature [8, 11, 19], poor outcomes of surgical treatment of degenerative spinal diseases, referred to in the literature as the Failed Back Surgery Syndrome, account for 5.0—74.6 %, and related reoperation rate is 13.4—35.0 %. Preoperative examination of patients and careful planning of the tactics and extent of surgical treatment is one of the most important preconditions for a favorable surgical outcome [1—3, 5, 10].

Advances in radiodiagnosis have reduced the blind spots in the treatment of most degenerative spinal diseases. However, the choice of the method and required extent of survey should be specified and justified from the clinical viewpoint.

The study was aimed at specifying the extent of preoperative examination of patients with degenerative lumbar diseases and studying the impact of examination results on the tactics of surgical treatment.

Material and Methods

We carried out a retrospective analysis of data of 1340 patients with degenerative lumbar diseases who were admitted to the neurosurgical department No 2 of the Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan in 2017. All patients were selected for surgical treatment after consultative visit, on-site or remote consultations.

The intensity of pain in the lumbar spine and lower extremities was assessed using the 10-point VAS scale; the level of patient's disability was assessed using the Oswestry questionnaire.

X-ray examination of the lumbar spine in the standard projections (fron-

tal and lateral) with functional tests in the maximum flexion and extension position was used to assess the state of the vertebral bodies, interbody spaces, joints, arches, intervertebral disc height, lumbar lordosis, the range of segmental motion, and the presence and degree of vertebral body displacement. The diagnosis of segmental instability is a challenging and ambiguous problem. In everyday practice, we were guided by the principles set forth by A.V. Krutko et al. [4]. The patients with signs of osteoporosis (coarse bone pattern, thinned cortical layer, pronounced margins of the cortical layer), as well as patients older than 50 years underwent a densitometric study. Sagittal balance was assessed using X-ray images of the spine including hip joints and the upper third of the femur in patient's standing position in the lateral projection. X-rays images were processed using the K-Pacs software, the sagittal balance parameters were measured using the Surgimap Spine software.

The severity of degenerative-dystrophic changes in the vertebral segment was assessed according to MRI, including the height, hydration, and degeneration of the intervertebral disc, its topography, spinal canal structure and its contents, the presence of protrusions, hernias, displaced fragments, sequesters, their size, localization (median, paramedian, posterolateral, foraminal, extraphoraminal), the relationship between the hernial protrusion and neurovascular structures. The type of hernia was determined based on MRT scans according to the classification proposed by the North American Spine Society in 2001 as a protrusion, extrusion, or sequestered hernia. The degree of the intervertebral disc degeneration was determined according to the classification of Pfirrmann. The state of the endplates and the reactive changes in the bone marrow in the subchondral parts of the vertebral bodies associated with the degenerative-dystrophic process were evaluated according to the Modic classification. In the case of doubtful nature of the substrate, contrast-enhanced MRI was performed for differential diagnosis of the hernial fragment and/or scar tissue, and space-occupying masses of the nerve roots.

MSCT was performed to determine the condition of the vertebral bodies, presence of osteophytes, vacuum phenomenon of the intervertebral disc, condition of the facet joints, size of the spinal canal, degree and nature of compressing pathomorphological changes, topography and size of the pedicles, anteroposterior size of the vertebral bodies, intervertebral disc height, condition of the endplates and the entrance to the disc from the spinal canal.

When the pathomorphological substrate causing the symptoms of compression of the spinal nerve roots could not be clearly and unambiguously identified using X-ray, CT, and MRT data, examination complex was supplemented with radiopaque myelography.

About 80 % of patients were admitted to the hospital more than 3 months after the last examination. For this reason, additional tests were carried out just before the operation. Examination of patients scheduled for single-level decompression surgery included MRI and X-ray examination of the lumbar spine. In patients admitted for decompression and stabilization surgery, examination was supplemented with MSCT and X-ray examination of the spine in step mode. MSCT was also carried out in patients with herniated discs to determine the possibility of reconstruction of the annulus fibrosus defect.

Statistical analysis of the data was carried out using the Microsoft Excel-2016 software. Descriptive statistics are presented in the form M ± SD, where M is the mean value and SD is the standard deviation. The statistical significance of the difference between the values was determined using the Student's t-test. The differences were considered significant at $p < 0.05$.

Results

In 2017, 1340 patients were admitted to the neurosurgical department No 2 of the Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, including 1185 patients with degenerative diseases of the spine, who were operated on. The average age of the patients was 55.5 ± 11.5 years. There were more females (59.2 %). Preoperative examination in the hospital was used to verify the pathological substrate, specify and plan the tactics and extent of surgical treatment.

Two groups of patients were retrospectively formed in this study:

1) Patients with degenerative lumbar diseases who required decompression without rigid fixation elements (n = 153);

2) Patients with degenerative lumbar diseases who required rigid decompression and stabilization interventions (n = 417).

Patients with degenerative lumbar diseases, requiring decompression surgery without rigid fixation elements. The proportion of herniated intervertebral discs accounted for 45.6 % (588 patients) in the pattern of degenerative lumbar pathology in 2017. We selected a group of patients with lumbar intervertebral disc herniation associated with high risk of recurrence in the postoperative period, which was predicted based on radiological parameters: high disc, protrusion-type herniation, Pfirrmann's grade III disc degeneration, flattening of lumbar lordosis [7, 9]. A group of 153 (23.8 %) patients with herniated lumbar intervertebral discs was formed taking into account these parameters.

Reconstruction of the defect of the annulus fibrosus after microdiscectomy was considered as a possible treatment option in this category of patients. It was recommended in patients with herniated disc at the levels L2—L3, L3—L4, L4—L5, L5—S1 with an intervertebral disc height of more than 5 mm in the posterior sections as shown by MRI [14]. The final decision whether to insert the implant was taken intraoperatively based on the result of measurement of the interbody space and the defect of the annulus fibrous. The technique was actually used in 85 (55.6 %) of 153 patients who were previously scheduled for reconstruction of the defect of the annulus fibrosus, since insufficient intervertebral disc height was intraoperatively detected in

some patients. In 33 (21.6 %) patients, MSCT detected erosive and resorptive lesions of the endplates of the vertebral bodies; however, the location and size of these changes did not preclude from grafting.

A retrospective analysis of the preoperative examination data of the remaining 68 (44.4 %) patients showed that the average height of the disc was 7.4 ± 1.8 mm according to MRI and 4.9 ± 1.5 mm according to MSCT. There was a statistically significant difference between these values ($p < 0.05$). There were also marginal osteophytes of the vertebral bodies, narrow interbody spaces (<5 mm), vacuum phenomenon of the intervertebral disc, and ossification of the hernial protrusion (Table 1).

Case 1. Patient T., 65 years old, complained of persistent pain in the lumbar spine and inguinal areas, more intense on the left. MRI (Fig. 1) showed multiple degenerative changes in the lumbar spine, herniated disc at L2—L3, Modic 1 changes in adjacent parts of the L2—L3 and L5—S1 vertebral bodies.

X-ray examination of the lumbar spine with functional tests (flexion, extension) showed no segmental instability. However, the absence of segmental lordosis was found at the level of L2—L3. Parameters of the global sagittal balance and vertebropelvic relationships are compensated. MSCT of the lumbar spine (Fig. 2) showed ossification of the hernial fragment at the level of L2—L3, degenerative stenosis of the spinal canal at the level of L2—L3. Based on the patient's complaints, history, and additional research methods, it was decided to perform decompression and stabilization operation at the level of L2—L3.

Therefore, SCT can be used in patients with herniated lumbar intervertebral discs to measure the actual disc height at the preoperative stage, to detect usurations, marginal osteophytes, ossification of the hernial fragment, and to decide whether reconstruction of the annulus fibrosus is possible.

Reduction or lysis of a hernial fragment was detected in some patients during preoperative examination. Decrease in radicular pain and dimensions of roots by 50 % or more and lysis of the disc herniation fragment as evidenced by MRI was observed in 21 (3.2 %) patients. Characteristics of patients are shown in Table 2.

Case 2. Patient M., 27 years old, was examined and consulted by neurosurgeon. He was diagnosed with osteochondrosis of the lumbar spine, herniated disc at L4—L5 on the left, degenerative stenosis of the spinal canal at the level of L4—L5, and compression-ischemic radiculopathy of L5 on the left and sent to surgical treatment. When he was admitted to the hospital (3 months later), decrease in the intensity of pain in the lower limbs was observed. Repeated MRI examination of the lumbar spine showed significant decrease in disc herniation size at the level of L4—L5, which allowed to avoid surgical treatment (Fig. 3).

In our small cohort of patients, regression of lumbar disc herniation was mainly observed in males (61.9 % of cases), most often at the level of L4—L5 (56.5 %). The average age of the patients was 43.1 ± 11.6 years. Sequestered hernias were observed in 65.2 % of cases.

According to the medical history, the duration of the radicular pain in these patients was 4.4 ± 1.9 months. Despite the fact that the time of MRI study did not match the onset and remission of radicular symptoms for objective reasons, the time interval between MRI studies can be considered as the disc herniation regression period. It averaged 2.9 ± 1.8 months.

The intensity of the pain in the back and leg during the exacerbation was 4.6 ± 0.8 and 5.7 ± 0.8 points as assessed by VAS score. After regression of disc hernia, these values were 3.9 ± 1.4 and 1.7 ± 0.9 points, respectively. Despite the persistence of pain in the lumbar spine, the patients' quality of life improved as evidenced by the Oswestry index (52.4 ± 5.5% during exacerbation and 23.8 ± 10.2% after hernia regression).

In two patients, two-level regression of disc hernia was observed. In one case, both hernias decreased in size; in the second case, there was decrease in hernia size at one level and lysis of hernial protrusion at the other level.

Lysis of the hernial fragment was observed in one patient with recurrent disc herniation at the level of L4—L5. Recurrent disc herniation was observed 2 months after microdiscectomy and

Table 1
Characteristics of patients with herniated lumbar intervertebral discs and high risk of recurrence

Parameter	Value
Number of patients, n	153
Age, years	47.5 ± 9.5
Sex, n (%)	
Males	48 (31.4)
Females	105 (68.6)
Level, n (%)	
L3—L4	7 (4.6)
L4—L5	59 (38.6)
L5—S1	87 (56.8)
Vacuum phenomenon of the intervertebral disc, n (%)	12 (7.8)
Marginal osteophytes of the vertebral bodies, n (%)	21 (13.7)
Ossification of the hernial fragment, n (%)	8 (5.2)
Resorption foci in the endplates of the overlying vertebra, n (%)	1 9 (12.4)
Resorption foci in the endplates of the underlying vertebra, n (%)	14 (9.2)
Height of the posterior disc portions as shown by MRI, mm	7.4 ± 1.8*
Height of the posterior disc portions as shown by MSCT, mm	4.9 ± 1.5*

*p < 0,05.

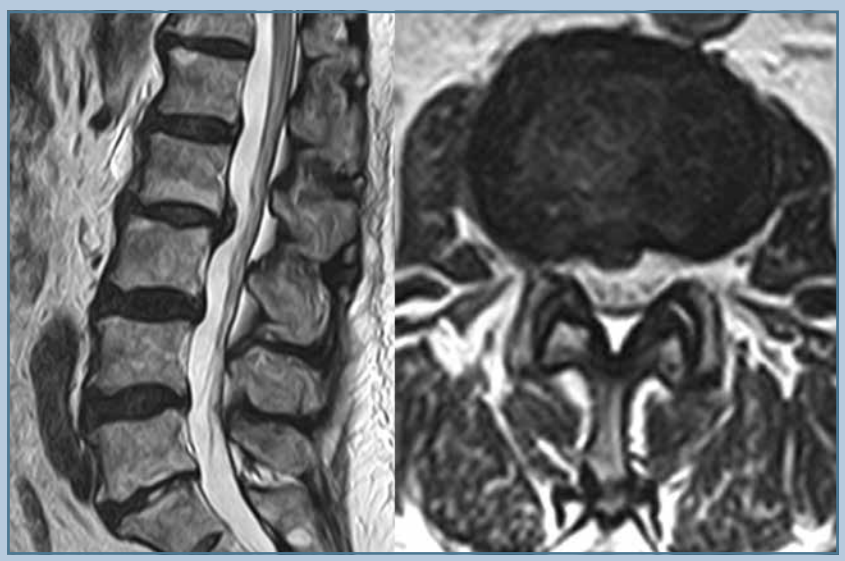

Fig. 1
MRI of the lumbar spine of the patient T., 65 years old, sagittal and axial slices at the level of L2—L3

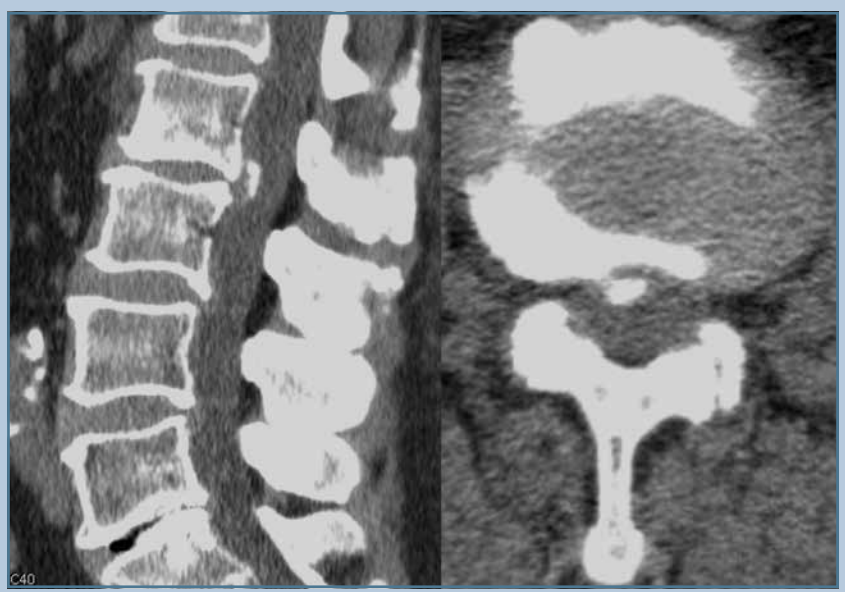

Fig. 2
MSCT of the lumbar spine of the patient T., 65 years old, sagittal and axial slices at the level of L2—L3

interspinous dynamic fixation. Lysis of the hernial fragment was observed in 5 months.

In one case, relapse of radicular pain was observed in 3 months. Previously, significant decrease in the size of hernial fragment was observed as evidenced by decrease in the characteristic radicular pain syndrome. MRI of the lumbar spine showed anterior disc herniation. Given the frequent recurrence and ineffectiveness of conservative therapy, the patient underwent decompression and stabilization surgery. In other cases, there were no relapse of radicular pain syndrome and/or disc herniation requiring surgical treatment.

Therefore, MRI of the lumbar spine in patients with herniated lumbar intervertebral discs just before surgery enabled avoiding surgical treatment in cases of lysis or significant reduction of the hernial fragment.

Patients with degenerative lumbar diseases, requiring rigid decompression and stabilization surgery. The average age of the patients was 58.3 ± 10.3 years. There were 191 (45.8 %) males and 226 (54.2 %) females. Single-level surgery was carried out in 275 (65.9%) patients, two-level — in 103 (24.7 %) patients, three-level or more — 39 (9.4 %) patients. In all cases, surgery was carried out taking into account the parameters of the sagittal balance. Corrective interventions included Shevron, SPO, and PSO vertebrectomies. The following variants of interbody fusion were used: ALIF, DLIF, TLIF, and PLIF. In most cases, transpedicular fixation was carried out transcutaneously using minimally invasive techniques. Characteristics of patients are shown in Table 3.

Compression radicular syndrome, persistent lumbalgia or lumboischialgia, neurogenic intermittent claudication syndrome, and compression radiculopathy were the most common clinical manifestations of degenerative disease. Deviations in the sagittal balance parameters were detected in 229 (54.9%) patients.

Analysis of preplanned surgical procedures and actually performed operations showed that tactics and/or extent of surgical treatment was changed in 37.6 % of cases (157 patients; Table 4). In this group of patients, surgical treatment was planned based on findings of the multimodal X-ray, tomographic, and, in some cases, puncture examination. Puncture-based diagnostic examinations were performed in 69 cases (16.5 %).

The most significant change in the extent of surgical intervention occurred in the cases where single-level decompression and stabilization surgery was planned, 89 (21.3 %) cases. In patients

Table 2
Characteristics of patients with regression of lumbar disc herniation

Parameter	Value
Number of patients, n (%)	21
Number of hernias, n	23
Sex, n (%)	
Males	13 (61.9)
Females	8 (38.1)
Age	43.1 ± 11.6
Level, n (%)	
L3—L4	3 (13)
L4—L5	13 (56.5)
L5—S1	7 (30.5)
Smoking, n (%)	
Yes	12 (57.1)
No	9 (42.9)
Type of hernia, n (%)	
Protrusion	6 (26.1)
Extrusion	2 (8.7)
Sequestered	15 (65.2)
VAS: back during exacerbation, points	4.6 ± 0.8
VAS: back during regression, points	3.9 ± 1.4
VAS: leg during exacerbation, points	5.7 ± 0.8
VAS: leg during regression, points	1.7 ± 0.9
ODI during exacerbations	52.4 ± 5.5
ODI during regression	23.8 ± 10.2
Change in disc hernia, n (%)	
Lysis	13 (56.5)
Decrease in hernia size	10 (43.5)
Time of lysis or decrease in hernial fragment, months*	2.9 ± 1.8
Duration of radicular symptoms, months	4.4 ± 1.9

*the time interval between MRI studies that detected lysis or reduction of the hernial fragment.

who were scheduled for decompression and stabilization surgery on two or more spinal motion segments, the extent of actual operation differed from the planned one in 68 (16.3 %) cases. The change in the extent of surgical treatment was mainly due to abnormal parameters of the sagittal balance.

Case 3. Patient P., 71 years old, complained of pains and burning in the lumbar spine and along the posterior surface of both legs, weakness in the legs when walking for a distance of 10—15 m. Medical history showed that the patients suffered from pain in the lumbar spine for 5 years and from pain in the legs for the last 2 years. The patient was sent for surgical treatment in connection with ineffective conservative therapy.

MRI of the lumbar spine showed degenerative spondylolisthesis of L3 and degenerative spinal stenosis at the level of L3—L4 (Fig. 4).

X-ray examination of the lumbar spine showed extended degenerative changes in the lumbar spine and grade I degenerative ante-spondylolisthesis of L3 (Fig. 5).

Taking into account the patient's complaints, as well as X-ray and tomographic data, the primary plan of operation suggested decompression and stabilization surgery at the level of L3—L4. The patient underwent X-ray examination of the spine including the upper third of the thighs in standing position in the lateral projection (Fig. 6). Abnormal parameters of the sagittal balance in the form of lumbar lordosis, forward inclination of the body, (SVA approximately 138 mm), and high RT value (31.1°) were detected. Compensatory mechanisms in the form of reduced thoracic kyphosis and flexion of knee joints were observed.

The patient was offered with surgical treatment in the form of L4 pedicle subtraction osteotomy (PSO) taking into account Roussouly type III lordosis, L3 laminectomy, decompression of the spinal nerve roots, transpedicular fixation of the lower thoracic and lumbar spine, including pelvic bones.

Thus, we believe that complex preoperative examination is required when planning decompression and stabilization operations in patients with degenerative lumbar diseases. Complex evaluation of degenerative spinal pathology with allowance for the data of neuroimaging studies and parameters of the sagittal balance enables selecting an effective surgical strategy.

Discussion

X-ray and neuroimaging techniques play an important role in the diagnosis and surgical treatment of patients with degenerative diseases of the spine. The results obtained in this study show that multimodal preoperative examination provides data that are used to plan treatment strategy.

We reported the largest series of cases of spontaneous regression of lumbar intervertebral disc herniation (21 patients). The review by Yang et al. [22] provides data from 9 studies reporting 22 cases of spontaneous regression of disc herniation. On the average, reduction or lysis of hernial protrusions was observed within 5.5 months. Extrusion and sequestered hernias were the most common ones. The results of our observations agree with the data of Yang et al. However, the time of regression of disc herniation is somewhat shorter in our studies, 2.9 months.

Although there are no publications reporting the time of repeated preop-

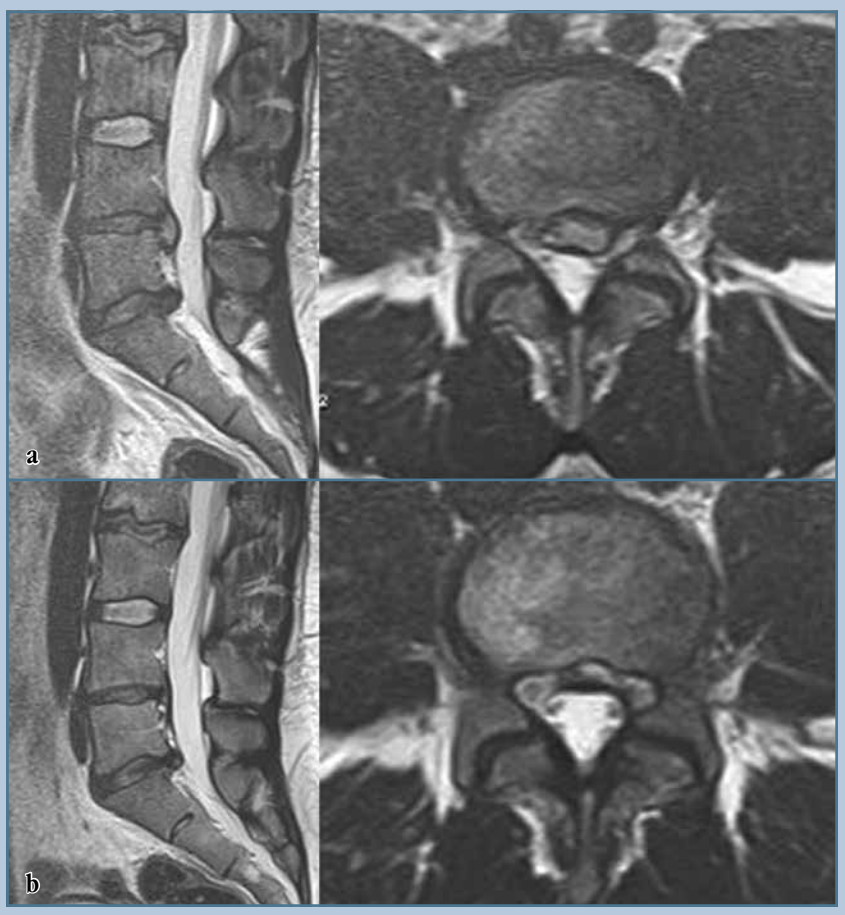

Fig. 3
MRI of the lumbar spine of the patient M., 27 years old, sagittal and axial slices at the level of L4—L5 **(a)**, sagittal and axial slices in 3 months **(b)**

Table 3
Nosologic characteristics of patients

Nosology	Patients, n (%)
Degenerative stenosis of the spinal canal	73 (17.5)
Degenerative spondylolisthesis	154 (36.9)
Isthmic/dysplastic spondylolisthesis	68 (16.3)
Degenerative scoliosis	20 (4.8)
Segmental instability	6 (1.4)
Herniated intervertebral disc	41 (9.8)
Recurrent disc herniation	28 (6.7)
Pseudoarthrosis, failure of the metal structure	11 (2.6)
Pathology of the adjacent segment	16 (3.8)
Including patients with abnormal parameters of sagittal balance	229 (54.9)

erative MRI studies in patients with herniated lumbar intervertebral discs and it was mainly determined individually, our practice shows that diagnostic value of MRI of the lumbar spine in patients with degenerative diseases is on the average no more than 1 month.

Wide variety of clinical manifestations of degenerative spinal diseases caused the development of a large number of implants for surgical treatment of patients. The procedure for reconstruction of the defect of the annulus fibrosus after limited microdiscectomy in patients with herniated lumbar intervertebral discs is actively discussed and implemented. This technique can be useful for patients with a high risk of disc herniation recurrence, which can be predicted by evaluating the predictors based on analysis of preoperative radiological and tomographic studies [7, 18]. In our study, high risk of disc herniation recurrence after microdiscectomy was observed in 23.8 % of patients admitted for surgical treatment. Preoperative MSCT of the lumbar spine showed the true disc height that significantly differed from the results of MRI study, which allowed us to select the correct treatment strategy. We believe that intervertebral disc height should be evaluated only based on SCT data, and this, in turn, determines the possibility of using the Barricaid system at the preoperative stage.

X-ray and neuroimaging methods of examination are not always capable of identifying clinical and pathomorphological correspondence. In the case of polysegmental degenerative lesions of the lumbar spine, the choice of the tactics and extent of the surgery should be based on the results of provocative tests (discography, stimulation of the roots at the foraminal openings, drug-induced and provocative action on the spinal motion segment). According to the literature [17, 21], the outcomes of surgical treatment turned out to be better in patients with pathomorphological substrates identified based on the results of tomographic studies and verified by provocative tests.

In 2017, we used puncture-based treatment and diagnostic methods affect-

Table 4
Characteristics of planned and actual surgery

Decompression and stabilization surgery	Planned. n (%)	Carried out. n (%)
On one spinal motion segment	271 (65.0)	262 (62.8)
On two spinal motion segments	127 (30.4)	113 (27.1)
On three spinal motion segments	19 (4.6)	42 (10.1)

ing the spinal motion segment in 16.5 % of cases, mainly in patients with multilevel degenerative changes, in order to identify the source of the pain syndrome and determine the optimal extent of surgical treatment. This stage of preoperative examination enabled identifying the source of the pain syndrome and correct selection of the tactics and extent of surgical treatment to improve its outcome.

Special attention should be paid to patients with degenerative lumbar diseases with abnormal parameters of the sagittal balance. Le Huec et al. [13] studied the effect of sagittal balance parameters on the clinical outcome of surgical treatment in patients with degenerative diseases of the spine. They found a correlation between the sagittal balance parameters and clinical outcome, the incidence of adjacent segment pathology, and patient's satisfaction. The authors concluded that intraoperative restoration of segmental lordosis plays great clinical and prognostic role in the outcome of surgical treatment of degenerative spinal diseases.

The results of our studies showed that degenerative spondylolisthesis and spinal stenosis in 80% of cases occur in combination with abnormal parameters of the sagittal balance. Assessment of these parameters should be an integral part of preoperative examination of patients with degenerative diseases of the spine [1, 12]. Of course, high-quality X-ray examination of the spine in the step mode should be used for this purpose with the software for more accurate assessment of the sagittal balance parameters. The study of the sagittal balance parameters enables surgeon to specify the extent of surgical treatment and to make a weighted decision about the need for surgical treatment, which was demonstrated by the case 3. The tactics and/or extent of surgical treatment was changed in 246 (20.4 %) patients as a result of multimodal preoperative examination.

Conclusion

The complex of instrumental X-ray and neuroimaging studies, as well as the puncture-based methods for the diagnosis of pain substrate in the lumbar spine carried out just before the planned surgical treatment enable surgeon to select the correct treatment tactics, specify or adjust the extent of surgical treatment, and predict its outcome in patients with degenerative diseases of the lumbar spine.

The study was not sponsored. The authors declare no conflict of interest.

Fig. 4
MRI of the lumbar spine of patient P., 71 years old, sagittal and axial slices at the level of L3—L4

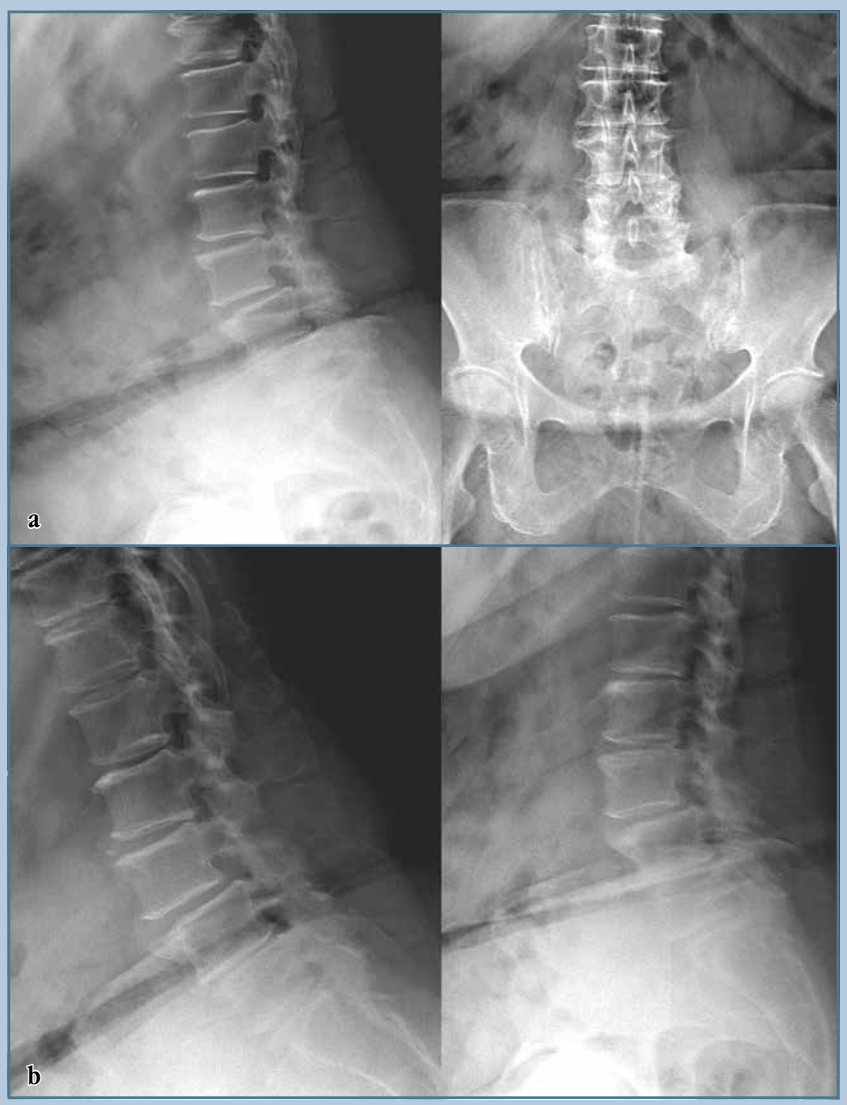

Fig. 5
X-ray image of the lumbar spine of patient P., 71 years old, in lateral and frontal projections **(a)**, in the flexion and extension position **(b)**

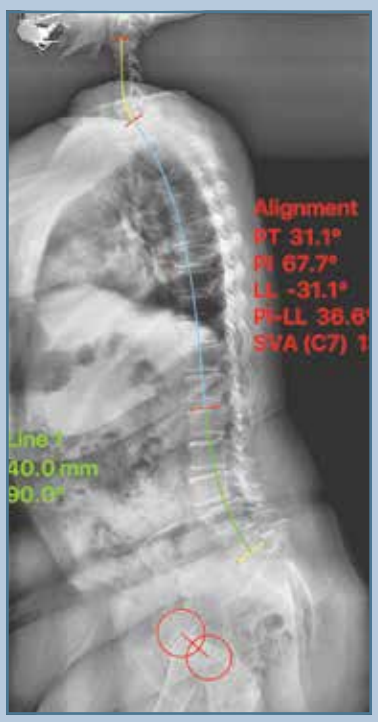

Fig. 6
Radiography of the spine of patient P., 71 years old, including the upper third of the thighs in standing position in the lateral projection

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