PERCUTANEOUS ENDOSCOPIC TRANSFORAMINAL AND INTERLAMINAR LUMBAR DISCECTOMY FOR CRANIALLY MIGRATED DISC HERNIA

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Objective. To evaluate clinical outcomes, safety, and technical peculiarities of percutaneous endoscopic transforaminal and interlaminar removal of the lumber spine cranially migrated disc hernias.
Material and Methods. In 2015–2018, percutaneous endoscopic transforaminal and interlaminar removal of cranially migrated hernias of the lumbar spine was performed in 53 patients (23 men and 30 women): 2 (3.8 %) at L2–L3 level, 13 (24.5 %) at L3–L4, 18 (34.0 %) at L4–L5, and 20 (37.7 %) at L5–S1. The age of patients ranged from 25 to 76 years and averaged 43.4 ± 11.6 years. Transforaminal approach was performed at the L4–L5 level and higher (62.3 % of cases), and interlaminar approach – at the L5–S1 level (37.7 %). Based on MRI, hernias with cranial migration were divided into zones: zone I – hernias with migration to the lower edge of the superjacent vertebra pedicle – 21 (39.6 %) patients; and zone II – hernias with migration above this border – 32 (60.4 %). Results were evaluated using ODI, VAS, and the McNab scale. Statistical analysis of VAS indicators (leg and back pain) and ODI scores before and after surgery was performed using the R and Microsoft Excel 2007 software.
Results. Data collection was carried out using patient questionnaires at in-person examination, telephone interviews and electronic communications. Follow-up data of different terms were monitored in all patients. In one case (when mastering this technology), at the second stage, microdiscectomy was performed at the L4–L5 level for a residual hernia fragment in migration zone II, and in another case, a conversion into microdiscectomy was performed at L3–L4 level with a hernia in zone II due to lack of venous bleeding control in a patient receiving anticoagulants. In other patients, the mean VAS scores of preoperative radicular and axial pain decreased from 7.5 ± 1.4 and 3.8 ± 1.2 to 1.4 ± 1.2 and 3.5 ± 1.3, respectively, on the next day, to 1.7 ± 1.4 and 3.2 ± 1.1 in 1 month, to 1.5 ± 1.3 and 2.8 ± 1.4 in 6 months, to 1.6 ± 1.2 and 2.0 ± 1.3 in 12 months, and to 1.6 ± 1.2 and 2.0 ± 1.3 in 24 months after surgery. In the long-term follow-up period, no radicular leg pain was observed in any patient. According to the McNab scale, up to 6 months treatment results were assessed as excellent by 19 (35.8 %) patients, and as good – by 32 (60.3 %). In the case of lumbar pain in the long term period, blockade of facet joints and radiofrequency ablation of the medial nerve branch were performed. Relapse of hernias and instability of the operated spinal segment were not revealed. The average ODI score improved from 66.4 ± 7.2 to 20.5 ± 3.2 in 1 month, to 13.6 ± 2.1 in 6 months, to 12.4 ± 2.3 in 12 months, and to 12.4 ± 2.3 in 24 months after surgery.
Conclusion. Percutaneous endoscopic transforaminal and interlaminar discectomy for cranially migrated lumbar disc hernia, while adhering the surgical technique target and exclusion criteria, is a safe and effective method, avoids excessive resection of the bone-ligamentous structures of the spine, can prevent iatrogenic instability of the spinal motion segment, and promotes early postoperative activation and recovery of the patient. Cranially migrated disc henias have a low probability of recurrence.
Key Words: percutaneous endoscopic transforaminal and interlaminar cranially migrated lumbar hernia discectomy.
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Conventional microsurgery for hernias of the lumbar spine with cranial migration is carried out through the interlaminar approach, which often requires wide resection of the interarticular portion of the vertebral arch and facet joint, especially in the upper spinal motion segments [1, 2]. Such resection can cause segmental instability of the spinal motion segment and local vertebrogenic back pain [3–5]. Percutaneous endoscopic surgeries allow removing such hernias by using the transforaminal and interlaminar approaches [6–8]. In 1951, Hult [9] was the first to introduce the concept of indirect decompression of the spinal canal by nucleotomy through the anterolateral extraperitoneal approach. In a real sense, minimally invasive spinal surgery was first introduced into practice by L.Smith. In 1963, he performed intradiscal injection of chymopapain using the posterolateral approach. Having been encouraged by the results of chemonucleolysis in the early 1970's, Kambin [10] initiated a study on the possibility of indirect decompression of the spinal canal via nucleotomy through the posterolateral approach using a Craig cannula. Percutaneous discectomy was first described by Hijikata et al. [11] in 1975. Since then, new approaches and techniques of percutaneous endoscopic transforaminal discectomy have been improved, developed, and introduced [6, 12–15].

Currently, percutaneous endoscopic transforaminal lumbar discectomy is considered as an alternative to conventional microdiscectomy with some advantages associated with minimal invasiveness and the possibility of using it in a day-surgery protocol [14, 16–18]. The concept of transforaminal surgery has undergone changes from intradiscal decompression to intracanal epiduroscopic targeted removal of hernia fragments, especially in cases of migrated disc herniation [13, 14, 16, 19–21]. Other researchers described percutaneous endoscopic resection of highly migrated disc herniation using the interlaminar approach [22]. The authors found the approach to be advantageous due to the absence of the risk of exiting root injury and the possibility of removing highly migrated hernia fragments. The main cause of failures in endoscopic lumbar discectomy is migration of hernia sequestration. It should be noted that all transforaminal interventions for intervertebral disc herniation pass through the "triangle of safety" described by Kambin [10] and named after him. Technical peculiarities of transforaminal discectomy depend on the location relative to the disc and the spinal canal, the direction and degree of migration of hernia sequestration, as well as the presence of stenotic changes, since the main principle of this surgery is its targeted action. Based on the MRI data, a series of authors [14–16, 19] proposed anatomical classification of hernia location relative to the position of the disc, intervertebral foramen, and vertebral pedicle. Consideration of these features, as well as the principle of targeting, in our opinion, play a key role in the success of endoscopic transforaminal and interlaminar approaches.

The aim of the study was to evaluate the clinical outcomes, safety, and technical peculiarities of percutaneous endoscopic transforaminal and interlaminar resection of lumbar disc herniation with cranial migration.

Material and Methods

Percutaneous endoscopic transforaminal and interlaminar resection of lumbar disc herniation with cranial migration was performed in 53 patients (23 men and 30 women) in the period of 2015–2018: two (3.8 %) interventions at the L2–L3 level, 13 (24.5 %) surgeries at L3–L4, as well as 18 (34.0 %) and 20 (37.7 %) operations at the L4–L5 and L5–S1 levels, respectively. The patients' age ranged from 25 to 76 years and averaged 43.4 ± 11.6 years. Transforaminal approach was performed at the L4–L5 level and above; interlaminar approach was carried out at the L5–S1 level. All patients underwent MRI prior to surgery. Hernias were divided into two migration zones based on the MRI data: zone I included hernias with migration to the lower edge of the superjacent vertebral pedicle (21 (39.6 %) patients); zone II involved hernias with migration above this border (32 (60.4 %) cases)

The inclusion criteria were the following: hernias of specific localization; ipsilateral compression of the exiting root with radicular pain in the leg and/or focal neurological symptoms in the form of leg numbness and weakness of varying severity corresponding to the level of root compression provided that no effect of conservative therapy was observed.

The exclusion criteria included significant narrowing of the intervertebral foramen preventing the safe placement of a working cannula for the exiting root in the region of the vertebral pedicle and intervertebral foramen, especially hernias of migration zone II; complete median sequestration of hernia (usually clinically insignificant); concomitant severe stenosis of the spinal canal.

A C-arm X-ray system (Philips BV Endura), a Vertebris endoscopic spinal instrumentation (Richard Wolf) with a 4.1-mm working channel, and a CombiDrive microsurgery burr with a flexible tip (Richard Wolf) were used during surgery.

The ODI, VAS, and McNab scales were used to assess the results of surgical treatment. The data were evaluated before surgery, on the next day, and one, six, 12, and 24 months after operation. Statistical analysis of VAS (leg pain), VAS (back pain), and ODI scores was performed before and after surgery during the follow-up period using the R software package (t.test function of the package "stats" with the following parameters: two-tailed test, dependent samples, confidence probability of 0.95; equal variances for VAS (leg pain) and VAS (back pain), unequal variances for ODI) and Microsoft Excel 2007.

Surgery technique. Surgeries were performed under general anesthesia with the patient in the prone position and X-ray navigation in the frontal and lateral projections. The entry point for transforaminal approach was calculated from the MRI measurements in the Dicom format and then marked on the lateral abdominal wall under lateral X-Ray control. A line parallel to the lower vertebral endplate was marked in frontal projection. A 0.7-cm incision was made at the intersection of the lines. Position of the entry point relative to the midline may vary significantly depending on the patient's constitution. A more medial posterolateral approach was performed at levels L1–L2 and L2–L3 due to the risk of injury to internal organs [23]. A more lateral approach is most feasible for levels L3–L4 and below, since it creates favorable conditions for intracanal placement of the working cannula, thus avoiding the intradiscal approach [13].

An 18G needle was guided under the C-arm control until reaching the lower edge of the fibrous ring or the superior endplate. The needle tip was placed as optimally and safely as possible at the intersection of the medial pedicular line, lower edge of the intervertebral disc in frontal projection, and the posterior edge of the superior endplate in the lateral fluoroscopic image. After that, a guidewire, a dilator, and a working cannula (with the bevel tip facing the exiting root) were introduced sequentially until reaching the fibrous ring. A peculiarity of placing the working cannula for hernias with cranial migration is its position relative to the sagittal plane, as well as the need for its further cranial displacement. Then an endoscope was inserted, and a saline irrigation pump was connected to the endoscope. After examination of the structures of intervertebral foramen, tissues were dissected using a bipolar electrode; foraminal ligaments and the excess of adipose tissue were removed by gradually shifting the tip of the working cannula in the cranial direction until detecting the exiting root. Clear visualization of the exiting root is one of the important stages of the operation, and one have to be extremely careful at this point, since the ischemic spinal root may look pale and resemble a herniated disc. After that, hernia sequestration was detected and resected during mediocranial dissection (Fig. 1). If necessary, especially in case of narrowed foramens and migration of sequestration to zone II, resection of the medial facet and ligamentum flavum was performed, which provided an additional view of the axillary region of the exiting root. Extraforaminal approach was applied in some patients with a narrow intervertebral foramen: the working sleeve was placed as close as possible to the upper edge of the vertebral pedicle without entering the intervertebral foramen in order to prevent injury to the exiting root. In cases with a disc height index ⩾0.35 according to Belykh et al. [24] and, as a consequence, an increased likelihood of hernia recurrence, the fibrous ring in the Kambin's triangle zone was additionally opened for intradiscal removal of the degenerated nucleus pulposus without expanding the defect in the fibrous ring at the site of rupture. Periodic X-ray control of the position of microsurgical instrumentation was performed during intervention (Fig. 2).

Interlaminar approach at L5–S1 was also performed with the patient in prone position under radiological control. After marking the site of entry, a 0.7-cm paravertebral skin incision was made in the projection of the interlaminar window. The dilator and the working cannula were installed sequentially and perpendicularly to the lateral edge of the interarch space. An important aspect of interlaminar approach in hernias with cranial migration is positioning of the skin incision with taking into account the need for cranial advancement of the working sleeve, as previously described [25]. This allows increasing the mobility of the working cannula within the spinal canal (Fig. 3, 4). After removal of the dilator, the surgery was performed under visual endoscopic control and constant saline irrigation. The ligamentum flavum was opened and minimally resected using a special perforator. The working cannula extended the defect in the ligamentum flavum and penetrated into the spinal canal for its further use as a radicular retractor. The root and the dural sac were exposed and slightly retracted medially. Hernia was visualized and resected using a microsurgical burr under constant visual endoscopic control. If necessary, partial resection of the lower edge of the L5 vertebral arch was conducted using a microsurgical burr. The intervention was carried out under constant saline irrigation. A radiofrequency coagulator was used for tissue preparation and hemostasis.

Results

Data were taken from the patients' medical records containing information obtained during in-person examination, telephone interviews, and electronic communications. Follow-up data were collected for all patients. In one (1.9 %) case, microdiscectomy for a residual hernia fragment was performed at the L4–L5 level in migration zone II at the second stage of surgery during adoption of this technology. One (1.9 %) case with a hernia in migration zone II required conversion to microdiscectomy at L3–L4 due to the lack of venous bleeding control in a patient receiving anticoagulants. In other patients, the mean VAS scores for preoperative radicular and axial pain decreased from 7.5 ± 1.4 and 3.8 ± 1.2 to 1.4 ± 1.2 (on average by 5.9 points, 95 % CI: from 5.4 to 6.3; t = 26.86; p < 2.2   10-16) and 3.5 ± 1.3 (on average by 0.6 points, 95 % CI: from 0.1 to 1.0; t = 2.349; p = 0.0228) on the next day, to 1.7 ± 1.4 (on average by 5.7 points, 95 % CI: from 5.2 to 6.2; t = 22.82; p < 2.2   10-16) and 3.2 ± 1.1 (on average by 0.8 points, 95 % CI: 0.3 to 1.3; t = 3.444; p = 0.001168) in one month, to 1.5 ± 1.3 (on average by 6.0 points, 95 % CI: from 5.5 to 6.4; t = 25.07; $p < 2.2 \times 10^{-16}$) and 2.8 ± 1.4 (on average by 1.1 points, 95 % CI: 0.7 to 1.6; t = 4.717; $p = 1.958 \times 10^{-5}$) in six months, to 1.6 ± 1.2 (on average by 5.9 points, 95 % CI: from 5.4 to 6.4; t = 25.31; $p < 2.2 \times 10^{-16}$) and 2.0 ± 1.3 (on average by 1.9 points, 9 % CI: 1.4 to 2.4; t = 7.5602; p = 8.008   10-10) in 12 months, and to 1.6 ± 1.2 (on average by 5.9 points, 95 % CI: from 5.4 to 6.4; t = 25.31; $p < 2.2 \times 10^{-16}$) and 2.0 ± 1.3 (on average by 1.9 points, 95 % CI: 1.4 to 2.4; t = 7.5602; $p = 8.008 \times 10^{-10}$) in 24 months, after surgery, respectively (Fig. 5). No radicular leg pain was observed in any patient in the long-term follow-up period. According to the McNab criteria, 12-month surgery outcomes were considered excellent in 19 (35.8 %) patients and good in 32 (60.3 %) cases. In case of lumbar pain in the long-term period, blockade of facet joints and radiofrequency ablation of the medial nerve branch were performed. No hernia recurrence and instability of the operated spinal segment were revealed. It should be mentioned that hernias of this localization have a low probability of recurrence. No damage to the dura mater and internal organs during the approach, as well as postoperative infections, were observed in patients of this group. Transient sensory and movement disorders occurred in two (3.8 %) cases with further regression within three months: in one (1.9 %) case in the innervation zone of the exiting root at L4–L5 and in one (1.9 %) patient in the case of a passing root at L5–S1.

The mean ODI score improved from 66.4 ± 7.2 to 20.5 ± 3.2 (on average by 46.5 points, 95% CI: from 44.3 to 48.7; t = 43.003; $p < 2.2 \times 10^{-16}$) in one month, to 13.6 ± 2.1 (on average by 52.8 points, 95% CI: from 50.6 to 55.0; t = 48.96; $p < 2.2 \times 10^{-16}$) in six months, to 12.4 ± 2.3 (on average, by 54.3 points, 95% CI: from 52.0 to 56.6; t = 47.83; $p < 22.2 \times 10^{-16}$) in 12 months, and to 12.4 ± 2.3 (on average by 54.3 points, 95% CI: from 52.0 to 56.6; t = 47.83; $p < 22.2 \times 10^{-16}$) in 24 months after surgery, respectively (Fig. 5).

All patients gave their consent to undergo the surgery if required. As a rule, patients were activated 2–3 hours after operation within the patient's ward and left the hospital on the next day after surgery (or even on the same day). The mean hospital stay was 18.0 ± 1.4 hours (range, 8 to 24 hours). Physical therapy was prescribed only in the case of focal neurological symptoms. Postoperative MRI scans showed no signs of epidural fibrosis, as well as intramuscular fibrosis along the approach route, while the ligamentum flavum and the facet joint remained intact (Fig. 6, 7).

Discussion

Percutaneous endoscopic lumbar discectomy achieves comparable results with microdiscectomy but has a number of advantages such as minimal invasiveness, preservation of normal anatomy, earlier rehabilitation, as well as reduced hospital stay and quick return to work [17, 26]. Migration of a disc fragment occurs in 35–72 % of cases [27, 28]. Conventional removal of cranially migrated fragments may require wide resection of the interarticular portion of the vertebral arch and facet joint, especially in the upper spinal motion segments [1, 2]. Such resection can cause segmental instability and local vertebrogenic back pain. Although it is technically more demanding, percutaneous endoscopic resection of migrated hernias preserves the integrity of the osteoligamentous structures. However, the results often depend on the surgeon's experience, and preservation of residual fragments is one of the most common reasons for the failure of this surgery [29]. Various modifications of the surgical technique improving the approach to such hernias have been proposed [14, 16, 19–22, 30]. In 2007, Lee et al. [19] was the first to classify lumbar disc migration into zones depending on the direction and degree of migration. In particular, hernias with cranial migration were divided into far- and near-migrated discs. The first zone included hernias migrated to the lower edge of the superior vertebral pedicle, the second zone involved hernias located in the region from the lower edge of the vertebra to the border located 3 mm below the lower edge of the vertebral pedicle. One of the disadvantages of this classification, in our opinion, is that it does not consider hernias located above the lower edge of the vertebral pedicle. This was taken into account by Ahn et al. [21] and later by other authors. Thus, the third degree of migration was identified: far-migrated disc herniation, which included hernias located above the lower edge of the vertebral pedicle. Nevertheless, the most optimal classification from a strategic point of view and the simplest in practical use in our opinion is the division of migrated hernias into two zones: located below the lower edge of the vertebral pedicle (zone I + II according to Lee) and above this zone (zone III according to Ahn). This is due to the fact that zone I hernias according to Lee et al., in our experience, do not provide significant mechanical compression of the exiting root, they are treated well with conservative management (e.g., by transforaminal epidural steroid injection) and do not require surgery. Radicular pain in these cases is usually associated with an inflammatory response around the root.

Fig. 1
Endoscopic camera view after hernia resection, right side: *a* – dural sac; *b* – exiting root; *c* – axilla; *d* – disc

Fig. 2
Monitoring of the position of the working cannula and microsurgical instrument during hernia resection

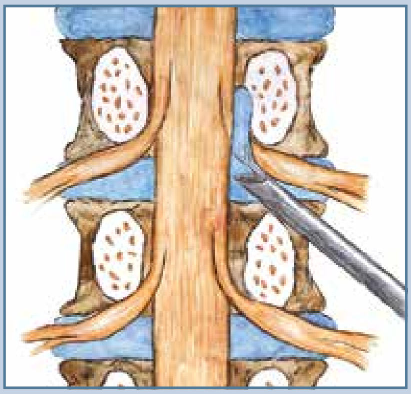

Fig. 3
Schematic representation of the position of the working cannula and instrument

Fig. 4
Mobility of the working cannula in the spinal canal at L5–S1 through the interlaminar approach

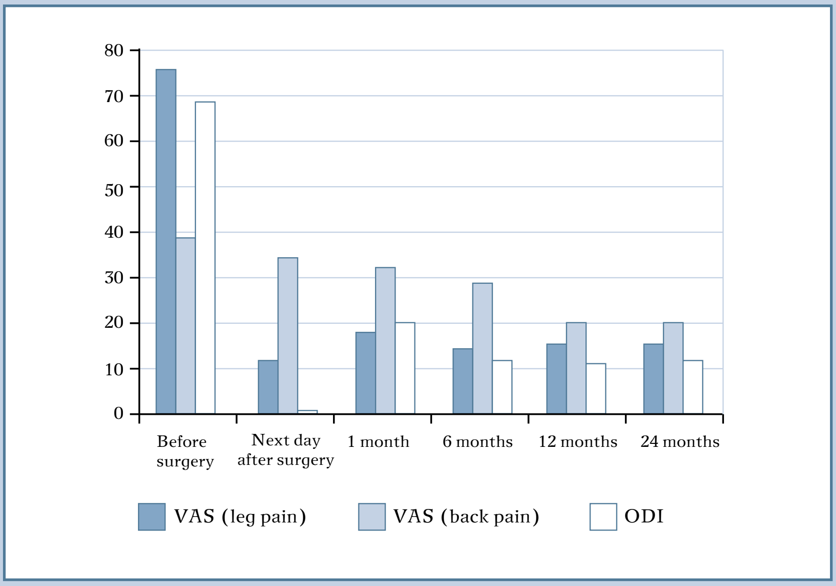

Fig. 5
The change in pain and quality of life: a significant decrease in pain severity after surgery according to the VAS (pain in the leg and back) and improvement in the quality of life according to Oswestry

Lee et al. [19] also proposed a surgical strategy depending on the migration zone: half-and-half technique and epiduroscopic technique for migration zones II and I, respectively. We used the half-and-half technique only for hernias with caudal migration. In cases of hernias with cranial migration, the epiduroscopic technique was used, in which the bevel tip of the cannula does not penetrate into the disc space but is gradually shifted in the cranial direction until the exiting root and hernia are detected. In cases with a disc height index ⩾ 0.35 according to Belykh et al. [24], and, as a consequence, an increased likelihood of hernia recurrence, the fibrous ring in the Kambin's triangle zone was additionally opened for intradiscal removal of the degenerated nucleus pulposus without expanding the defect in the fibrous ring at the site of rupture. The latter might explain the absence of relapses in our series. A distinctive feature of surgical intervention for hernias is the resection of the medial facet and ligamentum flavum in the cranial part and the superior foraminal ligament for far-migrated hernias (zone II according to our classification), which provides an additional view of the axillary region of the exiting root, where such hernias are located. As for the L5–S1 level, we used the interlaminar approach targeting the root shoulder in any degree of migration, with taking into account the need for cranial advancement of the working sleeve. High iliac crest and, as a rule, narrow intervertebral foramen in such hernias complicate free and safe manipulations at this level through the transforaminal approach. Ruetten et al. [31] proposed that migration of more than half of the vertebral body should be an exclusion criterion for endoscopic surgery. However, based on our experience of using percutaneous endoscopy, the surgery is possible even in the case of a greater displacement of hernia sequestration (Fig. 7). A relative obstacle may be the small size of the interarch space; if necessary, a marginal resection of the vertebral arch is performed to expand the interlaminar window.

Correctly targeted approach determines the success of such surgery. It is necessary to position a skin incision and strictly consider both the degree of migration of hernia sequestration and the presence of a narrowed intervertebral foramen and interlaminar window. We analyzed the intervertebral foramen using preoperative MRI data. The size and shape of the intervertebral foramen, the presence of osteophytes and hypertrophy of the ligamentum flavum, the angle and area of the root tip, as well as the height of the intervertebral disc were taken into consideration. An important feature of the surgical technique is that the approach should be carried out first within the safety triangle zone, and only then revision of the epidural space while monitoring the exiting root should be performed. In cases of a narrowed foramen, it is advisable to perform an extraforaminal approach first in order to prevent injury to the exiting root. A specific feature of transforaminal endoscopic surgery for hernias of the upper lumbar discs with cranial migration (L1–L2, L2–L3) is that, in contrast to the lower lumbar segments, it requires a more medial posterolateral approach to prevent damage to internal organs. A safe approach route was calculated using preoperative MRI scans.

Hernias with cranial migration in our series are mainly caused by monoradicular syndrome associated with compression of the exiting root and, to a lesser extent, with vertebral back pain. bilateral radicular symptoms (at the L5–S1 level) was noted in three (5.7 %) cases.

In our series, transient sensory and movement disorders occurred in two (3.8 %) cases with further regression within three months: in one (1.9 %) case in the innervation zone of the exiting root at L4–L5 and in one (1.9 %) patient in the case of a passing root at L5–S1. On order to prevent neurological deficit, the root should be treated delicately, especially at the stage of its dissection during the search for hernia sequestration.

One of the important aspects of such surgery is the control of epidural venous bleeding. It can occur during both the resection of hernia sequestration and revision of the epidural space when searching for hernia, which will significantly complicate further intervention due to poor visualization of neural structures. In our series, a conversion to microdiscectomy was performed at L3–L4 in one (1.9 %) case due to the lack of venous bleeding control in a patient receiving anticoagulants. In order to minimize the risk of bleeding, it is recommended to perform a careful gradual dissection of the epidural space, not to use instruments blindly, and, if necessary, carry out timely coagulation of epidural veins and preoperative preparation of patients. In case of bleeding, temporarily increasing the fluid pump pressure or clamping the outflow in the working channel of the endoscope may be useful. It improves the endoscopic picture, after which it is possible to use bipolar coagulation. In one (1.9 %) case, microdiscectomy for residual hernia fragment was performed at the L4–L5 level at the second stage of surgery during adoption of the technology in migration zone II. In our opinion, complete isolation and complete fixation of the basis of hernia sequestration with microsurgical instrumentation are necessary to prevent the detachment of the distal hernia fragment, especially in cases if the sequestration is located more centrally.

No clinical and radiological signs of segmental instability were revealed during the follow-up period. This can be possible due to the fact that no resection of the osteoligamentous structures of the spine, primarily facet joints, was performed during the endoscopic approach. Meanwhile, many authors [1–5] describe the need for wide resection of the interarticular portion of the vertebral arch and facet joint on order to remove cranially migrated hernias as the cause of segmental instability and local vertebrogenic back pain.

Further accumulation of the experience and a comparative study of the results of endoscopic and microsurgical resection of hernias with migration will determine the advantages and disadvantages of each of the techniques.

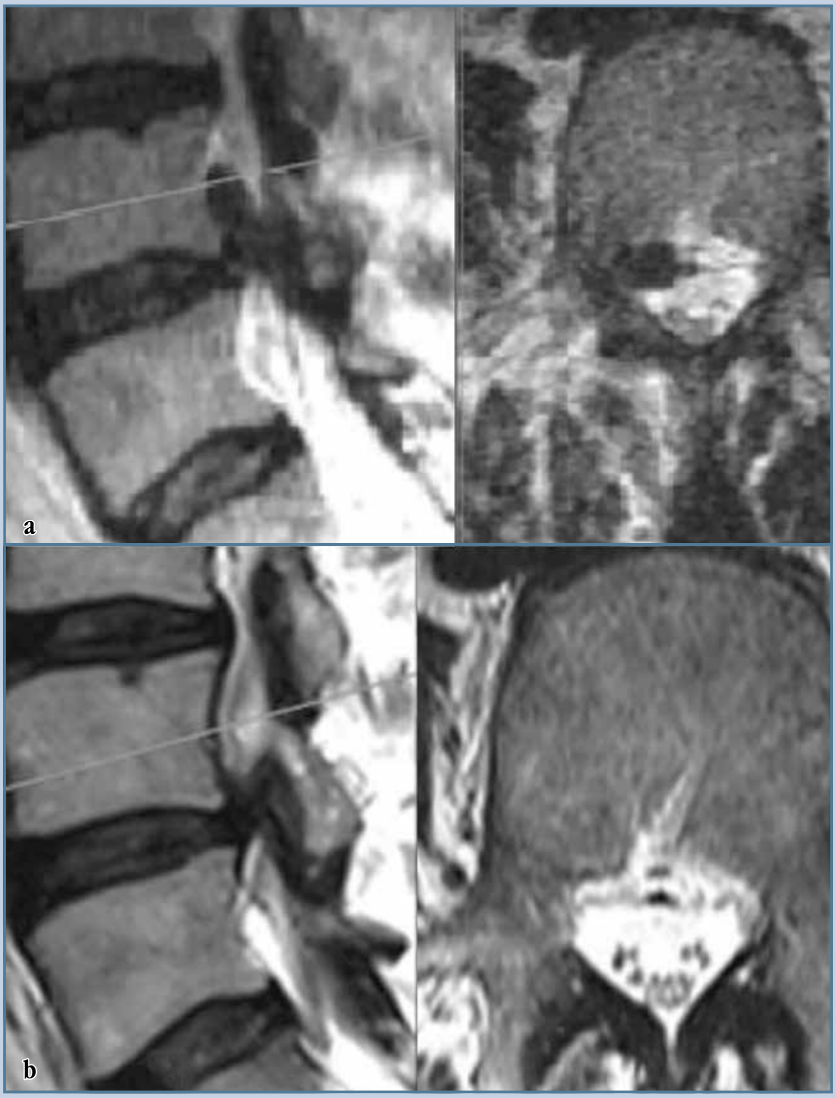

Fig. 6
MRI before **(a)** and after **(b)** surgery: L4–L5 hernia on the right side with cranial migration to zone II, to the axillary region of the exiting root; endoscopic resection through the transforaminal approach

Conclusion

Percutaneous endoscopic transforaminal and interlaminar resection of lumbar disc herniation with cranial migration is a safe and effective method (in case of meeting the principle of targeted surgery and exclusion criteria). The approach allows avoiding excessive resection of the osteoligamentous structures of the spine and preventing iatrogenic instability of the spinal motion segment. In addition, the method promotes early postoperative activation and recovery of the patient, while hernias with cranial migration have a low probability of recurrence.

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The patient signed an informed consent for the publication of his data.
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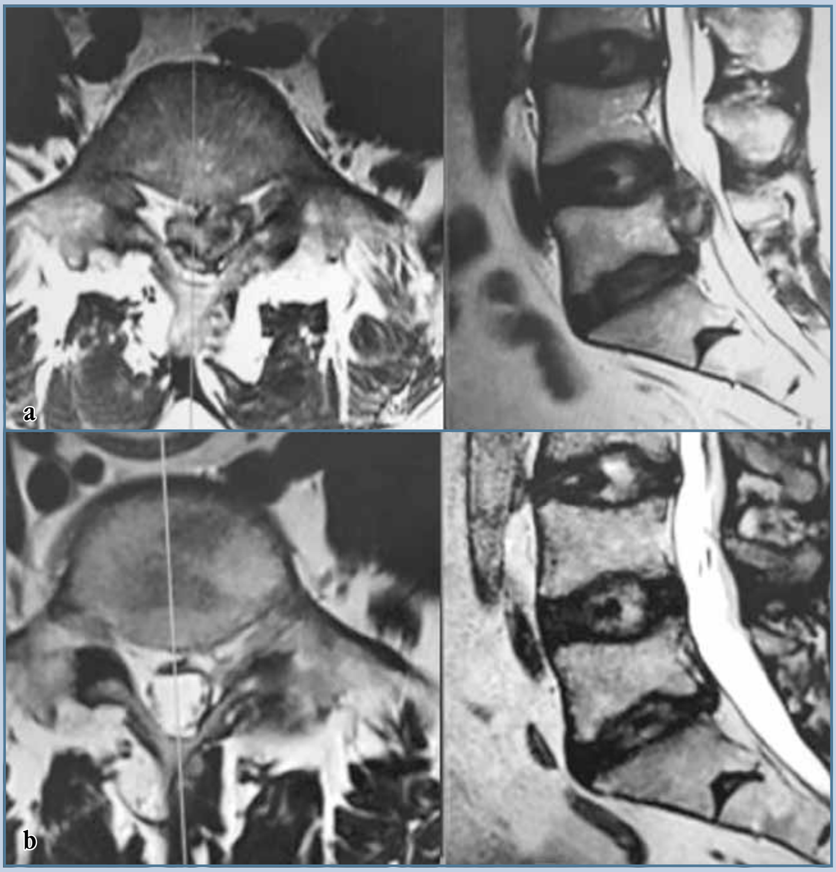

Fig. 7
MRI before **(a)** and after **(b)** surgery: L5–S1 disc herniation with cranial migration on the left side; endoscopic resection through the interlaminar approach (control examination after two days)

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