



COMBINATION OF TRANSPEDICULAR AND TRANSFORAMINAL ENDOSCOPIC APPROACHES FOR REMOVAL OF LUMBAR DISC HERNIATIONS WITH VERY HIGH DEGREE OF MIGRATION: A SMALL CASE SERIES AND LITERATURE REVIEW

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Objective. To evaluate the effectiveness of a combination of transpedicular and transforaminal endoscopic approaches for the removal of lumbar spine herniations with a double compressive intracanal component: significant protrusion in the disc plane combined with an extremely high degree of rostral or caudal migration.

Material and Methods. An analysis of two clinical cases and literature data on the use of a combination of transpedicular and transforaminal endoscopic approaches through a single skin incision was performed. The dynamics of pain syndrome according to the Visual Analog Scale (VAS), neurological status and MRI results were assessed.

Results. In both cases, the migrated sequestered fragments and significant disc plane protrusions were successfully removed, with complete regression of pain syndrome and restoration of function. No complications were reported.

Conclusion. The presented combination of transpedicular and transforaminal endoscopic approaches is a promising and safe surgical method for treating patients with disc herniations, compressing neural structures both in the plane of the disc and in the area of the migrated fragment. Further studies on a larger sample are required.

Key Words: spine; disc herniation; migration; endoscopic surgery; transpedicular-transforaminal approach; combination.

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Statistical data on the migration rate of herniated disc fragments vary from 35% to 72% [1]. According to Daghighi et al. [2], rostral and caudal migrations are found in 27.8% and 72.2% of patients, respectively. However, we did not find any data in the literature on the frequency of the combination of a significant hernial protrusion in the disc plane and the presence of a far-migrated sequester. Removal of herniations with a high degree of migration through the intralaminar approach requires significant resection of the pars interarticularis and facet joint, which in turn may result in segmental instability. The use of endoscopic techniques to remove migrated fragments is

technically more challenging, but it preserves the stability of the spinal motion segment. Nowadays, there are a variety of endoscopic approaches for removing migrated herniations described in the literature, such as transforaminal approaches with different variations (foraminoplasty, half-and-half technique, epiduroscopic technique, etc.), transpedicular, and interlaminar approaches [3–5].

While there is a wide range of endoscopic techniques available for treating discoradicular interaction, the outcomes in some cases are not satisfying for either the patient or the surgeon. The reasons for this may be not only the surgeon's experience and skills, but also the spe-

cific location of the pathological substrate. The preservation of residual herniation fragments after surgery is one of the common reasons for unfavorable outcomes [6].

As far as we know, there are currently no studies reporting combined transpedicular-transforaminal endoscopic approach for lumbar disc herniation removal with extreme migration and a significant component in the disc plane.

The objective is to evaluate the effectiveness of a combination of transpedicular and transforaminal endoscopic approaches for the removal of lumbar spine herniations with a double compressive intracanal component: significant protrusion in the disc plane com-

bined with an extremely high degree of rostral or caudal migration.

Material and Methods

The study was conducted at the Research Institute – Krasnodar Regional Clinical Hospital No. 1 n.a. Prof. S.V. Ochapovsky (Krasnodar). The study examined the treatment of two patients who had lumbar spine herniations characterized by an extremely high degree of sequester migration in zones 1 and 6, as classified by Ahn et al. [7]. These patients also presented with a significant component in the disc plane, neurological deficits, and failure of conservative treatment. The results were analyzed in the context of pain (VAS), neurological status, and follow-up MRI to evaluate decompression. The study was approved by the local ethics committee of the institution, and patients gave their informed consent.

The literature data analysis was performed according to the PRISMA-2020 guidelines (qualitative review without meta-analysis because of clinical and methodological heterogeneity of studies). The search was conducted in PubMed/MEDLINE, Scopus, Web of Science, Cochrane Library, Google Scholar, and eLibrary. The search covered articles published between January 1, 2000, and June 1, 2024, with no language restrictions; in addition, the reference lists of the articles included in the review were reviewed manually. The following queries were used: (“lumbar disc herniation” OR “migrated disc” OR “far-migrated” OR “high-grade migration”) AND (endoscopic OR “transforaminal” OR “suprapedicular” OR “interlaminar” OR “transpedicular” OR UBE) and their Russian equivalents: (“lumbar disc herniation” AND/OR “sequester migration” AND (“endoscopic” OR “transforaminal” OR “interlaminar” OR “transpedicular”). Inclusion criteria: clinical studies (randomized, cohort, retrospective, case series) on endoscopic removal of lumbar herniations with a high/very high degree of migration (including zones 1 and 6 according to Ahn et al. [7]), with a description of the approach and clinical outcomes/complications.

During the identification stage, 420 records were found; 384 of them remained after removing duplicates. During the screening of titles/abstracts, 310 articles with irrelevant topics were excluded. Seventy-four articles were assessed in full text; 55 of them were excluded for the following reasons: mixed procedures without separate analysis of the endoscopic subgroup ($n = 14$), no focus on high migration ($n = 16$), no clinical outcomes/reports only on technique ($n = 9$), experimental studies ($n = 6$), and reviews/editorial letters/comments ($n = 10$). Nineteen studies were included in the final qualitative synthesis. A meta-analysis was not performed because of methodological and clinical heterogeneity.

Results

Clinical case 1

Male patient S., 38 years old, was admitted with complaints of pain in the right lower extremity (7 points out of 10 on the VAS), in the lumbar spine (4 points), and weakness and numbness in the right foot. According to the past medical history, the patient has been suffering from intermittent lumbar spine pain and pain in the right lower extremity for a year. During the last few weeks, the pain has been constant and progressive, and conservative treatment has had no significant positive effect. Instrumental imaging revealed a right-sided L4–L5 disc herniation with a superiorly sequestered and migrated fragment located in zone 1 according to Ahn et al. [7]. It should be noted that most of the herniation was located behind the vertebral pedicle, its upper edge was at the level of the upper endplate of the L4 vertebra, and there was a hernial protrusion in the disc plane that narrowed the lateral recess (Fig. 1).

Physical examination. Normosthenic type. Organs and systems are without pathological findings. The patient is ambulant, limping on the right leg.

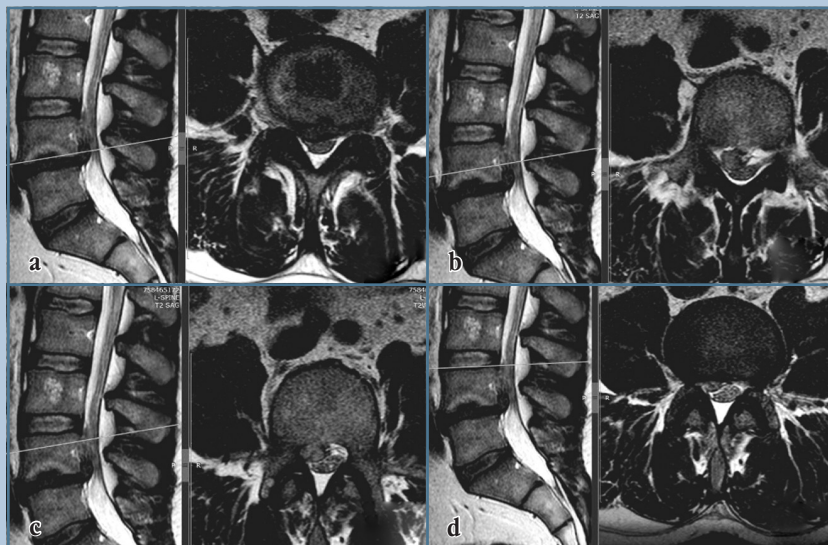
Neurological status. The patient is conscious, oriented to person, place, and time. Range of motion in the lumbar spine is limited because of pain. Muscle strength in the left lower extremity is 5

points in all muscle groups; and there is paresis of the extensors of the right foot in the right lower extremity, 3 points out of 5. Positive Lasegue sign on the right at an angle of 40°. Hypoesthesia with hyperpathy in the L4 and L5 innervation zone on the right. Function of pelvic organs not impaired.

Considering the clinical and radiological pattern of the disease and the topographic and anatomical features of the sequester, we decided to go with endoscopic removal of the disc herniation using a single-stage combined transpedicular-transforaminal approach. Surgery duration was 80 min. Intraoperative blood loss was 50 ml.

Surgery course. General anesthesia. Prone position. Marking (center of the right L4 pedicle). Treatment of the skin on the back with antiseptics. A single skin incision 1 cm long. A bone biopsy needle is placed in the center of the right L4 pedicle under radiological image intensifier control and is inserted to the base and medial cortical plate of the vertebral pedicle. The cannula, retractor system, and endoscope are inserted stepwise. The anatomical structures, nerve root, and dural sac are visualized. An intervertebral disc sequester located behind the pedicle was detected under the nerve root and removed. Decompression of the nerve root was achieved (Fig. 2). By sequentially rotating the endoscope in the cranial and caudal directions, a visual examination of the epidural space was performed, and residual disc material was removed. An attempt was made to remove the proximal portion of the sequester within the disc plane; nevertheless, it turned out to be unsuccessful because of the risk of injuring neural structures during uncontrolled actions beyond the visual field.

After the removal of the endoscope and port from the pedicle, a cannula, retractor system, and endoscope were sequentially introduced into the right L4–L5 intervertebral foramen through the same skin incision under radiological image intensifier control. The anatomical structures, nerve root, and dural sac were visualized. The latter structures were compressed; they did not show flo-

**Fig. 1**

Herniation in the disc plane, narrowing the right lateral recess at the level of L4–L5 (a); herniation in the infrapedicular space (b); sequester behind the pedicle of the L4 vertebra (c); the upper pole of the sequester at the level of the superior endplate of the L4 vertebra (d)

tation. Sequential removal of herniated disc fragments (Fig. 3). Hemostasis by coagulation. Interrupted suture. Blood loss of approximately 20 ml.

Postoperative period: complete relief of pain syndrome. According to clinical investigations, there was complete decompression of the nerve structures (Fig. 4).

The patient was discharged from the hospital on the day 2 after surgery. One-year follow-up; paresis of the extensors of the right foot in the right lower extremity was rated at 4 out of 5 points (positive changes) during the last examination. Complete relief of pain and esthesioneurosis.

Clinical case 2

Male patient M., 48 years old, was admitted with complaints of pain in the right lower extremity (8 points out of 10 on the VAS) and in the lumbar spine (5 points). According to the past medical history, the patient has been suffering from intermittent lumbar spine pain and pain in the right lower extremity for a year. Clinical investigations revealed a

right-sided L4–L5 disc herniation with migration of the sequestered fragment caudally into zone 6 according to Ahn et al. (Fig. 5). In the disc plane, extrusion with total narrowing of the right lateral recess.

Physical examination. Normosthenic type. Organs and systems are without pathological findings. The patient is ambulant, limping on the right leg.

Neurological status. The patient is conscious, oriented to person, place, and time. Muscle strength in the left lower extremity is 5 points in all muscle groups. Positive Lasegue sign on the right at an angle of 60°. Given the clinical and radiological pattern and the topographical-anatomical features of the sequester, the surgical strategy of endoscopic disc herniation removal using a single-stage combined transpedicular-transforaminal approach was chosen. Surgery duration of 100 minutes. Intraoperative blood loss volume of 60 ml.

The surgery was done using the technique described in the previous clinical case, in a similar order, independently of the direction of sequester migration.

A complete relief of pain was observed in the postoperative period. According to clinical investigations, complete decompression of nerve structures was achieved (Fig. 6).

The patient was discharged from the hospital on the day 2 after surgery. One-year follow-up. The patient reported a complete relief of pain during the last examination.

Discussion

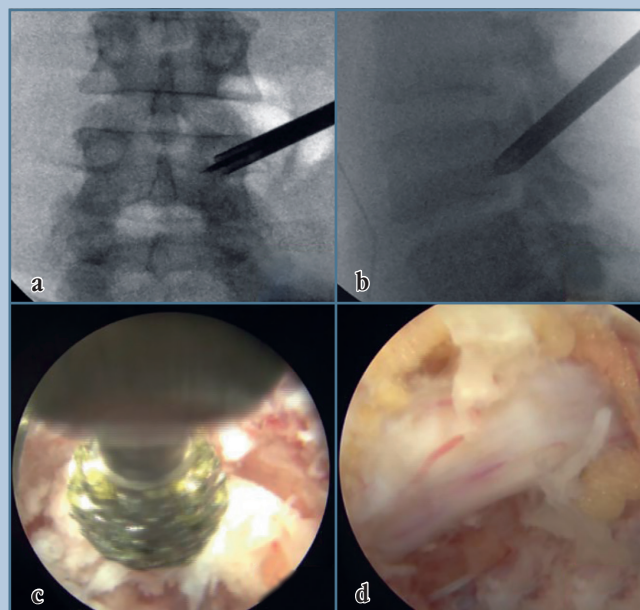
According to Daghighi et al. [2], age and intervertebral disc level are independent significant factors determining the direction of herniation migration in the vertical plane. The rate of rostral migration increases significantly in elderly patients and at the L1–L2, L2–L3, and L3–L4 levels [2].

Classification of sequester migration is crucial when planning an approach. Previously, Lee et al. [8] proposed to subdivide migration into zones based on distance from the disc. Nevertheless, the use of a fixed threshold of 3 mm proved to be non-universal, as disc height and vertebral anatomy are both individualized. Later, Kim et al. [9] suggested a more complex classification, but it is difficult to apply it in practice.

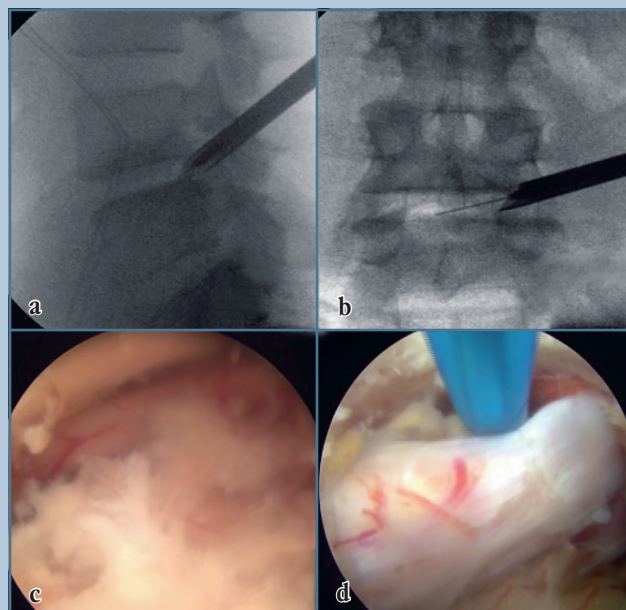
In 2022, Ahn et al. [7] proposed an improved and more comprehensive system considering the individual anatomy of the spinal segment (Fig. 7). The core of this classification is that the intervertebral disc and the lower and upper edges of the pedicles of adjacent vertebrae are used as anatomical landmarks. All levels are divided according to their natural anatomical boundaries, rather than by random distances. For cranial migration, these are zones 1, 2, and 3, and for caudal migration, zones 4, 5, and 6. The basis is the classification of herniated fragment migration into three grades:

1) low migration (zones 3 and 4) – the fragment slightly extends beyond the disc but remains in its immediate surrounding area;

2) high migration (zones 2 and 5) – the herniation migrates significantly upward or downward, reaching the level

**Fig. 2**

Intraoperative radiological examination showing the positioning of endoscopic instrumentation in the vertebral pedicle (**a, b**); approach to the migrated sequestrum located behind the vertebral pedicle using a high-speed drill (**c**); decompressed L4 nerve root after sequestrum removal (**d**)

**Fig. 3**

Intraoperative radiological examination showing the positioning of endoscopic instrumentation during transforaminal approach (**a, b**); compression of the nerve root by a herniation at the level of the intervertebral disc (**c**); complete decompression of the nerve root after herniation removal (**d**)

of the pedicle but not extending beyond its boundaries;

3) very high migration (zones 1 and 6) – the herniated fragment migrates to a point beyond the pedicle; these cases are the most challenging to remove.

The main benefit of the Ahn et al. classification is that its application does not require complex measurements – the clinician uses clear anatomical landmarks, which are easy to identify on standard MRI images. This approach results in a faster evaluation of the complexity of the case and provides an opportunity to select the optimal surgical technique in advance.

It is vital to emphasize that herniation migration does not always represent the same pattern. There are two distinct types of highly migrated herniations. One type is the sequestered fragment is displaced almost completely behind the pedicle, and there is either no significant hernial protrusion or just minimal clin-

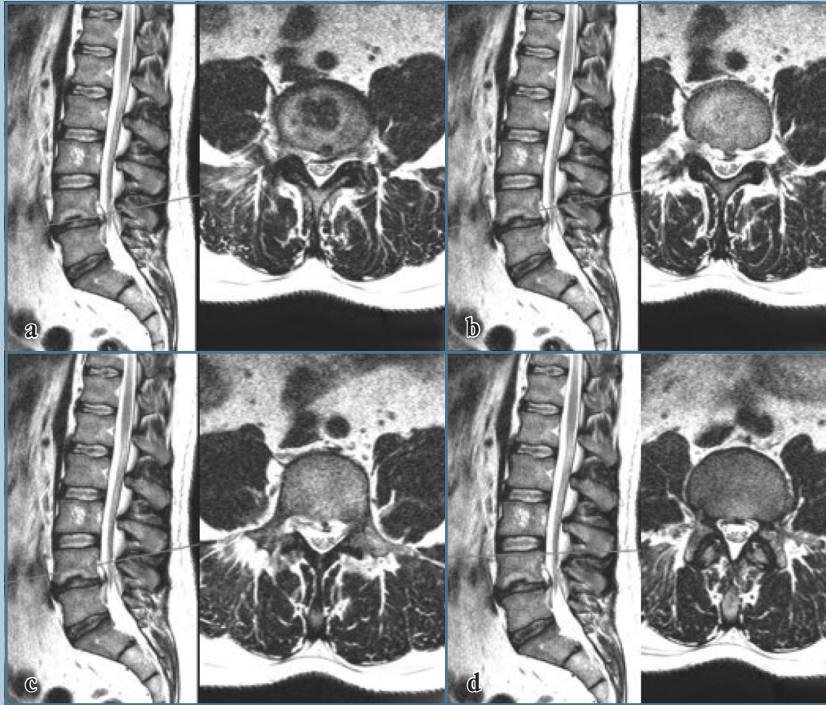
ically insignificant residual protrusion at the level of the intervertebral disc. In such cases, the surgeon's main task is to remove the fragment in the migration zone. However, there are more complex cases where herniated fragments are identified both behind the pedicle and in the intervertebral disc plane. These are the herniations that are particularly challenging: the risk of retention of a clinically significant residual fragment increases when a single approach is used for removal.

Our study focuses precisely on such herniations, which require a combined approach for complete removal of both vertically migrated and herniated material in the disc plane.

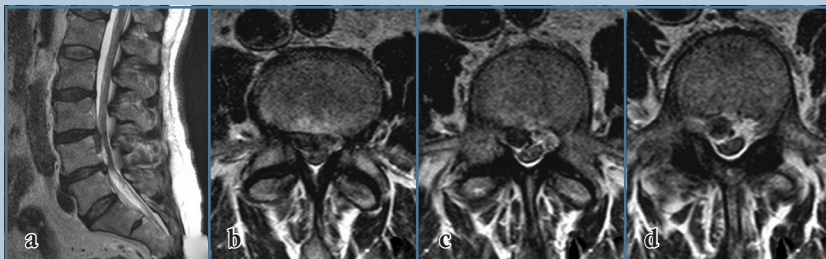
Percutaneous transforaminal endoscopic lumbar discectomy (PTELD) for high and very high migrated herniations is still a complex challenge even for experienced neurosurgeons. In their 2006 study, Lee et al. [10] showed that

PTELD achieved satisfactory outcomes in 78.9% of patients with high and very high migrated herniations. In light of this, the authors recommended microdiscectomy as the procedure of choice for high-migrated herniations.

As the endoscopic tools have evolved and surgical techniques have been improved over the last decade, the indications for percutaneous endoscopic discectomy have continuously expanded, and excellent clinical outcomes have been achieved [11, 12]. Choi et al. [13] presented a foraminoplasty procedure for far-migrated herniations using an endoscopic drill. Part of the upper articular process and the upper edge of the pedicle of the subjacent vertebra were resected in cases of descending herniations. A positive outcome was achieved in 91.4% of patients during a 25-month follow-up period. Kim et al. [14] also reported a similar foraminoplasty technique (known as the suprapedicular approach)

**Fig. 4**

Postoperative MRI images (a–d) show total removal of the sequestered herniation; posterior longitudinal ligament protrusion is visualized in the plane of the intervertebral disc, complete decompression of the right lateral recess L4–L5 on the right

**Fig. 5**

L3–L4 intervertebral disc herniation on the right with migration to zone 6 according to Ahn et al. (a); herniation in the disc plane, narrowing the lateral recess and compressing the nerve root (b); part of the sequester behind the vertebral pedicle (c); part of the sequester located below the lower edge of the vertebral pedicle (d)

for herniations with a very high grade of migration, with a positive clinical outcome in 94% of patients. Wu et al. [15] described a two-level approach (L2–L3 and L3–L4) for L3–L4 herniations with a high grade of upward migration, with excellent clinical outcomes. In 2016,

Krzok et al. [16] proposed a transpedicular approach for herniations with a high grade of migration. This approach was subsequently widely adopted and is now used in daily practice [17].

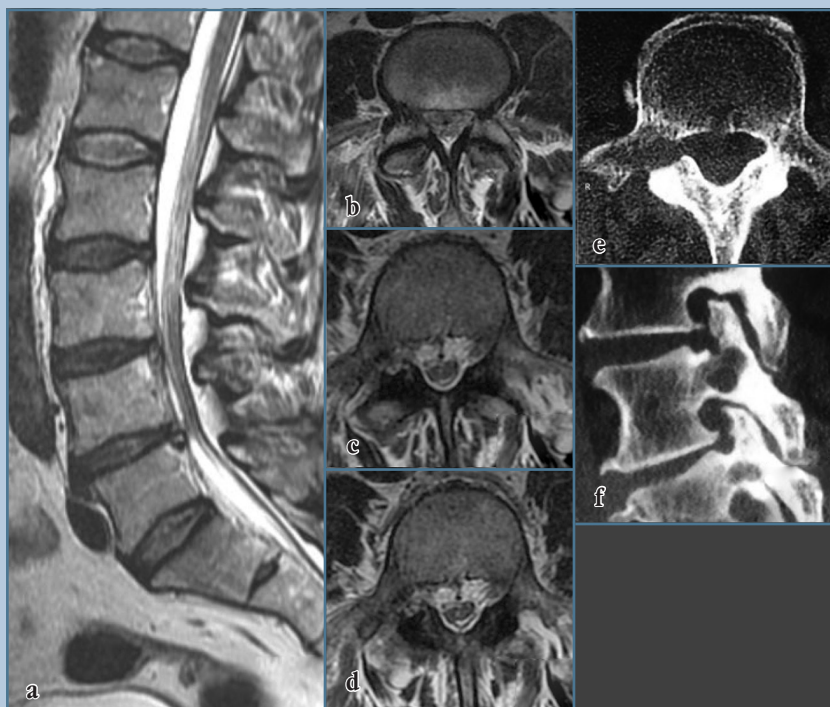
The endoscopic interlaminar approach is also widely used for herni-

ations with high and very high migration and demonstrates comparable clinical outcomes. In a number of cases, it reduces radiation exposure to the surgical team, provides a direct approach with median fragment location, and eliminates the need for combination with other approaches [18]. Additionally, unilateral biportal percutaneous translaminar endoscopy (UBE) has recently been described in the literature as an option to potentially simplify the removal of multifragmentary sequestra [19].

The above-mentioned endoscopic techniques are reliable. The results of studies using these approaches were evidently better than those reported by Lee et al. [10]; nevertheless, the use of these surgeries also poses a potential hazard of postoperative residual herniations. According to Choi et al. [13], 5 (8%) patients underwent recurrent surgery during the follow-up period. Three (5%) of them experienced pain in the leg after surgery associated with incomplete removal of the migrated fragment. In the study by Kim et al. [14], residual disc fragments remained in 7 (13%) of 53 patients after surgery, according to MRI data; nevertheless, because of their extremely small size, no clinical symptoms were reported, and patients were satisfied with the surgical outcomes. According to Kim et al. [9], MRI data showed that the interlaminar approach resulted in complete removal of disc herniation in 89% of patients (16/18). Two patients subsequently underwent recurrent surgery to remove residual herniations.

The most probable reason for less favorable treatment outcomes in cases of herniations with very high migration is their morphology. The crucial factor is the multifragmentary aspect of the sequester and its additional fragmentation during disc material traction. According to Kim et al. [14], multifragmentary sequestra were reported in 19 (≈36%) of 53 patients. This morphology restricts the effectiveness of isolated techniques for capturing and extracting the proximal fragment and requires targeted revision of the migration bed.

We used two approaches in our study to simultaneously solve these problems and completely remove the sequester,

**Fig. 6**

Postoperative MRI images (a–d) show total removal of the sequestered herniation in the disc plane and its migrated fragment; postoperative CT scans clearly show a bone defect in the pedicle of the L4 vertebra after transpedicular approach (e, f)

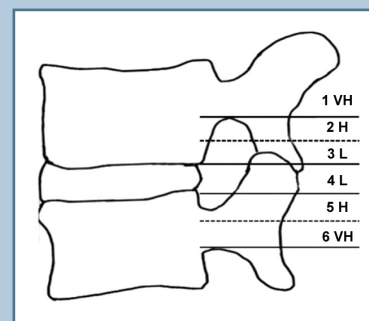
fully visualizing its bed from two entry points.

This technique can be applied in cases of cranially or caudally migrated herniation with dislocation of the distal pole of the sequester deep behind the pedicle, as well as in cases of extrusion in the disc plane.

The presented technique of combined endoscopic approach is explained by the need to remove disc material both from the disc plane and from the migration area behind the pedicle. At the same time, we consider the fact that the nucleus pulposus, which forms the basis of the sequester, can be fragmented, especially in cases of long-standing sequester and adhesive changes. Correspondingly, attempts to remove a herniation from a single approach exclusively in the area of its formation or in the “tail” region are associated with the risk of only a partial removal of the pathological substrate

and the preservation of residual volume. Both approaches are performed through a single skin incision; only the trajectory of the instrumentation changes. The use of curved graspers in different directions, moving in opposite directions from two entry points, ensures that the entire volume of pathological substrate is removed.

The order of approaches to removing sequester is of strategic significance. In the overwhelming preponderance of cases of this type of herniation, the maximum volume of disc material is located directly behind the pedicle of the vertebra, with a smaller part of it is at the level of the disc and around it. Moreover, the volume of the herniation behind the pedicle serves as a pad between the pedicle and the dura mater, which ensures the safety of pedicle trepanation using a crown drill. Considering this fact, as well as the high probability of fragmented sequester, it can be stated that the first

**Fig. 7**

Scheme of the six grades of lumbar intervertebral herniation migration in the sagittal plane according to Ahn [7]. The disc displacement grades: very high (VH), high (H), and low (L).

of the two approaches should be transpedicular, with sequester removal and thorough revision of the epidural space both in the fenestration area and in the cranial and caudal directions in the area of direct visualization. After completing the work in the area of the pedicle, the endoscope is moved to the intervertebral foramen, where the herniation residuals are removed in the disc plane and revision is carried out in the cranial or caudal directions along the course of herniation under full visual control. Therefore, complete and safe removal of the herniation is ensured.

Using the reverse (transforaminal–transpedicular) sequence does not provide complete removal of the pathological substrate and, most importantly, does not ensure the safety of the procedure.

After removing the herniation in the disc plane, the next challenge is to operate along the path of the migrated sequester in the caudal (more favorable scenario) or cranial (less favorable scenario) direction. The migrated fragment may be removed entirely or partially. Meanwhile, the surgeon often cannot be certain whether sequester is removed completely or partially. A further, more distant recurrent surgery is insecure for the nervous struc-

tures because of the lack of direct visual control. A subsequent transpedicular approach is associated with the risk of injury to the dura mater or nerve root if the sequester has been completely removed through a transforaminal approach.

Therefore, it is essential to start removing the herniation from the area of maximum sequester volume and then continue removing smaller fragments.

Limitations of the study. The study is limited by the small number of cases (two clinical cases), its single-center design, and the omission of a control group. The evaluation of outcomes consisted mainly of clinical assessments (VAS,

neurological status), without standardized quantitative evaluation of radiation exposure and surgery duration. The obtained results should be considered as hypothesis-generating.

Conclusion

The introduced combination of transpedicular and transforaminal endoscopic approaches provides reliable visualization of the sequester bed behind the pedicle for very high migration cases, as well as targeted removal of disc material in the disc plane. Moreover, the choice of surgical technique must be individualized: depending on the

anatomy and location of the migration, other endoscopic approaches or combinations of them may be indicated (transforaminal, interlaminar, translaminar, transpedicular). There is a further need for studies on larger cohorts comparing alternative techniques.

The study had no sponsors. The authors declare that they have no conflict of interest.

The study was approved by the local ethics committee of the institution.

All authors contributed significantly to the research and preparation of the article, read and approved the final version before publication.

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