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DIGEST AND REVIEWS

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Current trends of surgical treatment intervertebralnhernias and lumbar stenosis the spine

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Objective. On the basis of a study of scientific literature on the treatment of patients with intercho-ribbus hernias and stenosis of the spinal canal of the lumbar spine to determine the tendencies of development of methods of performing surgical treatment of these diseases and the conditions of their appointment. Methods. The literature search was performed in the PubMed database. The inclusion criteria were original clinical studies in English. Results. We selected and studied 47 studies. Conclusions. The advantages of modern endoscopic spine surgery include less tissue damage, lower blood loss, less damage to the epidural blood supply with less fibrosis, shorter hospital stay, and early cosmetic recovery. Percutaneous endoscopic partial discectomy (PEPD) allows to avoid significant damage to the skin, muscles, plates and synapses, excessive load on the dura mater, it is performed under local anesthesia. This type of discectomy is more suitable for the treatment of foraminal and extraforaminal hernias, when the transforaminal approach facilitates visualization of the lesion. In the middle type hernias, the limitations of the intervertebral opening and the interference of the solid meninge when performing this technique leads to the worst clinical results. In general, after PEPD, the results are better than after microdiscectomy. Surgical treatment of lumbar spinal stenosis is mainly performed using single-channel endoscopic surgery, which allows for complete preservation of the physiological structure of the lumbar spine with minor surgical trauma and rapid postoperative recovery. The disadvantages are a small field, as well as the difficulty of expanding the boundaries of decompression. One of the most recent developments in the treatment of intervertebral hernias is unilateral biportal endoscopic discectomy (UBED). The effectiveness of discectomy and release of nerve roots in the spinal canal is higher than that of percutaneous endoscopic interlaminar partial discectomy, but UBED is longer, with greater actual blood loss during surgery.

Мета. На основі дослідження наукової літератури щодо методів оперативного лікування пацієнтів із міжхребцевими грижами та стенозом поперекового відділу хребта визначити тенденції їх розвитку та умов призначення. Методи. Пошук літератури виконано у базі даних PubMed. Критеріями включення були оригінальні клінічні дослідження англійською мовою. Результати. Відібрано та проаналізовано 47 робіт. Висновки. Переваги сучасних ендоскопічних операцій на хребті включають менше ураження тканин, нижчу крововтрату, мінімальне ушкодження епідурального кровопостачання з меншою фібротизацією, коротше перебування в лікарні, раннє косметичне відновлення. Черезшкірна ендоскопічна парціальна дискектомія (ЧЕПД) дозволяє уникнути значного ушкодження шкіри, м'язів, пластинок і синапсів, надмірного навантаження на тверду мозкову оболонку, його проводять під місцевою анестезією. Цей вид дискектомії більше підходить для лікування форамінальних та екстрафорамінальних гриж — трансфорамінальний доступ полегшує візуалізацію ураження. За гриж серединного типу обмеженість міжхребцевого отвору і заважання твердої мозкової оболонки під час виконання цієї методики призводить до гірших клінічних результатів. Загалом, після ЧЕПД спостерігаються кращі результати, ніж після мікродискектомії. Хірургічне лікування стенозу поперекового відділу хребта здебільшого здійснюється за допомогою одноканальної ендоскопічної хірургії, що дозволяє повністю зберегти фізіологічну структуру відділу за незначної травми та швидкому післяопераційному відновленні. Недоліки — мале поле, складність розширення меж декомпресивного впливу. Однобічна біпортальна ендоскопічна дискектомія (ОБЕД) дієва для корекції майже всіх дегенеративних захворювань хребта. Ефективність дискектомії та звільнення нервових корінців у хребетному каналі перевищує її за умов черезшкірної ендоскопічної інтерламінарної парціальної дискектомії, але ОБЕД довша, з більшою фактичною крововтратою під час операції. Ключові слова. Хребет, міжхребцевий диск, дискектомія, відкрита дискектомія, мікродискектомія, трансфорамінальна дискектомія, ендоскопічна дискектомія, монопортальна дискектомія, біпортальна дискектомія, декомпресія, ускладнення.

Keywords. Spine, intervertebral hernia, discectomy, open discectomy, microdiscectomy, transforaminal discectomy, endoscopic discectomy, monoportal discectomy, biportal discectomy, decompressia, complication

Introduction

In modern conditions, the treatment of patients with spinal diseases increasingly requires highly specialized surgical intervention.

The introduction of new developments has significantly expanded the possibilities of qualified care for patients with spine disorders. Currently, a significant amount of knowledge has been accumulated regarding the surgical treatment of degenerative spinal diseases, new methods and approaches have been developed for performing spinal canal decompression and discectomies, and a significant amount of highly specialized equipment has been created to better achieve goals in each specific case. At the same time, it is necessary to determine the best option individually, taking into account the characteristics of each patient's anatomy, health status, and social needs.

Purpose: based on the study of scientific literature on the treatment of patients with intervertebral hernias and spinal canal stenosis of the lumbar spine, to determine the trends in the development of methods for performing surgical treatment of these diseases and the conditions for their administration.

Material and methods

A literature search was performed in the PubMed database using the keywords Mesh for the following search queries (English): ("Intervertebral Hernia / Open Discectomy" and "Intervertebral Hernia / Microdiscectomy" and "Intervertebral Hernia / Transforaminal Discectomy" and "Intervertebral Hernia / Endoscopic Discectomy" and "Intervertebral Hernia / Monoportal Discectomy" and "Intervertebral Hernia / Biportal Discectomy" and "Intervertebral Hernia / Decompressia" and "Intervertebral Hernia / Stabilization" and "Intervertebral Hernia / Transpedicular Fixation" and "Intervertebral Hernia / discectomy / Complication". The inclusion criteria were original experimental and clinical studies in English. The search depth was set at 8 years.

Results and their discussion

In total, 47 papers were selected for assessment. They recorded a comparative analysis of the techniques and results of performing discectomies using different methods in the case of degenerative diseases of the spine, primarily in the lumbar region.

Open discectomy (OD)

This technique, as before, remains the standard procedure for the treatment of herniated intervertebral discs of the lumbar spine (HIDLS) and gives good results. The success rates of traditional OD for HIDLS range from 75 to 100 %. Before the introduction of minimally invasive methods, OD was considered the gold standard for operating on this condition [1].

OD is performed through a posterior approach, where the epidural space is exposed along the posterior midline, dividing the paravertebral muscles, partially resect the arch, and remove the ligamentum flavum. The herniation is removed by resection of a portion of the facet joint on the symptomatic side, protecting the dural sheath and nerve roots [2]. The surgery may cause destabilization due to the necessary resection of spinal structures, which can lead to post-discectomy syndrome [3].

Microdiscectomy (MD)

Many surgical techniques have evolved from traditional to minimally invasive.

MD, like OD, is the standard procedure for symptomatic lumbar disc herniation and involves the spontaneous removal of a portion of the intervertebral disc that is compressing a nerve root or spinal cord (or both). MD is also called minimally invasive discectomy, tubular retractor discectomy, or tubular microdiscectomy, because it causes minimal tissue damage and results in less blood loss and postoperative pain and faster recovery. Proponents of MD believe that it improves patient outcomes, shortens hospital stays, and reduces hospital costs. However, this surgical technique is not without complications and drawbacks. These range from iatrogenic injuries such as durotomy, nerve root injury, or instability, to recurrent disc herniation, hematoma, infection, and more. [4].

Endoscopic discectomies and spinal canal decompression

The technique of spinal surgery is also changing:

Endoscopic spine surgery (ESS) has become the mainstay of surgery. Results show that this procedure generally has a lower complication rate than traditional surgical approaches [5].

However, although ESS has the advantages of less soft tissue dissection and damage to normal structures, reduced blood loss and epidural scarring, shorter hospital stays, and earlier functional recovery, it cannot replace all spinal surgical techniques with endoscopic ones. ESS was first used for lumbar discectomy, but its scope has expanded to include the entire spine, including the cervical and thoracic spine. New technologies such as navigation, augmented and virtual reality, robotics, and ultra-high-resolution 3D imaging are now being used to improve outcomes during ESS [6].

Lateral access during transforaminal endoscopic surgery to optimize the path to the spinal canal with continuous visualization has been performed since

the late 1990s [7]. Minimally invasive discectomy (MID) procedures include microendoscopic discectomy (MED) and percutaneous endoscopic partial discectomy (PEPD). Potential advantages of MID over standard MD/OD include less blood loss and postoperative pain, shorter hospital stay, and earlier return to work, but their complexity has not yet been fully evaluated [8]. Advantages of endoscopic spinal surgery include reduced tissue damage, blood loss, subsequent epidural fibrosis and scarring, minimal disruption of the epidural blood supply, shorter hospital stay, early cosmetic recovery, and improved quality of life [9]. With precise indications, correct diagnosis and good preparation, endoscopic spine surgery can give the same high result as during open intervention. Initially, endoscopic technique was limited to the lumbar region, but now it is also used in cases of interventions for herniated discs in the cervical and thoracic regions. In the past, endoscopy was used to treat disc herniations that were localized without migration, and now it is also used to operate on herniated discs with high migration up and down.

The use of this technique in the lumbar spine has been limited to disc herniation, but it is gradually being used for spinal stenosis and endoscopic fusion. It is ESS that can most clearly demonstrate its advantages in the treatment of herniated intervertebral discs in adolescents, especially in people involved in sports and in professional athletes, for whom less tissue trauma and earlier functional recovery are desirable [10].

Many studies have shown that PEPD has the same therapeutic effect as open discectomy. Since it can be performed under local anesthesia (LA), it is also prescribed to elderly patients with a more serious general condition [11].

With the development of minimally invasive techniques, PEPD is rapidly replacing OD in cases requiring discectomy and decompression. Experienced surgeons can reach the affected area directly through the Kambin's triangle. This method does not cause significant damage to the skin, muscles, laminae and synapses and, more importantly, avoids excessive stress on the dura mater [12]. It has been shown to achieve satisfactory results in the treatment of HIDLS with a reduced incidence of iatrogenic injury and minimal activity limitations, thereby accelerating rapid recovery [13].

It has been proven that endoscopic surgery can provide direct removal of the damaged intervertebral disc using a 7.5 mm working tunnel [14].

PEDD involves 2 intervention options: percutaneous endoscopic transforaminal discectomy (PETD) and percutaneous endoscopic interlaminar discectomy (PEID). Possible complications of such operations include excessive removal of the inferior articular process, which can cause iatrogenic lumbar instability [15], nerve root injury [16], and infection in the surgical area [17].

Z. Chen et al. (2020) showed that PEPD is more suitable for the treatment of paracentral hernias, when the transforaminal approach facilitates visualization of the lesion. In the case of median hernias, the limitation of the intervertebral foramen and the dura mater leads to worse clinical outcomes [18].

In favor of PEPD is the fact that unilateral nerve root compression was recorded in all patients with buttock pain in the study by J. An et al. (2022). In addition, the absence of stenosis at the L_{IV}–L_V level gives PEPD a greater advantage for the treatment of popliteal pain [11].

At the same time, it should be noted that PEPD focuses on surgical removal of the nucleus pulposus and does not affect the annulus fibrosus and posterior longitudinal ligament [19].

J. Xu et al. (2020) reported better outcomes after PEPD in terms of visual analogue scale (VAS) pain scores, reduction in low back pain, Oswestry Disability Index (ODI), and ratio of "excellent" to "unsatisfactory" outcome ratings 24 months after surgery compared to MED. At the same time, no significant difference was found in the frequency of complications, relapses, and re-interventions during this period [20].

The data presented show that more pronounced lower limb pain was observed after MED than after MD/OD during follow-up in the range of 6 months to 2 years, but the differences were insignificant (less than 0.5 points on a scale from 0 to 10). MED led to a more noticeable reduction in pain in the lumbar spine than MD/OD during follow-up in 6 months and in 2 years. At the same time, after MED, a lower quality of life (less than 5 points on a 100-point scale) and a higher risk of rehospitalization due to recurrence of intervertebral disc herniation were observed [21].

MED combines the traditional posterior fenestration technique with modern endoscopic surgery, allowing vertebrologists to obtain adequate decompression through a small incision. The 16 mm working tunnel is large enough to accommodate both the endoscope and surgical instruments. The endoscope reduces the expansion of the surgical field and the risk of nerve and vascular damage during decompression. In addition, because MED involves limited soft tissue and bone destruction, spinal stability is maintained.

Complications of MED documented in the literature include wound infection, cerebrospinal fluid leakage due to intraoperative dural rupture, nerve root and vascular injury, bleeding, and postoperative epidural hematoma [22].

MED, repeat PEPD, and minimally invasive transforaminal interbody fusion (MITIF) are the three most common minimally invasive surgical treatments for recurrent herniation after PEPD [9].

MED and repeat PEPD are associated with a significantly higher recurrence rate than MITIF [23].

Complications of PEPD include dura rupture, nerve root injury, and recurrent HID [11].

N. Fan et al. (2021) reported that, in a retrospective analysis of complications in 738 patients with HIDLS who underwent single-level PEPD, the incidence of various types of complications was 9.76 % (72/738): recurrent disc herniation — 2.30 % (17/738); persistent low back or lower extremity pain — 3.79 % (28/738); Dural tear — 1.90 % (14/738); incomplete decompression — 0.81 % (6/738); surgical site infection — 0.41 % (3/738); epidural hematoma — 0.27 % (2/738) and intraoperative posterior neck pain — 0.27 % (2/738). Univariate analysis showed that the development of complications was provoked by age, the degree of disc degeneration at the surgical level ($p < 0.001$) and the number of levels of disc degeneration ($p = 0.004$) [27].

In a retrospective analysis, J. An et al. (2022) reported the results of 93 patients who underwent PEPD and OD for buttock pain due to HIDLS, and the rate of "excellent" in the PEPD group was 89.36 % according to the modified MacNab scale. There was no significant difference compared to the OD group (89.13 %, $p > 0.05$). Currently, a modified PEPD method is used, which is safer and more effective for buttock pain caused by L_{IV}–L_V disc herniation. It has the advantages of lower complication rates, faster postoperative recovery, shorter hospital stay, lower anesthesia risks, and lower cost compared to conventional procedures. However, modified PEPD has a higher recurrence rate [11].

K. Zhao et al. (2022) noted that after 2 years of follow-up after PEPD, 85.71 % of patients rated the outcome of the operation as excellent or good, 9.66 % as satisfactory, and 4.62 % as unsatisfactory. The average improvement in the spine was 5.71 points, and the back was 5.85 points on the VAS scale (1–10). According to the Macnab scale, 30.67 % of patients felt completely recovered, 50 % reported that their functional capabilities were slightly limited, 16.81 % presented with noticeable functional limitations, and 2.52 % did not experience any improvement or deterioration. The overall complication rate was 10/262 (3.8 %), including 3 nerve root irritations and 7 early recurrent herniations (less than 3 months) [21].

A meta-analysis of 35 articles showed that OD, MD, MED and PEPD are associated with: recurrence of lumbar disc herniation in 4.1; 5.1; 3.9 and 3.5 %, respectively; reoperations in 5.2; 7.5; 4.9 and 4 %, respectively; wound complications in 3.5; 3.5; 1.2 and 2 %, respectively; durotomy in 6.6; 2.3; 4.4 and 1.1 %, respectively; neurological complications in 1.8; 2.8; 4.5 and 4.9 %, respectively. Nerve root damage was reported in 0.3 % of MD, 0.8 cases of MED and 1.2 cases of PEPD [24].

Currently, the clinical treatment of lumbar spinal stenosis is mostly performed using single-channel endoscopic surgery, including PEPD and MED. These methods allow for complete preservation of the physiological structure of the department with minimal surgical trauma and rapid postoperative recovery [25]. However, they also have disadvantages: a small field of view, which limits the work, as well as the difficulty of expanding the decompression range [36].

To overcome the anatomical limitations (pronounced transverse process of the L_V, developed arcuate joints, narrow disc space and foraminal space with high iliac crest), interlaminar endoscopic discectomy at the L_V–S_I level is used. The interlaminar endoscopic discectomy procedure can overcome the bony limitations of transforaminal access at this level and is performed under local anesthesia or general anesthesia.

From the perspective of preventing or reducing traumatic damage to the spinal canal, endoscopic surgery is an option for the treatment of HIDLS [27]. The patient's postoperative functional recovery is almost complete, and rehabilitation programs are not required [28].

J. D. Golan et al. (2023) emphasize the advantages of endoscopic surgery, including lower complication rates and procedure duration, shorter hospital stay, which together contribute to a faster return to work and socio-economic adaptation [29].

In the case of posterior lateral disc herniation, the L_V–S_I nerve root is displaced, creating more space for entry through the vertebral body defect [30].

The ligamentum flavum forms a tentacle-like depression with its apex in the midline and just below the inferior edge of the meninges. In the dura mater, it is 3–4 mm and is usually occupied by epidural fat. The ligament can be partially resected in the event of a disc prolapse in the canal, then a working space is created for the introduction of an endoscope in PEID [31].

A direct consequence of penetrating the spinal canal and disrupting this effective barrier is epidural fibrosis. Epidural fat, which acts as a lubricant, is largely preserved. T. W. Kang et al. (2021) reported that MRI examination of patients after PEID revealed scarring at the access site and only minor scarring in the spinal canal. Revision procedures were not more complex or required longer operative times than primary operations [1].

The treatment of descending disc herniation is clinically challenging due to anatomical obstructions and disc fragmentation. This is especially true if the disc herniation is distant (i.e. medial pedicles, inferior intervertebral disc) [32].

G. Krzok et al. (2016) demonstrated a new technique for CEPD that creates a tunnel through the root of the arch to reach its medial wall, where the descending disc herniation can be removed [33]. Similarly, H. S. Kim et al. (2018) developed a suprapedicular circular approach for PEPD that involves drilling the articular process, the superior facet, and the superior posterior border of the lower vertebra to widen the opening and expose the ventral epidural zone. They obtained good to very good clinical results for herniated intervertebral discs with downward migration [34]. However, less migrated HIDLS are treated with modified techniques and PEPD with good clinical results. This method also has a number of disadvantages and limitations. In a study by H. Huang et al. (2022) described the details of a unique inner border inferior transpedicular approach performed using a C-hook trephine fenestration laminectomy technique and guided visualization [35].

One of the recent developments in the surgery of intervertebral disc herniations of the spine is unilateral biportal endoscopic discectomy (UBED) [32].

Percutaneous single-portal or biportal endoscopic lumbar access can be effective in the treatment of central lumbar stenosis and is a novel alternative to traditional MD. The advantage of percutaneous biportal or single-portal endoscopic approaches is the reduction of pain syndrome in the postoperative period [36–38].

UBED requires formation of two channels, one for an endoscope to provide visual control, and the other for a surgical instrument, which combines the advantages of traditional minimally invasive and open surgery [39].

Compared with traditional lumbar stenosis surgery, minimally invasive spinal surgery using a microscope or endoscopic access shows more effective clinical results [40]. However, in the latter method, there are disagreements about which is more appropriate for the treatment of lumbar spinal stenosis — a microscope or an endoscope [14, 41, 42].

A study by Y. Niu, Z. Shen, and H. Li (2022) showed that compared with MED, UBED has the advantages of a short hospital stay and a good therapeutic effect [43].

A comparison of the clinical outcomes of posterior UBED and PEID for the treatment of L_V–S_I HID in 92 patients showed that UBED required more time to identify tissue structures and a wider space to work outside the spinal canal. The efficiency of removing the nucleus pulposus and releasing nerve roots in the spinal canal was greater than that of PEID. However, the surgical incision in UBED was longer, with greater actual blood loss than in PEID [44]. A comparative study of UBED and PEID for the treatment of HID in 281 patients (142 cases in the UBED group and 139 in the PEID group) found no significant differences in clinical efficacy between them. However, PEID was inferior in terms of such indicators as the duration of surgery and the amount of intraoperative blood loss. The authors concluded that PEID was better suited for the treatment of HIDLS, which is confirmed by other researchers [45].

J. Hao, J. Cheng, H. Xue, F. Zhang (2022) retrospectively analyzed the treatment outcomes of 40 patients with HIDLS from 2018 to 2021. All patients underwent UBED (20) and PEID (20) operations. Compared with the UBED group, the PEID group had less intraoperative blood loss, shorter intervention time, and shorter hospital stay. Both groups had satisfactory clinical outcomes; VAS and ODI scores in the PEID group decreased more significantly. The authors concluded that for HIDLS, UBED provides the same clinical results as PEID and minimally invasive surgery, but PEID was better than UBED in terms of intraoperative blood loss, duration of surgery, postoperative hospitalization, and short postoperative anesthesia [46].

When comparing the clinical results of UBED (42 patients) via posterior access with PEID (50 subjects) for the treatment of HIDLS L_V–S_I involving 92 patients from January 2020 to July 2021, UBED was shown to be more effective in removing the gelatinous nucleus and releasing nerve roots in the spinal canal than PEID. The surgical access using the UBED technique is longer, with greater blood loss [47].

A retrospective analysis of patients with two-level lumbar herniation L_{IV}–L_V and L_V–S_I who underwent single- or double-access PEID from January 2017 to December 2020 (25 patients each) found that the single-incision group had better results than the double-incision group in terms of incision length,

operation time, and fluoroscopy ($p < 0.001$). VAS scores, quality of life scores, and ODI scores in the two groups were significantly lower at the time of surgery, one month after the intervention, and at the last follow-up ($p < 0.01$), but there was no statistical significance between the groups ($p > 0.05$). At the last follow-up, the excellent and good efficacy according to the Macnab scale in the two groups was 92 % and 88 %, respectively, but a significant difference was recorded between the above parameters ($p > 0.05$). Single incision for performing PEID for the treatment of lumbar spine herniations on two segments L_{IV}–L_V and L_V–S_I had the advantages of less trauma, shorter time of both intraoperative fluoroscopy and surgery compared to double incision. Therefore, removal of hernias on two segments of the HIDLS through one laminar incision turned out to be a more complex surgical intervention [27].

A systematic evaluation of the effectiveness and safety of UBED and MD for the treatment of HID stenosis showed that the duration of UBED is shorter than MD. Compared with patients with MD, after UBED, back pain in patients was less pronounced on the 1st day, in 1–2 months and in 6 months. The time of UBED was shorter than MD, but after UBED, pain syndrome in the back, lower extremities according to the VAS scale and the level of C-reactive protein in the early postoperative period were greater than after MD [47].

Conclusions

The advantages of modern endoscopic spinal surgery include less tissue damage and injury to the epidural blood supply with little fibrosis, lower blood loss, shorter hospital stay, and early cosmetic recovery. With verified indications, correct diagnosis, and the use of high-quality instrumentation, endoscopic spinal surgery provides a good clinical outcome.

Percutaneous endoscopic partial discectomy focuses on surgical removal of the nucleus pulposus and does not affect the annulus fibrosus and posterior longitudinal ligament, avoiding significant trauma to the skin, muscles, laminae, and synapses, and excessive stress on the dura mater. This procedure can be performed under local anesthesia, which opens the possibility for elderly patients with a more severe general condition. This type of discectomy is more suitable for the treatment of foraminal and extraforaminal hernias, when transforaminal access facilitates visualization of the lesion. For median herniations, the narrowing of the intervertebral foramen and the obstruction of the dura mater during this technique lead to worse clinical results. In general, better results are observed after percutaneous endoscopic partial discectomy than after microdiscectomy.

Surgical treatment of lumbar spinal stenosis is mostly performed using single-channel endoscopic surgery, which allows for complete preservation of the physiological structure of the lumbar spine with minimal trauma and rapid postoperative recovery. Disadvantages include a small field and the difficulty of expanding the boundaries of decompressive action.

One of the latest developments in the treatment of intervertebral herniations of the spine is unilateral biportal endoscopic discectomy. Its effectiveness and release of nerve roots in the spinal canal exceeds that of percutaneous endoscopic interlaminar partial discectomy, but unilateral biportal endoscopic discectomy is longer, with greater actual blood loss during the operation.

Conflict of interest. The authors declare the absence of a conflict of interest.

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CURRENT TRENDS OF SURGICAL TREATMENT INTERVERTEBRAL HERNIAS AND LUMBAR STENOSIS THE SPINE

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