



MANAGEMENT OF LUMBAR DISC HERNIATION – A REVIEW OF CONSERVATIVE AND SURGICAL TREATMENT

Postępowanie w przepuklinie dysku lędźwiowego –
przegląd leczenia zachowawczego i chirurgicznego



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Abstract

Lumbar disc herniation is considered one of the leading causes of disability worldwide, with a lifetime risk of occurrence as high as 30%. A common initial symptom is pain in the sacro-lumbar region, which may radiate to the buttocks or lower extremities. The management of patients with lumbar disc herniation includes both conservative and surgical treatments. Conservative treatment involves medications, physical therapy, traction and appropriate exercises, and often yields good clinical results in 60–90% of patients. Surgical options include various techniques, such as open discectomy, microdiscectomy, percutaneous laser disc decompression, and percutaneous microscopic discectomy, among others. The purpose of this article is to present therapeutic methods used in the conservative and surgical treatment of lumbar disc herniation and to assess these methods in terms of clinical outcomes.

Streszczenie

Przepuklina dysku lędźwiowego jest zaliczana do jednej z głównych przyczyn niepełnosprawności na świecie. W ciągu całego życia ryzyko jej wystąpienia wynosi nawet 30%. Częstym pierwszym objawem jest ból w okolicy krzyżowo-lędźwiowej, który może promieniować do pośladków czy kończyny dolnej. W postępowaniu u pacjentów z przepukliną dysku lędźwiowego stosuje się leczenie zachowawcze oraz chirurgiczne. Leczenie zachowawcze składa się z leków, fizykoterapii, trakcji oraz odpowiednich ćwiczeń. Takie postępowanie często przynosi dobre efekty kliniczne u 60–90% pacjentów. W leczeniu chirurgicznym stosuje się różne techniki, takie jak otwarta discektomia, mikrodiscektomia, przezskórna laserowa dekompresja dysku, przezskórna mikroskopowa discektomia i wiele innych. Celem niniejszej pracy jest przedstawienie metod terapeutycznych używanych w leczeniu zachowawczym i chirurgicznym przepukliny dysku lędźwiowego oraz ich ocena w kontekście wyników klinicznych.

Keywords: disc herniation; LDH management; discectomy; disc; spinal surgery

Słowa kluczowe: przepuklina dysku; postępowanie w LDH; discektomia; dysk; operacja kręgosłupa

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Introduction

Lumbar disc herniation (LDH) is a common cause of patient complaints of back pain and radiculopathy. It predominantly occurs in patients between the ages of 24 and 45, with a male-to-female ratio of 2:1. Over 95% of lumbar herniations occur at the L4–L5 or L5–S1 levels in patients aged 25 to 55. LDH is considered one of the leading causes of disability worldwide, with a lifetime risk of approximately 30% [1–4].

Intervertebral disc herniation refers to a situation where the nucleus pulposus protrudes or extrudes through the fibrous ring beyond the intervertebral space. This may result in compression of the spinal nerve roots and the meningeal sac, leading to radiculopathy. Low back pain is a common initial symptom of LDH. It can radiate to the buttocks or lower extremities, typically unilaterally. Symptoms often worsen with physical exertion, sedentary lifestyle, squatting, and tend to subside after rest. Root symptoms, on the other hand, may be increased by activities such as sneezing, coughing, standing, or walking [3, 4].

In the diagnosis of LDH with radiculopathy, assessment of sphincter function, evaluation of muscle strength and sensory disturbances, as well as Lasegue's sign and crossed Lasegue's sign, may be useful. The gold standard in suspected LDH is MRI, which has a diagnostic accuracy of up to 97% [4].

The basis of treatment is conservative management focused on exercise and pain control with pharmacological agents. Nearly 60–90% of patients experience clinical improvement or even spontaneous regression already at this stage of treatment. If conservative treatment fails, surgical intervention with discectomy is indicated [1, 5, 6]. Advances in technology have contributed to the development of various surgical techniques aimed at removing herniated intervertebral discs with minimal tissue damage and, at the same time, the best possible clinical outcomes [7]. Especially important is the development of endoscopic techniques, which allow surgery to be performed under local anesthesia [3].

The traditional technique that finds application in LDH is open discectomy (OD) (with or without fusion surgery), but other surgical approaches can also be employed, such as microdiscectomy (MD), tubular discectomy (TD) (a subtype of microdiscectomy), and percutaneous laser disc decompression (PLDD) [8].

In addition, endoscopic spine surgery can be divided by the characteristics of the endoscopes into percutaneous endoscopic (PED) (or full-endoscopic), microendoscopic (MED), epiduroscopic, and biportal endoscopic techniques [7, 9].

Historical overview

The first true discectomy surgery took place in 1932 and is attributed to Mixter and Barr. Barr's published results (1947) indicated better clinical outcomes for LDH patients treated with surgical decompression and fusion than those treated with discectomy alone. In the 1970s,

these surgeries became so popular that they were even offered to patients with very early, acute symptoms of lumbar disc herniation [10].

In 1977, Caspar and Yaşargil introduced the concept of microsurgical techniques in lumbar disc surgery. The smaller incision and tissue-sparing surgical approach made them superior to open discectomy. This marked the origin of microendoscopic discectomy, which has been improved over the years [11]. Percutaneous decompression surgery was inspired by Hijikata's theory developed in 1975, whose premise was "Reducing intradiscal pressure reduces the irritation of the nerve root and the pain receptors in the annulus and peridiscal area." [12].

Percutaneous endoscopic lumbar discectomy (PELD) through the intervertebral foramen emerged around 1980. It quickly became popular and a common technique, along with percutaneous endoscopic interlaminar discectomy (PEID) [9]. Seventeen years later, Smith and Foley described microendoscopic discectomy for the first time. The treatment of LDH patients using an endoscope and a minimally invasive transmuscular approach quickly became widespread [13]. In a short period, other minimally invasive surgical procedures such as PED and PLDD also emerged [3]. Tubular retractors combined with endoscopes became the foundation of the MED surgical technique, which was described in 1999 by Foley and Smith [14]. In the United States alone, approximately 200,000 discectomies were performed per year in the mid-1990s [10].

Conservative treatment

The foundation of conservative treatment is a combination of physical therapy and pharmacological management. However, there is a difference of opinion regarding the use of pharmacotherapy in the management of LDH. For instance, the American College of Physicians (ACP) recommends that pharmacological therapy should be introduced only when there is an unsatisfactory response to non-pharmacological therapy [15]. Some of the pharmacological agents commonly used in the conservative treatment of patients with LDH are described below.

Nonsteroidal anti-inflammatory drugs (NSAID)

NSAIDs are a well-known group of medications commonly used in clinical practice, including in the treatment of patients with LDH. However, study findings differ regarding the improvement of function and pain relief in such patients. Jung Hwan Lee et al. recommend the use of NSAIDs. A slightly different consideration is described in the article by Jo Jordan et al., who report that these medications have a comparable effect to placebo, since no significant difference was found in overall improvement after 5–30 days of use. It is important to note that NSAID therapy is not without side effects. These may include abdominal pain, gastrointestinal bleeding/perforation, cardiovascular incidents, headaches, and dizziness. Therefore, consideration should be given to the appropriate use of these medications so that their potential side effects do not outweigh the benefits. According to United Kingdom guidelines, the lowest effective dose should be used for the shortest possible time [2, 15–17].

Opioids

Opioid medications may also be used in LDH therapy, especially in combination with other drugs (antiepileptic, analgesic). This approach is very commonly used in the United States and Canada. Opioids have helped to reduce pain and improve patient functionality. However, with their use, vomiting and addiction, among others, may occur as adverse effects [2, 15].

Antidepressants and antiepileptic drugs

NICE (which provides evidence-based recommendations for health and care in England and Wales) recommends antidepressants and antiepileptic drugs as first-line treatment for neuropathic pain. These medications help improve function and reduce pain. Popular among these are amitriptyline, duloxetine, gabapentin, and pregabalin [2, 15].

Steroids

In clinical practice, epidural corticosteroid injections and systemic steroids are often used. However, if patients do not experience improvement after 4–8 weeks, surgical treatment is indicated [2, 5].

According to the article by Jung Hwan et al., epidural steroid injections are recommended for patients with LDH. They have demonstrated a high level of evidence and strength of recommendation for relieving pain and improving function. These injections can be administered via transforaminal, caudal, or interlaminar approaches. Although the caudal and interlaminar approaches were preferred for years, this trend has been reversed with the increasing use of transforaminal epidural injections. This is reflected in studies that are inconclusive, but point to the clinical benefit of the transforaminal approach over the mentioned above. In these interventions, the use of nonparticulate steroids is recommended, while particulate steroids are not advised [16, 18]. It is worth mentioning, however, that discectomy provides better results after 1–3 months in terms of functional improvement and pain reduction compared to epidural injections [17].

The effect of systemically administered steroids remains inconclusive. Significant pain reduction was experienced by patients with acute lumbosacral pain after systemic administration of dexamethasone. However, this improvement diminished after six months. Also, 14 days of oral triamcinolone therapy provided better pain control than oral anticonvulsant drug therapy. The clinical benefit of systemic steroid use is rated as clinically favorable, which supports its recommendation [16].

Other treatments

Non-pharmacological conservative treatments such as acupuncture or electroacupuncture of the spine do not show a significant difference compared to pharmacological treatment during the intervention period. Kim Doori et al. compared the treatment methods used above. The results demonstrated that non-pharmacological conservative treatment showed a significant improvement in the LDH patient's condition compared to pharmacological treatment, but only after 14 weeks of follow-up (difference: -0.56 , 95% CI -1.62 to 0.50 , $p = 0.003$). A meta-

analysis by Shujie Tang et al. showed that acupuncture in the treatment of LDH has a more favorable clinical effect than NSAIDs and lumbar traction [15, 19].

A meta-analysis by Jung Hwan Lee et al. presented functional improvement and pain reduction in LDH patients suffering from root pain who used manual therapy, exercise and traction. In addition, patients who underwent traction therapy showed favorable changes on magnetic resonance imaging (MRI) in just two months, although no reduction in pain was observed [16].

A common practice recommended by physicians for patients with LDH-induced back pain is bed rest. However, studies have shown that this practice is not advisable and may even slightly worsen the patient's clinical condition. In such a case, the patient should be encouraged to return to daily physical activity with restriction to activities that do not cause pain [16, 20].

Surgical treatment

Patients with LDH are generally recommended to start with conservative treatment. If this proves ineffective, surgical intervention may be considered. However, some clinical situations require the implementation of surgical treatment first. Among these are severe neurological motor deficits, cauda equina syndrome, sphincter dysfunction, or insufficient pain control [21]. The surgeon, therefore, has to consider many factors in selecting the most appropriate surgical method. Some of the available techniques are described below.

Open discectomy

Open discectomy is a traditional surgical procedure used to treat patients with LDH. However, it is being performed less frequently, with minimally invasive surgeries becoming more popular. Compared to other surgical approaches, it is a technique associated with greater blood loss, prolonged hospitalization, and the formation of scarring and adhesions, which may contribute to decreased activity of the lumbar spine. This has led to the development of less invasive surgical approaches. A more modern approach – with shorter recovery times and lower surgical costs – is minimally invasive surgery (MIC) [3, 22].

Percutaneous laser disc decompression

Percutaneous laser disc decompression (PLDD) is a procedure that can be performed under local anesthesia. It involves percutaneously accessing the nucleus pulposus and then vaporizing it using the photothermal effect of laser energy. This reduces intradiscal pressure, allowing the disc to return to its normal position and relieving compression of the nerve root. In addition, the photochemical effect of the laser causes the destruction of pain mediators (neurokinins, cytokines). The study by Ivan Radoš et al. showed satisfactory pain reduction in LDH patients and a low risk of complications after the PLDD procedure [22, 23].

Percutaneous endoscopic lumbar discectomy

Percutaneous endoscopic lumbar discectomy (PELD) is a minimally invasive alternative to microdiscectomy

surgery. It is currently the most commonly used technique in endoscopic spine surgery. It is usually equated with percutaneous endoscopic interlaminar discectomy (PEID) and percutaneous endoscopic transforaminal discectomy (PETD). PELD is becoming an increasingly routine surgical approach. In comparison with open discectomy, it offers shorter operative times, with less soft tissue damage, fewer post-operative complications, and faster recovery. The main difference between the above-mentioned procedures is the surgical approach: PEID is performed between the lumbar vertebral arch laminae, while PETD is performed through the intervertebral foramen [7, 24, 25]. PEID is a well-suited surgical approach for subarticular disc herniations and concurrent stenosis of the lateral recess. In contrast, spinal disc herniations in the foramen but also in the lateral recess ventral to the traversing nerve root are a suitable indication for PETD. Notably, both surgical approaches are particularly appropriate for the lower lumbar spine – L4/5 and L5/S1 for PEID, and L5/S1 for PETD [5]. In the study results, PETD was characterized by better postoperative improvements in pain and function, but longer surgery times than PEID at the L5–S1 level. However, when comparing both surgical techniques, the clinical outcomes were very similar in terms of patient satisfaction, days of hospitalization, postoperative complications, blood loss, VAS (visual analog scale), and ODI (Oswestry Disability Index). Also, the PETD procedure was found to expose patients to higher levels of radiation than PEID [12, 26, 27]. A meta-analysis by Lu Qin et al. compared the effectiveness of PELD and microendoscopic discectomy to open discectomy. The minimally invasive procedures had better short-term outcomes based on VAS and ODI scores, but the difference at six months after surgery was not significant [3].

Microdiscectomy

Microdiscectomy is considered the gold standard in LDH surgery. The technique involves a small incision (up to a maximum of 2 cm), relatively little muscle damage, and faster recovery [9, 22]. However, it can lead to postoperative back pain or spinal instability. This is mainly caused by incision of the midline ligament and separation of the spinal muscles from the spinous process. A retrospective study by Konsta Koivunen et al. of 353 patients revealed that the level of pain decreased within a year after microdiscectomy but slightly worsened thereafter [14, 28].

Tubular microdiscectomy (TMD) is not based on standard subperiosteal muscle dissection, but rather the insertion of small tubes and dilators through a small incision to create a working corridor for the operation. This approach results in less tissue damage and supports faster recovery [14].

A meta-analysis by Tingxin Zhang et al. showed that tubular microdiscectomy achieved better ODI rates than conventional microdiscectomy. However, there were no significant differences in surgical blood loss, length of hospitalization, VAS score, reoperation rates, and operation time. The results show similar clinical effects of both surgical methods. In addition, the results of a meta-analysis by Shichao Liu et al. comparing TMD to PETD revealed no significant differences in clinical outcomes between these two techniques [14, 29].

Also worth mentioning is unilateral biportal endoscopic discectomy (UBED), which is similar to open MD. It combines endoscopic spine surgery and standard open surgery. UBED produced similar clinical results in terms of patient satisfaction and pain control compared to PELD. However, UBED was associated with increased blood loss, longer hospitalization, and higher costs [9, 30].

Discussion

Treatment of symptomatic LDH patients should be approached individually. The goal of treatment is to reduce or completely eliminate pain and to improve or restore limb function [29]. Correct diagnosis is a crucial element in further management. Lumbar pain should be differentiated from facet joint, discogenic, or sacroiliacal joint pain. In addition to diagnostic manual testing, current guidelines recommend magnetic resonance imaging (MRI) whenever symptoms persist for more than six weeks to confirm the presence of LDH. MRI should be performed as soon as possible if neurological deficits are present. In patients in whom MRI cannot be performed, or if the results are inconclusive, CT (computed tomography) or CT myelography is recommended [4]. Therapeutic management should begin with conservative treatment, which leads to improvement in 60–90% of patients. Pharmacological agents, physical therapy procedures, and physiotherapy exercises should be selected on an individual basis. It should be noted that for some conservative treatments, the question of clinical improvement is still unclear and requires further research.

If there is no improvement with conservative treatment, surgical intervention is indicated. Patients with insufficient pain control, symptoms of sphincter dysfunction, neurological motor deficits, or cauda equina syndrome require urgent surgery [21]. Patients should be cautiously qualified for surgical treatment. The risk of LDH recurrence is approximately 9.1%, of which 38% cases recur within the first year after surgery. In addition, postoperative pain may be worse in some patients than before surgery. While patients usually blame the operator for such outcomes, the predominant factor is actually the patient's individual predisposition – particularly the formation of scar tissue after surgery, which presses on the nerve root. This issue is the most important factor in failed spinal surgeries due to LDH. It is important to note that reoperations in such patients tend to worsen their clinical outcomes [4, 22]. When selecting a surgical method, minimally invasive spinal surgery techniques should be the main consideration, as studies have shown that they produce better clinical outcomes than open discectomy. In 2024, a meta-analysis by Qin Lu et al. was published, comparing standard open discectomy, microdiscectomy, microendoscopic discectomy, PELD, PLDD, TMD, and chemonucleolysis. It showed that microendoscopic discectomy is the best surgical intervention for back and leg pain, based on VAS scores [3]. However, it is important to note that each of the listed surgical methods has its own indications and contraindications, which are often individual. Therefore, the final choice of surgical technique is made by the surgeon, who looks at the patient on an individual basis and selects the most appropriate surgical method.

In addition to the aforementioned surgical treatment methods, risk factors for LDH are also worth highlighting. A prospective study conducted in Copenhagen on thousands of men found that heavy physical activity at work was a strong risk factor for LDH. On the other hand, physical activity outside of work did not correlate with the occurrence of LDH. This suggests that different types of physical and ergonomic loads at work influence the development of lumbar disc herniation. Sørensen et al. additionally described body height as a predictor associated with lumbar herniated discs, while body weight was only slightly associated with LDH [31]. In a surprising finding, Mirza Pojskic et al. indicated an increased relative risk of LDH in cigarette smokers [4]. Risk factors that may contribute to lumbar spinal herniation should be avoided whenever possible.

References

- Bansal P, Vatkar AJ, Baburaj V, et al. Effect of obesity on results of endoscopic versus open lumbar discectomy: a systematic review and meta-analysis. *Arch Orthop Trauma Surg*, 2023; 143: 5589–5601. doi: 10.1007/s00402-023-04870-6
- Manafi A, Mirbolook A, Darestani R, et al. Conservative treatment of low back pain in lumbar disc herniation: comparison of three therapeutic regimens. *Syst Rev Pharm*, 2020; 11: 765–769. doi: 10.31838/srp.2020.8.110
- Qin L, Jiang X, Zhao S, et al. A comparison of minimally invasive surgical techniques and standard open discectomy for lumbar disc herniation: a network meta-analysis. *Pain Physician*, 2024; 27: E305–E316
- Pojskic M, Bisson E, Oertel J, et al. Lumbar disc herniation: Epidemiology, clinical and radiologic diagnosis – WFNS spine committee recommendations. *World Neurosurg*, 2024; 22: 100279. doi: 10.1016/j.wnsx.2024.100279
- Sivakanthan S, Hasan S, Hofstetter C. Full-endoscopic lumbar discectomy. *Neurosurg Clin N Am*, 2020; 31: 1–7. doi: 10.1016/j.nec.2019.08.016
- Agarwal N. *Neurosurgery Fundamentals*. New York, Thieme Medical Publishers, 2019
- Ahn Y. Endoscopic spine discectomy: indications and outcomes. *Int Orthop*, 2019; 43: 909–916. doi: 10.1007/s00264-018-04283-w
- Wei F, Zhou C, Zhu K, et al. Comparison of different operative approaches for lumbar disc herniation: a network meta-analysis and systematic review. *Pain Physician*, 2021; 24: E381–E392
- Choi K, Shim H, Hwang J, et al. Comparison of surgical invasiveness between microdiscectomy and three different endoscopic discectomy techniques for lumbar disc herniation. *World Neurosurg*, 2018; 116: e750–e758. doi: 10.1016/j.wneu.2018.05.085
- Truumees E. A history of lumbar disc herniation from Hippocrates to the 1990s. *Clin Orthop Relat Res*, 2015; 473: 1885–1895. doi: 10.1007/s11999-014-3633-7
- Clark A, Safaei M, Khan N, et al. Tubular microdiscectomy: techniques, complication avoidance, and review of the literature. *Neurosurg Focus*, 2017; 43: E7. doi: 10.3171/2017.5.FOCUS17202
- Amoretti N, Dalili D, Palominos D, et al. Percutaneous discectomy under CT and fluoroscopy guidance: an international multicentric study. *Neuroradiology*, 2021; 63: 1135–1143. doi: 10.1007/s00234-021-02633-x
- Xu J, Li Y, Wang B, et al. Minimum 2-year efficacy of percutaneous endoscopic lumbar discectomy versus microendoscopic discectomy: a meta-analysis. *World Neurosurg*, 2020; 138: 19–26. doi: 10.1016/j.wneu.2020.02.096
- Zhang T, Guo N, Wang K, et al. Comparison of outcomes between tubular microdiscectomy and conventional microdiscectomy for lumbar disc herniation: a systematic review and meta-analysis of randomized controlled trials. *J Orthop Surg Res*, 2023; 18: 479. doi: 10.1186/s13018-023-03962-8
- Kim D, Kim ES, Lee YJ, et al. A pilot study for effectiveness of non-pharmacological versus pharmacological treatment strategies for lumbar disc herniation: a pragmatic randomized controlled trial. *J Pain Res*, 2023; 16: 3197–3216. doi: 10.2147/JPR.S421148
- Lee JH, Choi KH, Kang S, et al. Nonsurgical treatments for patients with radicular pain from lumbosacral disc herniation. *Spine J*, 2019; 19: 1478–1489. doi: 10.1016/j.spinee.2019.06.004
- Jordan J, Konstantinou K, O'Dowd J. Herniated lumbar disc. *BMJ Clin Evid*, 2009; 2009: 1118
- Manchikanti L, Knezevic E, Knezevic NN, et al. A comparative systematic review and meta-analysis of 3 routes of administration of epidural injections in lumbar disc herniation. *Pain Physician*, 2021; 24: 425–440
- Tang S, Mo Z, Zhang R. Acupuncture for lumbar disc herniation: a systematic review and meta-analysis. *Acupunct Med*, 2018; 36: 62–70. doi: 10.1136/acupmed-2016-011332
- Malmivaara A, Häkkinen U, Aro T, et al. The treatment of acute low back pain – bed rest, exercises, or ordinary activity? *N Engl J Med*, 1995; 332: 351–355. doi: 10.1056/NEJM199502093320602
- Kurzbuch A, Tuleasca C, Fournier J. Lumbar discectomy with annulus fibrosus closure: a retrospective series of 53 consecutive patients. *Neurochirurgie*, 2022; 68: 393–397. doi: 10.1016/J.NEUCHI.2021.12.009
- Radoš I, Katušin M, Budrovac D, et al. Percutaneous laser disc decompression for lumbar radicular pain: a systemic review of pubmed in the last five years. *Acta Clin Croat*, 2023; 62: 63–67. doi: 10.20471/acc.2023.62.s4.9
- Eghosa M, Benedict O, Obiora A, et al. A narrative review of percutaneous laser disc decompression – early experience in Lagos, Nigeria. *Rom J Neurol*, 2023; 2: 208–213. doi: 10.37897/RJN.2023.3.5
- Pan M, Li Q, Li S, et al. Percutaneous endoscopic lumbar discectomy: indications and complications. *Pain Physician*, 2020; 23: 49–56
- Yan Y, Zhu M, Cao X, et al. Different approaches to percutaneous endoscopic lumbar discectomy for L5/S1 lumbar disc herniation: a retrospective study. *Br J Neurosurg*, 2024; 38: 16–22. doi: 10.1080/02688697.2020.1861218
- Jitpakdee K, Liu Y, Kotheeranurak V, Kim JS. Transforaminal versus interlaminar endoscopic lumbar discectomy for lumbar disc herniation: a systematic review and meta-analysis. *Global Spine J*, 2023; 13: 575–587. doi: 10.1177/21925682221120530
- Chen J, Jing X, Li C, et al. Percutaneous endoscopic lumbar discectomy for L5/S1 lumbar disc herniation using a transforaminal approach versus an interlaminar approach: a systematic review and meta-analysis. *World Neurosurg*, 2018; 116: 412–420.e2. doi: 10.1016/j.wneu.2018.05.075
- Koivunen K, Perna K, Saltychev M. Back pain and radicular pain after lumbar microdiscectomy. *BMC Surg*, 2023; 23: 210. doi: 10.1186/s12893-023-02114-3

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29. Liu S, Wang R, Chen H, et al. Comparison of efficacy and safety between percutaneous transforaminal endoscopic discectomy and tubular microdiscectomy for lumbar disc herniation: a network meta-analysis [preprint]. *Res Sq*, 2023. <https://doi.org/10.21203/rs.3.rs-2930604/v1>
30. Jiang HW, Chen CD, Zhan BS, Wang YL, Tang P, Jiang XS. Unilateral biportal endoscopic discectomy versus percutaneous endoscopic lumbar discectomy in the treatment of lumbar disc herniation: a retrospective study. *J Orthop Surg Res*, 2022 ; 17: 30. doi: 10.1186/s13018-022-02929-5
31. Sørensen IG, Jacobsen P, Gyntelberg F, Suadicani P. Occupational and other predictors of herniated lumbar disc disease-a 33-year follow-up in the Copenhagen male study. *Spine (Phila Pa 1976)*, 2011; 36: 1541-1546. doi: 10.1097/BRS.0b013e3181f9b8d4