BANYŚ, Filip, WIAK, Iga, BOCHEN, Konrad, CZYŻEWSKI, Filip, DZIEGCIARCZYK, Anna, GÓRSKA, Weronika, JASIŃSKI, Filip, ŁUKAWSKI, Artur, SZAŁAJSKA, Julia and WOJTACH, Klaudia. Approaches to Managing Herniated Disc Surgical vs. Conservative Treatment. Quality in Sport. 2024;29:55578. eISSN 2450-3118.
https://dx.doi.org/10.12775/QS.2024.29.55578
https://apcz.umk.pl/QS/article/view/55578

The journal has been 20 points in the Ministry of Higher Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Higher Education and Science of 05.01.2024. No. 32553.
Has a Journal's Unique Identifier: 201398. Scientific disciplines assigned: Economics and finance (Field of social sciences); Management and Quality Sciences (Field of social sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 r. Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398.
Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).

The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 09.10.2024. Revised: 25.10.2024. Accepted: 26.10.2024. Published: 26.10.2024.

Approaches to Managing Herniated Disc: Surgical vs. Conservative Treatment

AUTHORS:

Filip Banyś, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland

https://orcid.org/0009-0002-6231-0904

filipbany607@gmail.com

Iga Wiak, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland

https://orcid.org/0009-0003-6419-7287

wiak.igakinga@gmail.com

Konrad Bochen, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland

https://orcid.org/0009-0000-9757-0744

konrad.bochen@gmail.com

Filip Czyżewski, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland
https://orcid.org/0009-0006-8556-6565
czyzewskifilip@gmail.com
Anna Dziegciarczyk, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland
https://orcid.org/0009-0008-5233-4826
dziegciarczyk.ania@gmail.com
Weronika Górska, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland
https://orcid.org/0009-0005-3155-9573
weronika.maslow@gmail.com
Filip Jasiński, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland
https://orcid.org/0009-0005-3327-255X
filip.jasinski00@wp.pl
Artur Łukawski, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland
https://orcid.org/0009-0006-6252-1655
arturlukawski010120@op.pl
Julia Szałajska, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland
https://orcid.org/0009-0007-8866-5419
juliaszalajska.mail@gmail.com
Klaudia Wojtach, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland
https://orcid.org/0009-0007-2220-0088
klaudiaw2000@o2.pl

ABSTRAKT

Introduction

Disc herniation is a displacement of an intervertebral disc, most often caused by degeneration of its outer layer, the annulus fibrosus. This condition can cause various symptoms such as numbness, pain, muscle weakness or lose of sensation. While many patients can be successfully treated with non-surgical methods, some of them some require surgical intervention.

Aim of study

The objective of this study is to evaluate both surgical and non-surgical treatment methods for herniated disc and seeks to introduce doctors and patients to the advantages and disadvantages associated with them.

State of Knowledge

Disk herniation occurs when disk material prolapses beyond intervertebral disk's space. The symptoms may arise when displaced material start to compress major structures located nearby, such as spinal nerves. The most common causes include age-related degeneration, repetitive movements, obesity, trauma or genetic predisposition.

Summary (Conclusion)

Disk herniation can be managed with various non-surgical and surgical methods. Conservative treatment should be considered as first line treatment showing high success rate for mild to moderate cases in long term relief and preventing recurrence of symptoms. Surgical options offer better short-term relief for sever and more advanced cases but carry greater risks of side effects and involve longer recovery time. Best approach should be carefully selected based on the severity of symptoms and patient needs.

Keywords: *Intervertebral Disc Herniation, Conservative Therapy, Surgery, Review, Low Back Pain, Sciatic*

INTRODUCTION

Disk herniation refers to the displacement of nucleus pulposus, central part of the intervertebral disk. This displacement may lead to compression of adject structures like nerves, typically manifesting with burning or stinging pain, often radiating into extremities. In more advanced cases, patient may already present more severe pain associated with muscle weakness and lose of sensation in extremities. Given the numerous individuals affected by back pain, it is essential to correctly diagnosed disk herniation and choose the most appropriate treatment option for each patient.

There are multiple treatment options available for disk herniation, both conservative and surgical included. Non-surgical approaches, such as regular exercise, physiotherapy or analgesics have proven to successfully managing patients' symptoms. These methods aim to reduce symptoms and delay the need for surgical intervention. For patients with severe or persistent symptoms unresponsive to conservative care, surgical options have proven to be the most effective in term of symptoms relief.

Microdiscectomy, considered as the gold standard for surgical treatment, provides rapid pain relief with minimal risk of complications due to its minimally invasive nature. However, microdiscectomy is not suitable for all patients, therefore more complex cases are dependent on more sophisticated methods. These techniques, involving open surgeries with artificial implants or spinal stabilizers, carry greater risks of complications and longer recovery time, but may be most effective solution.

Each treatment option has its own advantages and limitations, underscoring the importance of personalising the treatment approach to ensure best outcomes with least risk of adverse effects for the patient (Dydyk et al., 2024).

Epidemiology

Intervertebral disc herniation affects approximately 5 to 20 per 1,000 adults annually, twice as often in men. The typical patient age ranges from 30 to 50 years. However, recent studies indicate downward shift in this trend with younger individuals being diagnosed more frequently (Fjeld et al., 2019).

Around 80% of people will experience episode of lower back pain during their lifetime, with lumbar disc herniation (LDH) being one of the most common underlying causes. Among these cases only 1 to 3% of them represents symptomatic LDH. The majority of approximately 95% LDH cases is located either between L4-L5 or L5-S1 vertebrae (Jordan et al., 2009).

Although, to our best knowledge, data on the exact prevalence of disc herniation subtypes is limited, current evidence indicates that LDH is by far the most common one. Cervical disc herniation is diagnosed over ten times less frequently than LDH, while thoracic disc herniation is even rarer (Zhang et al., 2023).

Anatomy and Function

Intervertebral disk (IVD) consists of centrally located nucleus pulposus surrounded by an outer annulus. It is situated between adjacent vertebral bodies, supported by anterior and posterior longitudinal ligaments which run along the front and back of the vertebral column. There are 23 IVDs in the vertebral spine: 6 in cervical region of the spine, 12 in thoracic region, 5 in lumbar region and any of them can be a cause of symptoms when prolapsed. Due to its collagen-based structure, the primary function of IVD is to absorb compressive forces like gravity and prevent friction between surfaces of vertebral bodies (Desmoulin et al., 2020).

Stages of progression

Disk herniation progress through four stages, successively listed with increasing severity:

1. Bulging – symmetrical flattening of IVD. Small fissures may appear but the annulus fibrosus remains intact.
2. Protrusion - bulging protuberance in the form of nucleus pulposus with uninterrupted outer layer of annulus fibrosus.
3. Extrusion – the fibrous ring has been completely ruptured, although the excessive material is integrated with the disk,
4. Sequestration – extruded segment is completely separated from the rest of the disk (Lachman, 2015).

Characteristics

In result of being exposed to major forces such as compression and friction, IVDs' structure weakens over time becoming more vulnerable. The most common cause of disk herniation is age-related degenerative process of IVD involving dehydration. Trauma and injuries contribute as second most common cause. Risk factors like excessive body weight, physical work, smoking and genetics are also relevant and increase the risk of hernia (Feng et al., 2016; Zielinska et al., 2021).

Division and symptoms

Disk herniation can be subdivided based on direction of IVD prolapse, each may present with characteristic symptoms:

- Central, growing posteriorly into spinal canal may compress spinal cord resulting in pain, weakness, loss of sensation and motor function typically in both limbs, urinary incontinence depending on level and stage of herniation (Bach et al., 1990).
- Posterolateral, growing into intervertebral foramen usually compressing spinal nerve or its roots presenting with back pain, which may radiate along the limb, numbness, partial loss of motor and sensational function of the limb depending on stage of herniation (Wang et al., 2022).

Disk herniation can also be classified by the region of the vertebral column, where disk herniation occurs, respectively: cervical disc herniation (CDH), thoracic disc herniation (TDH) and lumbar disc herniation (LDH).

Based on the site of the pain and affected limbs, we can more accurately suspect likely location of the herniation. However, while these mentioned divisions being helpful in directing diagnostic suspicion, it should be remembered that diagnostic imaging is essential for definitive diagnosis (Ebrahim et al., 2024; Rydevik, 1992).

Treatment Methods

Both surgical and conservative approaches should be considered in every case based on patient's current state, duration and intensity of symptoms, diagnostic images, taking into account the potential benefits and complications of each method. Non-surgical options, such as change of habits, regular exercise (excluding static exertion), physiotherapy-based rehabilitation, analgesics, NSAIDs and glucocorticoid injection are significantly less invasive, therefore should be considered as first-line treatments. However, these methods may not be sufficient for all patients, so the operation technics may be necessary (Akinduro et al., 2017; El Melhat et al., 2024; Grasso et al., 2020; Legrand et al., 2007).

Systematic review objective

The aim of this study is to summarise the existing systematic reviews and clinical trials introducing doctors and patients to different treatment approaches of this condition. We intend to provide a better understanding of managing patients' symptoms and when to escalate to more radical interventions.

Treatment options will be categorized into conservative care, presented sequentially to more advanced methods, and surgical approaches, ordered from less invasive to more extensive surgeries.

Tabl. 1 Comparison of non-surgical treatment methods

(Amjad et al., 2022; Antohne et al., 2023; Ariel et al., 2019; Cao et al., 2024; Daniel, 2007; Gregory et al., 2008; Grześkowiak et al., 2019; Hossain et al., 2020; Jegede et al., 2010; Jensen et al., 2019; Li et al., 2019; Machado et al., 2017; Namnaqani et al., 2019; Olson et al., 2011; Öten et al., 2022; Ozen et al., 2023; Rampazo É et al., 2023; Sharma et al., 2017; Wilkinson & Cohen, 2012; Wongjarupong et al., 2023; Yu et al., 2021)

METHOD	**INFORMATION**	**SUCCES RATE** *(% of patients)*	**ASSETES**	**DISADVANTAGES**
Patient Education	Familiarising the patient with modifiable risk factors, regular exercise, avoiding bed rest	Great overall improvement, especially in the long term	Easy to access, requires only patient involvement	Lack of patient cooperation
Pain Medication	Depending on VAS scale NSAIDs or weaker opioids given orally. No hard evidence that paracetamol will manage pain enough	~75%; Great short-acting pain relief, their impact on improving the long-term prognosis of patients is limited	Widely available and easy to use, rapid pain relief	Side effects, Limited long-term efficacy
Exercise Therapy	Therapeutic exercises including repeated spinal extension, flexion,	44% to 85%; reducing and preventing the recurrence of	Improved mobility and posture, no side effects of	Requires commitment and regularity, lack of immediate results,

	and lateral movements towards to the lesion, improving spinal function, reducing and preventing the recurrence of pain	pain, mainly by stabilising the spine and strengthening the deep muscles	pharmacotherapy	potential for deterioration at the beginning of treatment, risk of improper exercise
Electrotherapy	Electrodes placed on the skin sending out electric waves of different intensity and frequency in order to block neuronal conduction of pain and improve tissue regeneration.	After few sessions reducing pain by 50-85%; improving motor function	No need for pharmacotherapy, low risk of complications, reduced pain and need for analgesics	Need for regular treatments, no clear evidence of long-term benefits, variable individual effectiveness
Ultrasound	Ultrasound - uses sound waves to create heat which alters the neuronal activity and modify the blood flow of region.	Moderate success, exact percentages vary ; significant pain relief, with substantial improvements in physical function and well-being up	Non-invasive, widely available	Requires multiple sessions, results vary depending on individual cases, not superior to other therapies.

		to three months post-treatment.		
Shortwave diathermy (SWD)	SWD - modality that produces heat by converting electromagnetic energy to thermal energy. The heat has a similar effect as in ultrasounds.	Similar to ultrasounds	Non-invasive; reducing muscle spasms; increased blood flow can aid in healing process	Not suitable for metal implants or in pregnant patients, can be expensive, not widely available
Acupuncture	Stimulating specific points on the body with thin needles, triggering the release of natural pain-relieving chemicals such as endorphins.	Varies across studies, it generally shows positive outcomes in pain reduction and function improvement.	Improves overall well-being by reducing stress and muscle tension, low risk of side effects	Varied results, requires multiple sessions
Traction	Applying a pulling force with specific equipment to decompress the spinal cord	Varies across studies, individual cases of great improvement, rarely condition worsened, need to be examined further	Short-term great pain reduction, non-invasive	Risks of further injury worsening the condition in rare cases; very individual approach is needed due to patients' different nature of the condition

Physiotherapy (Based on McKenzie therapy plus Manual Therapy)	Individually selected combination of different methods and exercises by physiotherapist to alleviate pain, restore normal function, and prevent recurrence of the issue	44% ~ 85% depending on the treatment program and adherence to rehabilitation	Customizable, non-invasive	Requires regular sessions up to few months, depends heavily on the patient's commitment
Epidural Steroid Injections	Epidural spinal injection of anti-inflammatory drugs outside of the meningeal sac	Single injection can last from several weeks to a few months	Strong evidence for great short-term relief of radicular symptoms	Lack of convincing evidence for a long-term effect or alleviation of back pain. Possible side effects include infection, cerebrospinal fluid leakage or headaches.
"Platelet-Rich Plasma"	Epidural spinal injection of Platelet-Rich Plasma outside of the meningeal sac	84 ~ 90%; Lasting up to 8 years; significant improvement in pain reduction and average disability rating	Long-lasting symptom relief, reduced number of injections compared to cortisone treatments, can promote tissue	Lack of large, high-quality randomized trials to further validate its long-term effectiveness, experimental nature of treatment, possible side effects include

	regeneration and healing through growth factors.		infection, cerebrospinal fluid leakage or headaches.

Tabl. 2 Comparison of surgical treatment methods
(Cai et al., 2022; Choy, 1998; Cui et al., 2018; Gazzeri et al., 2023; Gelalis et al., 2019; Gołębiowska, 2018; Javid & Hadar, 1998; Krutko et al., 2020; Li et al., 2020; Protzer et al., 2021; Schenk et al., 2006; Shi et al., 2021; Wang et al., 2014)

METHOD	**INFORMATION**	**SUCCES RATE** *(% of patients)*	**ASSETES**	**DISADVANTAGES**
Percutaneous laser disk decompression (guided by USG)	Least invasive spinal surgery performed under local anaesthesia with a small incision where excessive part of disk is evaporated through laser energy	75% ~ 87%; However, 4.4% to 25% of patients may need additional surgical intervention due to insufficient improvement or recurrent herniation.	Local anaesthesia is sufficient, quicker recovery, reduced risk of complications	Not suitable for all types of herniations, patients with extruded or sequestered discs are not ideal candidates, risk of diskitis, recurrent herniation risk
Microdiscectomy	Using a 2.5 cm surgical incision, only the bulged part of the disc is	74 ~ 89% improvement in pain and functionality.	Immediate pain relief, patients typically return home the same	~ 10% risk of re-herniation, potential complications like dural tears, nerve

	extracted.		day, minimally invasive	damage, infection or persist pain
Endoscopic Foraminoplasty	Minimally invasive method using endoscopic to eliminate the cause of narrowing of the foramina.	Due to lack of evidence, it is difficult to estimate success ratio. However, there is some suggestion that it may be used as a minimally invasive alternative, but it need to be investigated further	Minimally invasive, small number of surgery-related complications	Challenging to perform, need a high level of expertise, some patients may require a second procedure if symptoms recur, or if the initial surgery does not fully resolve the issue.
Laminectomy	Partial removal of the vertebra called the lamina used to expose and remove prolapsed part of the disk	~ 80% at 6 weeks after surgery; downward trend over time up to 65% rate	Effectively relieves pain and improves mobility; Relatively fast recovery	long-term effects may diminish, surgical risks like dural tears, nerve damage, infection
Spinal Fusion (SF)	Permanently joining two or more vertebrae to stabilize the segment. this procedure is only	Studies show less efficacy in comparison to patients without SF, nevertheless in select patients	High success in select patients, improved stability	Longer recovery time, risk of complications like infection, pseudarthrosis, and adjacent segment

	performed if the individual case requires it as a complementary method after bulging part removal	can offer significant benefits.		disease,
Artificial Disc Replacement (ADR)	Damaged disc replacement with an artificial one made of plastic or/and metal	60% ~ 90% mid- to long-term follow-up improvement in quality of life and pain relief. Some studies suggest better clinical results and patient satisfaction for ADR than SF	Better motion preservation and faster recovery than SF	Risk of implant failure or dislocation over time, surgery, complications, only selected patient may be treated this way

Conclusion

Disc herniation is a common condition affecting many patients, causing considerable discomfort. Therefore, knowing how to manage them properly is important. Conservative treatment approaches, including lifestyle modification, regular exercise, physiotherapy or analgesics, have demonstrated great results in terms of success rate with minor side effects potential, making them effective first-line therapies for mild to moderate cases, especially when combined.

Surgical interventions, ranging from minimally invasive techniques to open surgeries, present higher success rate and rapid symptoms relieve for patients

with more advanced disk herniation, experiencing severe pain or neurological symptoms. Minimally invasive surgeries such as microdiscectomy are associated with faster recovery and fewer complications, making them gold standard for surgical interventions. More invasive procedures like spinal fusion or artificial disc replacement, may be necessary for more complex cases.

Based on the available evidence, treatment should be personalized, with conservative management as the first option. Surgical approaches should be considered when non-surgical methods fail to relieve symptoms, in cases diagnosed at an advanced stage, particularly when neurological symptoms occur. Clinical evaluation and diagnostic imaging are essential in determining appropriate methods, ensuring most beneficial outcome for the patient.

Disclosure

Author's contribution

Conceptualization: F. Czyżewski; methodology: I. Wiak; F. Jasiński; software: K. Wojtach; check: F. Banyś, F. Czyżewski; formal analysis: K. Bochen, W. Górska, J. Szałajska; investigation: F. Czyżewski, A. Łukawski, I. Wiak; resources: A. Dziegciarczyk, K. Wojtach, F. Banyś; data curation: K. Bochen; F. Jasiński;

writing-rough preparation: F. Czyżewski, W. Górska, J. Szałajska; writing – review and editing: A. Łukawski, I. Wiak, A. Dziegciarczyk; visualization: F. Banyś, A. Łukawski, K. Wojtach; supervision: F. Czyżewski, J. Szałajska; project

administration: F.Banyś

All authors have read and agreed with the published version of the manuscript.

Financing statement

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Conflict of interest

The authors deny any conflict of interest.

REFERENCES

Akinduro, O. O., Kerezoudis, P., Alvi, M. A., Yoon, J. W., Eluchie, J., Murad, M. H., Wang, Z., Chen, S. G., & Bydon, M. (2017). Open Versus Minimally Invasive Surgery for Extraforaminal Lumbar Disk Herniation: A Systematic Review and Meta-Analysis. *World Neurosurg*, *108*, 924-938.e923. https://doi.org/10.1016/j.wneu.2017.08.025

Amjad, F., Mohseni-Bandpei, M. A., Gilani, S. A., Ahmad, A., & Hanif, A. (2022). Effects of non-surgical decompression therapy in addition to routine physical therapy on pain, range of motion, endurance, functional disability and quality of life versus routine physical therapy alone in patients with lumbar radiculopathy; a randomized controlled trial. *BMC Musculoskelet Disord*, *23*(1), 255. https://doi.org/10.1186/s12891-022-05196-x

Antohne, B., Rață, M., Rață, B. C., & Rață, G. (2023). *Efficiency Of Mckenzie Exercises And Manual Therapy In Disc Herniation* Proceedings of the 9th International Conference Education Facing Contemporary World Issues (Edu World 2022), 3-4 June, 2022, University of Pitești, Pitești, Romania,

Ariel, E., Ratmansky, M., Levkovitz, Y., & Goor-Aryeh, I. (2019). Efficiency of Tissue Penetration by Currents Induced by 3 Electrotherapeutic Techniques: A Comparative Study Using a Novel Deep-Tissue Measuring Technique. *Phys Ther*, *99*(5), 540-548. https://doi.org/10.1093/ptj/pzz005

Bach, F., Larsen, B. H., Rohde, K., Børgesen, S. E., Gjerris, F., Bøge-Rasmussen, T., Agerlin, N., Rasmusson, B., Stjernholm, P., & Sørensen, P. S. (1990). Metastatic spinal cord compression. Occurrence, symptoms, clinical presentations and prognosis in 398 patients with spinal cord compression. *Acta Neurochir (Wien)*, *107*(1-2), 37-43. https://doi.org/10.1007/bf01402610

Cai, H., Liu, C., Lin, H., Wu, Z., Chen, X., & Zhang, H. (2022). Full-endoscopic foraminoplasty for highly down-migrated lumbar disc herniation. *BMC Musculoskeletal Disorders*, *23*(1), 303. https://doi.org/10.1186/s12891-022-05254-4

Cao, Z., Han, K., Lu, H., Illangamudalige, S., Shaheed, C. A., Chen, L., McLachlan, A. J., Patanwala, A. E., Maher, C. G., Lin, C. C., March, L., Ferreira, M. L., & Mathieson, S. (2024). Paracetamol Combination Therapy for Back Pain and Osteoarthritis: A Systematic Review and Meta-Analyses. *Drugs*, *84*(8), 953-967. https://doi.org/10.1007/s40265-024-02065-w

Choy, D. S. (1998). Percutaneous laser disc decompression (PLDD): twelve years' experience with 752 procedures in 518 patients. *J Clin Laser Med Surg*, *16*(6), 325-331. https://doi.org/10.1089/clm.1998.16.325

Cui, X.-D., Li, H.-T., Zhang, W., Zhang, L.-L., Luo, Z.-P., & Yang, H.-L. (2018). Mid- to long-term results of total disc replacement for lumbar degenerative disc disease: a

systematic review. *Journal of Orthopaedic Surgery and Research*, *13*(1), 326. https://doi.org/10.1186/s13018-018-1032-6

Daniel, D. M. (2007). Non-surgical spinal decompression therapy: does the scientific literature support efficacy claims made in the advertising media? *Chiropr Osteopat*, *15*, 7. https://doi.org/10.1186/1746-1340-15-7

Desmoulin, G. T., Pradhan, V., & Milner, T. E. (2020). Mechanical Aspects of Intervertebral Disc Injury and Implications on Biomechanics. *Spine (Phila Pa 1976)*, *45*(8), E457-e464. https://doi.org/10.1097/brs.0000000000003291

Dydyk, A. M., Ngnitewe Massa, R., & Mesfin, F. B. (2024). Disc Herniation. In *StatPearls*. StatPearls Publishing

Ebrahim, M., Alsmirat, M., & Al-Ayyoub, M. (2024). Advanced disk herniation computer aided diagnosis system. *Sci Rep*, *14*(1), 8071. https://doi.org/10.1038/s41598-024-58283-5

El Melhat, A. M., Youssef, A. S. A., Zebdawi, M. R., Hafez, M. A., Khalil, L. H., & Harrison, D. E. (2024). Non-Surgical Approaches to the Management of Lumbar Disc Herniation Associated with Radiculopathy: A Narrative Review. *J Clin Med*, *13*(4). https://doi.org/10.3390/jcm13040974

Feng, Y., Egan, B., & Wang, J. (2016). Genetic Factors in Intervertebral Disc Degeneration. *Genes Dis*, *3*(3), 178-185. https://doi.org/10.1016/j.gendis.2016.04.005

Gazzeri, R., Tribuzi, S., Galarza, M., Leoni, M. L. G., & Occhigrossi, F. (2023). Ultrasound-guided Percutaneous Laser Disc Decompression (PLDD) with Fluoroscopic Validation for the Treatment of Cervical Disc Herniation: Technical Note. *Pain Med*, *24*(6), 625-632. https://doi.org/10.1093/pm/pnac188

Gelalis, I. D., Papanastasiou, E. I., Pakos, E. E., Ploumis, A., Papadopoulos, D., Mantzari, M., Gkiatas, I. S., Vekris, M. D., & Korompilias, A. V. (2019). Clinical outcomes after lumbar spine microdiscectomy: a 5-year follow-up prospective study in 100 patients. *Eur J Orthop Surg Traumatol*, *29*(2), 321-327. https://doi.org/10.1007/s00590-018-2359-8

Gołębiowska, N. (2018). A review of surgical techniques of lumbar disc herniation. *Medical Studies*, *34*, 241-245. https://doi.org/10.5114/ms.2018.78688

Grasso, G., Canseco, J. A., Minetos, P. D., & Vaccaro, A. R. (2020). Surgery versus Conservative Treatment for Symptomatic Lumbar Disk Herniation: A Never-Ending Story. *World Neurosurg*, *141*, 521-522. https://doi.org/10.1016/j.wneu.2020.07.006

Gregory, D. S., Seto, C. K., Wortley, G. C., & Shugart, C. M. (2008). Acute lumbar disk pain: navigating evaluation and treatment choices. *Am Fam Physician*, *78*(7), 835-842.

Grześkowiak, M., Krawiecki, Z., Łabędź, W., Kaczmarczyk, J., Lewandowski, J., & Łochyński, D. (2019). Short-Term Effects of Kinesio Taping® on Electromyographic Characteristics of Paraspinal Muscles, Pain, and Disability in Patients With Lumbar Disk Herniation. *J Sport Rehabil*, *28*(5), 402-412. https://doi.org/10.1123/jsr.2017-0086

Hossain, M. A., Jahid, I. K., Hossain, M. F., Uddin, Z., Kabir, M. F., Hossain, K. M. A., Hassan, M. N., & Walton, L. M. (2020). Efficacy of McKenzie Manipulative Therapy on Pain, Functional Activity and Disability for Lumbar Disc Herniation. *medRxiv*, 2020.2007.2013.20152843. https://doi.org/10.1101/2020.07.13.20152843

Javid, M. J., & Hadar, E. J. (1998). Long-term follow-up review of patients who underwent laminectomy for lumbar stenosis: a prospective study. *J Neurosurg*, *89*(1), 1-7. https://doi.org/10.3171/jns.1998.89.1.0001

Jegede, K. A., Ndu, A., & Grauer, J. N. (2010). Contemporary management of symptomatic lumbar disc herniations. *Orthop Clin North Am*, *41*(2), 217-224. https://doi.org/10.1016/j.ocl.2010.01.003

Jensen, R. K., Kongsted, A., Kjaer, P., & Koes, B. (2019). Diagnosis and treatment of sciatica. *Bmj*, *367*, l6273. https://doi.org/10.1136/bmj.l6273

Jordan, J., Konstantinou, K., & O'Dowd, J. (2009). Herniated lumbar disc. *BMJ Clin Evid*, *2009*.

Krutko, A. V., Sanginov, A. J., & Baykov, E. S. (2020). Predictors of Treatment Success Following Limited Discectomy With Annular Closure for Lumbar Disc Herniation. *Int J Spine Surg*, *14*(1), 38-45. https://doi.org/10.14444/7005

Lachman, D. (2015). Analysis of the clinical picture in patients with osteoarthritis of the spine depending on the type and severity of lesions on magnetic resonance imaging. *Reumatologia*, *53*(4), 186-191. https://doi.org/10.5114/reum.2015.53995

Legrand, E., Bouvard, B., Audran, M., Fournier, D., & Valat, J. P. (2007). Sciatica from disk herniation: Medical treatment or surgery? *Joint Bone Spine*, *74*(6), 530-535. https://doi.org/10.1016/j.jbspin.2007.07.004

Li, T., Wang, S., Zhang, S., Shen, X., Song, Y., Yang, Z., & Huang, Z. (2019). Evaluation of clinical efficacy of silver-needle warm acupuncture in treating adults with acute low back pain due to lumbosacral disc herniation: study protocol for a randomized controlled trial. *Trials*, *20*(1), 470. https://doi.org/10.1186/s13063-019-3566-2

Li, Y. Z., Sun, P., Chen, D., Tang, L., Chen, C. H., & Wu, A. M. (2020). Artificial Total Disc Replacement Versus Fusion for Lumbar Degenerative Disc Disease: An Update Systematic Review and Meta-Analysis. *Turk Neurosurg*, *30*(1), 1-10. https://doi.org/10.5137/1019-5149.Jtn.24799-18.2

Machado, G. C., Maher, C. G., Ferreira, P. H., Day, R. O., Pinheiro, M. B., & Ferreira, M. L. (2017). Non-steroidal anti-inflammatory drugs for spinal pain: a systematic review and meta-analysis. *Ann Rheum Dis*, *76*(7), 1269-1278. https://doi.org/10.1136/annrheumdis-2016-210597

Namnaqani, F. I., Mashabi, A. S., Yaseen, K. M., & Alshehri, M. A. (2019). The effectiveness of McKenzie method compared to manual therapy for treating chronic low back pain: a systematic review. *J Musculoskelet Neuronal Interact*, *19*(4), 492-499.

Olson, P. R., Lurie, J. D., Frymoyer, J., Walsh, T., Zhao, W., Morgan, T. S., Abdu, W. A., & Weinstein, J. N. (2011). Lumbar disc herniation in the Spine Patient Outcomes Research Trial: does educational attainment impact outcome? *Spine (Phila Pa 1976)*, *36*(26), 2324-2332. https://doi.org/10.1097/BRS.0b013e31820bfb9a

Öten, E., Civan, O., & Uğur, L. (2022). Traction therapy in lumbar disc hernias: A finite element analysis study. *Jt Dis Relat Surg*, *33*(1), 86-92. https://doi.org/10.52312/jdrs.2022.516

Ozen, S., Guzel, S., Senlikci, H. B., Cosar, S. N. S., & Selcuk, E. S. (2023). Efficacy of ultrasound versus short wave diathermy in the treatment of chronic low back pain in patients with lumbar disk herniation: a prospective randomized control study. *BMC Sports Sci Med Rehabil*, *15*(1), 157. https://doi.org/10.1186/s13102-023-00769-2

Protzer, L. A., Glassman, S. D., Mummaneni, P. V., Bydon, M., Bisson, E. F., Djurasovic, M., & Carreon, L. Y. (2021). Return to work in patients with lumbar disc herniation undergoing fusion. *Journal of Orthopaedic Surgery and Research*, *16*(1), 534. https://doi.org/10.1186/s13018-021-02682-1

Rampazo É, P., Júnior, M. A. L., Corrêa, J. B., de Oliveira, N. T. B., Santos, I. D., Liebano, R. E., & Costa, L. O. P. (2023). Effectiveness of interferential current in patients with

chronic non-specific low back pain: a systematic review with meta-analysis. *Braz J Phys Ther*, *27*(5), 100549. https://doi.org/10.1016/j.bjpt.2023.100549

Rydevik, B. L. (1992). The effects of compression on the physiology of nerve roots. *J Manipulative Physiol Ther*, *15*(1), 62-66.

Schenk, B., Brouwer, P. A., Peul, W. C., & van Buchem, M. A. (2006). Percutaneous laser disk decompression: a review of the literature. *AJNR Am J Neuroradiol*, *27*(1), 232-235.

Sharma, A. K., Vorobeychik, Y., Wasserman, R., Jameson, J., Moradian, M., Duszynski, B., & Kennedy, D. J. (2017). The Effectiveness and Risks of Fluoroscopically Guided Lumbar Interlaminar Epidural Steroid Injections: A Systematic Review with Comprehensive Analysis of the Published Data. *Pain Med*, *18*(2), 239-251. https://doi.org/10.1093/pm/pnw131

Shi, C., Sun, B., Tang, G., Xu, N., He, H., Ye, X., Xu, G., & Gu, X. (2021). Clinical and radiological outcomes of endoscopic foraminoplasty and decompression assisted with preoperative planning software for lumbar foraminal stenosis. *International Journal of Computer Assisted Radiology and Surgery*, *16*(10), 1829-1839. https://doi.org/10.1007/s11548-021-02453-7

Wang, J. C., Dailey, A. T., Mummaneni, P. V., Ghogawala, Z., Resnick, D. K., Watters, W. C., 3rd, Groff, M. W., Choudhri, T. F., Eck, J. C., Sharan, A., Dhall, S. S., & Kaiser, M. G. (2014). Guideline update for the performance of fusion procedures for degenerative disease of the lumbar spine. Part 8: lumbar fusion for disc herniation and radiculopathy. *J Neurosurg Spine*, *21*(1), 48-53. https://doi.org/10.3171/2014.4.Spine14271

Wang, K., Yang, Q. Z., Wen, H. N., Hai, Y. X., Gao, G. D., & Song, M. (2022). Nerve root compression due to lumbar spinal canal tophi: A case report and review of the literature. *Medicine (Baltimore)*, *101*(45), e31562. https://doi.org/10.1097/md.0000000000031562

Wilkinson, I. M., & Cohen, S. P. (2012). Epidural Steroid Injections. *Current Pain and Headache Reports*, *16*(1), 50-59. https://doi.org/10.1007/s11916-011-0236-9

Wongjarupong, A., Pairuchvej, S., Laohapornsvan, P., Kotheeranurak, V., Jitpakdee, K., Yeekian, C., & Chanplakorn, P. (2023). "Platelet-Rich Plasma" epidural injection an emerging strategy in lumbar disc herniation: a Randomized Controlled Trial. *BMC Musculoskelet Disord*, *24*(1), 335. https://doi.org/10.1186/s12891-023-06429-3

Yu, F. T., Ni, G. X., Cai, G. W., Wan, W. J., Zhou, X. Q., Meng, X. L., Li, J. L., Tu, J. F., Wang, L. Q., Yang, J. W., Fu, H. Y., Zhang, X. C., Li, J., Wang, Y. F., Zhang, B., Zhang, X. H., Zhang, H. L., Shi, G. X., & Liu, C. Z. (2021). Efficacy of acupuncture for sciatica: study protocol for a randomized controlled pilot trial. *Trials*, *22*(1), 34. https://doi.org/10.1186/s13063-020-04961-4

Zhang, A. S., Xu, A., Ansari, K., Hardacker, K., Anderson, G., Alsoof, D., & Daniels, A. H. (2023). Lumbar Disc Herniation: Diagnosis and Management. *Am J Med*, *136*(7), 645-651. https://doi.org/10.1016/j.amjmed.2023.03.024

Zielinska, N., Podgórski, M., Haładaj, R., Polguj, M., & Olewnik, Ł. (2021). Risk Factors of Intervertebral Disc Pathology-A Point of View Formerly and Today-A Review. *J Clin Med*, *10*(3). https://doi.org/10.3390/jcm10030409