World Journal of Environmental Biosciences
Available Online at: **www.environmentaljournals.org**

Volume 11, Issue 1: 24-29

https://doi.org/10.51847/OJ2dQINEwx

ISSN 2277- 8047

An Overview on Lumbar Disc Herniation on Surgical Management Approach

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ABSTRACT

Lumbar disc herniation (LDH), the most frequent cause of sciatica, is a localized displacement of disc material beyond the usual boundaries of the intervertebral disc space, affecting 1% to 5% of the population yearly. Physiotherapy, medicinal therapy, and/or an epidural corticosteroid injection are nonsurgical first-line therapies for sciatica. However, compared to conservative treatment, surgery provides faster symptom alleviation. Over 40% of patients allocated to conservative treatment require surgery within two years. Nevertheless, surgical intervention in such cases is accompanied by several heated debates. The objective of the study is to look into the published works of literature that evaluated the role of surgery in LDH cases. Articles were selected through the use of the PubMed database in which the following points were put in ((“lumbar disc herniation"[Mesh]) AND (“surgical intervention” [Mesh]) OR (“discectomy"[Mesh])). It has been found that surgical intervention in patients with LDH resulted in improved patient-reported outcomes, including subjective work capacity and quality of life, when compared to non-operative treatment. When compared to open discectomy, minimally invasive discectomy is linked to reduced blood loss, shorter operating times with no increase in overall complications that resulted in reoperation or wound infection in LDH cases. However, minimally invasive discectomy comes with a steeper learning curve.

Keywords: *Lumbar disc herniation, Management, Evaluation, Complication*

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Received: 26 August 2021
Accepted: 29 November 2021

INTRODUCTION

LDH, the most frequent cause of sciatica, is a localized displacement of disc material beyond the usual boundaries of the intervertebral disc space, affecting 1% to 5% of the population yearly (Kreiner *et al*., 2014). Physiotherapy, medicinal therapy, and/or an epidural corticosteroid injection are nonsurgical first-line therapies for sciatica. Most individuals' acute sciatica symptoms go away on their own, regardless of therapy (Vroomen *et al*., 2002).

For symptoms that do not respond to early conservative treatments, lumbar discectomy to remove the offending herniated disc material may be considered, however, the topic of which treatment is preferable has generated heated controversy.

Compared to conservative treatment, surgery provides faster symptom alleviation (Arts *et al*., 2019). Nevertheless, with time, discrepancies follow the same pattern, although surgery continues to be preferred (Kreiner *et al*., 2014). Over 40% of patients allocated to conservative treatment require surgery within two years, according to the results of randomized controlled studies (Weinstein *et al*., 2006a; Peul *et al*., 2008). Recurrent disc herniation occurs in 7%-18% of patients after surgery within two years, necessitating reoperation in almost 80% of instances (Arts *et al*., 2011; 2019). Furthermore, after surgery, the risk of recurrence and reoperation is more than twice higher in individuals with big annular abnormalities vs minor annular defects. One of the therapeutic problems of LDH with chronic radicular symptoms is whether to continue conservative therapies, which in many cases result in partial symptom relief, or to perform surgery, which may result in symptomatic re-herniation (Arts *et al*., 2019). Therefore, the

goal of this research is to look into the articles that discussed the role of surgical intervention in cases of LDH.

MATERIALS AND METHODS

We utilized the PubMed database for the selection process of relevant articles, and the following keys used in the mesh "lumbar disc herniation"[Mesh]) AND ("surgical intervention" [Mesh]) OR ("discectomy"[Mesh])). For the inclusion criteria, the articles were selected based on including one of the following: lumbar disc herniation, surgical management. All other articles without the inclusion criteria result in their topic being excluded.

RESULTS AND DISCUSSION

One of the most conventional problems in the world is lower back pain, with over 80% of the population experiencing an episode at some point in their life. The most prevalent differential diagnosis for low back pain is degenerative disc disease and LDH. Approximately 95% of LDHs happen at the L4-L5 or L5-S1 level. A lordotic curve is created by the lumbar spines' five vertebrae and intervertebral discs. The gap in which the spinal nerves leave is created by the intervertebral discs and the laminae, articular processes of neighboring vertebrae, and pedicles (Amin *et al*., 2017).

The inner nucleus pulposus, outer annulus fibrosus, and cartilaginous endplates bind the disc to its vertebras making up the intervertebral discs. The gel-like nucleus pulposus is made up of type 2 collagen and proteoglycans with 80% of it being water. The bigger aggrecan, which is important for holding water within the nucleus pulposus, is among the proteoglycans. It also contains versican, which attaches to hyaluronic acid. This hydrophilic matrix is in charge of keeping the height of the intervertebral disc constant.

The nucleus pulposus is surrounded by the annulus fibrosus, which is a ring-shaped structure. It is made up of mostly collagen lamellae with proteoglycans, glycoproteins, and elastic fiber stacked in 15-25 sheets intermingled with the extracellular matrix producer connective tissue cells. The annulus fibrosus's inner section is primarily comprised of type 2 collagen, whereas the outside half is mainly made of type 1 (Kepler *et al*., 2013; Kadow *et al*., 2015; Chidambaranathan & Culathur, 2022).

Protruding the disc through an intact annulus fibrosus, nucleus pulposus expulsion through the annulus fibrosus while maintaining the disc space continuum, or total loss of continuity with the disc space and sequestration of a free fragment can all cause constriction of the area available for the thecal sac in LDH. LDH is considered to be caused by many alterations in the biology of the intervertebral disc (Amin *et al*., 2017). Lessened water holding in the nucleus pulposus, intensified the percentage of type 1 collagen in the nucleus pulposus and inner annulus fibrosus, degradation of extracellular matrix elements and collagen, and upregulation of degradation procedures like cell death, expression of matrix metalloproteinase, and inflammatory pathways are just a few of the suggested alterations (Kalb *et al*., 2012; Kepler *et al*., 2013; Brayda-Bruno *et al*., 2014; Kadow *et al*., 2015; Amin *et al*., 2017). There are more risk factors and pathogenic causes but they are out of the scope of this article.

Clinical picture

Initial lumbalgia may progress to lumbar sciatica (usually after 7 days), and then pure sciatica may develop. However, because of the vast variety of possible acute or chronic form presentations, it is necessary to keep a close eye out for unusual forms of presentation and be prepared to undertake a differential diagnosis. Despite that a herniated disc is the most common root of sciatic pain, other causes must be checked out such as instability, tumors, or infection. This requires a thorough physical examination, which may involve finding the spinal space where the herniation has developed by careful examination of myotomes and dermatomes. What is crucial to remember is in the innate course of sciatica caused by a disc herniation, the signs subside after approximately one month. This is why the first intervention should always be cautious, and patients should be informed that the procedure will go normally (Vialle *et al*., 2010).

Imaging diagnostics

Plain radiography should be included in the imaging examination since it is commonly available and relatively cheap. Despite that the clinical appearance may be clear and indicative of disc herniation, it is important to keep in mind that additional pathologies detectable on radiography may coexist. Dynamic flexion and extension exams are crucial supplementary evaluations for a more thorough investigation of the spinal column. MRI should be the first recommended diagnosing technique (Vialle *et al*., 2010).

In some countries, there is still a mandate to use axial computed tomography, although while having the ability to detect disc herniation, it lacks the quality and, perhaps more importantly, MRI's sensitivity. The comprehensive visual details on soft tissue and bony structures that MRI gives, which may aid not only in making the accurate diagnosis but also in making treatment recommendations, make it an essential test for properly assessing patients. Hernias are categorized on MRI according to their morphology, as indicated in the morphological description below. The disc material derived from the pulposus nucleus is pushed beyond the intervertebral boundaries and can assume one of three shapes: protrusion, extrusion, or sequestration. In either of the planes, protrusion occurs when the elevation of the hernia (in the axile slice) is smaller than the length of the base. Extrusion occurs when the length of the base is smaller than the height of the hernia, whereas seizure occurs when the herniated material and the intervertebral disc have no connection (Fardon & Milette, 2001). The protrusion can be narrow and concentric, referred to as focal protrusion, or broad and concentric, referred to as concentric protrusion (Vialle *et al*., 2010).

Surgical management

Surgical LDH treatment has previously been linked to enhanced short-term advantages and contradictory benefits in the long-term outcomes in numerous big trials (Weinstein *et al*., 2006b). Recent randomized research comparing conservative therapy with microdiscectomy in LDH mirrored this conclusion. Their research revealed no significant differences among them but showed a substantial reduction in leg discomfort after 6 weeks, and patients expressed the satisfaction of treatment after 2 years. In addition, it has been revealed that microdiscectomy of L4/5 LDH led to improved results, including subjective work

capacity and quality of life when compared to non-operative treatment (Österman *et al*., 2006).

In terms of finances, it is found that the extra expenses per the quality of life improvement with surgical therapy were around $73,245 annually. Preoperative lower extremities pain intensity, intact mental health, younger age, a shorter course of symptoms, and normal physical activity before the surgery are all factors that have recently been linked to a positive result following discectomy (Ademi *et al*., 2016; Oba *et al*., 2017). Remarkably, postoperative results were unaffected by the existence of motor deficits, gender, side of herniation, or vertebral level (Amin *et al*., 2017).

Open discectomy

Major studies such as the SPORT have proven the effectiveness of open discectomy in LDH. Discectomy techniques differ depending on the kind of herniation if it was far lateral or paracentral. While the paracentral method has a lot of advantages, it also has a lot of disadvantages, such as longer incisions, greater muscle stripping, and more difficulties with far lateral discectomy (Lurie *et al*., 2014).

A renowned technique of discectomy in deep lateral herniation is the Wiltse paraspinal approach that because of the associated problems is between the multifidus and longissimus muscles. As outcome data has been widely documented over the previous few decades, most of the recent evidence addressing open discectomy for LDH focuses on infection risk. The absence of prophylactic antibiotic dosage and a surgical time of more than 68 minutes are both predictors of infection after microdiscectomy (Habiba *et al*., 2017). Surprisingly, one study found no evidence that pretreatment lumbar epidural corticosteroid injection increased the risk of infection.

115 patients had single-level discectomy with and without closed suction drains (CSDs), according to Kotil *et al*. Their results showed substantially greater incidences of epidural hematoma and fibrosis contrasted to the non-CSD group on MRI postoperative days 1, 180, and 365. There was no change in impairment ratings or significant post-surgical problems after a year (Kotil, 2016; Ansari *et al.,* 2022).

Murphy *et al*. recently looked at the impact of using a microscope in open discectomy in 23,583 individuals (Murphy *et al*., 2017). Their results of longer operational times and similar perioperative number of impediments in discectomy conducted with and without the use of a microscope led to a suggestion that the microscope usage during decompression is according to the surgeon's discretion.

Open discectomy surgical technique

The patient is placed prone on a spine frame or a specialized table after completing general anesthesia. The iliac crest and chest transverse pads enable hip flexion to improve interlaminar space while avoiding pressure on the abdomen to minimize central venous pressure. The start point and trajectory of the surgical intervention may be guided by palpation of bone landmarks, such as the sacrum and iliac crests relating to the L4/L5 disc level. At the midline, a small longitudinal incision is marked, centered on the radiographic marker.

The lumbar fascia is slit just off the medial, as indicated by pulsing the processes of the spine, ipsilateral to the addressed disc pathology. A scalpel is used to cut the skin, and subcutaneous dissection with electrocautery reveals the lumbar fascia. At the desired level, this fascia should span the interspinous space. On a lateral fluoroscopic picture, a radiographic pointer can be utilized to validate the level of the spine and cranially indicated arc in line with the space in between the spine. A subperiosteal elevation of paraspinal muscles from the superior and inferior spinous processes down to the laminar junction is accomplished using electrocautery. Lateral dissection is continued bluntly as far as the facet joint. Visualization of the interlaminar space is critical. Using a curette, the surgeon separates the ligamentum flavum from its connection to the anterior side of the superior vertebra's lamina. The ligamentum is then severely cut to allow for the retraction of the nerve root and accompanying epidural fat with a Penfield elevator and visibility of the exiting nerve root. After that, a Penfield or blunt probe is inserted into the neuroforamen to muster the root and allow it to withdraw medially. Pituitary rongeurs can then be used to remove fractured or herniated tissue once the intervertebral disc space has been properly seen. A scalpel may be required to slit the annulus for access if a part of the herniation persists under the posterior longitudinal muscle. A Woodson elevator should be used to probe the epidural space in all directions for any more disc or ligamentous tissue. Bipolar electrocautery is used to establish meticulous hemostasis, and the wound is extensively dampened with saline. The fascia and subcutaneous strata are sutured together, and the skin is closed according to the surgeon's discretion.

Complications

Discectomy for LDH is connected with a number of serious consequences. Dural tears occur at a rate of 1 to 17% after LDH and are more common with advanced age, obesity, and revision operations. Incidental durotomy has a $4000 increase in hospitalization expenditures and a 2.4-fold increase in wound dehiscence probabilities. Postoperative infection (1–5%), decreased functional ability (4%), and nerve root damage are among the other complications (0.2%) (Kotil, 2016; Murphy *et al*., 2017).

Preoperative disc height index, trauma, advanced age, smoking, disc protrusion, disc sequestration, longer sick leave, workers' compensation, greater preoperative symptom intensity, and diabetes are all risk factors for recurrent herniation (Huang *et al*., 2016). With a significant rise in perioperative morbidity in revision LDH discectomy, reducing recurrence risk factors is important; nevertheless, activity limitation has not been shown to reduce the likelihood of LDH recurrence.

Minimally invasive surgery

Over the last 2 decades, minimally invasive methods to spine surgery have been developed and widely used. These methods are linked to reduced soft tissue injury and bone damage, cheaper acute care costs, and shorter hospital stay, but they also come with a steeper learning curve (Cahill *et al*., 2013).

As a result, the outcomes of these operations are becoming more widely publicized. LDHs can be treated using a variety of percutaneous endoscopic techniques, including interlaminar, transforaminal, posterolateral, and transiliac.

When compared to open discectomy, endoscopic discectomy is linked with shorter operating times and reduced blood loss, with no escalation in general problems, reoperation amounts, or contamination of the wound. In 325 patients, however, a

double-blind unsystematic control study was not able to discern endoscopic from open surgery in terms of long-term patient-centered results (Overdevest *et al*., 2017). Choi *et al*. looked at the results of 149 individuals who had migrating disc herniations and underwent percutaneous endoscopic lumbar discectomy (Choi *et al*., 2017). At a one-year development, they uncovered a 90% good or excellent result proportion and a generally better quality of life. High-grade disc herniations with upward migration, on the other hand, had a 13% rate of remaining disc fragments and a 3% rate of revision surgery (Choi *et al*., 2017).

The interlaminar technique offers the benefit of being able to place the device directly under endoscopic supervision. Interlaminar resection, in contrast to the aforementioned methods, necessitates nerve root and thecal sac retraction, which might be difficult in big LDH. However, studies show that LDH resection with this technique improves outcome indicators significantly (Tonosu *et al*., 2016; Taher *et al.,* 2022). However, Tonusu *et al*. found three neurologic perioperative problems using the shoulder route, and as a result, they advocate using the axillary technique for significant disc herniations with caudal extrusion (Tonosu *et al*., 2016).

Tubular discectomy surgical technique

As previously said, the patient is positioned and prepared. On the afflicted side, a 1.5 to 2.0 cm operating slit is indicated longitudinally, 1.5 cm off the medial. The insertion of a K-wire for guidance, that is progressed under lateral fluoroscopy to guarantee adequate depth and docking to the lamina cranial to the afflicted level, is made by a stab incision using a scalpel. After confirming the start location and direction, a complete skin incision is performed, followed by a fascial incision centered over the wire. Visualization can be aided by using magnifying surgical loupes or intra-operative microscopes. The remainder of the process is performed as described above, using tools intended for a tubular approach. The case is finished with thorough hemostasis, removal of the tubular retractor system, and closure of the subcutaneous tissue and skin.

Endoscopic discectomy surgical technique

As mentioned earlier, the patient is positioned and prepared. The functional section limited by the Kambin triangle that is made up of the superior portion of the caudal vertebra, traversing nerve root, and exiting nerve root, is addressed at the focus level with a spinal needle, starting 1 to 2 cm off of midline ipsilateral to disease. A 5 to 10 mm skin slit is created, and consecutive cannulated dilaters allow the entry of an 8 mm working cannula whereby the endoscope is inserted for viewing of the disc space, crossing and leaving roots of nerves, and instrument passage. Endoscopic curettes, rongeurs, drills, and bipolar electrocautery can be used to make a laminotomy of the cranial vertebra and decompress specific nerve roots. The material from a herniated disc can therefore be removed. A subcuticular suture is used to seal a single tiny endoscopic incision.

Post-operative care

On the first postoperative day, most patients are released. Physical therapy rehabilitation or oral pain management may need an extra postoperative stay. Some facilities have described and conducted a discectomy as an outpatient procedure. For spinal stabilization, no external bracing is required. Due to concerns about re-herniation, many surgeons recommend lessening substantial twisting motions, bending, and lifting for 3 to 6 weeks following the operation, while more efficient or immediate unrestricted activities may give equal results without higher re-herniation frequencies (Bono *et al*., 2017).

Complications

Deep contamination or wounds occur in 2 to 3% of cases, whereas dehiscence or other wound infections occur in 1 to 2% of cases. Direct intraoperative nerve root damage is reported to occur in 1 to 2% of instances. In the literature, the degree of accidental durotomy varies from 0% to 4%. The insertion of a durotomy can result in the leaking of cerebrospinal fluid, increasing the risk of meningitis.

The risk of LDH recurrence after discectomy varies from 1 to 25%, and the extent of intragenic dural rupture is around 9% (Atlas *et al*., 2005). Risk factors include male gender, smoking status, and hard labor (Shimia *et al*., 2013). As per the SPORT database's 8-year follow-up, people with concurrent retrolisthesis at L5-S1 appear to have similar enduring medical results as those without retrolisthesis (Lurie *et al*., 2014; Shenoy *et al*., 2019).

Because recurrence has been studied at various follow-up intervals and using a variety of outcome measures, such as recurring symptoms and reoperation, patient-specific variables should guide an honest conversation about the likelihood of repeated illness before surgery. Following lumbar disc surgery, the patient may have chronic discomfort, which might be a sign of failed back surgery syndrome (Daniell & Osti, 2018).

CONCLUSION

It has been found that surgical intervention in patients with LDH resulted in improved patient-reported outcomes, including subjective work capacity and quality of life, when compared to non-operative treatment.

When compared to open discectomy, minimally invasive discectomy is linked with shorter operating times and reduced blood loss, with no increase in overall complications, reoperation rates, or wound infection in LDH cases. However, minimally invasive discectomy comes with a steeper learning curve.

ACKNOWLEDGMENTS: None

CONFLICT OF INTEREST: None

FINANCIAL SUPPORT: None

ETHICS STATEMENT: None

REFERENCES

Ademi, Z., Gloy, V., Glinz, D., Raatz, H., Van Stiphout, J., Bucher, H. C., & Schwenkglenks, M. (2016). Cost-effectiveness of primarily surgical versus primarily conservative treatment of acute and subacute radiculopathies due to intervertebral disc herniation from the Swiss

perspective. *Swiss Medical Weekly*, *146*, w14382. doi:10.4414/smw.2016.14382

Amin, R. M., Andrade, N. S., & Neuman, B. J. (2017). Lumbar disc herniation. *Current Reviews in Musculoskeletal Medicine*, *10*(4), 507-516. doi:10.1007/s12178-017-9441-4

Ansari, S., Alshamrani, B., Alzahrani, A., Alfayez, A., Alhebshan, N., & Alshamrani, A. (2022). Prevalence of dental fluorosis among teenagers; A cross-sectional study in the schools of riyadh. *Bulletin of Pioneering Researches of Medical and Clinical Science, 1*(1), 13-17.

Arts, M. P., Brand, R., van den Akker, M. E., Koes, B. W., Bartels, R. H., Tan, W. F., & Peul, W. C. (2011). Tubular diskectomy vs conventional microdiskectomy for the treatment of lumbar disk herniation: 2-year results of a double-blind randomized controlled trial. *Neurosurgery*, *69*(1), 135-144. doi:10.1227/neu.0b013e318214a98c

Arts, M. P., Kuršumović, A., Miller, L. E., Wolfs, J. F., Perrin, J. M., Van de Kelft, E., & Heidecke, V. (2019). Comparison of treatments for lumbar disc herniation: Systematic review with network meta-analysis. *Medicine*, *98*(7). doi:10.1097/md.0000000000014410

Atlas, S. J., Keller, R. B., Wu, Y. A., Deyo, R. A., & Singer, D. E. (2005). Long-term outcomes of surgical and nonsurgical management of sciatica secondary to a lumbar disc herniation: 10 year results from the maine lumbar spine study. *Spine*, *30*(8), 927-935. doi:10.1097/01.brs.0000158954.68522.2a

Bono, C. M., Leonard, D. A., Cha, T. D., Schwab, J. H., Wood, K. B., Harris, M. B., & Schoenfeld, A. J. (2017). The effect of short (2-weeks) versus long (6-weeks) post-operative restrictions following lumbar discectomy: A prospective randomized control trial. *European Spine Journal*, *26*(3), 905-912. doi:10.1007/s00586-016-4821-9

Brayda-Bruno, M., Tibiletti, M., Ito, K., Fairbank, J., Galbusera, F., Zerbi, A., Roberts, S., Wachtel, E., Merkher, Y., & Sivan, S. S. (2014). Advances in the diagnosis of degenerated lumbar discs and their possible clinical application. *European Spine Journal*, *23*(3), 315-323. doi:10.1007/s00586-013-2960-9

Cahill, K. S., Levi, A. D., Cummock, M. D., Liao, W., & Wang, M. Y. (2013). A comparison of acute hospital charges after tubular versus open microdiskectomy. *World Neurosurgery*, *80*(1-2), 208-212. doi:10.1016/j.wneu.2012.08.015

Chidambaranathan, A. S., & Culathur, T. (2022). A prospective clinical study to evaluate the effectiveness of acupuncture treatment for temporomandibular joint muscular disorder. *Annals of Dental Specialty, 10*(1), 34-38.

Choi, K. C., Lee, D. C., Shim, H. K., Shin, S. H., & Park, C. K. (2017). A strategy of percutaneous endoscopic lumbar discectomy for migrated disc herniation. *World Neurosurgery*, *99*, 259-266. doi:10.1016/j.wneu.2016.12.052

Daniell, J. R., & Osti, O. L. (2018). Failed back surgery syndrome: A review article. *Asian Spine Journal*, *12*(2), 372-379. doi:10.4184/asj.2018.12.2.372

Fardon, D. F., & Milette, P. C. (2001). Nomenclature and classification of lumbar disc pathology: Recommendations of the combined task forces of the north American spine society, American society of spine radiology, and American society of neuroradiology. *Spine*, *26*(5), E93-E113. doi:10.1097/00007632-200103010-00006

Habiba, S., Nygaard, Ø. P., Brox, J. I., Hellum, C., Austevoll, I. M., & Solberg, T. K. (2017). Risk factors for surgical site infections among 1,772 patients operated on for lumbar disc herniation: A multicentre observational registry-based study. *Acta Neurochirurgica*, *159*(6), 1113-1118. doi:10.1007/s00701-017-3184-2

Huang, W., Han, Z., Liu, J., Yu, L., & Yu, X. (2016). Risk factors for recurrent lumbar disc herniation: A systematic review and meta-analysis. *Medicine*, *95*(2). doi:10.1097/md.0000000000002378

Kadow, T., Sowa, G., Vo, N., & Kang, J. D. (2015). Molecular basis of intervertebral disc degeneration and herniations: What are the important translational questions? *Clinical Orthopaedics and Related Research®*, *473*(6), 1903-1912. doi:10.1007/s11999-014-3774-8

Kalb, S., Martirosyan, N. L., Kalani, M. Y. S., Broc, G. G., & Theodore, N. (2012). Genetics of the degenerated intervertebral disc. *World Neurosurgery*, *77*(3-4), 491-501. doi:10.1016/j.wneu.2011.07.014

Kepler, C. K., Ponnappan, R. K., Tannoury, C. A., Risbud, M. V., & Anderson, D. G. (2013). The molecular basis of intervertebral disc degeneration. *The Spine Journal*, *13*(3), 318-330. doi:10.1016/j.spinee.2012.12.003

Kotil, K. (2016). Closed drainage versus non-drainage for single-level lumbar disc surgery: Relationship between epidural hematoma and fibrosis. *Asian Spine Journal*, *10*(6), 1072. doi:10.4184/asj.2016.10.6.1072

Kreiner, D. S., Hwang, S. W., Easa, J. E., Resnick, D. K., Baisden, J. L., Bess, S., Cho, C. H., DePalma, M. J., Dougherty II, P., Fernand, R., et al. (2014). An evidence-based clinical guideline for the diagnosis and treatment of lumbar disc herniation with radiculopathy. *The Spine Journal*, *14*(1), 180-191. doi:10.1016/j.spinee.2013.08.003

Lurie, J. D., Tosteson, T. D., Tosteson, A. N., Zhao, W., Morgan, T. S., Abdu, W. A., Herkowitz, H., & Weinstein, J. N. (2014). Surgical versus non-operative treatment for lumbar disc herniation: Eight-year results for the spine patient outcomes research trial (SPORT). *Spine*, *39*(1), 3. doi:10.1097/brs.0000000000000088

Murphy, M. E., Hakim, J. S., Kerezoudis, P., Alvi, M. A., Ubl, D. S., Habermann, E. B., & Bydon, M. (2017). Micro vs. macrodiscectomy: Does use of the microscope reduce complication rates? *Clinical Neurology and Neurosurgery*, *152*, 28-33. doi:10.1016/j.clineuro.2016.11.010

Oba, H., Takahashi, J., Tsutsumimoto, T., Ikegami, S., Ohta, H., Yui, M., Kosaku, H., Kamanaka, T., Misawa, H., & Kato, H. (2017). Predictors of improvement in low back pain after lumbar decompression surgery: Prospective study of 140 patients. *Journal of Orthopaedic Science*, *22*(4), 641-646. doi:10.1016/j.jos.2017.03.011

Österman, H., Seitsalo, S., Karppinen, J., & Malmivaara, A. (2006). Effectiveness of microdiscectomy for lumbar disc herniation: A randomized controlled trial with 2 years of follow-up. *Spine*, *31*(21), 2409-2414. doi:10.1097/01.brs.0000239178.08796.52

Overdevest, G. M., Peul, W. C., Brand, R., Koes, B. W., Bartels, R. H., Tan, W. F., & Arts, M. P. (2017). Tubular discectomy versus conventional microdiscectomy for the treatment of lumbar disc herniation: Long-term results of a randomised

controlled trial. *Journal of Neurology, Neurosurgery & Psychiatry*, *88*(12), 1008-1016. doi:10.1136/jnnp-2016-315306

Peul, W. C., van den Hout, W. B., Brand, R., Thomeer, R. T., Koes, B. W., & Leiden-The Hague Spine Intervention Prognostic Study Group. (2008). Prolonged conservative care versus early surgery in patients with sciatica caused by lumbar disc herniation: Two year results of a randomised controlled trial. *BMJ*, *336*(7657), 1355-1358. doi:10.1136/bmj.a143

Shenoy, K., Stekas, N., Donnally III, C. J., Zhao, W., Kim, Y. H., Lurie, J. D., & Razi, A. E. (2019). Retrolisthesis and lumbar disc herniation: A postoperative assessment of outcomes at 8-year follow-up. *The Spine Journal*, *19*(6), 995-1000. doi:10.1016/j.spinee.2018.12.010

Shimia, M., Babaei-Ghazani, A., Sadat, B. E., Habibi, B., & Habibzadeh, A. (2013). Risk factors of recurrent lumbar disk herniation. *Asian Journal of Neurosurgery*, *8*(2), 93. doi:10.4103/1793-5482.116384

Taher, S. S., Al-Kinani, K. K., Hammoudi, Z. M., & Ghareeb, M. M. (2022). Co-surfactant effect of polyethylene glycol 400 on microemulsion using BCS class II model drug. *Journal of Advanced Pharmacy Education and Research, 12*(1), 63-69.

Tonosu, J., Oshima, Y., Shiboi, R., Hayashi, A., Takano, Y., Inanami, H., & Koga, H. (2016). Consideration of proper operative route for interlaminar approach for percutaneous endoscopic lumbar discectomy. *Journal of Spine Surgery*, *2*(4), 281-288. doi:10.21037/jss.2016.11.05

Vialle, L. R., Vialle, E. N., Henao, J. E. S., & Giraldo, G. (2010). Lumbar disc herniation. *Revista Brasileira de Ortopedia (English Edition)*, *45*(1), 17-22. doi:10.1016/s2255-4971(15)30211-1

Vroomen, P. C., De Krom, M. C. T. F. M., & Knottnerus, J. A. (2002). Predicting the outcome of sciatica at short-term follow-up. *British Journal of General Practice*, *52*(475), 119-123.

Weinstein, J. N., Lurie, J. D., Tosteson, T. D., Skinner, J. S., Brett, H., Tosteson, A. N., Herkowitz, H., Fischgrund, J., Cammisa, F. P., Albert, T., et al. (2006a). Surgical vs nonoperative treatment for lumbar disk herniation: The spine patient outcomes research trial (SPORT): A randomized trial. *JAMA*, *296*(20), 2451-2459. doi:10.1001/jama.296.20.2451

Weinstein, J. N., Tosteson, T. D., Lurie, J. D., Tosteson, A. N., Hanscom, B., Skinner, J. S., Abdu, W. A., Hilibrand, A. S., Boden, S. D., & Deyo, R. A. (2006b). Surgical vs nonoperative treatment for lumbar disk herniation: The spine patient outcomes research trial (SPORT): A randomized trial. *Jama*, *296*(20), 2441-2450. doi:10.1001/jama.296.20.2441