Pathophysiology and Classification of Disc Herniation

Subjects: Rehabilitation

Contributor: Ahmed M. El Melhat, Ahmed S. A. Youssef, Moustafa R. Zebdawi, Maya A. Hafez, Lamia H. Khalil, Deed E. Harrison

Low-back pain (LBP) is a broad category of musculoskeletal disorders regarded as one of the primary causes of disability in the general population, with a lifetime incidence of 65–85% of individuals worldwide. One of the specific causes of LBP is lumbar intervertebral disc disorders with nerve root irritation. Most individuals affected fall within the age range of 30 to 50 years, with a higher prevalence in men than in women. The intervertebral disc is formed by an inner nucleus pulposus (NP), an outer annulus fibrosus (AF), and the cartilaginous endplates that attach the disc to its vertebrae. The protrusion of disc material into the spinal canal from outside the annular lining is known as herniation. When compared to other regions, the lumbar region is where disc herniation is most commonly observed, especially at the L4-L5 and L5-S1 levels. Lumbar disc herniation associated with radiculopathy (LDHR) is the outcome of the extruded disc material pressing into or contacting the lumbar nerve roots.

Keywords: lumbar disc herniation ; discogenic pain ; lumbar radiculopathy ; conservative management ; spinal decompression

1. Introduction

A combination of inflammation brought on by local pressure and neurochemical inflammatory substances found in the disc material causes the pain linked to lumbar radiculopathy [1]. Radiculopathy is characterized by numbness, tingling, weakness, and radiating neuropathic type pain, which usually manifests unilaterally. Physical examination findings typically involve decreases or losses in deep tendon reflex in relation to a specific root level, sensory reduction or loss in a specific dermatomal distribution, and muscular weakness in a specific myotomal distribution [2]. Increased symptom severity, a worse prognosis, greater disability, lost productivity, and higher medical expenses have all been linked to nerve root involvement [3].

The treatment of LDHR consists of both non-surgical and surgical procedures. Attempts have been made over the past decade to reduce the necessity for spinal surgery [4]. Most patients prefer conservative treatment over surgery because it carries a lower risk of complications and lower costs [5]. Surgery is recommended when LDHR is severe, lasts longer than six weeks, or fails to improve with conservative treatment [6][7]. Research findings suggest that in the absence of deteriorating neurological symptoms, such as saddle anesthesia, bowel or bladder incontinence, sudden paresis in an extremity, or cauda equina syndrome, non-surgical approaches for lumbar radiculopathy should be considered before surgical approaches [8].

2. Pathophysiology of Disc Herniation

The pathophysiology of lumbar disc herniation is crucial to understand in order to develop effective management and treatment strategies, which includes conservative approaches such as physical therapy, and in some cases, surgical intervention. Lumbar disc herniation is a consequence of degenerative changes in the AF, as age-related changes occur, leading to several alterations in the intervertebral disc [9]. These changes include: (1) a reduction in water concentration in the nucleus pulposus, (2) an elevation in type 1 collagen ratio in the nucleus pulposus and inner AF, (3) damage in collagen and extracellular material [10], and (4) an upregulation of matrix metalloproteinase expression (MMP), apoptosis, and inflammatory pathways, leading to the increased breakdown of tissue components, a higher rate of programmed cell death, and an intensified inflammatory response [11]. Eventually, this results in an increased local inflammatory response and mechanical compression affecting the intervertebral disc and compressing on the exiting nerve root.

The intervertebral disc is subject to complex biochemical processes that have a major effect on its mechanical behavior to maintain its integrity. These processes involve an extracellular matrix (ECM) that contains collagen type II, which forms the nucleus pulposus, contributing to its gel-like structure, and proteoglycan, which attracts water molecules to maintain disc hydration. In addition, increases in osmotic pressure help in resisting compression forces and distribute mechanical forces. Simultaneously, collagen fibers give the AF structural integrity, which affects the tensile strength. However,

excessive or prolonged mechanical stress can lead to disc degeneration by causing imbalances in extracellular matrix synthesis and degradation. Disc degeneration is facilitated by biochemical interactions, such as the enzymatic breakdown of proteoglycans by matrix MMPs. Elevated MMP activity, for example, may disrupt the balance between matrix synthesis and degradation, which could result in changed mechanical properties and decreased water retention. Recognizing these biochemical complexities highlights the translation of molecular events into mechanical changes, providing significant perspectives for therapeutic approaches aimed at targeting disc health [12][13].

Generally speaking, the progression of degeneration in the annulus fibrosus contributes to the risk of disc herniation [14]. Several mechanisms for disc herniation have been proposed, and these include: (1) nucleus pulposus protrusion through pre-existing AF tears or fissures, (2) AF protrusion due to AF buckling, and (3) mixed herniation types with both NP and AF protrusions [14]. Due to the tissue type and micro-architecture of the AF, the posterior, or the posterolateral region, of the AF contains thinner and incomplete lamellae compared to the anterior AF. These architectural design differences in the posterior and posterior–lateral AF region are the likely explanations for higher failure rates and disc herniation in these regions [14].

Early diagnosis and targeted interventions play a crucial role in significantly improving outcomes and alleviating the impact of lumbar disc herniation on an individual's quality of life. A herniated disc leads to pressure on the longitudinal ligament and local inflammation, resulting in low back pain caused by irritation. When a disc material exerts and causes a direct contact with the thecal sac or lumbar nerve root, it results in lumbar radicular pain with inflammation and nerve root ischemia. The posterolateral aspect is unsupported by the posterior longitudinal ligament; additionally, on the posterolateral aspect, the annulus fibrosus exhibits a thinner structure, and the proximity of the nerve root makes it more susceptible to herniation of the disc resulting in nerve root compression [10][15].

In lumbar disc herniation (LDH), the constriction of the space surrounding the thecal sac is caused by multiple factors. Among these are the protrusion of the intervertebral disc through an undamaged annulus fibrosus, preserving the continuity of the disc space; there is also extrusion of the nucleus pulposus through the annulus fibrosus, and the obliteration of disc space continuity with the isolation of a free fragment [15]. Each of these mechanisms contributes to a reduction in available space around the thecal sac, potentially leading to nerve compression and associated symptoms.

3. Classification of Lumbar Disc Herniation

The classification of lumbar disc herniation is based on several factors such as location, extent of nerve root involvement, clinical presentation, severity and direction. Lumbar disc herniation is classified into disc bulge, protrusion, extrusion and sequestration. Disc bulge occurs when the circumference of the disc exceeds beyond the regular margins of the vertebral body while maintaining the circumferences of the disc, causing asymmetric bulging mainly on one side. Disc protrusion is recognized when the base width of the protrusion is wider than the diameter of the disc material that is herniated, and it projects beyond the normal disc margins without damage to the annulus fibrous. Disc extrusion occurs when there is damage of the annulus fibrous, allowing the nucleus pulposus to extend beyond the normal margins [15]. In situations where the annulus structure undergoes complete disruption, there exists the potential for the nucleus content to extrude outside the disc space, resulting in the migration of a nucleus pulposus fragment called sequestration [9].

Certain patients with lumbar disc extrusion or protrusion may not experience symptoms, a condition known as "asymptomatic disc herniation", as the presence of disc abnormalities on imaging does not correlate with the presence or severity of the symptoms [16]. Many factors contribute to the expression of symptoms, including different pain thresholds, as individual variations in pain perception can influence whether a herniated disc becomes symptomatic. Moreover, inflammatory processes contribute to symptoms; in addition, the body's immune response to disc material that leaks out in herniation leads to irritation and swelling [17]. Furthermore, not all disc tissue will cause radicular pain that radiates along nerve pathways, as some individuals may experience localized back pain without radiation, and will experience discogenic pain rather than nerve compression [18]. Furthermore, in some cases, the body's natural healing process can lead to a resorption or reduction in size of a herniated disc over time; this can occur without the individual ever experiencing significant symptoms [19]. All of the aforementioned variables contribute to the variety in the expression of symptoms among individuals with similar disc herniations. A comprehensive classification system contributes to improving patient outcomes and ensuring that therapeutic strategies align with the unique characteristics of lumbar disc herniation in each individual case.

Many factors, including pain thresholds, inflammation, and the body's ability to adapt, contribute to the variety in the symptoms among individuals with similar disc issues. A comprehensive classification system contributes to improving patient outcomes and ensuring that therapeutic strategies align with the unique characteristics of lumbar disc herniation in

each individual case. The Michigan State University (MSU) classification for lumbar disc herniation is recommended herein as it is a simple and reliable method to objectively measure herniated lumbar discs [20]. The MSU provides classifications of disc herniation magnitude as 1, 2, or 3, and provides a herniation location of A, B, or C; the MSU has excellent reliability for its classifications [20].

References

1. Schoenfeld, A.J.; Weiner, B.K. Treatment of lumbar disc herniation: Evidence-based practice. Int. J. Gen. Med. 2010, 3, 209–214.
2. Tamarkin, R.G.; Isaacson, A.C. Electrodiagnostic Evaluation of Lumbosacral Radiculopathy. In StatPearls; StatPearls Publishing: Treasure Island, FL, USA, 2023.
3. Fritz, J.M.; Thackeray, A.; Childs, J.D.; Brennan, G.P. A randomized clinical trial of the effectiveness of mechanical traction for sub-groups of patients with low back pain: Study methods and rationale. BMC Musculoskelet. Disord. 2010, 11, 81.
4. Eichen, P.M.; Achilles, N.; Konig, V.; Mosges, R.; Hellmich, M.; Himpe, B.; Kirchner, R. Nucleoplasty, a minimally invasive procedure for disc decompression: A systematic review and meta-analysis of published clinical studies. Pain Physician 2014, 17, E149–E173.
5. Hahne, A.J.; Ford, J.J.; McMeeken, J.M. Conservative management of lumbar disc herniation with associated radiculopathy: A systematic review. Spine 2010, 35, E488–E504.
6. Alentado, V.J.; Lubelski, D.; Steinmetz, M.P.; Benzel, E.C.; Mroz, T.E. Optimal Duration of Conservative Management Prior to Surgery for Cervical and Lumbar Radiculopathy: A Literature Review. Glob. Spine J. 2014, 4, 279–286.
7. Kreiner, D.S.; Hwang, S.W.; Easa, J.E.; Resnick, D.K.; Baisden, J.L.; Bess, S.; Cho, C.H.; DePalma, M.J.; Dougherty, P.; Fernand, R.; et al. An evidence-based clinical guideline for the diagnosis and treatment of lumbar disc herniation with radiculopathy. Spine J. 2014, 14, 180–191.
8. Berry, J.A.; Elia, C.; Saini, H.S.; Miulli, D.E. A Review of Lumbar Radiculopathy, Diagnosis, and Treatment. Cureus 2019, 11, e5934.
9. De Cicco, F.L.; Camino Willhuber, G.O. Nucleus Pulposus Herniation. In StatPearls; StatPearls Publishing: Treasure Island, FL, USA, 2023.
10. Al Qaraghli, M.I.; De Jesus, O. Lumbar Disc Herniation. In StatPearls; StatPearls Publishing: Treasure Island, FL, USA, 2023.
11. Martin, M.D.; Boxell, C.M.; Malone, D.G. Pathophysiology of lumbar disc degeneration: A review of the literature. Neurosurg. Focus 2002, 13, E1.
12. Martins, D.E.; de Medeiros, V.P.; Wajchenberg, M.; Paredes-Gamero, E.J.; Lima, M.; Reginato, R.D.; Nader, H.B.; Puertas, E.B.; Faloppa, F. Changes in human intervertebral disc biochemical composition and bony end plates between middle and old age. PLoS ONE 2018, 13, e0203932.
13. Żak, M.; Pezowicz, C. Effect of overload on changes in mechanical and structural properties of the annulus fibrosus of the intervertebral disc. Biomech. Model. Mechanobiol. 2021, 20, 2259–2267.
14. Zhou, M.; Theologis, A.A.; O'connell, G.D. Understanding the etiopathogenesis of lumbar intervertebral disc herniation: From clinical evidence to basic scientific research. JOR Spine 2023, 7, e1289.
15. Waxenbaum, J.A.; Reddy, V.; Futterman, B. Anatomy, Back, Intervertebral Discs. In StatPearls; StatPearls Publishing: Treasure Island, FL, USA, 2023.
16. Chadha, M.; Srivastava, A.; Kumar, V.; Tandon, A. Disc Degeneration in Lumbar Spine of Asymptomatic Young Adults: A Descriptive Cross-Sectional Study. Indian J. Orthop. 2022, 56, 1083–1089.
17. Ye, F.; Lyu, F.; Wang, H.; Zheng, Z. The involvement of immune system in intervertebral disc herniation and degeneration. JOR Spine 2022, 5, e1196.
18. Fujii, K.; Yamazaki, M.; Kang, J.D.; Risbud, M.V.; Cho, S.K.; A Qureshi, S.; Hecht, A.C.; Iatridis, J.C. Discogenic Back Pain: Literature Review of Definition, Diagnosis, and Treatment. JBMR Plus 2019, 3, e10180.
19. Hornung, A.L.; Baker, J.D.; Mallow, G.M.; Sayari, A.J.; Albert, H.B.; Tkachev, A.; An, H.S.; Samartzis, D. Resorption of Lumbar Disk Herniation. JBJS Rev. 2023, 11, e22.00148.
20. Mysliwiec, L.W.; Cholewicki, J.; Winkelpleck, M.D.; Eis, G.P. MSU Classification for herniated lumbar discs on MRI: Toward developing objective criteria for surgical selection. Eur. Spine J. 2010, 19, 1087–1093.