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Lumbar disc herniation: Epidemiology, clinical and radiologic diagnosis WFNS spine committee recommendations

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ABSTRACT

Objective: To formulate the most current, evidence-based recommendations regarding the epidemiology, clinical diagnosis, and radiographic diagnosis of lumbar herniated disk (LDH).
Methods: A systematic literature search in PubMed, MEDLINE, and CENTRAL was performed from 2012 to 2022 using the search terms "herniated lumbar disc", "epidemiology", "prevention" "clinical diagnosis", and "radiological diagnosis". Screening criteria resulted in 17, 16, and 90 studies respectively that were analyzed regarding epidemiology, clinical diagnosis, and radiographic diagnosis of LDH. Using the Delphi method and two rounds of voting at two separate international meetings, ten members of the WFNS (World Federation of Neurosurgical Societies) Spine Committee generated eleven final consensus statements.
Results: The lifetime risk for symptomatic LDH is 1–3%; of these, 60–90% resolve spontaneously. Risk factors for LDH include genetic and environmental factors, strenuous activity, and smoking. LDH is more common in males and in 30–50 year olds. A set of clinical tests, including manual muscle testing, sensory testing, Lasegue sign, and crossed Lasegue sign are recommended to diagnose LDH. Magnetic resonance imaging (MRI) is the gold standard for confirming suspected LDH.
Conclusions: These eleven final consensus statements provide current, evidence-based guidelines on the epidemiology, clinical diagnosis, and radiographic diagnosis of LDH for practicing spine surgeons worldwide.

1. Introduction

Low back pain (LBP) is extremely common, with nearly two-thirds of adults reporting back pain at some point in their lives.[1,2] Interestingly, however, disc disease is believed to be the underlying etiology in less than five percent of patients with LBP.[3] Herniation, which refers to displacement of intervertebral disk material beyond the normal margins of the disk space, was initially described as disk "rupture."[1,4] The North American Spine Society (NASS) defines lumbar herniated disc (LHD) as a localized displacement of disc material beyond the normal margins of the intervertebral disc space resulting in pain, weakness, or numbness in a myotomal or dermatomal distribution, which differentiates it from facetogenic, discogenic, myofascial, and other non-specific LBP.[5] In a national longitudinal observational study from all public hospitals in Norway, the incidence of LHD was found to be approximately 5–20 cases per 1000 adults annually.[6] LHD was most common in adults in their third to the fifth decade of life, with a male to female ratio of 2:1[6]. Among patients 25–55 years old, >95% of LHD occur at either L4-L5 or L5-S1.[7] Clinical tests including manual muscle testing, sensory testing, and straight leg raise test are recommended for use in diagnosing LHD with radiculopathy.[5] Several studies suggest that magnetic resonance imaging (MRI) is the preferred study to diagnose a suspected LDH, due to its soft tissue visualization and reported diagnostic accuracy of up to 97%.[8]

While several guidelines on clinical and neuroradiological diagnosis of herniated lumbar disc have been published, the goal of this work is to produce the latest evidence-based recommendations on the

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Abbreviations

WFNS	World Federation of Neurosurgical Societies
MRI	magnetic resonance imaging
CT	computer tomography
LHD	lumbar herniated disc

epidemiology, clinical, and radiographic diagnosis of lumbar herniated disk, with a particular relevance for practicing spinal surgeons in low and middle income countries. The goals of this specific paper are to summarize the latest evidence on the estimated incidence and life-time risk of lumbar herniated disks (LHD), as well as specific age groups, gender, genetic factors, occupations, and activities (e.g. smoking) that pose a risk for the development of LHD. With regards to clinical diagnosis, we aimed to define the assessment of pain in LHD patients, including which clinical tests are recommended in the physical examination of LHD patients and how to distinguish LHD pain from other types of pain such as facetogenic or discogenic LBP. Finally, with regards to radiographic diagnosis, we specifically sought to examine the diagnostic accuracy of imaging for LHD, define the indications for radiological tests, and determine which is the most appropriate diagnostic test and when radiologic work-up should be initiated. The World Federation of Neurosurgical Societies (WFNS) Spine Committee formulated eleven final consensus statements on LHD via two-rounds of Delphi meetings.

2. Methods

The systematic review and meta-analysis were conducted following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and Cochrane guidelines.[9]

2.1. Search strategy

We searched the electronic databases of PubMed, MEDLINE, and CENTRAL (Cochrane Central Register of Controlled Trials) in the period 2012–2022 using the terms “herniated lumbar disc”, “epidemiology”, “prevention” “clinical diagnosis”, and “radiological diagnosis”. Only articles that specifically dealt with aspects of epidemiology and prevention, clinical diagnosis and radiological diagnosis of herniated lumbar disc were included in the analysis. We focused explicitly on official guidelines of neurosurgical and spine societies, randomized controlled trials, and retrospective and prospective studies with more than 50 patients. Case reports with less than 50 patients, nonhuman studies, studies without full text available, and studies not in English were excluded.

In addition to the electronic database search, coauthors manually checked the list of references of eligible trials and reviews. The complete search strategy is available. The coauthors screened titles and abstracts of all records after duplicates were removed, followed by screening of full texts. A standardized data extraction form to collate study characteristics (publication year, country, number of patients), as well as main subject of the study (epidemiology, clinical diagnosis, radiological diagnosis) was independently used by all authors.

For epidemiology and prevention of LHD, 1047 articles across all databases were obtained. After removing duplicates, abstract review by two independent reviewers, and full text review of the remaining 127 studies, the authors selected 17 studies for analysis (Fig. 1). For clinical diagnosis of LHD 4656 articles were obtained. After removing duplicates, abstract, and full text review, 16 studies were included in the final analysis (Fig. 2). For LHD radiological diagnosis, 3370 articles were initially obtained. Full text review of 123 manuscripts was performed, resulting in 90 total studies included in the final analysis (Fig. 3).

2.2. Consensus meetings

An international committee of spinal surgeons, specifically members of the World Federation of Neurosurgical Societies (WFNS) Spine

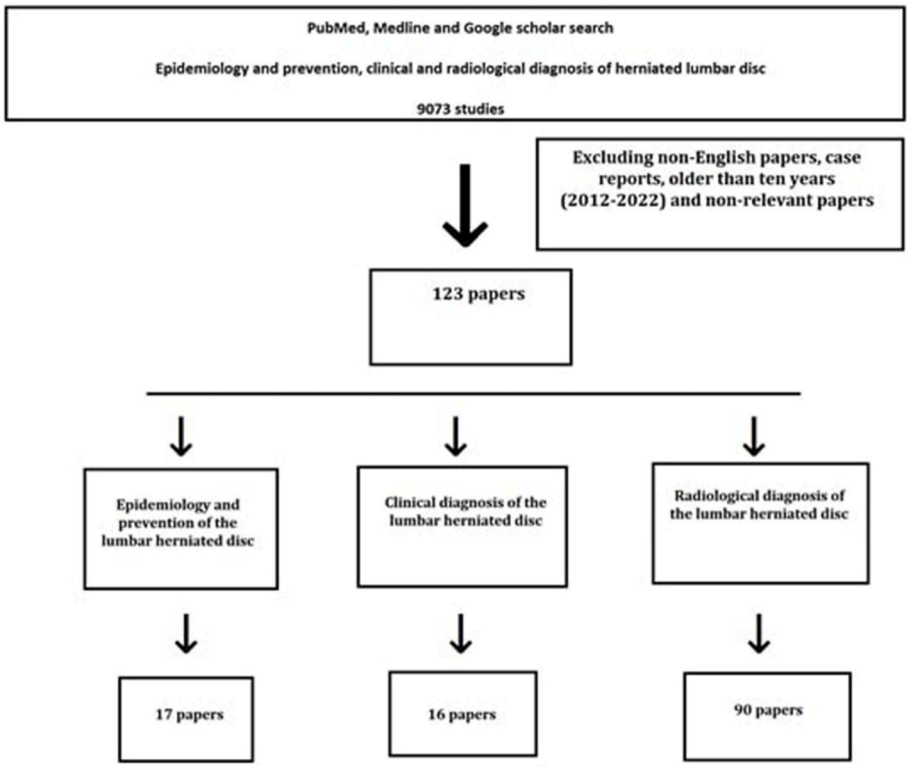

Fig. 1. Search strategy for Epidemiology and prevention, clinical and radiological diagnosis of herniated lumbar disc.

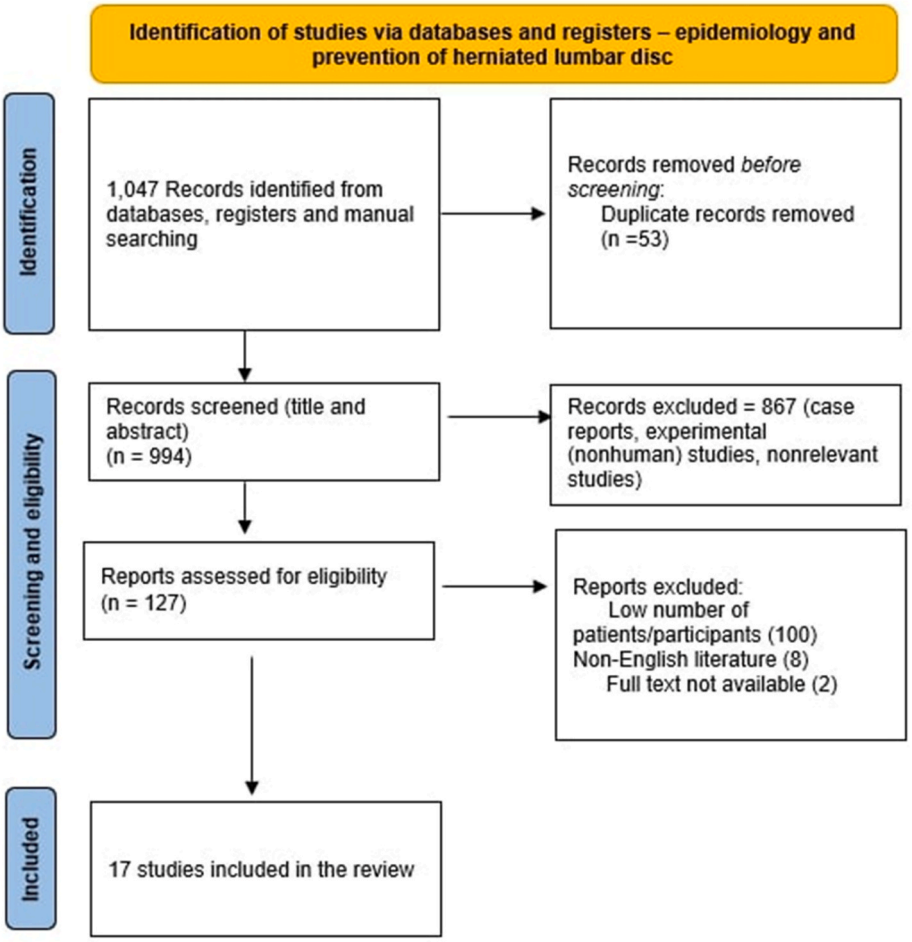

Fig. 2. PRISMA flow chart for epidemiology and prevention of herniated lumbar disc.

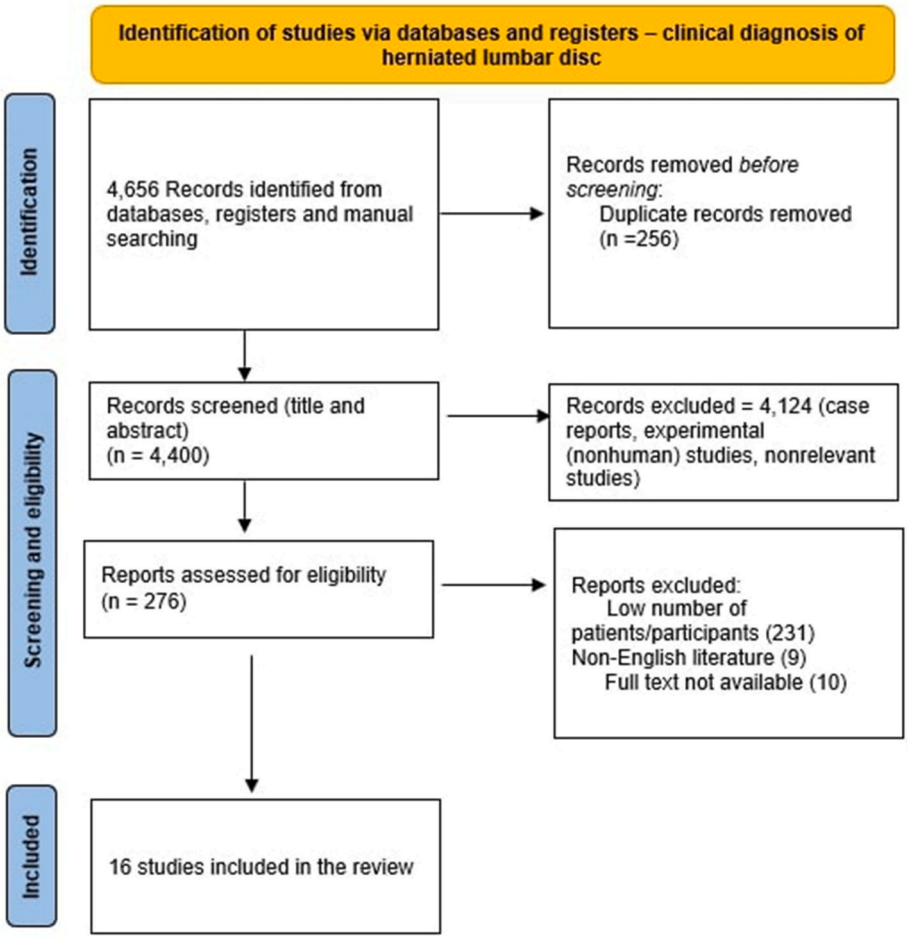

Fig. 3. PRISMA flow chart for clinical diagnosis of herniated lumbar disc.

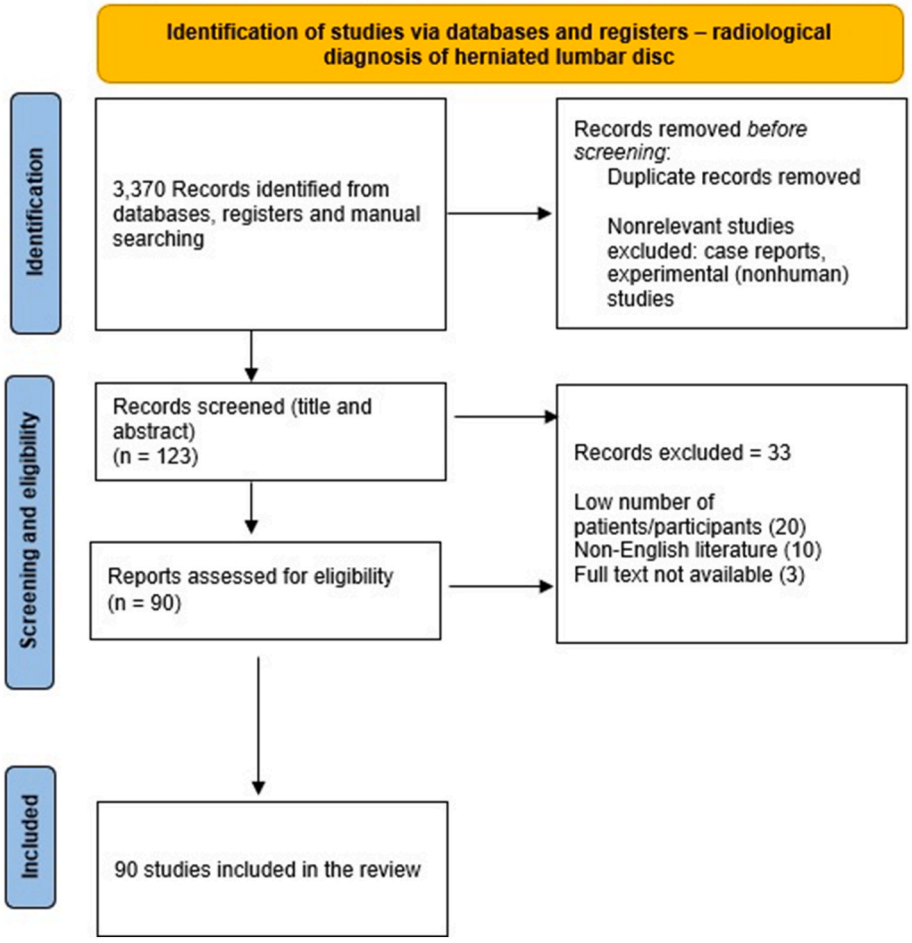

Fig. 4. PRISMA flow chart for identification of studies for radiological diagnosis of hernited lumbar disc.

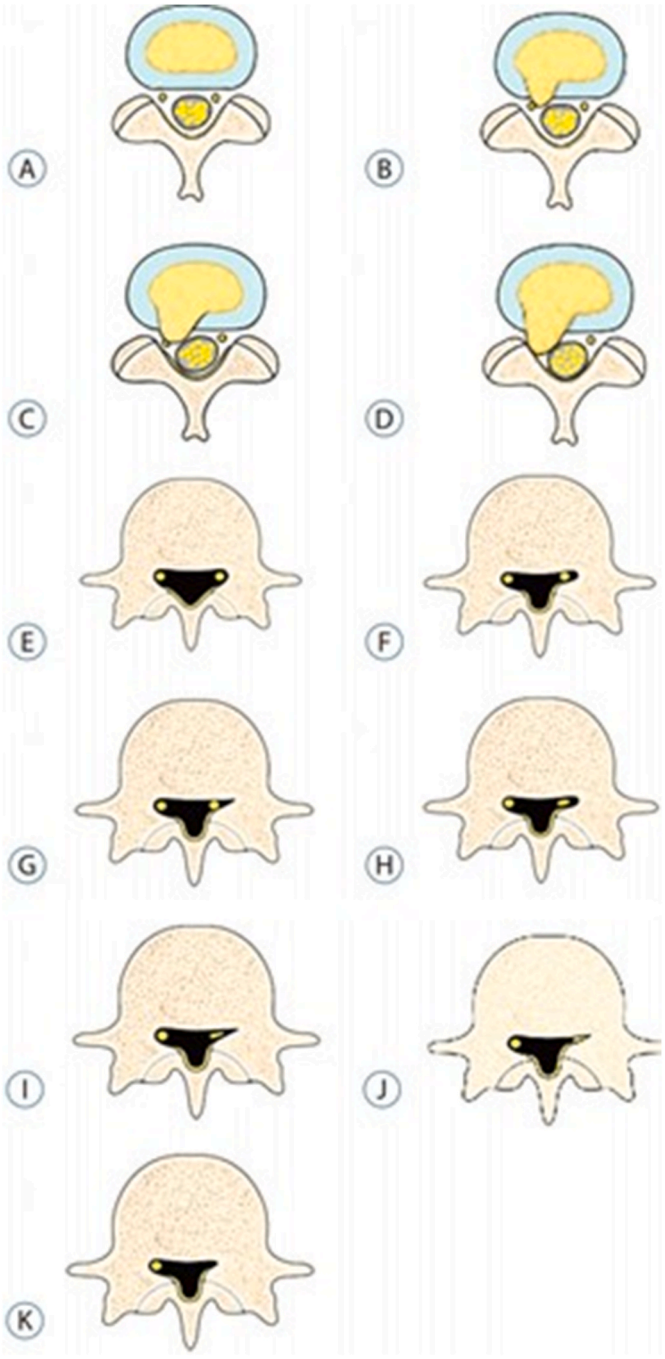

Fig. 5. Grading of nerve root images in the herniated nucleus pulposus and lateral recess stenosis. A: No compromise of the nerve root (grade 0). B: The nerve root is abutted but does not show any signs of deviation or deformation (grade I). C: The nerve root is displaced (deviated) and deformed by compression (grade II). D: Definite nerve root compression with the nerve root completely nonvisualized (grade III). E: No compromise of the nerve root in the lateral recess (grade 0). F: Trefoil-shape change of the lateral recess (grade I). G: Early acute angular narrowing of the lateral recess (grade I). H: Trefoil-shape narrowing of the lateral recess, and displaced (deviated) and deformed nerve root (grade II). I: Angular pinch-like narrowing of the lateral recess, and displaced (deviated) and deformed nerve root (grade II). J: Severe angular pinch-like narrowing of the lateral recess and flattened nerve root (grade III). K: The root image is completely nonvisualized in the lateral recess (grade III). From: Park CK, Lee HJ, Ryu KS. Comparison of Root Images between Post-Myelographic Computed Tomography and Magnetic Resonance Imaging in Patients with Lumbar Radiculopathy. J Korean Neurosurg Soc. 2017 Sep; 60 (5):540–549. doi: 10.3340/jkns.2016.0809.008. Epub 2017 Aug 30. PMID: 28881117; PMCID: PMC5594622.

Committee, organized two consensus meetings on acute back pain and lumbar disc herniation, the first of which was conducted in Karachi, Pakistan, in May 2022, and the second in Istanbul, Turkey, in September 2022. Each participant provided a set of statements on LHD which were discussed and underwent revision at the initial meeting. After a preliminary voting session, some statements were excluded because of the low evidence of existing literature. Eleven revised statements were voted on at the second meeting.

We utilized the Delphi method to generate our consensus statements. The level of agreement or disagreement on each item was voted independently in a blind fashion through a Likert-type scale from 1 to 5 (1 = strongly agree, 2 = agree, 3 = somewhat agree, 4 = disagree, 5 = strongly disagree). Results were presented as a percentage of respondents who scored each item as 1, 2, or 3 (agreement) or as 4 or 5 (disagreement). Consensus was achieved when the sum for agreement or disagreement was ≥66%. See Table 4 that shows final voting on the final eleven statements.

3. Results and discussion

3.1. Epidemiology of lumbar herniated disk (LHD)

Approximately 403 million people (5.5% of the worldwide population) are estimated to have symptomatic disc degeneration.[34] The SPORT trial (Spine Patients Outcome Research Trial), conducted at the beginning of the 21st century, was the first serious attempt at defining treatment for most common spine conditions. A significant portion of data on epidemiology, prevention, diagnosis and treatment of lumbar herniated disc (LHD) are therefore derived from its analysis. SPORT was designed to assess the outcomes and relative efficacy of treatments for three spinal conditions: intervertebral disc herniation, spinal stenosis, and degenerative spondylolisthesis, and simultaneously performed three multi-center randomized controlled trials (RCT) comparing surgical and nonsurgical treatments of these conditions.[35] Compared to patients with spinal stenosis and spondylolisthesis, LHD patients were significantly younger (mean age 41 years old) and had higher baseline pain ratings, with significant disability and associated healthcare utilization.[36] The lifetime risk of occurrence of LHD is approximately 30%.[37] 60–90% of patients with LHD respond to non-operative treatment; of those who undergo surgery, the risk of LHD recurrence is 9.1%, with 38% recurring within one year of index surgery.[37]

3.1.1. Risk factors for LHD

In a prospective study of several thousand males in Copenhagen with 33 years of follow-up, the strongest predictor of hospitalization for LHD was strenuous physical activity at work.[38] Several occupations have been identified as having increased risk of development of LHD. Meta-analysis of work-related musculoskeletal disorders revealed low back pain in 62% of surgeons; 31% of these surgeons had a diagnosed lumbar disc herniation, and 23% required surgery, which is six times greater risk than the general population.[39] Increased LHD incidence has also been observed in astronauts,[40] American football players,[41] athletes,[42] and professional drivers.[43] While body weight was not significantly associated with LHD hospitalization in the Copenhagen male cohort,[38] visceral fat area and abdominal circumference were identified as risk factors for LHD in a study of 90 adults in Mexico.[44] LHD has also been found to be more common in males, with a male:female ratio of 2:1 in an analysis of >30,000 surgically treated cases in a Norwegian longitudinal observational study.[6]

The Twin Spine Study, a research program on the etiology and pathogenesis of disc degeneration, was a multinational multicenter study from Canada, United States, and Finland.[45] Among the most significant findings were a substantial influence of heredity on lumbar disc degeneration and the identification of the first genes associated with disc degeneration. There was surprisingly little effect of occupational physical loading on LHD in twin siblings, suggesting a strong genetic

Table 1
Addition to current literature on clinical diagnosis of LHD – studies on clinical diagnosis of LHD (2012–2022).

Author, country, year	Name of the study	Type of study	Number of patients/ studies	Relevant conclusions
Fujii et al,[10] USA, 2019	Discogenic Back Pain: Literature Review of Definition, Diagnosis, and Treatment	Literature review	168 studies	• Discogenic pain is multifactorial, occurring with late IVD degeneration • the most specific existing diagnostic criteria, such as discography, are invasive with evidence suggesting it can lead to accelerated IVD degeneration
Min Yao et al, China, 2020[11]	A comparison between the low back pain scales for patients with lumbar disc herniation: validity, reliability, and responsiveness	Prospective study	353 patients with LDH	• NPRS, and ODI or RMDQ is recommended in studies related to LDH patients, while if the quality of life also is needed to observe, the NPRS, and JOABPEQ would be more appropriate rather than SF-36
Petersen et al, Denmark, 2017[12]	Clinical classification in low back pain: best-evidence diagnostic rules based on systematic reviews	Literature review	64 studies	• Centralization of symptoms is pathognomic for pain from intervertebral disc • Sacroiliac joint pain is dominant in the joint itself without tuber area, shows no centralization, 3/5 physical tests are required for diagnosis • In LHD straight leg raise test is positive for referred leg pain, 3/4 history or physical examination tests are required for diagnosis
Verwoerd et al, 2014, The Netherlands[13]	Diagnostic accuracy of history taking to assess lumbosacral nerve root compression	Prospective, multicenter, cross-sectional diagnostic study	395 patients	• A few history items used in isolation had significant diagnostic value: “male sex," “pain worse in leg than in back," “a non-sudden onset." “body mass index <30," " and “sensory loss."

Table 2
Sensitivity and specificity of diagnostic methods for LHD.

Diagnostic method	Sensitivity	Specificity
CT	77.4%[14]–81.3%[15]	77.1[50] - 73.7%[14]
CT Myelography	75.7%[15]	76.5%[15]
Multidetector CT	98.8%[16]	96.5%[16]
MRI	75%[17]–80.9[50] – 92%[18]	77%[17]–81%[15] - 99[48]

influence.[45] In addition, the effect of anthropometric factors, such as body weight and muscle strength, appeared to be greater than the effect of occupational physical demands.[45]

Finally, a systematic review of 12 studies (6 cohort, 6 case–control) has shown increased relative risk of LDH in smokers [RR 1.27; 95 % confidence interval (CI), 1.15–1.40], suggesting that smoking promotes the development of LDH.[46]

3.2. Clinical diagnosis of LHD

There are multiple national and international guidelines on clinical and neuroradiological diagnosis of LHD, including guidelines from the North American Spine Society5, German Spine Society and German Society for Neurology [47], and the Chinese association for the Study of Pain25. In addition to these recommendations, there are several articles (summarized in Table 1) that focus on pain differentiation in patients with LHD and appropriate clinical diagnostic tests.

3.2.1. Pain assessment

It is of utmost importance to ask patients regarding pain intensity, onset, and localization, when evaluating a patient with suspected LHD. Low back pain is often the initial symptom of LHD, generally in the lumbosacral region, which can radiate to the buttocks. This pain is often aggravated by sedentary conditions, squatting, or physical exertion, and relieved with rest.[48] The pain may radiate into the lower extremities, usually affecting only one side. Radicular symptoms may worsen after standing, walking, sneezing, or coughing, and may or may not be accompanied by paresthesias/numbness in a specific nerve root distribution.[48,49] Radiculopathy can present as an isolated L1, L2, L3, L4, L5, or S1 syndrome, but it can also present with mixed clinical symptoms.[49–51] Recent analysis of six history items pre-selected from the literature (age, gender, pain worse in leg than in back, sensory loss, muscle weakness, and increased pain with coughing/sneezing/straining) showed a poor accuracy for LHD diagnosis in 395 patients.[13] However, patients with body mass index<30, non-sudden onset of pain, and sensory loss were more likely to have a diagnosis of LHD in this cohort.[13]

Several scales are used to assess pain in patients with LHD, including the Japanese Orthopedic Association Back Pain Evaluation Questionnaire (JOABPEQ), Numerical Pain Rating Scale (NPRS), Oswestry Disability Index (ODI), Roland Morris Disability Questionnaire (RMDQ), and Short Form 36 Health Survey (SF-36).[11] While NPRS only addresses pain intensity, the other scales also incorporate quality of life and disability measures.

An important aspect in pain assessment in LHD is to differentiate this pain from facet joint, discogenic, or sacroiliacal joint pain. Extensive literature review on forty studies by Hancock et al[52] has shown that centralized pain location was the only clinical feature associated with increased likelihood that the disk was the source of pain,[52] compared to pain lateralization in facetogenic pain or radiculopathy in pain due to LHD.

Discogenic back pain and axial back pain are terms commonly used to describe back pain associated with intervertebral disc degeneration without herniation, anatomical deformity, or other clear causes of pain and disability.[10] Provocation discography is a diagnostic test that is intended to confirm or exclude the intervertebral disc(s) as the source of back pain. It involves puncture of the disc with a fine-gauge needle under fluoroscopic guidance and pressurization of the disc via the injection of contrast media, which seeks to provoke pain of a concordant nature to the patient’s index pain.[53] It is sometimes performed for chronic low back pain (≥3 months) if adequate attempts at conservative therapy have been unsuccessful.[53] Failure to adhere to standards of the procedure may be associated with an unacceptably high false positive rate,[54] and a lack of consensus exists regarding the diagnostic value of this procedure.[53,55] One group has suggested that discography can actually lead to accelerated disc degeneration.[10] However, a recent study on 77 discs in patients with symptomatic LHD exposed to provocative discography, compared to 260 discs in the matched control cohort, showed similar rates of disc degeneration and herniations between the two groups.[56]

Facetogenic pain can be further differentiated from LDH pain using Revels criteria, proposed in 1998.[57] Specifically, faceteogenic pain criteria includes patients age >65 years with back pain well relieved by recumbent posture and pain not worsened with coughing, forward

Table 3
Recent literature (2012–2022) on clinical and radiographic diagnosis of LHD.

Author, country, year	Name of the study	Type of study	Number of patients/ studies	Main conclusions
Ahn et al, South Korea, 2018[19]	Grading system for migrated lumbar disc herniation on sagittal magnetic resonance imaging: an agreement study	Retrospective	101 patients	• The most common migrated LDH grade was grade 4 (30.94%; caudal, low-grade migration). • Rostral and caudal migrations were more common in the upper and lower lumbar levels
Oh et al, South Korea, 2013[20]	Comparison of MR imaging findings between extraligamentous and subligamentous disk herniations in the lumbar spine	Retrospective	117 patients	• 5 proposed MR imaging criteria for extraligamentous LHD show the sensitivity, specificity, accuracy, and odds ratio were 77.3%, 74.5%, 76.1%, and 9.93
Lee et al, 2015, China[21]	Diagnostic Capability of Low- Versus High-Field Magnetic Resonance Imaging for Lumbar Degenerative Disease	Prospective	100 patients	• Excellent reliability between low- and high- field MRI was found for most features of lumbar disc degeneration, with good agreement for nerve root compression. • 0.25T MRI was more susceptible to motion artifact, probably due to longer scanning time
Byun et al,[22] South Korea, 2012	Three-dimensional magnetic resonance rendering imaging of lumbosacral radiculography in the diagnosis of symptomatic extraforaminal disc herniation with or without foraminal extension	Prospective	24 patients	• Based on lumbosacral radiculography through 3D MR rendering, diagnosis of extraforaminal disc herniation is facilitated through detection of swelling of dorsal root ganglion (DRG) and/or nerve roots and DRG indentation
Jia et al,[23] 2019, China	Coronal magnetic resonance imaging of three-dimensional fast-field echo with water-selective excitation improves the sensitivity and reliability of identification of extraforaminal lumbar disc herniation	Retrospective	140 patients	• CMRI showed higher agreement for the identification of extraforaminal lumbar disc herniation and higher sensitivity than conventional MRI and 3D MRI
Messner et al,[24] 2017, Austria	Does T2 mapping of the posterior annulus fibrosus indicate the presence of lumbar intervertebral disc herniation? A 3.0 T magnetic resonance study	Retrospective	64 patients, 313 lumbar discs	• High T2 values in the PAF-10 suggest the presence of disc herniation (DH)
Raudner et al,[25] 2019, Austria	Prediction of Lumbar Disk Herniation and Clinical Outcome Using Quantitative Magnetic Resonance Imaging: A 5-Year Follow-Up Study	Prospective	25 patients	• Quantitative T2 mapping may serve as a clinically feasible, noninvasive imaging biomarker that can indicate disks at risk for herniation and correlates with clinical outcome and subjective patient burden in a representative cohort of patients with low back pain
Raudner et al, 2021, Austria[26]	Clinical implementation of accelerated T2 mapping: Quantitative magnetic resonance imaging as a biomarker for annular tear and lumbar disc herniation	Prospective	58 participants	• GRAPPATINI, an accelerated T2 mapping sequence, of the nucleus pulposus of normal discs differed significantly from those of discs with bulging or herniation and can be used as imaging biomarker for degenerative disc changes
Teraguchi et al, 2020, Japan[27]	Lumbar high-intensity zones on MRI: imaging biomarkers for severe, prolonged low back pain and sciatica in a population-based cohort	Cross-sectional, population-based Southern Chinese cohort study	1214 participants	• Lumbar HIZs are potentially clinically-relevant imaging biomarkers that are independently and significantly associated with prolonged/severe LBP and sciatica
Nordberg et al,[28] 2021, Denmark	Positional changes in lumbar disc herniation during standing or lumbar extension: a cross-sectional weight-bearing MRI study	Prospective	37 patients	• Lumbar herniated discs increased in size in the axial plane during standing. • Increased nerve root compression grades for paracentral herniated discs were found during standing. • Weight-bearing MRI may increase the diagnostic sensitivity of nerve root compression in lumbar disc herniations.
Menon et al,[29] USA, 2021	Measurement of Three-Dimensional Internal Dynamic Strains in the Intervertebral Disc of the Lumbar Spine With Mechanical Loading and Golden-Angle Radial Sparse Parallel-Magnetic Resonance Imaging	Prospective	8 health volunteers	• The most compressive strain experienced by the IVD segments under loaded conditions was in the L4/L5 segment • The change in minimum strain from load to recovery was the most for the L4/L5 segment and the least for the L1/L2 segment
Oikawa et al, 2015, Japan[30]	Diffusion tensor imaging of lumbar spinal nerve in subjects with degenerative lumbar disorders	Retrospective	34 patients	• MR tractography shows abnormal findings for nerve roots in lumbar spinal degeneration and that fractional anisotropy (FA) decreases in symptomatic roots
Eguchi et al, 2016, Japan[31]	Diffusion tensor imaging of radiculopathy in patients with lumbar disc herniation: preliminary results	Prospective	13 patients	• The mean FA values were significantly lower and mean apparent diffusion coefficient (ADC) values were significantly higher in compressed nerves than in intact nerves. • Although the FA values increased significantly at six months after surgical treatment, the ADC values decreased but not significantly.
Tsai et al,[32] 2021, Taiwan	Lumbar Disc Herniation Automatic Detection in Magnetic Resonance Imaging Based on Deep Learning	Retrospective	168 male participants	• Description of the method of rapid initial test and auto-detection of LHD on a limited data set with use of deep learning
Han et al,[33] 2022, China	Medical expert and machine learning analysis of lumbar disc herniation based on magnetic resonance imaging	Prospective		• The human observation and machine learning prediction is NOT significantly different

Table 4
Statements voted after "Lumbar disc herniation: Epidemiology, clinical and radiological diagnostics as well as prevention" statements.

Statement	Likert type scale	No of respondents/ Percent
1- The lifetime risk for lumbar disc herniation is about 30%. Symptomatic disc herniation risk is 1–3%, of these 60–90% resolve spontaneously	1. Strongly agree	9 90%
	2. Agree	1 10%
	3. Somewhat agree	
	4. Disagree	
	5. Strongly disagree	
2- Risk factors for lumbar disc herniation include genetic and environmental factors, strenuous activities and smoking	1. Strongly agree	5 50%
	2. Agree	4 40%
	3. Somewhat agree	1 10%
	4. Disagree	
	5. Strongly disagree	
3- Radicular pain having specific radiation in one or both legs is usually associated with herniated disc	1. Strongly agree	5 50%
	2. Agree	3 30%
	3. Somewhat agree	2 20%
	4. Disagree	
	5. Strongly disagree	
4- Pain history is the most important part of clinical evaluation. It should include questions on intensity, onset and localization. Pain should be assessed with visual or numeric analogue scale and Oswestry disability index.	1. Strongly agree	7 70%
	2. Agree	3 30%
	3. Somewhat agree	
	4. Disagree	
	5. Strongly disagree	
5- Essential diagnostic tests in patients with suspected herniated disc are evaluation of muscle strength, sensory disturbance, sphincter dysfunction as well as supine straight leg raise, Lasegue sign, and crossed Lasegue sign.	1. Strongly agree	5 50%
	2. Agree	4 40%
	3. Somewhat agree	1 10%
	4. Disagree	
	5. Strongly disagree	
6- Muscle strength testing should be examined and documented using MRC (Medical Research Council) scale	1. Strongly agree	9 90%
	2. Agree	
	3. Somewhat agree	1 10%
	4. Disagree	
	5. Strongly disagree	
7- Lumbar facet joint blocks are gold standard for diagnosis of facet joint syndrome.	1. Strongly agree	8 80%
	2. Agree	2 20%
	3. Somewhat agree	
	4. Disagree	
	5. Strongly disagree	
8- There is no convincing evidence for lumbar discography in the diagnostic of discogenic pain	1. Strongly agree	6 60%
	2. Agree	3 30%
	3. Somewhat agree	
	4. Disagree	1 10%
	5. Strongly disagree	
9- In case of symptoms consistent for lumbar disc herniation a radiological assessment is suggested between 6 and 12 weeks without neurological deficit and persistent symptoms. In presence of motor deficit radiological investigation is recommended to be performed earlier	1. Strongly agree	6 60%
	2. Agree	2 20%
	3. Somewhat agree	2 20%
	4. Disagree	
	5. Strongly disagree	
10- Magnetic Resonance Imaging (MRI) is the most appropriate non-invasive test to confirm the presence of lumbar disc herniation	1. Strongly agree	9 90%
	2. Agree	1 10%
	3. Somewhat agree	
	4. Disagree	
	5. Strongly disagree	
11- Plain X-ray images can only be considered in adjunct for differential diagnosis of lumbar disc herniation from other lumbar pathological diseases.	1. Strongly agree	6 60%
	2. Agree	3 30%
	3. Somewhat agree	
	4. Disagree	1 10%
	5. Strongly disagree	

flexion, rising from sitting, hyperextension or extension-rotation, to be most likely suffering from facet joint pain. There is level I evidence that lumbar facet blocks aid in the diagnosis of chronic lumbar facet joint pain if there is >75% of >80% pain relief.[58,59]

3.2.2. Physical exam and tests

Essential diagnostic tests in patients with suspected lumbar herniated disc are evaluation of muscle strength, sensory disturbance, sphincter dysfunction as well as the Lasegue sign (reproduction of same-sided leg pain with raising of straight leg with the patient supine), and crossed Lasegue sign (reproduction of contralateral leg pain with raising of straight leg with the patient supine).[5] There is Level I evidence that sensory and motor testing aids in the diagnosis of LHD: in a 1987 study of 52 consecutive patients, the positive predictive value (PPV) of foot dorsiflexion weakness was 69% for a L4-5 herniated disk, while the negative predictive value (NPV) was 47%.[60]

Muscle strength testing should be documented using the MRC (Medical Research Council) scale (0–5).[61] The MRC grading system provides the following grades: 0, paralysis; 1, only a trace or flicker of muscle contraction is seen or felt; 2, muscle movement is possible with gravity eliminated; 3, muscle movement is possible against gravity; 4, muscle strength is reduced, but movement against resistance is possible and 5, normal strength.[61] It is important to note, however, that the test does not take into account musculoskeletal disorders that can affect MRC results, such as tendinopathy or arthritis. It also depends on the motivation of the patient, which may be insufficient due to pain, misunderstanding of instructions, psychological reasons, or secondary gain reasons.[62] Future research should move towards the development of noninvasive tests for objective measurements of muscle strength, such as platforms with foot pressure sensors.[62]

When used in isolation, most physical tests do not accurately diagnose lumbar disc herniation.[63] For this reason, several tests should be used in combination. Specifically, if patients have at least three of the following, they are more likely to have LHD: dermatomal pain in accordance with corresponding nerve root, corresponding sensory deficits, reflex or motor weakness, and/or positive straight raise leg (Lasegue test).[12] There is insufficient evidence on use of other tests for clinical diagnosis of LHD (Bragard test, Christodoulides test – femoral stretch test, slump test, Bowstring test, cough impulse test, Bell test, hyperextension test, lumbar range of motion, absence of reflexes).[63,64]

3.3. Radiological diagnosis of LHD

3.3.1. MRI

Current guidelines suggest MRI is the most appropriate noninvasive

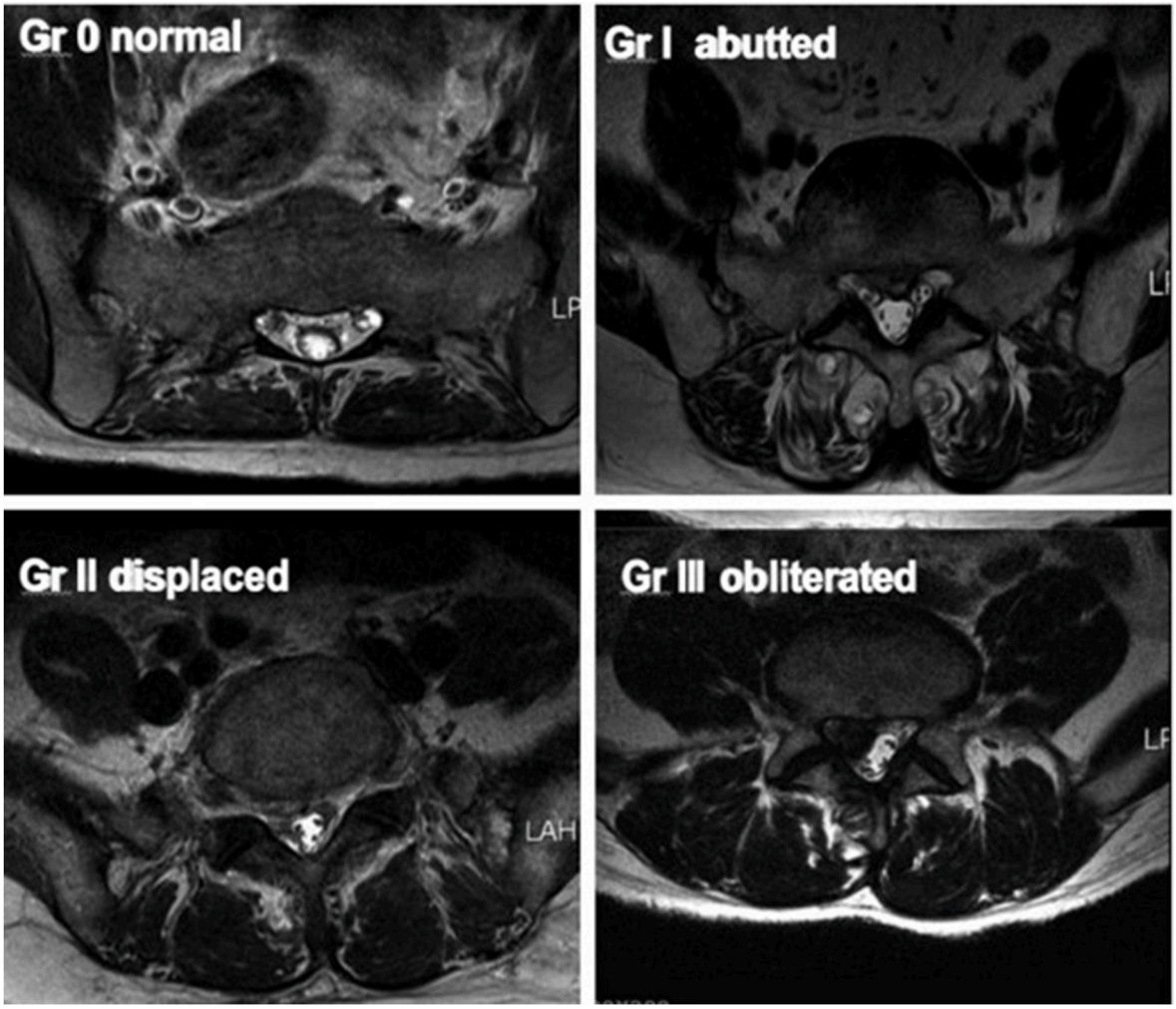

Fig. 6. Grading of nerve root images on magnetic resonance imaging. Gr: grade. From: From: Park CK, Lee HJ, Ryu KS. Comparison of Root Images between Post-Myelographic Computed Tomography and Magnetic Resonance Imaging in Patients with Lumbar Radiculopathy. J Korean Neurosurg Soc. 2017 Sep; 60 (5):540–549. doi: 10.3340/jkns.2016.0809.008. Epub 2017 Aug 30. PMID: 28881117; PMCID: PMC5594622.

test to confirm the presence of LHD.[5] An MRI is recommended if symptoms persist for more than 6 weeks (even without a neurologic deficit); it should be performed earlier if neurologic deficits are present.[65] MRI findings of increased T2-weighted signal from the posterior 10% of the disc diameter are highly suggestive of disc herniation.[24] MRI is the gold standard for imaging to confirm suspected LHD, with reported diagnostic accuracy of up to 97% and high inter-observer reliability.[5,66,18] However, diagnostic accuracy values for MRI vary in the literature. A literature review by Wassenaar et al (2012) analyzed 8 MRI studies, finding an estimated pooled sensitivity of 75% and specificity of 77% for LHD diagnosis.[17]

A substantial risk of misleading MRI findings exists, since disk bulging and protrusions are both common among asymptomatic persons (in approximately 60% and 36% of asymptomatic individuals greater than 50 years of age, respectively).[1] A recent literature review by Kim et al showed similar sensitivity and specificity of MRI, as compared to CT and CT myelogram, for diagnosis of LDH (see Table 2). However, this study is limited in that nearly all studies were done before 1995. As a result, the relative diagnostic accuracy of today's MRI versus CT/CT myelogram is unknown.[15]

Recent advances in MRI technology have further enabled and improved the diagnosis, treatment and even prognosis of extraforaminal herniated discs and symptomatic degenerative disc disease in general. Table 3 summarizes recent studies (2012–2022) on MRI-based neuroradiological diagnosis of LHD. Ahn et al proposed a six-level grading system based on sagittal MRI and graded according to the direction (rostral and caudal) and degree (low, high, and very high) of disc migration, validated on 101 migrated LDHs treated with minimally invasive endoscopic discectomy[19] (Fig. 8).

Oh et al suggested the following MRI criteria for diagnosis of extraligamentous LDH in the lumbar spine: 1) spinal canal compromised by more than half its dimension, 2) internal signal difference in the LHD, 3) an ill-defined margin of the LHD, 4) disruption of the continuous low-signal-intensity line covering the LHD, and 5) presence of an internal dark line in the LHD.[20]

Use of tractography has also been extensively researched since the first description of digital tractography (DTI) of lumbar nerve roots in 2011. Some studies indicate significant changes of diffusion parameters around compressed nerves[67]; however, no clinical benefit of this method has been demonstrated so far. In their review article on DTI use for LHD diagnosis, Eguchi et al[68] summarize that DTI can reveal significant decreases in fractional anisotropy (FA), with significant increases in apparent diffusion coefficient (ADC) values, in compressed nerve roots. FA values appear to have higher accuracy than ADC values and may also correlate with neurologic deficit severity.

3.3.2. *CT or CT myelogram*

CT or CT myelography are recommended as the next appropriate tests for diagnosis of LHD in patients who are not suitable for MRI or whose MRI is inconclusive.[5] A systematic review of 7 studies published

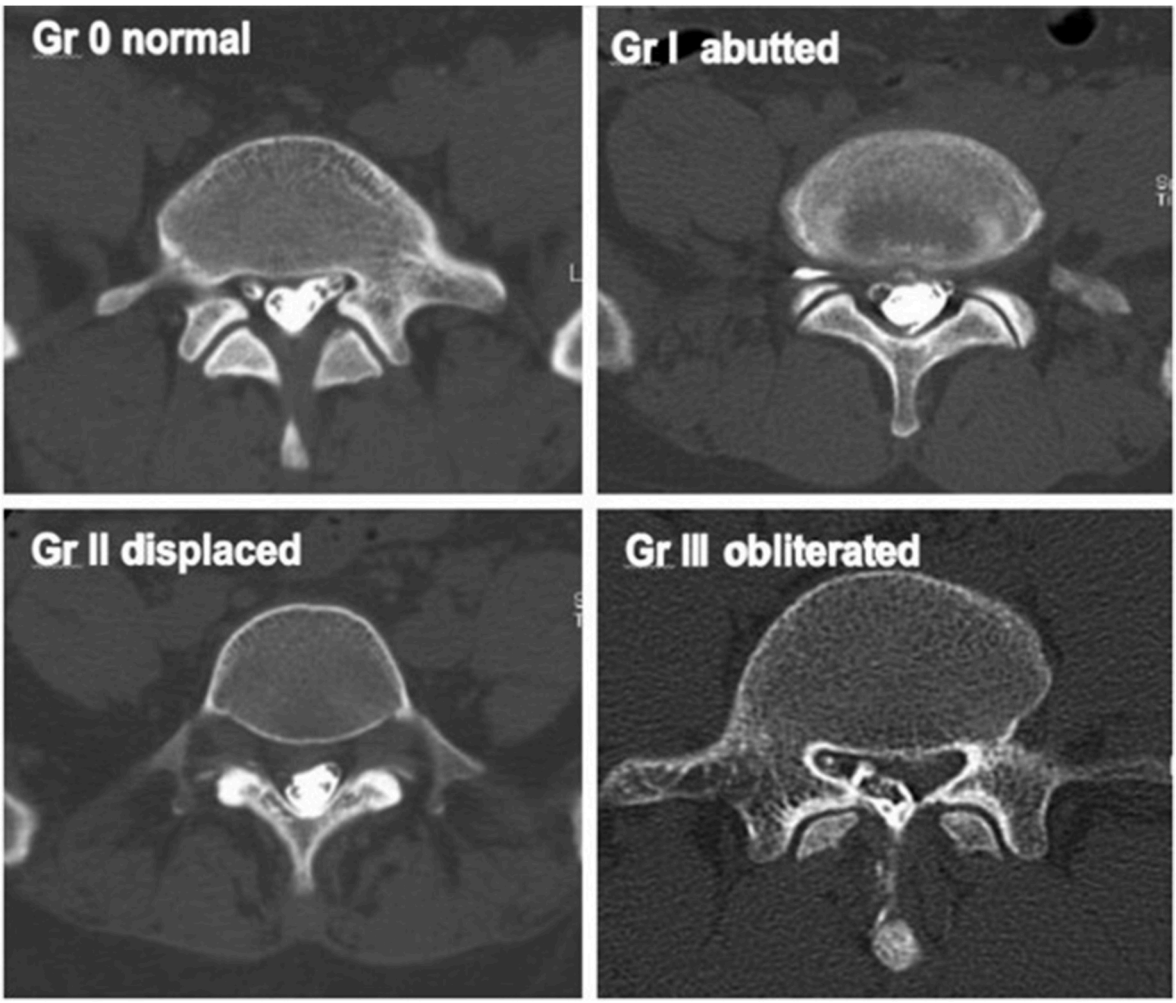

Fig. 7. Grading of nerve root images on computed tomography-myelography. Gr: grade. From: Park CK, Lee HJ, Ryu KS. Comparison of Root Images between Post-Myelographic Computed Tomography and Magnetic Resonance Imaging in Patients with Lumbar Radiculopathy. J Korean Neurosurg Soc. 2017 Sep; 60 (5):540–549. doi: 10.3340/jkns.2016.0809.008. Epub 2017 Aug 30. PMID: 28881117; PMCID: PMC5594622.

in 2012 by van Rijn et al showed a pooled sensitivity of 77.4% and specificity of 73.7% for CT.[14] One promising CT optimization was recently described using multidetector CT (MDCT) with iterative reconstruction as an accurate alternative to MRI in LHD diagnosis. Sensitivity, specificity, precision, and accuracy of MDCT for disc protrusion diagnosis were reported at 98.8%, 96.5%, 97.1%, and 97.8%, respectively at the disc level, and 97.7%, 92.9%, 98.6%, and 96.9%, respectively at the patient level.[16] Plain X-ray images can be considered as an adjunct imaging modality for differential diagnosis of lumbar disc herniation from other lumbar pathological diseases.

A study by Park et al.[69] on 91 patients with radicular leg pain found that visual pain analogue (VAS) scores correlated more strongly with CT-myelography than MRI, thereby suggesting that CT myelography can be a useful confirmative diagnostic tool in selected cases when the exact cause of radicular pain cannot be identified with MRI. These researchers proposed a grading system for nerve root compression in LHD based on MRI and CT myelography findings (Figs. 6- 9).

Finally, non-contrast CT can be a valuable method for the diagnosis of herniated lumbar disc in the absence of MRI or CT-myelography. In particular, CT may aid in the diagnosis of far lateral disc herniations. Isolated far lateral fragments appear isointense, while contralaterally the normal dorsal root ganglion is surrounded by fat. Far lateral stenosis attributed to limbus vertebral fracture, dorsal facet arthropathy, or deformity may also be seen on CT examinations including 2-D or 3-D reconstructed images[70](Fig. 10).

4. WFNS spine committee recommendations

After summarizing and discussing the available literature, as outlined above, the WFNS achieved consensus on the following eleven statements.

4.1. Epidemiology of LHD

(1) The lifetime risk for lumbar disc herniation is about 30%. Symptomatic disc herniation risk is 1–3%; of these, 60–90% resolve spontaneously.
(2) Risk factors for lumbar disc herniation include genetic and environmental factors, strenuous activities, and smoking.

4.1.1. Clinical diagnosis of LHD

(3) Radicular pain with specific dermatomal radiation in one or both legs is usually associated with herniated disc.
(4) Pain history is the most important part of clinical evaluation. It should include questions on intensity, onset, and localization. Pain should be assessed with visual or numeric analogue scale and Oswestry disability index.
(5) Essential diagnostic tests in patients with suspected herniated disc are evaluation of muscle strength, sensory disturbance, and

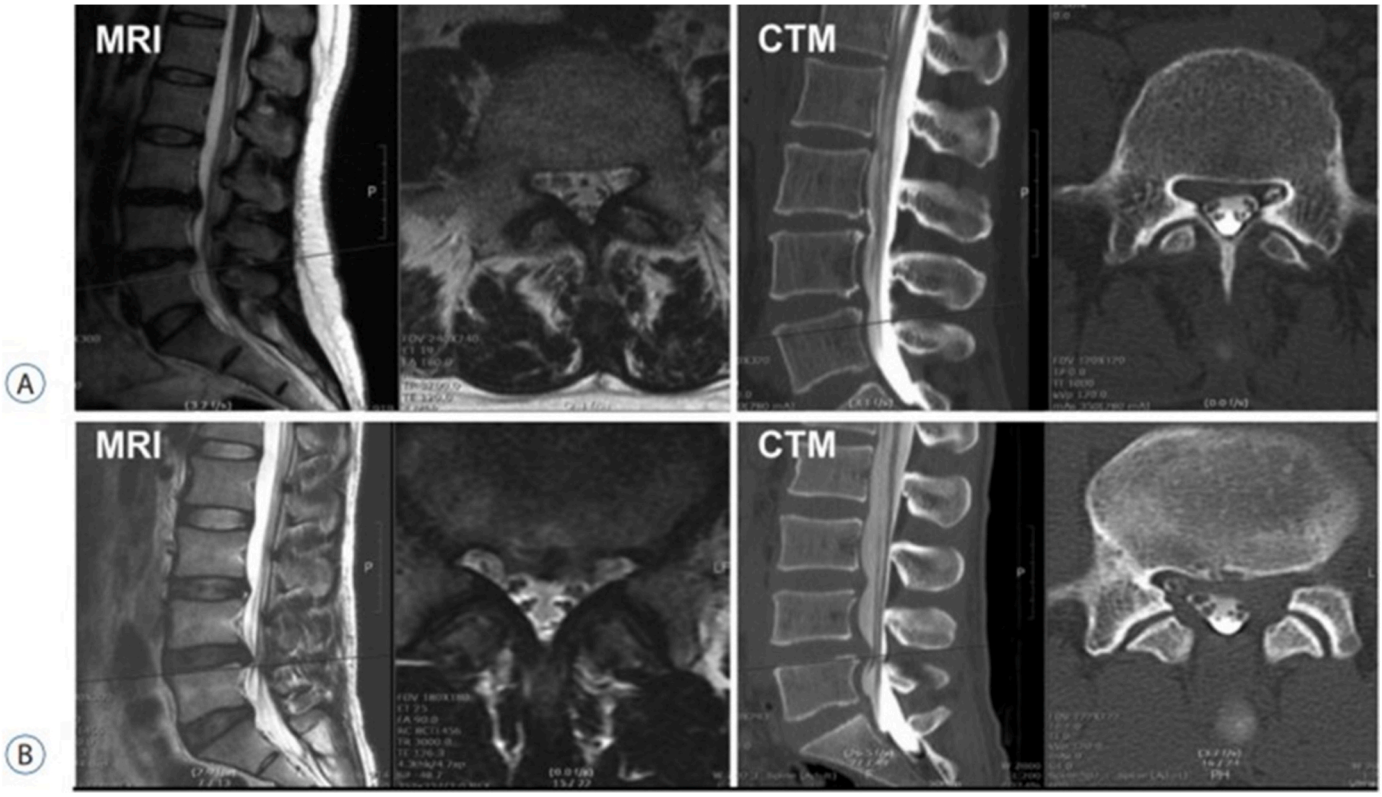

Fig. 8. A: Preoperative magnetic resonance imaging (MRI) T2 and computed tomography-myelography (CTM) axial scans showing differences in root compression finding. While the finding is grade I on the MRI axial scan, the finding is grade III on CTM. Grade I on MRI generally means less significant radicular pain that does not require surgical intervention. However, grade III on CTM generally means severe root compression that requires decompressive surgery. B: CTM axial scan showing severe left L5 root compression by obliteration of the nerve root not detectable on MRI axial scan. While grade II on MRI generally indicates a moderate degree of root compression, grade III on CTM generally means severe root compression that requires decompressive surgery. Grade III on CTM is congruent with the patients' clinical symptoms (severe radicular pain with a VAS score of 8). From: Park CK, Lee HJ, Ryu KS. Comparison of Root Images between Post-Myelographic Computed Tomography and Magnetic Resonance Imaging in Patients with Lumbar Radiculopathy. J Korean Neurosurg Soc. 2017 Sep; 60 (5):540–549. doi: 10.3340/jkns.2016.0809.008. Epub 2017 Aug 30. PMID: 28881117; PMCID: PMC5594622.

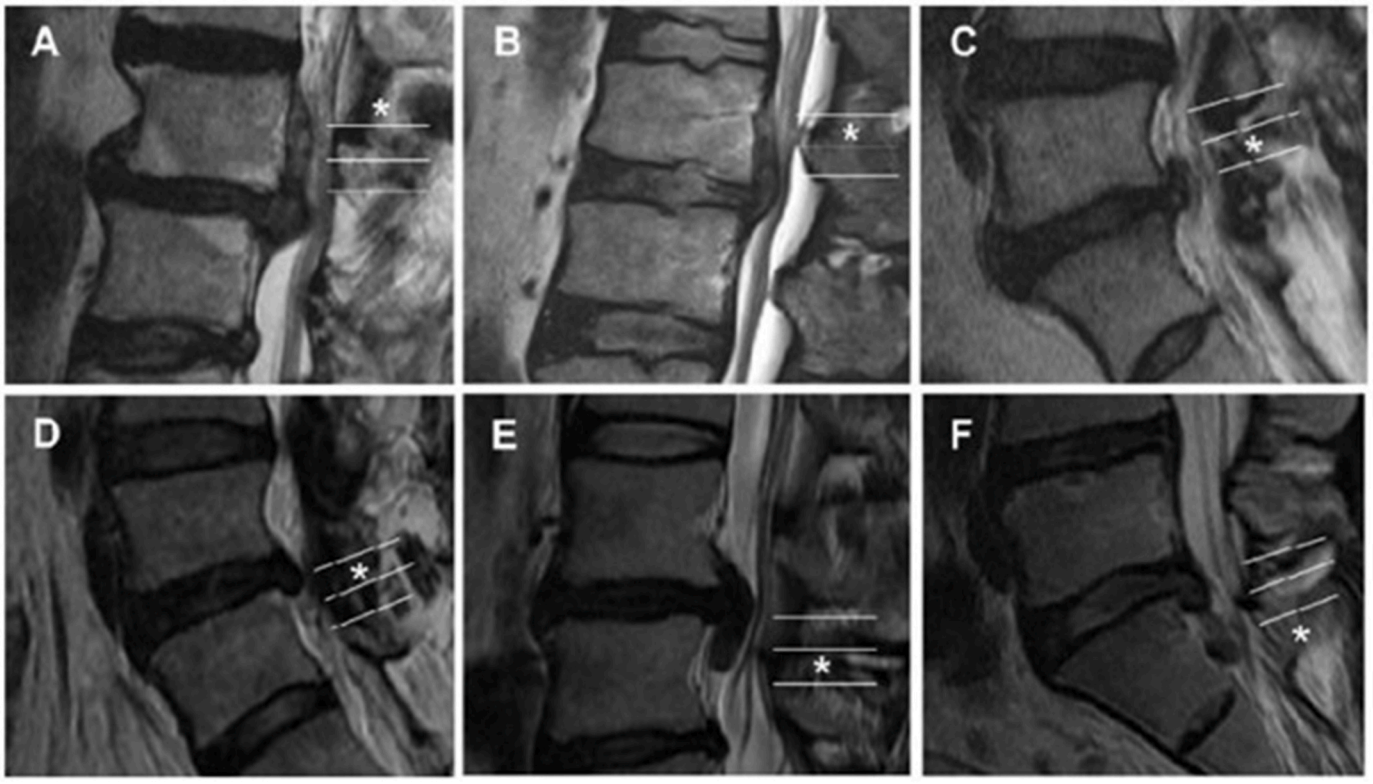

Fig. 9. Grade of migrated lumbar disc herniation on a sagittal MRI image (asterisk) (A) Grade 1, superior very high grade (B) Grade 2, superior high grade (C) Grade 3, superior low grade (D) Grade 4, inferior low grade (E) Grade 5, inferior high grade (F) Grade 6, inferior very high grade. From: Ahn Y, Kim JE, Yoo BR, Jeong YM. A New Grading System for Migrated Lumbar Disc Herniation on Sagittal Magnetic Resonance Imaging: An Agreement Study. J Clin Med. 2022 Mar 22; 11 (7):1750. doi: 10.3390/jcm11071750. PMID: 35407358; PMCID: PMC8999959.

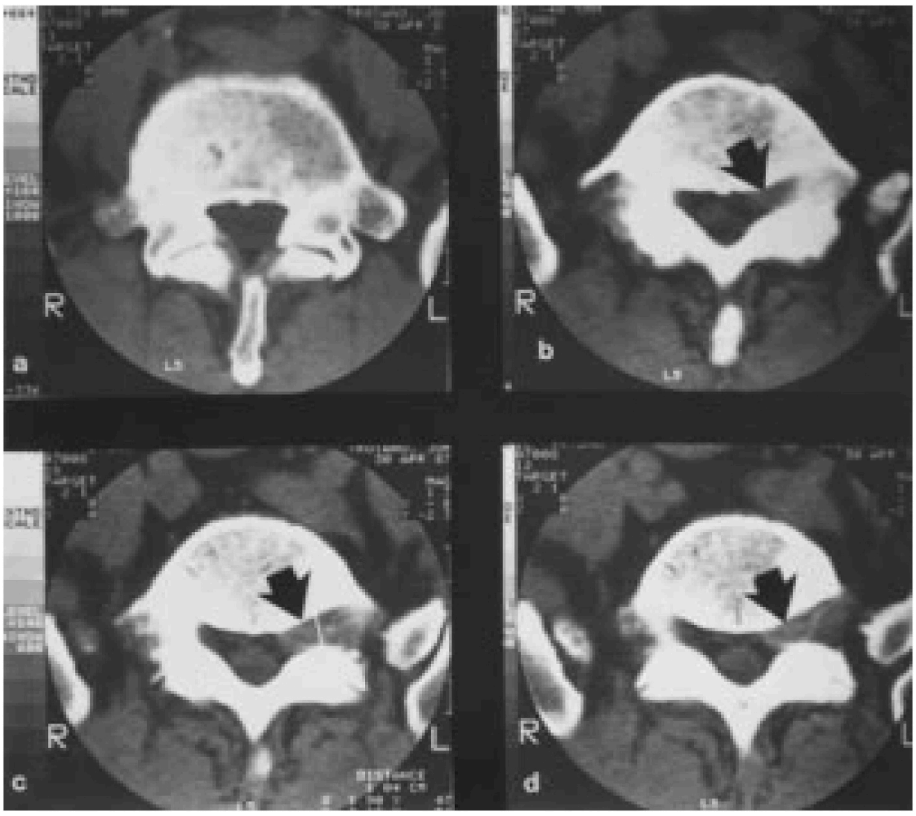

Fig. 10. **(a)** Non contrast CT scan obtained at the mid L5 vertebral level. **(b)** Non-Contrast CT scan at the upper level of the L5–S1 interspace showing disc material extending laterally, foraminally, and far laterally into the neural foramen (arrows). **(c)** The CT study at the mid foraminal level most clearly demonstrated disc extending from the lateral recess all the way to and through the far lateral compartment (arrows). **(d)** This CT image, obtained at the lower-most aspect of the L5–S1 neural foramen, showed foraminal and far lateral disc (arrows). From: Epstein NE. Foraminal and far lateral lumbar disc herniations: surgical alternatives and outcome measures. Spinal Cord. 2002 Oct;40(10):491-500. doi: 10.1038/sj.sc.3101319. PMID: 12235530.

sphincter dysfunction, as well as the supine straight leg raise, Lasegue sign, and crossed Lasegue sign.

(6) Muscle strength testing should be examined and documented using MRC (Medical Research Council) scale (0–5).

(7) Lumbar facet blocks are the gold standard for diagnosis of facet joint syndrome.

(8) There is no convincing evidence for lumbar discography in the diagnosis of discogenic pain.

4.1.2. Radiology diagnosis of LHD

10) When patients present with symptoms consistent with lumbar disc herniation without neurologic deficit, radiological assessment is suggested for persistent pain after 6–12 weeks. Earlier radiographic investigation is recommended if a motor deficit is present.

11) Magnetic Resonance Imaging (MRI) is the most appropriate non-invasive test to confirm the presence of lumbar disc herniation.

12) Plain X-ray images should only be considered as an adjunct imaging modality to differentiate lumbar disk herniation from other lumbar pathologies.

5. Conclusion

In summary, lumbar disk herniations (LDH)- the localized displacement of disc material beyond the normal margins of the intervertebral disc space– result in pain, weakness, or numbness in a myotomal or dermatomal distribution, which help to differentiate this entity from facetogenic, discogenic, or other nonspecific back pain. The majority of symptomatic LDH will resolve on their own, and there are multiple risk factors for LDH including age, male gender, smoking, strenuous activity, and smoking. A set of clinical tests, including manual muscle testing, sensory testing, Lasegue sign, and crossed Lasegue sign are recommended to diagnose LDH. Magnetic resonance imaging (MRI) is the gold standard for confirming suspected LDH. Our eleven final WFNS Spine Committee consensus statements provide current, evidence-based guidelines on the epidemiology, clinical diagnosis, and radiographic diagnosis of LDH for practicing spine surgeons worldwide, including those in low and middle income countries in particular.

CRediT authorship contribution statement

Mirza Pojskic: Writing – review & editing, Data curation, Conceptualization. **Erica Bisson:** Writing – original draft, Data curation, Conceptualization. **Joachim Oertel:** Writing – review & editing, Formal analysis, Data curation, Conceptualization. **Toshihiro Takami:** Writing – review & editing, Data curation, Conceptualization. **Corinna Zygourakis:** Writing – review & editing. **Francesco Costa:** Writing – review & editing, Data curation, Conceptualization.

Declaration of competing interest

N

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