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Evaluation of the Precision of Lumbosacral Radiography in Detecting Lumbar Herniated Nucleus Pulposus Compared to MRI 3 Tesla as the Gold Standard

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Abstract

Background: Low back pain is one of the leading causes of disability worldwide, and herniated nucleus pulposus (HNP) is among its most common causes. Magnetic resonance imaging (MRI) is the diagnostic gold standard, while lumbosacral radiography is still widely used as an initial imaging modality despite limited local evidence on its diagnostic performance.

Objective: To evaluate the diagnostic accuracy of lumbosacral radiography in detecting HNP compared with 3 Tesla MRI as the reference standard.

Methods: This analytic observational study used a cross-sectional design with secondary data from 62 subjects with clinical suspicion of HNP who underwent both lumbosacral radiography and 3 Tesla MRI at RSUP Dr. Wahidin Sudirohusodo Makassar during January-December 2024, selected by consecutive sampling. Sensitivity, specificity, and Cohen's Kappa agreement were calculated using a 2×2 cross-tabulation.

Results: Of 62 subjects, 17 (27.4%) had positive and 45 (72.6%) had negative lumbosacral radiography findings, while 55 (88.7%) had positive and 7 (11.3%) had negative MRI findings. Lumbosacral radiography showed a sensitivity of 25.45% (95% CI: 15.8-38.3%) and specificity of 57.14% (95% CI: 25.1-84.2%), with a Cohen's Kappa of −0.052 (p = 0.331), indicating poor agreement with MRI.

Conclusion: Lumbosacral radiography has limited diagnostic accuracy for detecting HNP and shows poor agreement with 3 Tesla MRI. It remains useful as an initial screening tool but should not be used as the sole basis for diagnosing HNP; MRI should be prioritized in patients with strong clinical suspicion.

Keywords: Lumbosacral Radiography, Herniated Nucleus Pulposus, Magnetic Resonance Imaging, Diagnostic Accuracy

Introduction

Low back pain is one of the most common musculoskeletal health problems and a leading cause of disability worldwide, affecting not only an individual's quality of life but also contributing to decreased work productivity and increased socioeconomic burden. One of its most frequent causes is herniated nucleus pulposus (HNP), a pathological condition characterized by protrusion of the nucleus pulposus through a tear in the annulus fibrosus, which may compress nerve roots or surrounding spinal structures; clinical manifestations commonly include radicular pain, muscle weakness, paresthesia, and sensory disturbance, which may lead to long-term disability if not managed appropriately.[1,2] The World Health Organization reported that approximately 619 million people worldwide experienced low back pain in 2020, with the number projected to increase to 843 million by 2050.[3] HNP is also frequently associated with sleep disturbance, limitations in daily activities, and decreased work performance, making it one of the main reasons for healthcare utilization, particularly among individuals of productive age.[4–6] Epidemiologically, symptomatic intervertebral disc degeneration is estimated to affect approximately 5.5% of the global population, with a lifetime risk of lumbar HNP reaching around 30% in adults, and an annual incidence of 5 to 20 cases per 1,000 individuals, predominantly among the working-age population.[2] Gradual intervertebral disc degeneration, combined with repetitive mechanical stress and inflammatory responses, plays a crucial role in the pathogenesis of HNP,[7,8] contact between the nucleus pulposus material and neural structures can trigger the release of pro-inflammatory mediators, such as interleukin and tumor necrosis factor-alpha, contributing to radicular pain and neurological deficits.[7] This interaction between mechanical compression and inflammatory processes explains why the severity of clinical symptoms does not always correspond to the extent of herniation observed on imaging, highlighting the importance of correlating radiological findings with clinical presentation; accurate diagnosis is therefore essential for determining appropriate management, whether conservative or surgical, and for preventing progression of neurological impairment.

Magnetic Resonance Imaging (MRI) is the imaging modality of choice for diagnosing HNP due to its ability to provide detailed visualization of intervertebral discs, soft tissues, and neural structures without exposure to ionizing radiation. Numerous studies have demonstrated that MRI has high diagnostic accuracy and shows significant correlation with patients' clinical manifestations, and it is thus widely recognized as the gold standard for diagnosing HNP,[9–12] advances in MRI technology have also enabled quantitative tissue evaluation and radiomic approaches for predicting clinical outcomes. In contrast, lumbosacral radiography is still frequently used as an initial imaging modality because of its accessibility, shorter examination time, and relatively lower cost; however, conventional radiography can only demonstrate structural changes in the vertebral column, such as disc space narrowing, osteophytes, or spondylolisthesis, without direct visualization of disc herniation, resulting in lower sensitivity in detecting HNP compared with MRI.[13–15] Although artificial intelligence-based approaches have been developed to improve the performance of radiographic imaging, MRI remains the primary diagnostic modality to date.[16,17] The World Federation of Neurosurgical Societies (WFNS) Spine Committee also recommends that radiography be used as an initial examination or to exclude other pathologies, while MRI is required for diagnostic confirmation and treatment planning.[2,18]

MRI's detailed visualization of soft tissue structures further enables more accurate identification of disc herniation and neural involvement.[16]

RSUP Dr. Wahidin Sudirohusodo Makassar is a tertiary referral hospital in Eastern Indonesia equipped with 3 Tesla MRI facilities. As in other Indonesian referral hospitals, HNP accounts for a considerable share of the spinal imaging caseload.[19] Even so, no study at this hospital has directly measured how well its routine lumbosacral radiography performs against MRI, even though radiographic findings still guide many initial clinical decisions in daily practice. This study therefore addresses that gap by providing the first institution-specific diagnostic accuracy data for lumbosacral radiography against 3 Tesla MRI at this hospital, covering sensitivity, specificity, and Cohen's Kappa agreement, in order to offer a concrete, hospital-based basis for deciding when patients with clinical suspicion of HNP should be referred for MRI. Accordingly, this study was conducted to evaluate the diagnostic accuracy of lumbosacral radiography in detecting HNP using 3 Tesla MRI as the reference standard, with the aim of supporting a more rational diagnostic pathway, better use of imaging resources, and earlier, more accurate diagnosis of HNP to improve patient safety and care.

Methods

This was an analytic observational study with a cross-sectional design, aimed at evaluating the diagnostic accuracy of lumbosacral radiography in detecting HNP compared with 3 Tesla MRI as the gold standard. The study was conducted at the Radiology Department of RSUP Dr. Wahidin Sudirohusodo Makassar using secondary data obtained from the medical records of patients examined during the period January-December 2024. Data collection and analysis were carried out from December 2025 to January 2026.

The study population consisted of all patients with clinical suspicion of HNP who underwent both lumbosacral radiography and 3 Tesla MRI at RSUP Dr. Wahidin Sudirohusodo Makassar during the study period. A total of 62 subjects were included using a consecutive sampling technique. The inclusion criteria were patients who underwent both imaging examinations during the January-December 2024 period and had complete radiological data, including interpretation reports by a radiologist; the exclusion criteria included patients with a history of severe spinal trauma, spinal tumors, prior spinal surgery, or incomplete/unreadable radiological examination data.

The study procedure began with identification of eligible subjects through medical records, followed by collection of lumbosacral radiography and 3 Tesla MRI findings. MRI examinations were performed with a SIGNA Pioneer 3.0 Tesla unit (GE Healthcare, Chicago, IL, USA); lumbosacral radiography was performed using the standard radiographic equipment of the Radiology Department at RSUP Dr. Wahidin Sudirohusodo Makassar. Both examinations were interpreted as part of routine clinical care by a radiologist (Sp.Rad), and these official reports were retrieved from the medical records; the researchers did not re-interpret the images themselves, and because the data were collected retrospectively, the exact number of radiologists involved in the original reporting could not be established.

The diagnosis of HNP on MRI was determined based on the terminology of the North American Spine Society (NASS) Lumbar Disc Nomenclature version 2.0, which differentiates

disc bulging from true disc herniation (protrusion, extrusion, and sequestration).[20] For analysis, MRI findings were graded on a five-point scale adapted from Ocello et al.[21] and aligned with NASS terminology, ranging from Grade 1 (normal disc) and Grade 2 (bulging, non-herniation) to Grade 3 (protrusion/contained herniation), Grade 4 (extrusion), and Grade 5 (sequestration). Grades 3-5, representing true herniation, were dichotomized as HNP positive, while Grades 1-2 were dichotomized as HNP negative.

Lumbosacral radiographs were evaluated based on radiological reports by considering the overall radiographic impression as well as indirect signs of disc abnormality. Lumbosacral radiography was categorized as HNP positive if the radiological impression suggested HNP/suspected HNP/disc herniation, or if at least two indirect signs were present, including disc space narrowing, traction osteophytes or traction spur, compensatory scoliosis, and/or vacuum phenomenon;[7,22] it was classified as negative if these criteria were not fulfilled. All collected data were documented using a standardized data collection form prepared prior to analysis.

This study received ethical approval from the Ethics Committee of the Faculty of Medicine and Health Sciences, Universitas Muhammadiyah Makassar, with approval number 112/UM.PKE/XI/47/2025.

The research instrument consisted of an observation sheet used to record subject characteristics and the results of lumbosacral radiography and 3 Tesla MRI examinations based on radiological reports. MRI 3 Tesla was used as the reference standard for determining the presence of HNP. Blinding was not performed in this study because all data were retrospectively obtained from available medical records and radiology reports.

Data processing and analysis were conducted using IBM SPSS Statistics version 31.0.2.0 (IBM Corp., Armonk, NY, USA). Univariate analysis was used to describe the frequency distribution of imaging results, while bivariate analysis was performed using 2×2 cross-tabulation to determine the values of true positive, false positive, false negative, and true negative. Sensitivity and specificity of lumbosacral radiography were subsequently calculated, and agreement between lumbosacral radiography and 3 Tesla MRI was assessed using Cohen's Kappa coefficient.

Results

Table 1 presents the characteristics of the 62 study subjects. Subjects had a mean age of 51.98 ± 14.68 years (range 21-93 years), and most fell within the 50-59-year age group. Female subjects (54.8%) were slightly more numerous than male subjects (45.2%).

Table 1. Characteristics of Study Subjects (n = 62)

Characteristic	n	%
Age (years), mean ± SD	51.98 ± 14.68	-
20-29	4	6.5
30-39	10	16.1
40-49	10	16.1
50-59	21	33.9
60-69	9	14.5
70-79	7	11.3
≥80	1	1.6
Sex		
Male	28	45.2
Female	34	54.8
Total	62	100

Source: Processed Data (2026)

Table 2 shows that this study involved a total of 62 subjects who met the inclusion criteria. Based on the findings, the majority of subjects were not identified as having HNP on lumbosacral radiography, indicating limitations of lumbosacral radiography in identifying HNP cases within the study population.

Table 2. Frequency Distribution of Lumbosacral Radiography Findings

Lumbosacral Radiography Findings	Number (n)	Percentage (%)
Negative	45	72.6
Positive	17	27.4
Total	62	100

Source: Processed Data (2026)

Table 3 shows that the majority of subjects were diagnosed as positive for HNP based on MRI findings, reflecting a high prevalence of HNP among patients with clinical suspicion who underwent imaging at RSUP Dr. Wahidin Sudirohusodo Makassar.

Table 3. Frequency Distribution of 3 Tesla MRI Findings

MRI 3 Tesla Findings	Number (n)	Percentage (%)
Negative HNP	7	11.3
Positive HNP	55	88.7
Total	62	100

Source: Processed Data (2026)

Table 4 presents the cross-tabulation between lumbosacral radiography and 3 Tesla MRI findings. A total of 14 patients with positive lumbosacral radiography and positive MRI findings were categorized as true positive (TP). There were 3 patients with positive lumbosacral radiography but negative MRI findings, categorized as false positive (FP). Additionally, 41 patients with negative lumbosacral radiography but positive MRI findings were categorized as false negative (FN), while 4 patients with negative findings on both examinations were categorized as true negative (TN). These results indicate a predominance of false negative cases, reflecting the limited capability of lumbosacral radiography in identifying HNP compared with 3 Tesla MRI as the gold standard.

Table 4. Cross-tabulation (2×2) of Lumbosacral Radiography and 3 Tesla MRI Findings

Lumbosacral Radiography	MRI Positive	MRI Negative	Total
Positive	14 (TP)	3 (FP)	17
Negative	41 (FN)	4 (TN)	45
Total	55	7	62

Source: Processed Data (2026)

Table 5 shows that the sensitivity of lumbosacral radiography in detecting HNP compared with 3 Tesla MRI as the gold standard was 25.45% (95% CI: 15.8-38.3%), indicating that the ability of lumbosacral radiography to correctly identify patients with HNP remains low. The specificity was 57.14% (95% CI: 25.1-84.2%), suggesting a moderate ability to correctly identify patients without HNP; however, the relatively wide confidence interval indicates limited precision, likely due to the small number of MRI-negative cases.

Furthermore, agreement between lumbosacral radiography and 3 Tesla MRI was analyzed using Cohen's Kappa test, yielding a kappa value of -0.052 and a p-value of 0.331. Since the p-value was greater than the significance level of $\alpha = 0.05$, the agreement between the two imaging modalities was considered statistically non-significant, indicating poor agreement between lumbosacral radiography and MRI in detecting HNP.

Table 5. Diagnostic Accuracy of Lumbosacral Radiography Using 3 Tesla MRI as the Reference Standard

Parameter	Result
Sensitivity	25.45% (95% CI: 15.8%-38.3%)
Specificity	57.14% (95% CI: 25.1%-84.2%)
Cohen's Kappa	-0.052
p-value (kappa)	0.331

Discussion

The results of this study showed that the majority of subjects were classified as negative for HNP based on lumbosacral radiography, whereas 3 Tesla MRI indicated that most subjects were positive for HNP. This marked discrepancy highlights the limitations of conventional radiography in detecting intervertebral disc abnormalities, as radiography can only demonstrate bony structures and secondary degenerative changes without direct visualization of soft tissue herniation. These findings are consistent with Santiago et al., who reported that plain spinal radiography has limited value in evaluating disc abnormalities and primarily serves as an initial examination to exclude structural abnormalities of the spine.[14]

In contrast, 3 Tesla MRI in this study demonstrated a high proportion of HNP among patients with clinical suspicion, reinforcing its role as the gold standard for diagnosing HNP. Harmawan et al. reported that MRI has high diagnostic accuracy compared with intraoperative findings, while Ghanim et al. found a significant correlation between MRI findings and clinical manifestations of HNP.[9,10] Huang et al., through a systematic review and meta-analysis, also concluded that MRI is the most accurate imaging modality for detecting lumbar disc herniation compared with other imaging techniques.[12] The advantage of MRI lies in its ability to visualize intervertebral discs, neural structures, and surrounding soft tissue in detail, allowing more precise identification of the degree of herniation and nerve root involvement.[11]

The low sensitivity of lumbosacral radiography observed in this study indicates that a substantial proportion of HNP cases were not detected on radiographic examination. The predominance of false negative cases reflects the limited capability of lumbosacral radiography in correctly identifying patients with HNP, consistent with Kim et al. and Lin et al., who reported significant limitations of conventional radiography in detecting disc herniation, even when combined with artificial intelligence-based approaches.[15,17] Kaya and Yakar also demonstrated that MRI is significantly superior to lateral radiography in diagnosing HNP, particularly in cases with clear clinical manifestations.[16]

This limitation may be explained by the inability of lumbosacral radiography to directly visualize the intervertebral discs and spinal canal. Disc herniation, particularly in posterolateral or central regions, is often not accompanied by evident bony changes on radiography. Individual anatomical variation, patient positioning, and the degree of disc degeneration may further influence radiographic appearance, potentially leading to undetected mild to moderate herniation, especially in early stages or in the absence of obvious degenerative changes.

The moderate specificity of lumbosacral radiography indicates that radiography was relatively more capable of identifying subjects without HNP than detecting those with HNP; however, the wide confidence interval suggests limited precision, likely influenced by the relatively small number of MRI-negative cases. This is consistent with the fundamental principle that disease prevalence within a study population may affect sensitivity, specificity, and the overall interpretation of diagnostic test results.[23]

Agreement analysis using Cohen's Kappa yielded a negative, non-significant value, indicating poor agreement between lumbosacral radiography and 3 Tesla MRI - lower than would be expected by chance alone. This is consistent with Altan et al., who found no significant relationship between MRI and radiographic findings in patients with degenerative lumbar spine disorders.[24] The low agreement may be attributed to substantial differences in imaging characteristics, as MRI evaluates soft tissue while radiography primarily assesses bony structures.

Beyond technical imaging aspects, the pathophysiology of HNP may also contribute to the limited radiographic detection capability. In many cases, radicular pain is more closely related to inflammatory responses from contact between nucleus pulposus material and nerve roots rather than mechanical compression alone, explaining why significant clinical manifestations may occur despite the absence of clear structural changes on lumbosacral radiography, underscoring the importance of clinical correlation and the use of MRI as a confirmatory diagnostic modality.

This study has several limitations, including its cross-sectional design with a relatively small sample size, which may affect the precision of sensitivity and specificity estimates; reliance on secondary data from medical records, which may introduce variability in the quality of radiological reports; absence of blinded image re-interpretation; an unbalanced distribution of imaging results with a relatively small number of MRI-negative cases; and the absence of analysis based on the location or severity of disc herniation. Inter-observer variability in radiological interpretation may also have influenced the results.

Clinically, these findings indicate that lumbosacral radiography cannot be used as a definitive diagnostic modality for HNP. It still plays a role as an initial examination for evaluating structural spinal abnormalities or excluding alternative diagnoses; however, it is not sufficiently

reliable for confirming HNP. The WFNS Spine Committee recommends MRI in patients with strong clinical suspicion or persistent neurological symptoms to establish the diagnosis and guide management[18]. These results support more selective and targeted use of MRI to prevent diagnostic delay, avoid suboptimal treatment, and improve patient safety - allowing MRI to be prioritized for patients with clear clinical indications, which may improve both the quality and efficiency of healthcare services.

Conclusion

Lumbosacral radiography showed limited diagnostic accuracy for HNP compared with 3 Tesla MRI, with low sensitivity, moderate specificity, and poor, non-significant agreement on Cohen's Kappa. Taken together, these results suggest that lumbosacral radiography alone is not adequate for confirming HNP and should be used mainly as an initial screening tool, while 3 Tesla MRI should be prioritized to confirm the diagnosis in patients with strong clinical suspicion, persistent radicular pain, or neurological symptoms. Because this study used a retrospective design, had an unbalanced distribution of imaging results, and did not analyze herniation by location or severity, future research with a prospective design, blinded interpretation by multiple observers, and a larger, more balanced sample is needed to build a more rational, evidence-based approach to diagnosing HNP.

Conflict of Interest

The authors declare that this study was conducted without any financial, commercial, or other relationships that could influence the results or interpretation of the research.

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