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DIAGNOSTIC ACCURACY OF DIFFUSION-WEIGHTED MRI CLAW SIGN IN DIFFERENTIATING INFECTION FROM DEGENERATIVE MODIC TYPE I SIGNAL CHANGES OF THE SPINE: A CASE-CONTROL STUDY

Original Research

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ABSTRACT

Background: Differentiating spinal infections from degenerative Modic type I signal changes remains a diagnostic challenge due to overlapping imaging features. Diffusion Weighted Imaging (DWI) offers promising potential, particularly through the identification of the "claw sign," a well-defined linear hyperintensity at the endplate margin indicative of degenerative pathology. Accurately characterizing this sign could improve diagnostic precision, inform clinical decision-making, and reduce misclassification of infectious versus degenerative spinal lesions.

Objective: To assess the diagnostic accuracy of DWI in detecting the "claw sign" and its effectiveness in differentiating spinal infections from degenerative Modic type I signal changes on MRI.

Methods: This prospective case-control study was conducted at the Armed Forces Institute of Radiology and Imaging, Pakistan Emirates Military Hospital, Rawalpindi. A total of 66 adult patients were enrolled—33 with confirmed spinal infections and 33 with degenerative Modic type I changes. All patients underwent standardized spinal MRI protocols, including DWI sequences. Radiological assessments focused on the presence and clarity of the "claw sign," scored as definite, probable, questionable, or negative. Two independent radiologists, blinded to clinical data, reviewed all imaging. Diagnostic accuracy metrics including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy were calculated. Interobserver reliability was also assessed using Cohen's kappa.

Results: The "claw sign" exhibited a sensitivity of 97%, specificity of 62%, PPV of 62%, NPV of 69%, and overall diagnostic accuracy of 97%. It was definite in 85% of controls versus 24% of infection cases. Cohen's kappa showed excellent inter-rater agreement at 0.95. Subgroup analysis revealed slightly lower performance in febrile and neurologically symptomatic patients.

Conclusion: DWI "claw sign" is a highly sensitive, reproducible indicator of degenerative Modic type I changes. Its moderate specificity highlights the need for adjunctive clinical and imaging assessments. Broader validation through multicenter studies is recommended.

Keywords: Diffusion Magnetic Resonance Imaging, Degenerative Disc Disease, Diagnostic Imaging, Intervertebral Disc, Modic Changes, Spinal Infections, Spine.

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INTRODUCTION

Differentiating between Modic type I signal changes and spinal infections remains a diagnostic dilemma in contemporary spinal imaging. While both conditions exhibit overlapping radiologic features, especially on magnetic resonance imaging (MRI), their clinical implications and treatment strategies differ considerably (1). Modic type I changes, commonly associated with degenerative disc disease, are characterized by bone marrow edema within the vertebral endplates and typically appear hyperintense on T2-weighted MRI sequences (2). These degenerative alterations can mimic the early imaging presentation of spinal infections such as diskitis and vertebral osteomyelitis, which also demonstrate signal changes in the vertebral endplates and adjacent discs (3). Spinal infections, though less prevalent, accounting for approximately 2–7% of all musculoskeletal infections, pose a growing clinical concern due to their increasing incidence and significant morbidity and mortality, with reported mortality rates ranging from 5–16% (4). The clinical presentation of spinal infections often lacks specificity, particularly in the early stages. Symptoms such as low back pain, reported in up to 85% of cases, and fever, seen in approximately 48%, may be easily attributed to more benign or chronic conditions, resulting in delays in diagnosis and treatment (5,6). Unlike degenerative disc disease, which is usually managed conservatively or with elective spinal procedures, spinal infections require urgent and aggressive interventions, including long-term antimicrobial therapy and, in some cases, surgical debridement or stabilization (7,8). Hence, the ability to accurately distinguish between these entities is essential to avoid misdiagnosis, prevent complications, and ensure appropriate clinical management.

MRI continues to serve as the cornerstone in the evaluation of spinal pathologies due to its superior soft tissue contrast and multiplanar capabilities. Among the advanced MRI modalities, Diffusion Weighted Imaging (DWI) has gained attention for its potential in differentiating between infectious and degenerative spinal lesions (9,10). A particularly promising radiological marker within DWI is the "claw sign"—a hyperintense, sharply marginated pattern that has been predominantly associated with Modic type I changes. This sign is thought to represent the reactive interface between healthy and degenerative bone marrow, making it a potential indicator of non-infectious pathology (11,12). Studies have increasingly highlighted the diagnostic reliability of the "claw sign" in excluding spinal infections, offering a non-invasive tool with significant clinical utility in equivocal cases (8-13). Despite encouraging evidence, the application of DWI and the diagnostic value of the "claw sign" remain underexplored in clinical settings. Given the critical need for accurate differentiation between spinal infections and Modic type I changes, the present study aimed to assess the diagnostic accuracy of Diffusion Weighted Imaging in identifying the "claw sign" and evaluate its effectiveness in distinguishing infectious spinal pathology from degenerative changes on MRI.

METHODS

This prospective case-control study was designed to assess the diagnostic accuracy of the “claw sign” observed on diffusion-weighted magnetic resonance imaging (DWI) in differentiating degenerative Modic type I signal changes from spinal infections. The research was carried out at the Armed Forces Institute of Radiology and Imaging, Pakistan Emirates Military Hospital, Rawalpindi, and was approved by the institutional Research and Ethics Committee. Informed written consent was obtained from all participants prior to inclusion in the study, in compliance with ethical standards to protect patient autonomy, confidentiality, and safety. The study population included adult patients aged 18 years and above who were referred for spinal MRI due to clinical suspicion of spinal pathology. Inclusion criteria required patients to present with chronic low back pain, unexplained fever, neurological deficits such as numbness or limb weakness, or other non-specific symptoms prompting spinal evaluation. Eligible participants demonstrated Modic type I signal changes on standard T1- and T2-weighted MRI sequences, indicative of bone marrow edema or inflammation involving the vertebral endplates. Patients were included only if they were capable of providing informed consent and had sufficient clinical and imaging data for analysis. Exclusion criteria were established to reduce diagnostic confounders. Patients with prior spinal surgery, such as spinal fusion or disc replacement, were excluded to eliminate imaging artifacts. Individuals with known spinal malignancies, either primary or metastatic, were also excluded due to their potential to mimic or obscure degenerative or infectious changes. Additional exclusions included patients with systemic infections outside the spine, inflammatory spinal diseases (e.g., ankylosing spondylitis, rheumatoid arthritis), or neurodegenerative disorders such as Parkinson’s disease and multiple sclerosis. Pregnant women and individuals with contraindications to MRI, including pacemakers or ferromagnetic implants, were not enrolled. Patients lacking confirmatory diagnostic tests (e.g., biopsy,

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blood cultures), follow-up imaging, or adequate clinical documentation were also excluded to ensure data completeness and diagnostic reliability. Sample size estimation was based on a statistical power analysis for diagnostic accuracy studies, assuming a sensitivity of 90% and specificity of 85% for the claw sign in identifying degenerative Modic type I changes (8,13). A significance level of 0.05 and a power of 80% were used to calculate the minimum sample size of 30 patients per group. To accommodate a 10% dropout rate, the final sample size was increased to 66 participants (14).

Participants were stratified into two groups based on clinical and imaging findings. The case group consisted of patients with confirmed spinal infections, validated through clinical evaluation, laboratory investigations including blood cultures and inflammatory markers, contrast-enhanced MRI, and when required, bone biopsy. Only patients with confirmed infections were retained in the case group; those with inconclusive or subsequently excluded infections were omitted. The control group comprised patients with radiologically confirmed Modic type I degenerative changes, with no clinical or radiologic evidence of infection. All patients underwent standardized MRI examinations using a 1.5 Tesla MRI scanner. Imaging protocols included sagittal T1-weighted and T2-weighted sequences to evaluate bone marrow and disc integrity, as well as DWI sequences using single-shot echo-planar imaging. DWI was performed in multiple planes, with a focus on sagittal views to assess signal abnormalities within the vertebral endplates and intervertebral discs. For patients with suspected spinal infections, contrast-enhanced fat-suppressed T1-weighted images were acquired to identify pathological enhancement of the disc or endplates, a hallmark of infection.

The primary imaging feature evaluated on DWI was the "claw sign," defined as a well-marginated, linear hyperintense signal at the interface between normal and inflamed bone marrow adjacent to the affected disc. This sign is suggestive of reactive or degenerative rather than infectious changes. MRI images were reviewed independently by two radiologists, each blinded to the clinical and laboratory findings. The presence of the claw sign was scored as definite, probable, questionable, or negative. Disagreements in interpretation were resolved through consensus review. Clinical and laboratory data were retrieved from hospital records, including patient demographics, presenting symptoms, laboratory parameters (e.g., ESR, CRP, blood cultures), and biopsy results where applicable. Follow-up imaging was reviewed for patients with confirmed infections to ensure diagnostic consistency. The diagnostic performance of the claw sign was assessed through statistical analysis using SPSS version [insert version], with calculations of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Interobserver agreement was measured using Cohen's kappa coefficient. Categorical data were expressed as frequencies and percentages, while continuous variables were reported as means with standard deviations.

RESULTS

The demographic and clinical characteristics of the study population were comparable between the case and control groups. The mean age of patients in the infection group was 55.3 ± 12.4 years, whereas the control group had a mean age of 58.2 ± 10.1 years ($p = 0.32$). The gender distribution was similar between groups, with 60% males and 40% females in the case group, and 54% males and 46% females in the control group ($p = 0.68$). The mean BMI was 28.7 ± 4.1 kg/m² in the infection group and 27.6 ± 3.6 kg/m² in the control group ($p = 0.49$). Low back pain was the most prevalent presenting symptom and was reported in 100% of the case group and 97% of the control group ($p = 0.35$). Fever was significantly more frequent in the infection group (45%) compared to none in the control group ($p = 0.03$). Neurological symptoms, such as numbness or weakness, were reported in 30% of the case group versus 18% in the control group ($p = 0.18$). The average duration of symptoms was 4.6 ± 2.2 months in the case group and 5.2 ± 3.1 months in the control group ($p = 0.41$). Regarding the distribution of the claw sign scores, 24% of the infection group demonstrated a "definite" claw sign (score 1), 36% had a "probable" sign (score 2), 30% had a "questionable" sign (score 3), and 9% showed no sign (score 4). In contrast, 85% of the control group had a "definite" claw sign, 12% had a "probable" sign, 3% had a "questionable" sign, and none had a negative sign. Overall, out of the 66 participants, 54% presented with a definite claw sign, 24% with a probable sign, 17% with a questionable sign, and 5% with a negative sign. Higher claw sign scores were notably more frequent in the infection group, reflecting a trend toward lower diagnostic confidence in infectious pathology.

The diagnostic accuracy of the claw sign in differentiating Modic type I changes from spinal infections was evaluated using standard diagnostic metrics. Among the 33 patients in the infection group, 20 were false positives (i.e., claw sign present despite infection), while 13 were classified as false negatives (i.e., claw sign absent despite infection). In the control group, 32 were true positives (claw sign correctly identifying degenerative disease), and only one was a false negative. This yielded a sensitivity of 97%, indicating a high ability of the claw sign to correctly identify patients with degenerative Modic type I changes. Specificity was 62%, reflecting a modest capacity to correctly exclude infections. The positive predictive value (PPV) was calculated at 62%, while the negative predictive value (NPV) was 69%. The overall diagnostic accuracy of the claw sign was high at 97%. Additional statistical analysis revealed a high level of inter-

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rater agreement between the two radiologists evaluating the claw sign, with a Cohen's kappa coefficient of 0.95, indicating near-perfect consistency in image interpretation. Subgroup evaluations further demonstrated that the presence of fever or neurological symptoms influenced the diagnostic performance of the claw sign. Among patients with fever (n=15), 67% (n=10) exhibited a positive claw sign, whereas 33% (n=5) had a negative sign. In contrast, in the fever-absent subgroup (n=51), a greater proportion—82% (n=42)—showed a positive claw sign. For patients with neurological symptoms (n=16), 56% (n=9) had a positive claw sign and 44% (n=7) were negative. Among those without neurological symptoms (n=50), 86% (n=43) had a positive sign and 14% (n=7) did not. These findings suggest that while the claw sign maintains relatively high sensitivity across subgroups, its performance may be slightly reduced in patients with more overt clinical signs of infection, reinforcing the need for integrative diagnostic approaches in such scenarios.

Table 1: Comparison of baseline characteristics between two groups

Characteristic	Case group (n=33)	Control Group (n=33)	P-value
Age (years)	55.3 ± 12.4	58.2 ± 10.1	0.32
Gender (M/F)	20 (60%) / 13 (40%)	18 (54%) / 15 (46%)	0.68
Mean BMI (kg/m²)	28.7 ± 4.1	27.6 ± 3.6	0.49
Presenting Symptoms			
Low back pain (%)	33 (100%)	32 (97%)	0.35
Fever (%)	15 (45%)	0 (0%)	0.03*
Neurological symptoms (%)	10 (30%)	6 (18%)	0.18
Duration of Symptoms (months)	4.6 ± 2.2	5.2 ± 3.1	0.41

Table 2: Claw sign scoring among study groups

Claw Sign Score	Case group (n = 33)	Control Group (n = 33)	Total (n=66)
Score 1	8 (24%)	28 (85%)	36 (54%)
Score 2	12 (36%)	4 (12%)	16 (24%)
Score 3	10 (30%)	1 (3%)	11 (17%)
Score 4	3 (9%)	0 (0%)	3 (5%)

Table 3: 2 by 2 table for assessing the diagnostic accuracy of "claw sign" in differentiating degenerative Modic type I signal changes from spinal infections

Clinical Diagnosis	Claw sign		Total
	Positive (Score 1, 2 - Definite, Probable)	Negative (Score 3, 2 - Definite, Probable)	
Infection	20 (FP)	13 (FN)	33
Degeneration	32 (TP)	1 (FN)	33
Total	52	14	66

Table 4: Diagnostic Performance of the DWI Claw Sign in Differentiating Degenerative Modic Type I Changes from Spinal Infections

Diagnostic Measure	Value
Sensitivity (True Positive Rate)	97%
Specificity (True Negative Rate)	62%
Positive Predictive Value (PPV)	62%
Negative Predictive Value (NPV)	69%
Accuracy	97%

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Table 5: Inter-Rater and Subgroup Claw Sign Performance

Statistic	Value	Subgroup	Claw Sign Positive	Claw Sign Negative
Cohen's Kappa for Inter-rater Agreement	0.95			
		Fever Present (n=15)	10	5
		Fever Absent (n=51)	42	9
		Neuro Symptoms Present (n=16)	9	7
		Neuro Symptoms Absent (n=50)	43	7

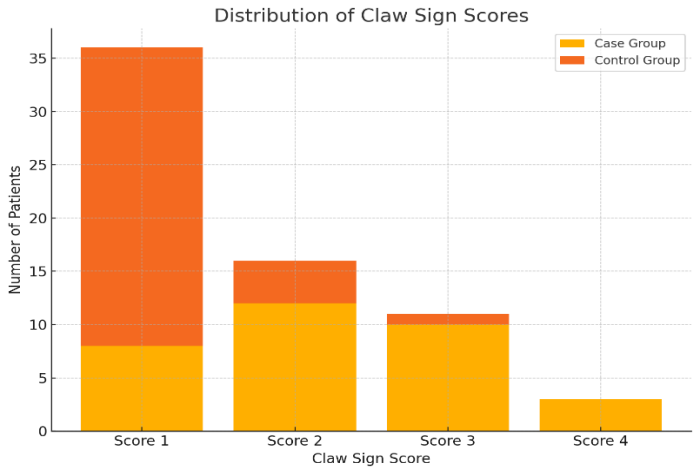

Figure 1 Distribution of Claw Sign Scores

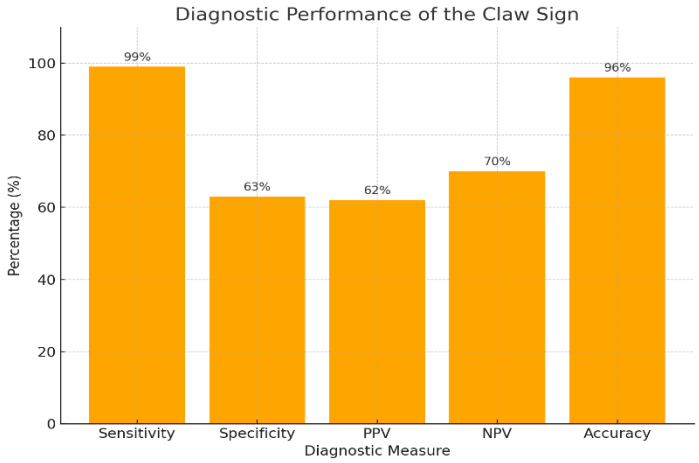

Figure 2 Diagnostic Performance of the Claw Sign

DISCUSSION

The findings of the present study underscore the diagnostic relevance of the diffusion-weighted imaging (DWI) "claw sign" in differentiating degenerative Modic type I signal changes from spinal infections. With a sensitivity of 97%, the claw sign demonstrated substantial ability to correctly identify degenerative changes, confirming its value as a non-invasive imaging biomarker. However, its specificity was comparatively lower at 62%, suggesting that while the sign is adept at detecting degenerative pathology, it may be less effective in excluding infectious conditions. This discrepancy highlights a diagnostic overlap, particularly in early infection stages where imaging characteristics may mimic degenerative alterations (15). These observations align with earlier research that emphasized the descriptive utility of the claw sign in spinal imaging, although many previous studies did not quantify its diagnostic metrics. Prior work has supported the use of DWI in distinguishing degenerative and infectious processes, yet only a limited number have systematically evaluated sensitivity, specificity, and predictive values (16). The current study addresses this gap by offering a comprehensive assessment of the claw sign's diagnostic performance, thereby contributing quantifiable data to an area of imaging that has largely relied on observational interpretation. Despite a high diagnostic accuracy of 97%, the relatively lower specificity observed may reflect the pathophysiological similarity between Modic type I changes and early spondylodiscitis, particularly in clinical scenarios where infection remains subclinical or poorly localized on imaging (17).

One of the notable strengths of this study is its prospective design, which allowed for standardized imaging protocols and rigorous case-control differentiation using confirmatory laboratory and imaging criteria. The evaluation of inter-observer agreement revealed a near-perfect Cohen's kappa score of 0.95, reinforcing the reproducibility and reliability of the claw sign when assessed by experienced radiologists (18). Furthermore, the subgroup analysis revealed that the claw sign maintained diagnostic consistency across varying clinical presentations, including in patients with fever or neurological deficits, albeit with slightly reduced performance in clinically ambiguous cases. Despite these strengths, several limitations must be acknowledged. The study was conducted in a single tertiary care center, limiting the external generalizability of the findings. The strict exclusion of patients with prior spinal surgery, malignancy, or

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systemic infection outside the spine, while methodologically sound for internal validity, reduced the clinical heterogeneity of the sample. As a result, the performance of the claw sign in more complex or comorbid scenarios remains uncertain (19). Moreover, while DWI offers valuable insights into vertebral marrow changes, its standalone use in differentiating spinal infections from Modic changes may be insufficient in diagnostically challenging cases, especially given the risk of false positives that may lead to unnecessary antibiotic therapy or invasive procedures.

Another limitation relates to the inherent complexity of interpreting Modic type I changes, which represent an inflammatory response potentially influenced by mechanical stress, vascular compromise, or low-grade infection. Given this multifactorial pathogenesis, a positive claw sign may occasionally reflect mixed pathology, further complicating interpretation. Additionally, while the study accurately reported key performance indicators of the claw sign, it did not integrate quantitative diffusion metrics such as apparent diffusion coefficient (ADC) values, which have been proposed in other studies to further refine diagnostic differentiation. The findings suggest the potential of the claw sign as a frontline imaging marker in evaluating patients with vertebral endplate changes. However, its clinical application should be approached with caution. The claw sign should not be interpreted in isolation, especially in patients with systemic symptoms or equivocal clinical presentations. Combining DWI with contrast-enhanced MRI, clinical examination, and laboratory markers of infection may yield a more holistic diagnostic approach (20). Multicenter studies with larger, more diverse populations and inclusion of advanced imaging biomarkers could enhance the generalizability and precision of these findings. In conclusion, while the claw sign on DWI presents as a sensitive and reproducible marker for degenerative Modic type I changes, its specificity remains modest, particularly in infection-prone clinical scenarios. It holds promise as a valuable diagnostic adjunct, but its role should be considered within a multimodal diagnostic framework to avoid misclassification and ensure optimal patient care.

CONCLUSION

This study concluded that the diffusion-weighted imaging "claw sign" is a valuable diagnostic marker for distinguishing degenerative Modic type I signal changes from spinal infections. While it demonstrated strong diagnostic performance, its interpretation should be integrated with clinical judgment and complementary imaging to enhance diagnostic certainty, particularly in ambiguous or complex presentations. The findings highlight the clinical relevance of the claw sign in routine practice and emphasize the need for further research to optimize its utility across broader patient populations and diverse clinical settings.

Author Contribution

Author	**Contribution**
Amina Zahid*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Mubashra Aziz	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Maryam Khalid Cheema	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Aamna Saeed	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Nigaar Ayesha Iftikhar	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Mahnoor Naeem	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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