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COMPARATIVE ANALYSIS OF CHEMICAL SHIFT - MRI VS. CT IN DETECTING PARS INTERARTICULARIS FRACTURES

Radio-Diagnosis

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ABSTRACT
Aims: To evaluate the diagnostic accuracy of chemical shift artifact MRI in comparison to CT scans for detecting pars interarticularis fractures. **Patients and Methods:** This prospective, analytical study involved 40 patients presenting with lower back pain and clinical suspicion of pars interarticularis fracture. Patients underwent MRI scans, and follow up CT scan results were collected and reviewed. Later MRI and CT images were assessed to determine the presence of pars interarticularis fractures. **Results:** CS-MRI shows a sensitivity of 76.5% for detecting spondylolysis, meaning it can correctly identify fractures in most cases. However, it has a specificity of 91%, indicating it can rule out fractures when absent, reducing the risk of false positives. **Conclusion:** This study provides a comprehensive evaluation of chemical shift artifact MRI's diagnostic accuracy in detecting pars interarticularis fractures, comparing its performance with CT.

KEYWORDS
Pars interarticularis defects, Spondylolysis, Chemical Shift MRI, MRI, Bone marrow edema, Spinal imaging

INTRODUCTION
Spondylolysis is characterized by a defect in the pars interarticularis, which can occur on one or both sides and may be associated with vertebral body slippage. It often results from repetitive trauma to the developing skeleton in individuals who are genetically predisposed. The pars interarticularis acts as a bony bridge between the inferior and superior articular surfaces of a single vertebra.

Spondylolysis can be either congenital or acquired. Although the exact cause is not known in all cases, it is frequently associated with fatigue or stress fracture of pars interarticularis that fails to heal properly. It typically arises in genetically predisposed children and adolescents who have biomechanical issues and engage in activities that involve repeated lumbar hyperextension and rotation, leading to repetitive microtrauma on the pars interarticularis. [1]

The occurrence of lumbar spondylolysis in the adult population is around 6%, with variations based on ethnicity, gender, and level of physical activity. Among young athletes experiencing lower back pain, the prevalence of spondylolysis is significantly higher, ranging between 11% and 52.6%. Several theories have been proposed to explain the pathophysiology of pars interarticularis defects. The most widely accepted explanation is that repetitive loading leads to a fatigue fracture. This injury is described as a continuum, with stress reactions on one end of the spectrum and chronic nonunion on the other [2]

Several imaging modalities are used for evaluation of pars. On plain radiography, lateral view is useful for visualizing the alignment of vertebrae and identifying any obvious defects or slippage. Oblique view is used to visualize the pars interarticularis, where the classic "Scottie dog" appearance can reveal a defect. In many medical centers, an initial MRI is conducted to evaluate the anatomy of the pars interarticularis and detect the presence of bone marrow edema. Identifying bone marrow edema helps distinguish between acute stress fractures and chronic nonunion or developmental lesions. If a pars defect is suspected based on the MRI, a targeted CT scan may follow. Although CT is considered superior to MRI for assessing bony anatomy, it involves exposure to ionizing radiation. [3]

Chemical Shift Imaging (CSI) relies on the difference in precession frequencies between fat and water molecules. Fat molecules have a higher shielding of protons compared to water molecules, causing protons in fat to precess at a slightly lower frequency than those in water. This frequency difference is known as the chemical shift effect. CSI exploits this effect during in-phase (IP) and out-of-phase (OP) imaging. The phase difference between images acquired at different echo times (TE) forms the basis of OP imaging. Phase refers to the angle of the magnetization vector in the transverse plane. Due to the different precession frequencies, the phase relationship between fat and water protons changes a few milliseconds after the initial excitation. Initially, fat and water protons are in-phase with each other. However, since fat protons precess more slowly than water protons, they become out-of-phase after a few milliseconds, reaching a 180° phase difference. Subsequently, the water protons complete a 360° rotation relative to the fat protons, returning to an in-phase state. In IP images, the signals from fat and water molecules are additive, while in OP images, the signal represents the difference between the fat and water signals. Consequently, OP imaging reduces or suppresses the signal from fatty tissue. At the boundaries between fat and non-fatty tissue, the signals from adjacent water and lipid molecules can cancel each other out, resulting in a signal void at the interface, known as the India ink artifact or black boundary artifact. [4]

The present study aimed to evaluate the diagnostic accuracy of chemical shift MRI imaging in comparison to CT scans for detecting pars interarticularis fractures.

MATERIALS AND METHODS
The study was conducted at the Department of Radiodiagnosis, J.J.M Medical College in Davanagere, Karnataka. This prospective, analytical study involved 40 patients presenting with lower back pain and clinical suspicion of spondylolysis. Patients were subjected to MRI scans and follow up CT scan results were collected and reviewed. Later the MRI and CT images were assessed to determine the presence of pars interarticularis fractures.

METHODS
The study included acquisition of T1, T2, short tau inversion recovery (STIR) and chemical shift MRI sequences with specific parameters for field of view (FOV), repetition time (TR), echo time (TE), slice thickness, and flip angle. The primary outcome measure was to assess diagnostic accuracy of MRI compared to CT, evaluated through sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV). The study spanned from September 2023 to April 2024, covering 8 months period with a sample size of 40 patients.

Inclusion Criteria
- Patients referred to the radiology department for low back pain.
- Initial radiographs suggestive of pars interarticularis fracture.

Exclusion Criteria
- MRI performed in cases of tumor, infection and postoperative assessment.
- Patients with contraindications to MRI (e.g., pacemakers, metallic implants).
- Pregnant women.

Methodology
The study commenced after institutional ethical committee clearance, with all enrolled cases undergoing imaging procedures after securing written consent. Patients with low back ache and clinical suspicion of spondylolysis were scanned with 1.5T Philips MRI machine.

The following sequences were acquired: T1, T2, STIR sagittal, T2 axial and chemical shift sagittal sequences. Follow-up CT scan results were collected and reviewed. Later MRI and CT images were assessed to determine the presence of pars interarticularis fractures.

The primary outcome measure was to assess diagnostic accuracy of MRI in comparison to CT, by evaluating sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV).

RESULTS

A total of 40 patients were included in this study. The statistical analysis of the data were obtained as follows:

- Sensitivity: 76.5%
- Specificity: 91.3%
- Positive Predictive Value (PPV): 86.7%
- Negative Predictive Value (NPV): 84.0%

These values indicate that MRI is quite effective in correctly identifying both the presence and absence of fractures as confirmed by CT scans. The high specificity (91.3%) and NPV (84.0%) suggest that MRI is particularly reliable in ruling out fractures when they are not present, reducing the risk of false positives. Meanwhile, the sensitivity (76.5%) and PPV (86.7%) suggest that MRI can correctly identifying fractures when present.

With chi-square value of 19.163 and the p-value of less than 0.001, we can conclude that there is a significant correlation between the CS-MRI findings and the actual presence of fractures as confirmed by CT scans. This supports the use of CS-MRI as a reliable diagnostic tool for detecting fractures, although it should ideally be used in conjunction with CT for comprehensive evaluation, especially in critical cases.

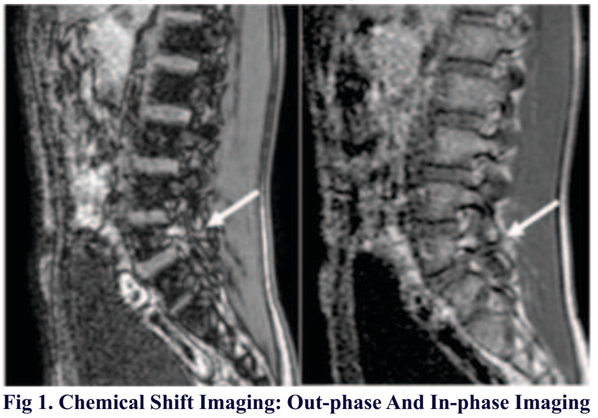

Fig 1. Chemical Shift Imaging: Out-phase And In-phase Imaging Showing Break In Pars Interarticularis Of L5 Vertebra (white Arrow).

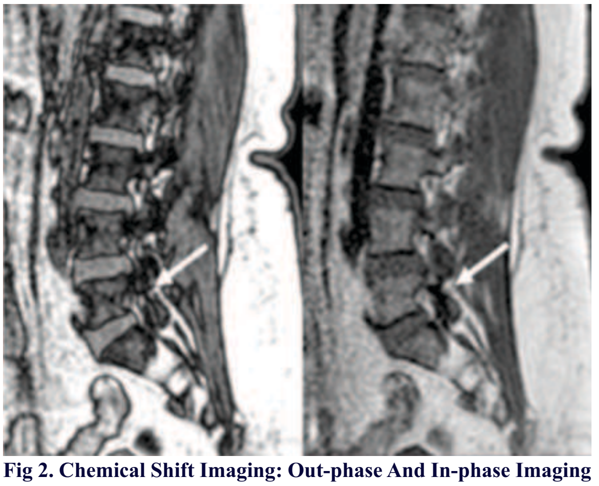

Fig 2. Chemical Shift Imaging: Out-phase And In-phase Imaging Showing Break In Pars Interarticularis Of L5 Vertebra (white Arrow).

Table 1: Cs-mri & Ct Findings Among Cases

CS-MRI Diagnosis	CT Confirmed Fracture	CT No Fracture	Total
Fracture	13	2	15
No Fracture	4	21	25
Total	17	23	40

DISCUSSION

The results of this study suggest that CS-MRI is a viable alternative to CT in detecting pars interarticularis fractures, offering comparable diagnostic accuracy with additional benefits such as better soft tissue contrast and no radiation exposure. This is particularly advantageous for younger patients and those requiring multiple follow-up imaging studies.

CONCLUSION

Although there is no established consensus on the best imaging pathway for diagnosing pars defects, many centres utilize a combination of MRI (T1 VIBE) with or without CT. MRI is preferred for its superior ability to detect bony edema and assess the chronicity of lesions, whereas CT excels at visualizing bony anatomy. However, the ionizing radiation from CT is a significant concern, especially for younger patients.

This study demonstrated that chemical shift imaging, a relatively quick sequence, can effectively delineate the pars and identify the presence of pars defects. In-phase sequences better identified intact pars, likely due to superior visualization of medullary fat. Conversely, out-of-phase sequences more effectively delineated pars defects, possibly due to the characteristic black boundary or India ink artifact, which occurs at tissue interfaces in abdominal imaging and fracture lines in musculoskeletal MRI. Thus CS-MRI is a reliable diagnostic tool for detecting fractures, although it should ideally be used in conjunction with CT for comprehensive evaluation.

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