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Original Article

Does Chemical Shift Magnetic Resonance Imaging Improve Visualization of Pars Interarticularis Defect?

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Abstract

Introduction A unilateral or bilateral pars interarticularis defect (spondylolysis) is a leading cause of axial back pain in adolescent athletes. Currently, a spectrum of imaging modalities is used for assessment of pars interarticularis defects.

Objectives The aim of this study is to compare the accuracy of chemical shift sequence (magnetic resonance imaging [MRI]) technique to conventional MRI sequences in the detection of pars defects.

Patients and Methods Conventional T1, T2, and short tau inversion recovery sagittal and axial, as well as "in-" and "out-" phase chemical shift sagittal MRI sequences of 70 consecutive patients referred for low back pain were reviewed. Demographic details, clinical indication, and presence/diagnosis of pars defects using a 5-point Likert scale on both conventional and chemical shift MRI sequences. Spearman's correlation was used for statistical analysis. Intraclass correlation coefficient analysis was evaluated to assess the intraclass reliability between observers. Data were analyzed using DATAtab web-based statistics software (2022).

Results A total of 70 patients with an average age of 54.34 years with a female predominance were included. There were 11 pars defects in the cohort. Both in and out phases of chemical shift imaging were able to identify pars defect and intact pars. However, out phase was relatively better in delineating pars defects, while the in phase was superior in identifying an intact pars, though this was not statistically significant. There was good intra- and interobserver reliabilities.

Conclusion Chemical shift MRI sequence is a quicker, complementary technique to assess and analyze pars interarticularis confidently than conventionally utilized MRI sequences in patients being evaluated for axial back pain.

Keywords
- spondylolysis
- magnetic resonance imaging
- chemical shift
- back pain
- athletes

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Introduction

Spondylolysis is the term given to defects (lysis) within the vertebra (spondylos). Specifically, this relates to defects of the pars interarticularis which is the junction of the vertebral pedicle, articular facets, and lamina. The defects are attributed to either a stress fracture through the pars interarticularis, traumatic, or could be developmental. Spondylolysis is a leading cause of back pain in adolescent athletes[1] with pars defects being attributed in up to 47% of cases.[2] Athletes who take part in sports (cricket, rugby, and tennis) that require repetitive lumbar loading in extension and rotation are particularly vulnerable.

Treatment of pars defects is usually conservative with a period of rest and activity restriction for a minimum of 3 months.[1] Accurate and early detection of a pars defects in a symptomatic patient is important to allow timely initiation of treatment, to optimize bony healing, and to prevent spondylolisthesis.[3] Roles of radiography, computed tomography (CT), magnetic resonance imaging (MRI), and bone scintigraphy in the diagnosis of pars defects have all been described.

Currently, a plethora of imaging modalities are used for assessment of pars. At many centers, an initial MRI is performed to assess the anatomy of the pars and the presence of bone marrow edema. The assessment of bone marrow edema helps differentiate acute stress fractures from chronic nonunion or developmental lesion. The initial MRI is then often followed by a focal CT in those with suspicion of pars defect in some centers. CT is currently considered superior to MRI in the assessment of the bony anatomy, but this involves ionizing radiation. There is increased used of T1 volumetric interpolated breath-hold examination (VIBE) imaging as an alternative to focal CT and studies have shown a 100% accuracy rate in diagnosing complete pars defects.[4] T1 VIBE imaging takes an average of 2.5 minutes and may not be practical in a busy imaging department.

Chemical shift imaging utilizes the difference in the precession frequencies of fat and water molecules. This difference is known as the chemical shift effect.[5] An initial image acquisition is performed when both the fat and water molecules are precessing "in phase" with each other. This creates a signal which is additive on the imaging (brighter). Shortly after, due to the lower precession frequency of the fat molecules, the second image acquisition is when the water and fat molecules are "out of phase" with each other. This creates a subtractive signal (darker) on the image.[6] In the out-of-phase imaging, this creates a signal void at the margin of fatty and normal tissue which is known as the black boundary effect or India ink artifact.[7]

Chemical shift imaging is quicker than T1 VIBE imaging taking ~13 seconds, compared with 2.5 minutes. Out-of-phase chemical shift imaging has been shown to be more sensitive than conventional protein density and T1-weighted imaging in detecting trabecular distortion and microfracture.[8] Recently, out-of-phase imaging obtained using the mDixon technique provided better sensitivity and improved fracture description than conventional MRI in the detection of ankle fractures.[9] To the best of our knowledge, the diagnosis of pars defects using chemical shift imaging has not been assessed. The aim of this study is to compare the accuracy of chemical shift imaging with conventional MRI in the detection of pars defects.

Materials and Methods

Study Design

A retrospective evaluation of our radiology information system and picture archiving and communication system was performed to identify all MRI studies undertaken for patients who were referred to the radiology department for low back pain over a 6-week period.

All patients who had T1, T2, short tau inversion recovery (STIR) sagittal and T1 and T2 axial as well as chemical shift sagittal MRI sequences were included in the study. MRIs performed for tumor, trauma, infection, and postoperative assessment were excluded. All MRIs were performed on Seimens 3T Skyra or Seimens 1.5T Sola (Erlangen, Germany). Local ethical committee approval was obtained for the study.

Image Analysis

The MRIs were then reviewed by two fellowship trained consultant musculoskeletal radiologist. Each reader individually reviewed the "in"-phase as well as "out-of-phase" chemical imaging sequence of each MRI for the presence of a pars defect at the L5 vertebra (►**Fig. 1**). A complete pars defect was defined as a disruption to the trabecular bone extending through the cortices of the pars interarticularis. They graded their confidence of the diagnosis using a 5-point Likert scale (1 being normal, 2—probably normal, 3—not sure, 4—probably pars defect, and 5—definite pars defect). They then repeated their reading after 1 week to allow for an analysis of intraobserver reliability. Following this, the T1 (field of view [FOV] 340 cm, repetition time [TR] 622 milliseconds, echo time [TE] 9.8 milliseconds, slice thickness 3 mm, flip angle 150 degrees), T2 (FOV 340 cm, TR 3,920 milliseconds, TE 88 milliseconds, slice thickness 3 mm, flip angle 150 degrees), STIR (FOV 340 cm, TR 4,940 milliseconds, TE 38 milliseconds, slice thickness 3 mm, flip angle 150 degrees), and in and out phases (FOV 340 cm, TR 137 milliseconds, slice thickness 3 mm, flip angle 70 degrees). The TE for chemical shift imaging in and out-of-phase imaging was 1.23 and 2.46 milliseconds on 3T MRI in comparison to 2.38 and 4.87 milliseconds on 1.5T MRI, respectively. This implies that TE on higher strength MRI (3T) is approximately half of that of 1.5T MRI. MRI sequences were reviewed by the two readers and senior consultant musculoskeletal radiologist with more than 10 years of experience together to determine a consensus on the presence of pars defects which was used at the gold standard.

Statistical Analysis

Microsoft Excel data sheet was used for data collection. Data were analyzed using DATAtab web-based statistics software

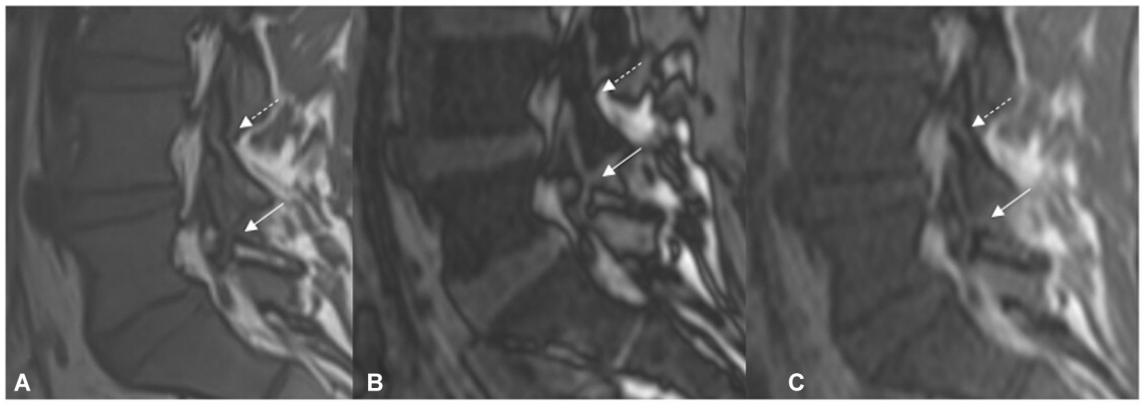

Fig. 1 Sagittal T1 (**A**), chemical shift out phase (**B**) and in phase (**C**) showing pars defect of L5 (arrow) and intact pars of L4 (dashed arrow).

Table 1 Demographic characteristics and descriptive statistics of patients with and without pars defect in the cohort study

	No pars defect	Pars defect
Number	129	11
Average age	48.7	37.2
Maximum age	87	64
Minimum age	15	14
Male	85	4
Female	44	7

(2022). Spearman's correlation was used for statistical analysis. Kendall's tau correlation test was used to assess for inter- and interobserver reliabilities.

Results

A total of 70 patients were included in the study with average age of 54.34 years (range: 14–88 years). There was a female predominance with 46 females and 24 males. There were 11 pars defects (male:female, 4:7, average age 37.2 years, range: 14–64 years) and 129 intact pars (male:female, 85:44, average age 48.7 years, range 15–87 years) in the cohort (►**Table 1**).

In those patients without pars defect analysis between both phases showed significant association between in and out phases, $r\,(122) = 0.8406$, $p = < 0.001$ (Spearman's correlation) with a very high positive correlation. In those patients with presence of pars defect analysis between both phases also showed a significant association between in and out phases, $r\,(14) = 0.5714$, $p = 0.0192$ (Spearman's correlation) with a high positive correlation. This shows that both phases are reliable in diagnosing or ruling out a pars defect (►**Figs. 1** and **2**).

A deeper analysis of marking shows that scores for the in phase for both with and without pars defects were lower in the in phase which may indicate that out phase may result in improved reporting of pars defect with increased confidence.

An in-phase analysis was performed between Reader 1 and Reader 2 and showed that there was a significant association between Reader 1 and Reader 2, $r\,(138) = 0.9538$, $p = 0.002$ (Kendall Tau correlation) with a very high positive correlation (►**Fig. 3**).

An out-phase analysis was performed between Reader 1 and Reader 2 and showed that there was a significant association between the two readers, $r\,(138) = 0.95$, $p = 0.001$ (Kendall Tau correlation) with a very high positive correlation (►**Fig. 4**). This indicates that readers were able to confidently diagnose correctly on both phases. Analysis was performed using DATAtab (2022).

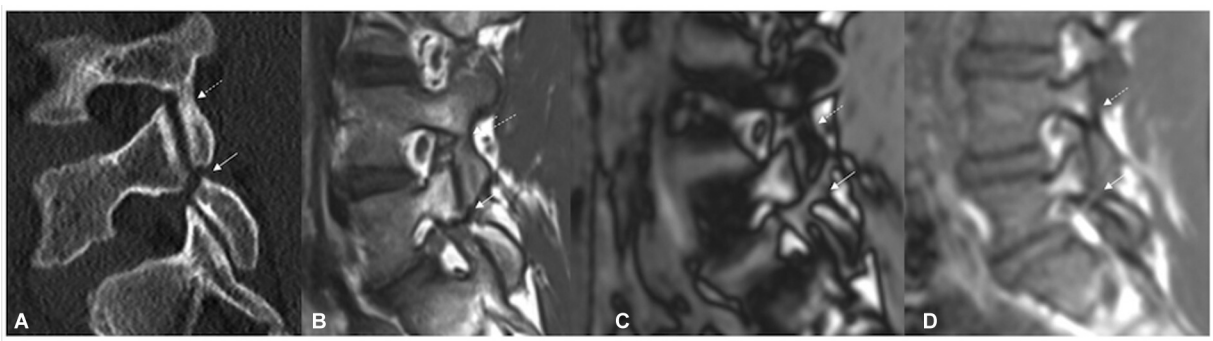

Fig. 2 Sagittal computed tomography (**A**), T1 (**B**), chemical shift out phase (**C**) and in phase (**D**) showing pars defect of L5 (arrow) and intact pars of L4 (dashed arrow).

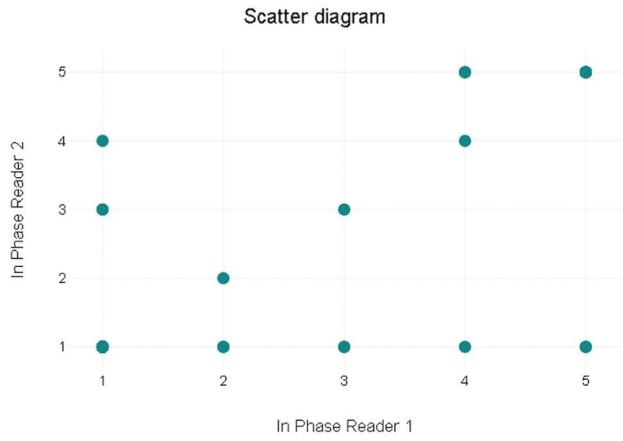

Fig. 3 Demographic statistics of cohorts. Scatter diagram showing correlation between both readers for in phase.

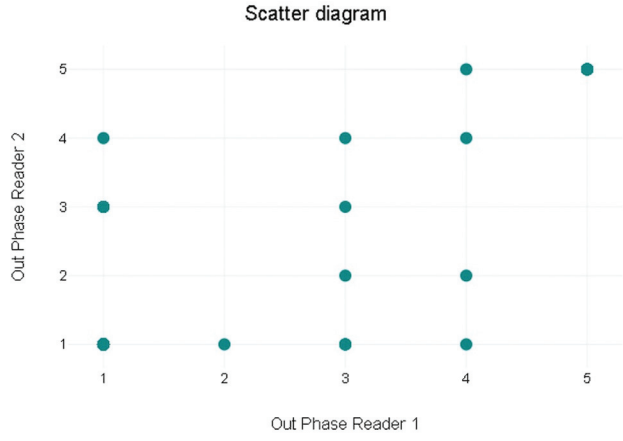

Fig. 4 Demographic statistics of cohorts. Scatter diagram showing correlation between both readers for out phase.

Discussion

Although there is no current consensus on the most appropriate imaging pathway for the diagnosis of pars defects, most centers will use a combination of MRI (T1 VIBE) with or without CT. This is mainly because although MRI provides superior information regarding bony edema and therefore the chronicity of the lesion, CT is far better at determining the bony anatomy. Unfortunately, CT carries the burden of ionizing radiation which is especially important in younger patients. Obviously, a single imaging modality that would provide information about the chronicity of lesion, soft tissue, and bony anatomy would be the ideal. It has been shown that performing T1 VIBE sequences on MRI has the potential to replace the need for CT, although these sequences are time consuming.

In this study, we showed that chemical shift imaging, a relatively quick sequence, can help delineate the pars comparable to T1 VIBE and decipher the presence of pars defect. The identification of those with intact pars was comparatively better with in-phase sequence in comparison to out-of-phase sequence which could be due to better visualization of medullary fat. The delineation of the pars defects was relatively better with out-of-phase sequence and this could be due to the characteristic black boundary or India ink artifact. This is known to occur at the margins of organs in abdominal imaging where there is an interface between tissue types[10] and has also been shown to occur at fracture lines in musculoskeletal MRI.[9]

There was good inter- and intraobserver reliabilities. When analyzing the Likert scale, the reviewer's confidence in making a diagnosis of the presence or absence of a pars defect was greatly improved with the use of out-of-phase imaging in those with pars defect.

A limitation of the study was relatively low number of pars defects in the cohort. Additionally, the gold standard that chemical shift imaging compared with entire MRI study which some might consider not to be as accurate as CT; however, consensus opinion of three authors ensured a robust diagnosis for the presence or absence of pars defect. Given the promising results from this study, a further study using CT as a gold standard is proposed. We propose that chemical shift imaging should be a part of routine MR of lumbar spine.

Conclusion

Chemical shift MRI sequencing is a quicker, complementary technique to assess and analyze pars interarticularis confidently. Out phase is relatively superior in identifying a pars defect, while the in-phase sequences are comparatively better in delineating an intact pars.

Further evaluation of chemical shift imaging in the detection of pars defects in comparison to CT-based evaluation would be of benefit in developing a future algorithm to assess this condition.

Funding
None.

Conflict of Interest
None declared.

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