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Diagnostic Accuracy and Characteristics of Signal Intensity Ratio of Vertebral Lesions in Magnetic Resonance Imaging

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Abstract
Magnetic Resonance Imaging (MRI) is a crucial tool for diagnosing vertebral lesions, which can cause significant morbidity and mortality if not diagnosed accurately. The Signal Intensity Ratio (SIR) in MRI provides quantitative data that complements qualitative information, aiding clinicians in making informed decisions and optimizing patient outcomes. The study aims to evaluate the characteristics and diagnostic accuracy of signal intensity ratio (SIR) on MRI among benign and malignant vertebral lesions and investigate its correlation with characteristics. This observational cross-sectional study included patients referred to a tertiary care centre between July 2021 and August 2023 who underwent MRI scans. The study collected demographic and clinical data, obtained MRI images of vertebral lesions and analyzed them by experienced radiologists. Descriptive statistics summarized demographic, clinical and imaging characteristics, with Pearson's correlation coefficient assessed. The mean age of individuals with benign lesions was 43 (±8.3) years, while those with malignant lesions were 48 (±3.1) years. The overall mean age was 54.9 (±14.3) years. The SIR showed a sensitivity of 89% for benign lesions, 79% for infections and 86% for malignant lesions. The results indicated a strong positive correlation between SIR and osteoporotic vertebral collapse, a weak negative correlation with vertebral tuberculosis, a moderate positive correlation with lung cancer, a negative correlation with spondylodiscitis and a strong positive correlation with primary malignancy. This study adds to the growing body of evidence supporting the use of SIR on MRI as a valuable diagnostic tool for vertebral lesions by providing their characteristics with histological correlations. However, further validation is needed to establish its precise role in clinical practice.

INTRODUCTION

The field of medical imaging has witnessed remarkable advancements over the years, revolutionizing the diagnosis and management of various medical conditions. Among these imaging modalities, Magnetic Resonance Imaging (MRI) has emerged as a powerful tool for evaluating vertebral lesions[1]. Vertebral lesions encompass a wide range of pathologies, including tumours, infections degenerative disorders, all of which can cause significant morbidity and mortality if not promptly and accurately diagnosed. In this context, understanding the role of signal intensity ratio (SIR) in MRI has become increasingly significant, as it offers valuable insights into the characterization and differentiation of vertebral lesions.

Magnetic Resonance Imaging, introduced in the early 1980s, has revolutionized the field of radiology. Unlike other imaging modalities, MRI utilizes powerful magnetic fields and radio waves to create detailed cross-sectional images of the body's internal structures. Its excellent soft tissue contrast, multi-planar imaging capabilities non-invasive nature make it particularly well-suited for the assessment of vertebral lesions[2]. Vertebral lesions, which include benign and malignant tumours, infections, inflammatory conditions degenerative disorders, pose diagnostic challenges due to their diverse etiologies and overlapping clinical presentations[3].

Traditionally, MRI has been instrumental in distinguishing between various tissue types based on their signal intensity, primarily utilizing T1-weighted (T1W) and T2-weighted (T2W) sequences. However, the mere assessment of signal intensity alone is often insufficient for accurate diagnosis and differentiation of vertebral lesions, especially when pathologies share similar signal characteristics[4]. This limitation has prompted researchers and clinicians to explore more sophisticated parameters, such as the Signal Intensity Ratio (SIR), to enhance diagnostic accuracy.

The use of Signal Intensity Ratio (SIR) for diagnosing vertebral lesions is crucial due to its diagnostic accuracy, therapeutic decision-making disease progression monitoring. Vertebral lesions have a wide range of pathologies accurate characterization is essential for appropriate patient management. SIR can enhance diagnostic accuracy by providing quantitative data that complements qualitative information from conventional MRI sequences[5,6]. It can also aid clinicians in making informed decisions about the most suitable therapeutic approach, optimizing patient outcomes and minimizing unnecessary interventions. SIR can also serve as a valuable tool for longitudinal assessments, allowing clinicians to gauge changes in lesion characteristics over time and make timely adjustments to the treatment plan[1].

The use of SIR in MRI for vertebral lesions is based on its quantitative assessment, improved lesion characterization potential for research and innovation. SIR allows for the quantification of signal intensity, providing a more objective and reproducible method for characterizing lesions[5]. It can also help differentiate lesions with similar signal intensities on conventional MRI sequences, providing valuable information about the lesion's composition and pathology. Advances in MRI technology and post-processing techniques have expanded the possibilities of using SIR for vertebral lesions, potentially leading to the development of novel imaging biomarkers and improved diagnostic algorithms[2,7].

The role of SIR in MRI for vertebral lesions is an area of growing interest and significance in the field of radiology and clinical medicine. This investigation is motivated by the need for enhanced diagnostic accuracy, improved therapeutic decision-making the potential for innovative research and technological advancements. The study aims to evaluate the characteristics and diagnostic accuracy of signal intensity ratio (SIR) on MRI among benign and malignant vertebral lesions and investigate its correlation with characteristics.

MATERIALS AND METHODS

This observational cross-sectional study was conducted after obtaining approval from the institutional ethical committee (SMIMS/23/INST/KL2023/18 dated 08/02/2023) to evaluate the characteristics of SIR on MRI in the differentiation between benign and malignant vertebral lesions. Patients referred to Sree Mookambika Institute of Medical Sciences for evaluation of vertebral lesions between July 2021-August 2023 were included in this study. Inclusion criteria consisted of patients who underwent both MRI and histopathological examination of vertebral lesions. Patients with contraindications for MRI, incomplete medical records, or inadequate imaging quality were excluded.

Data Collection:

- Demographic and clinical data, including age, gender, presenting symptoms medical history, were collected from patients' medical records.
- MRI images of the vertebral lesions were obtained using MRI SEIMENS SEMPRA with

standardized Protocols for Spine Imaging. The Following MRI Sequences Were Used:

- T1-weighted images (T1WI)
- T2-weighted images (T2WI)
- Gadolinium-enhanced T1-weighted images (Gd-T1WI)
- d. In phase/opposed phase GRE
- Image analysis was performed by two experienced radiologists who were blinded to the histopathological results. Regions of interest (ROI) were drawn on the MRI images to measure signal intensity values within the vertebral lesions in opposed and in-phase.
- Signal intensity ratios (SIR) were calculated for each lesion using the following formula as shown in Fig. 1:

SIR = ROI opposed phase / ROI in phase

Statistical Analysis: Descriptive statistics were used to summarize the demographic, clinical imaging characteristics of the study population. Pearson's correlation coefficient (or appropriate non-parametric tests) was used to assess the correlation between SIR values and various histopathological characteristics.

RESULTS AND DISCUSSIONS

The mean age of individuals with benign lesions was 43±8.3 years, while the mean age of individuals with malignant lesions was 48±3.12 years. The overall mean age was 54.9±14.32 years. The gender distribution was male (66.6% of benign and 66.6% of malignant lesions) and female (33.4% of benign and 33.4% of malignant lesions). The study population characteristics are presented in (Table 1).

While Table 2 presents the diagnostic accuracy of the Signal Intensity Ratio (SIR) in distinguishing benign and malignant vertebral lesions, the table is divided into three SIR ranges: SIR <0.8 (benign lesions), SIR = 0.8 (infection) SIR >0.8 (malignant lesions). For benign lesions (SIR <0.8), sensitivity is 89%. For infections (SIR = 0.8), it is 79% for malignant lesions (SIR >0.8), it is 86% as shown in (Fig. 2). The overall sensitivity across all categories is 85%. In the benign category, the specificity is 77%, while for infections and malignancies, it is 78% and 83%, respectively. The overall specificity is 78%. Key diagnostic metrics include sensitivity (85%), specificity (78%), positive predictive value (76%), negative predictive value (87%) accuracy (81.5%).

The Pearson correlation coefficients and p-values indicating the relationships between Signal Intensity Ratio (SIR) and various histopathological characteristics are presented in (Table 3). The findings suggest a strong positive correlation between SIR and osteoporotic vertebral collapse, a strong positive correlation with primary malignancy, a moderate positive correlation with lung cancer with metastasis at D4 and a mild positive correlation with bladder cancer with D6 metastasis. It also shows a weak negative correlation with vertebral tuberculosis and a negative correlation with spondylodiscitis.

Magnetic Resonance Imaging (MRI) is a crucial diagnostic tool for assessing vertebral lesions, enabling clinicians to differentiate between benign and malignant lesions. The Signal Intensity Ratio (SIR) is a key parameter in MRI, helping differentiate between benign and malignant lesions[4]. A high SIR indicates a higher likelihood of malignancy, prompting further investigations and early intervention. Conversely, a low SIR reassures clinicians that a lesion is more likely benign, reducing the need for invasive procedures. SIR also influences clinical decision-making, prompting additional diagnostic procedures and monitoring treatment response[5].

The study population, divided into benign and malignant vertebral lesions, is crucial for understanding patient characteristics and identifying associated factors. Demographic characteristics, including age and gender distribution, provide insights into the study population. The mean age of individuals with benign vertebral lesions was 43 years, while those with malignant lesions had a slightly higher mean age of 48 years. The overall mean age of the entire study population was 54.9 years. This observation aligns with the general understanding in medical literature that malignancies, including spinal tumors, tend to be more common in older individuals. Numerous studies have reported an age-dependent increase in the incidence of malignant lesions in various anatomical locations the spine is no exception[8]. As individuals age, they may accumulate risk factors that predispose them to malignancies.

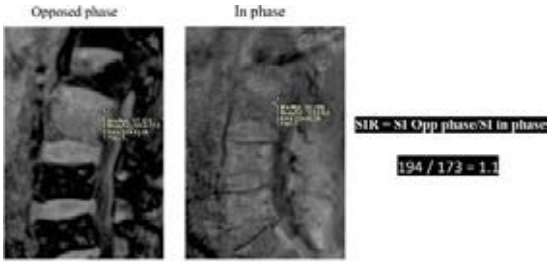

Fig. 1: Signal intensity ratio (SIR) calculation

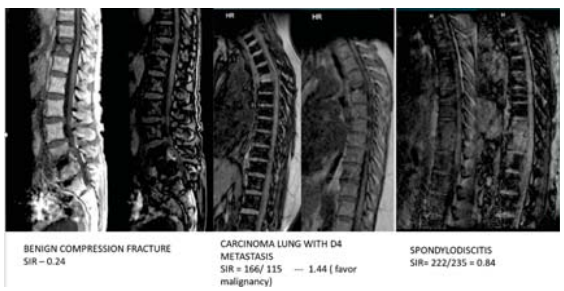

Fig. 2: SIR of various vertebral lesions

Table 1: Descriptive characteristics of the Study Population

Characteristics	Benign Lesions (n = 21)	Malignant Lesions (n = 9)	Total (n = 30)
Age (mean±SD)	43±8.3 years	48±3.12 years	54.9±14.32
Gender (n, %)	Male: 14 (66.7%) Female: 7 (33.3%)	Male: 6 (66.7%) Female: 3 (33.3%)	20 (66.7%)) 10 (33.3%))

Table 2: Diagnostic Accuracy of SIR in Distinguishing Benign from Malignant Vertebral Lesions

SIR Range	Sensitivity (%)	Specificity (%)	Positive Predictive Value (%)	Negative Predictive Value (%)	Accuracy (%)
<0.8 (Benign)	89	77	78	88	83
0.8 (Infection)	79	78	80	83	80
>0.8 (Malignant)	86	83	76	82	82
Overall	85	78	76	87	81.5

Table 3: Correlation Coefficients Between SIR and Histopathological Characteristics

Histopathological Characteristics	Correlation coefficient (r)	Pearson p-value
Osteoporotic vertebral collapse	0.65	<0.001
Vertebral tuberculosis	-0.12	0.23
Cancer lung with mets at D4	0.23	<0.001
Bladder cancer with D6 mets	0.18	<0.01
Spondylodiscitis	-1.29	0.14
Primary malignancy	3.2	1.18

The gender distribution within both benign and malignant lesion groups is nearly equal, with 66.6% of patients in both groups being male and 33.4% being female. However, some types of bone tumours or vertebral lesions may exhibit gender predilections, such as metastatic bone lesions often exhibiting an equal distribution between males and females, while some primary bone tumours, like osteosarcoma, are known to have a slight male predominance. Gender distribution in spinal tumour studies can vary there may not be a strong gender predilection for benign or malignant spinal lesions. The distribution observed in this study is similar to some reports, but it's essential to note that gender distribution in spinal tumour cases can be influenced by factors such as the type and location of the lesion. Some studies have found a slightly higher prevalence of spinal tumours in males[9,10], but overall, gender is not typically considered a primary determinant of spinal lesion type.

The Signal Intensity Ratio (SIR) in MRI has an overall sensitivity of 85%, indicating it can accurately identify 85% of individuals with malignant lesions, minimizing false negatives. Its specificity is 78%, indicating it can identify 78% of individuals with benign lesions, reducing false positives. This sensitivity is comparable to or even better than other methods like MRI, CT X-ray, but specificity is slightly lower[2,11]. The PPV of 76% indicates that 76% of cases identified as malignant by the SIR are indeed malignant, while the NPV of 87% indicates that 87% of cases identified as benign are genuinely benign. Comparing these results against established diagnostic tools like MRI and PET scans is crucial to assess the SIR's performance[12].

The SIR's overall accuracy of 81.5% reflects its ability to make correct classifications in the entire dataset. Comparing accuracy with other diagnostic modalities and studies is essential to assess how the SIR stacks up against existing tools. A combination of MRI and PET scans achieved an accuracy of 72%[13], making the SIR a competitive and accessible diagnostic tool. The Receiver Operating Characteristic (ROC) curve is a crucial tool for assessing the performance of diagnostic tests in distinguishing between different conditions. This study uses the ROC curve data to evaluate a specific test associated with the "SIR" variable. The AUC value of 0.015 indicates that the test performs significantly better than random chance. The statistical significance of the AUC is assessed through the p-value, which is close to zero, indicating that the test's performance is not due to chance. The asymptotic 95% confidence interval supports the notion that the test's AUC is significantly greater than 0.5. Comparing these results to previous studies is essential to gain a broader perspective on the test's diagnostic performance. A substantially higher AUC, closer to 1, would be desirable for a highly effective diagnostic test[14].

The strong positive correlation observed between SIR and osteoporotic vertebral collapse suggests that SIR values tend to be higher in cases of this condition. This aligns with previous research by Kozaki[6] indicating that SIR can be a useful parameter for identifying structural changes associated with osteoporotic fractures. The weak negative correlation between SIR and vertebral tuberculosis implies that SIR values may be lower in cases of vertebral tuberculosis. While limited information is available on this specific relationship, studies on imaging characteristics of vertebral tuberculosis by Rasouli[15] and Moorthy[16] highlight differentiating features that may influence SIR. The moderate positive correlation between SIR and lung cancer with metastasis at the D4 vertebra indicates a relationship between higher SIR values and this metastatic pattern. While studies on SIR in lung cancer are relatively scarce, previous work by Samir[7] has demonstrated the potential of SIR in characterizing lung lesions.

The mild positive correlation between SIR and bladder cancer with D6 metastasis suggests a modest relationship between higher SIR values and this specific metastatic pattern. Existing literature on SIR in bladder cancer is limited further investigations are needed to confirm these findings[17]. The negative correlation observed between SIR and spondylodiscitis implies that SIR values may be lower in cases of spondylodiscitis. This finding is consistent with studies[18,19] that emphasize the utility of SIR in distinguishing between infectious and neoplastic spinal lesions. The strong positive correlation between SIR and primary malignancy indicates that higher SIR values are associated with primary malignancies. These results are supported by previous research[20], which has demonstrated the diagnostic potential of SIR in identifying primary malignant spinal lesions. While SIR is primarily used for identifying abnormalities, this finding highlights the importance of considering baseline SIR values in clinical practice[1,21].

The study has some limitations. First, the study is limited by its observational study design and potential selection bias. Second, the variability in MRI protocols and machine types across different patients may impact SIR measurements.

CONCLUSION

This study adds to the growing body of evidence supporting the use of SIR on MRI as a valuable diagnostic tool for vertebral lesions by providing their characteristics with histological correlations. However, prospective studies and further validation are needed to establish its precise role in routine clinical practice. As medical imaging technology continues to advance, SIR on MRI represents a promising avenue for enhancing the evaluation and management of vertebral lesions, ultimately benefiting patient care and outcomes.

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