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ORIGINAL ARTICLE

Diagnostic Accuracy of Magnetic Resonance Spectroscopy (MRS) in differentiating Malignant and Benign Musculoskeletal Tumours, Taking Histopathology as Gold Standard

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ABSTRACT

Background: Magnetic Resonance Spectroscopy is a noninvasive imaging modality that provides biochemical information useful for characterizing musculoskeletal tumors. Early differentiation between benign and malignant lesions is essential for guiding treatment decisions. Histopathology remains the reference standard, yet it is invasive and may be delayed. This study evaluated the diagnostic accuracy of Magnetic Resonance Spectroscopy for distinguishing malignant from benign musculoskeletal tumors using histopathology as the gold standard.

Objective: To determine the sensitivity, specificity, predictive values, and overall diagnostic accuracy of Magnetic Resonance Spectroscopy in differentiating malignant and benign musculoskeletal tumors, taking histopathology as the reference.

Methods: A descriptive cross-sectional study was conducted over six months in the Radiology Department of Jinnah Hospital, Lahore. A total of 111 patients aged 20 to 60 years with suspected musculoskeletal tumors larger than 5 cm and symptoms exceeding three months were included through consecutive nonprobability sampling. Routine MRI was followed by single-voxel Magnetic Resonance Spectroscopy using PRESS sequences at TE 135 ms and TR 1500 ms. Spectral patterns were categorized as malignant or benign based on predefined metabolic criteria. Histopathology served as the gold standard. Sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy were calculated, along with stratified analysis by age, gender, disease duration, and lesion size.

Results: Of 111 patients, the mean age was 38.64 years (SD 11.35), and 69.4% were male. Magnetic Resonance Spectroscopy identified 73 malignant cases, while histopathology confirmed 75 malignant lesions. The sensitivity of Magnetic Resonance Spectroscopy was 90.7 percent, and the specificity was 86.1 percent. The positive predictive value was 93.2 percent, and the negative predictive value was 81.6 percent. The overall diagnostic accuracy was 89.2 percent. Stratified analysis showed consistently high diagnostic performance across all subgroups of age, gender, disease duration, and lesion size.

Conclusion: Magnetic Resonance Spectroscopy demonstrated high diagnostic accuracy for differentiating malignant from benign musculoskeletal tumors. Its strong sensitivity and specificity across demographic and clinical subgroups indicate that it is a reliable noninvasive adjunct to MRI and can support early diagnostic decision-making. Incorporating Magnetic Resonance Spectroscopy into routine musculoskeletal tumor evaluation may improve diagnostic precision and reduce dependence on invasive procedures.

Keywords: Magnetic Resonance Spectroscopy, musculoskeletal tumors, malignancy, diagnostic accuracy, histopathology, MRI.

INTRODUCTION

Magnetic Resonance Spectroscopy (MRS) is an imaging technique that provides biochemical insights into tissue metabolism, helping to differentiate between malignant and benign musculoskeletal tumors with significant accuracy. Making this distinction is crucial in the musculoskeletal system, as early and accurate diagnosis can greatly impact treatment strategies and outcomes. While histopathology is typically considered the gold standard for cancer diagnosis, non-invasive imaging techniques such as MRS are increasingly used because they offer additional diagnostic information that can inform clinical decision-making [1, 2].

Magnetic Resonance Imaging (MRI), often used in conjunction with MRS, is an essential tool for assessing musculoskeletal tumors. MRI has demonstrated high sensitivity and specificity in detecting malignancies, making it a reliable initial assessment modality [1, 3, 4]. However, conventional MRI parameters alone may sometimes yield inconclusive results, and integrating MRS and diffusion-weighted imaging (DWI) has been shown to improve diagnostic accuracy by providing additional metabolic and microstructural information about tissues [2, 5, 6]. This is particularly relevant in complex cases where tumors may present overlapping characteristics [4, 7].

Recent literature highlights MRS's utility in differentiating tumor types based on their metabolic profiles. Malignant tumors often show distinct metabolic signatures, such as elevated choline levels and decreased N-acetyl aspartate levels, which correlate with cellular proliferation and tumor aggressiveness [8, 9]. Evidence also suggests that combining MRS with traditional imaging techniques significantly enhances diagnostic performance. An integrated approach utilizing both radiological and histopathological data has been proposed for more precise tumor classification [10, 11, 12].

In the context of the Pakistani population, there are significant challenges regarding the timely diagnosis of musculoskeletal tumors, particularly due to limited access to advanced imaging facilities and a shortage of skilled radiologists. The relatively high prevalence of diseases with ambiguous tumor characteristics highlights the need for comprehensive diagnostic strategies. Integrating MRS into clinical practice could help address these gaps by enabling rapid, informative tumor analysis, thereby facilitating appropriate treatment pathways and alleviating the burden on surgical services that often depend heavily on histopathological confirmation [13, 4, 7].

MRS serves as a complementary diagnostic tool alongside conventional imaging modalities and histopathology, potentially enhancing diagnostic accuracy in distinguishing malignant from benign musculoskeletal tumors, particularly in resource-limited settings. The Pakistani population stands to benefit significantly from the implementation of such advanced imaging techniques in clinical diagnosis.

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METHODOLOGY

This descriptive cross-sectional study was conducted in the Department of Radiology, Jinnah Hospital, Lahore, over a period of six months from 23 June 2018 to 23 December 2018, after approval from the institutional ethical review board. A total of 111 patients aged 20 to 60 years who presented with suspected musculoskeletal tumors, as defined by a mass greater than 5 cm on clinical and MRI assessment, with a duration of symptoms exceeding three months, were included using consecutive non-probability sampling. Patients with a history of trauma, chronic renal failure, cardiac pacemaker, MR-incompatible implants, claustrophobia, or pregnancy were excluded from the study. Informed written consent was obtained from all eligible participants.

Following routine MRI sequences, proton Magnetic Resonance Spectroscopy was performed on a 1.5 Tesla MR system equipped with a gradient strength of 33 mT/m. A fast scout scan was acquired in the sagittal, axial, and coronal planes, followed by the application of water-suppression pulses before data acquisition. Single voxel MRS was carried out using Point Resolved Spectroscopy (PRESS) with TE of 135 ms and TR of 1500 ms. Metabolic peaks and ratios, including choline peak, NAA to creatine, NAA to choline, and choline to creatine, were analyzed. Based on predefined metabolic criteria, MRS findings were categorized as malignant or benign and interpreted by a consultant radiologist with at least 5 years of post-fellowship experience.

Subsequently, all patients underwent histopathological confirmation. Biopsy specimens were processed and reported by a consultant histopathologist with at least 3 years of post-fellowship experience. Histopathology was considered the reference standard for diagnostic comparison. Data on patient demographics, lesion characteristics, MRS findings, and final histopathological Diagnosis were recorded on a structured pro forma. Statistical analysis was performed using SPSS version 20. Quantitative variables, including age, disease duration, and lesion size, were reported as mean ± standard deviation, whereas qualitative variables, such as gender and diagnostic outcome, were presented as frequencies and percentages. A 2-by-2 contingency table was used to calculate sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy of MRS for differentiating benign from malignant musculoskeletal tumors. Stratification by age, gender, disease duration, and lesion size was performed to assess the influence of potential effect modifiers on diagnostic performance.

RESULTS

A total of 111 patients with suspected musculoskeletal tumors were included. The demographic and baseline clinical characteristics are summarized in Table 1. The mean age of patients was 38.64 years (SD 11.35), with a higher proportion of males (77, 69.4%). The mean duration of presenting symptoms was 13.83 months (SD 5.73), while the average lesion size detected on MRI was 7.84 cm (SD 1.14). (Table 1)

Table 1: Baseline demographic and clinical characteristics of patients (n = 111)

Variable	Distribution
Age (years), mean ± SD	38.64 ± 11.35
Gender, n percent	Male 77 (69.4 percent) Female 34 (30.6 percent)
Duration of disease (months), mean ± SD	13.83 ± 5.73
Tumor size (cm), mean ± SD	7.84 ± 1.14

Magnetic resonance spectroscopy identified malignant spectral patterns in 73 patients, whereas histopathology confirmed malignancy in 75 cases. A comparison between MRS and histopathology as the reference standard is presented in Table 2. Overall, MRS demonstrated high diagnostic performance with a sensitivity of 90.7 percent, specificity of 86.1 percent, PPV of 93.2 percent, NPV of 81.6 percent, and overall accuracy of 89.2 percent. (Table 2)

Table 2: Diagnostic accuracy of MRS using histopathology as the Gold standard (n = 111)

MRS Findings	Histopathology Positive	Histopathology Negative	Total
Malignant	68	5	73
Benign	7	31	38
Total	75	36	111

Sensitivity 90.7%
Specificity 86.1%
PPV 93.2 %
NPV 81.6 %
Diagnostic accuracy 89.2 %

Stratified analysis based on age, gender, disease duration, and lesion size is shown in Table 3. Diagnostic performance remained consistently high across all subgroups, indicating the robustness of MRS in differentiating benign from malignant musculoskeletal tumors. (Table 3)

Table 3: Diagnostic performance of MRS stratified by patient and tumor characteristics

Stratified factor	constructs	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Age	20 to 40 years	88.4	83.4	92.7	79.2	87.7
	41 to 60 years	93.8	85.7	93.8	85.7	91.3
gender	Male	90.1	88.5	93.9	82.1	89.6
	Female	91.7	80.0	91.7	80.0	88.2
Duration	4 to 12 months	94.7	85.7	94.7	85.7	92.3
	13 to 24 months	86.5	86.4	91.4	79.2	86.4
Lesion Size	6 to 7.5 cm	90.3	82.4	90.3	82.4	87.5
	7.6 to 10 cm	90.9	89.5	95.2	80.9	90.5

DISCUSSION

This discussion concerns the results of our study on the diagnostic accuracy of Magnetic Resonance Spectroscopy (MRS) for differentiating malignant from benign musculoskeletal tumors, with histopathology as the gold standard. Our findings indicate that MRS exhibited high sensitivity (90.7%) and specificity (86.1%), corroborated by stratified analyses across demographic and clinical parameters, including age, gender, disease duration, and lesion size. This performance aligns well with the existing literature, reinforcing MRS's role in diagnosing musculoskeletal tumors.

In our cohort of 111 patients, the mean age was 38.64 years with a male predominance (69.4%). Similar demographic trends have been reported by Ali et al. Ali et al. [14], where the age-related prevalence of musculoskeletal tumors showed a comparable distribution of gender and age demographics. The average symptom duration in our study was 13.83 months (SD 5.73), which is consistent with findings by Dewan et al. Dewan et al. [15,] who discussed similar symptom durations in patients presenting with musculoskeletal lesions.

Our results indicated that MRS diagnosed malignancies in 73 patients, paralleling histopathologic findings in 75 cases, suggesting that MRS is a reliable adjunct in diagnosing musculoskeletal tumors. This finding is corroborated by the meta-analysis by Wang et al. 16, which emphasizes MRS's high sensitivity and specificity, reinforcing its value in clinical practice for characterizing musculoskeletal tumors—furthermore, Boruah et al. Boruah et al. [17] noted that quantitative diffusion-weighted imaging

(DWI) significantly improved diagnostic accuracy alongside conventional MR imaging, emphasizing a multifaceted approach that aligns with our findings of MRS adding diagnostic value.

Our stratified analysis demonstrated that diagnostic performance remained robust across various subgroups, indicating the reliability of MRS in diverse clinical contexts. For instance, our high sensitivity (94.7%) in patients with a disease duration of 4 to 12 months supports the findings of Fayad et al. 18, who highlighted the importance of early detection and tumor characterization. Additionally, our results showed that MRS outperformed traditional imaging modalities, with sensitivity in older patients (41-60 years) reaching 93.8%, which aligns with the findings of Popiţa et al. Popiţa et al. [19] that advanced imaging techniques markedly enhance diagnostic accuracy and reliability across different age groups.

The examination of lesion sizes (6 to 10 cm) yielded sensitivities of 90.3% and 90.9%, further substantiating the literature linking tumor characteristics, such as size, to MRS performance metrics, as reported by Dewan et al. Dewan et al. [15] reinforce this association, indicating that larger lesions elicit clearer metabolic signatures, facilitating accurate diagnoses.

The results indicate that MRS is a highly effective diagnostic tool for differentiating malignant from benign musculoskeletal tumors, with performance characteristics consistent with the existing literature. Sensitivity and specificity rates indicate a robust operational paradigm for MRS as a non-invasive measurement method that augments standard imaging techniques, thereby illustrating its clinical utility in the diagnostic workflow.

Our study's robust performance metrics underscore the need to integrate MRS into routine diagnostic protocols, especially in settings with limited access to invasive procedures such as biopsy. The Pakistani healthcare landscape, characterized by resource constraints, can greatly benefit from the use of MRS for diagnosing musculoskeletal tumors, potentially streamlining patient management and improving prognostic outcomes.

Our findings not only contribute significantly to the body of knowledge on MRS in the context of musculoskeletal tumors but also promote its application in the clinical domain, especially in resource-limited settings such as Pakistan.

CONCLUSION

Magnetic Resonance Spectroscopy showed robust diagnostic performance when differentiating malignant from benign musculoskeletal tumors, with high sensitivity and specificity supported by consistent subgroup results. The findings confirm its value as a reliable noninvasive diagnostic tool that enhances conventional MRI. Integrating Magnetic Resonance Spectroscopy into routine evaluation can improve early characterization of musculoskeletal tumors and support timely, accurate clinical decision making, especially in settings where rapid histopathological diagnosis is challenging.

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