

DIAGNOSTIC ACCURACY OF MAGNETIC RESONANCE IMAGING (MRI) IN DIFFERENTIATING BENIGN FROM MALIGNANT BONE TUMOR, TAKING HISTOPATHOLOGY AS GOLD STANDARD

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Abstract

Background:

Bone tumors are a heterogeneous group of lesions with a wide range of biological behavior, from benign to highly aggressive malignant tumors. It is important to differentiate these tumors for appropriate management and prognosis. Magnetic resonance imaging (MRI) is useful in differentiating these tumors because of its high soft tissue resolution, as well as its ability to evaluate marrow and soft tissue involvement; however, diagnostic overlap occurs in these tumors.

Objective:

To determine the diagnostic accuracy of magnetic resonance imaging in differentiating benign from malignant bone tumors, using histopathology as the gold standard.

Methods:

This study was a cross-sectional diagnostic accuracy study conducted in the Department of Radiology, Mardan Medical Complex, Pakistan, from Nov 2024 to April 2025. A total of 136 patients with suspected bone tumors were included in the study. MRI was used as the index test, and histopathological examination was used as the reference standard for diagnosis. Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were used as performance measures for diagnosis.

Results:

MRI demonstrated a sensitivity of 91.36% and specificity of 87.27% in differentiating malignant from benign bone tumors, with an overall diagnostic accuracy of 89.70%. Malignant lesions were more frequently associated with larger size, ill-defined margins, cortical destruction, periosteal reaction, and soft tissue involvement, whereas benign lesions typically exhibited well-defined margins and less aggressive imaging features.

Conclusion:

MRI is a reliable and effective diagnostic tool for the differentiation of benign and malignant bone tumors, and it plays a vital role in the early diagnosis and

treatment of these conditions, although histopathological examination of the tumor tissue is necessary for the definitive diagnosis of the tumor.

INTRODUCTION

Bone tumors are a heterogeneous group of neoplastic processes that arise from osseous or cartilaginous tissue and are subdivided into benign and malignant bone tumors based on their biological behavior and metastatic ability^{1,2}. Though benign bone tumors such as osteochondromas and enchondromas are common, malignant bone tumors such as primary bone sarcomas such as osteosarcoma and Ewing's sarcoma, as well as metastatic bone disease, are associated with a high degree of morbidity and mortality^{3,4}. Therefore, differentiation between benign bone tumors and malignant bone tumors is crucial and has a direct bearing on their management, which may vary from conservative management to radical resection⁵. Misdiagnosis or delayed diagnosis may result in disease progression, incorrect management, and poor clinical outcomes, especially in malignant bone tumors where accurate diagnosis is crucial for improved survival outcomes⁶.

Imaging is a crucial part in the primary evaluation of bone tumors. Though conventional radiographs or X-rays are the primary imaging procedure for the evaluation of bone tumors, computed tomography (CT) scans have better delineation of cortical bone and matrix mineralization than conventional radiographs⁶. However, magnetic resonance imaging (MRI) has now become the preferred imaging procedure for the evaluation of bone tumors due to its superior soft tissue resolution capability⁷.

Though MRI is useful for bone tumor evaluation, MRI findings may sometimes overlap between benign bone tumors and malignant bone tumors; therefore, diagnosis may become challenging, and histopathological correlation is still considered the gold standard for bone tumor evaluation^{8,9}.

Previous research works have also explored the accuracy of MRI in differentiating benign from malignant bone tumors, showing a range of sensitivities and specificities in different populations¹⁰. Though high sensitivity, i.e., greater

than 90%, has been demonstrated in some research works, specificity results have varied significantly, showing considerable overlap in the imaging features of benign and malignant bone tumors, as well as considerable interobserver variability¹¹. Moreover, the results of most research works are based on the population of Western countries or high-resource countries, which may not be applicable in the context of low- and middle-income countries in South Asia, particularly Pakistan, where variations in disease patterns, healthcare facilities, and diagnostic tools may affect the accuracy of MRI in differentiating between benign and malignant bone tumors.

Therefore, in the context of the above facts, the diagnostic accuracy of MRI in differentiating benign from malignant bone tumors in comparison with histopathological results needs to be explored, which will help in establishing the reliability of MRI in clinical practice, thereby avoiding the use of invasive procedures in certain clinical conditions.

Objective: Therefore, the aim of the current study was to assess the accuracy of MRI in differentiating benign from malignant bone tumors in comparison with histopathological results in a tertiary care hospital setting.

MATERIALS AND METHODS

This cross-sectional diagnostic accuracy study was carried out at the Department of Radiology, Mardan Medical Complex, Mardan, Pakistan, from Nov 2024 to April 2025. The study was conducted following the guidelines of the Standards for Reporting Diagnostic Accuracy Studies (STARD) 2015. A sample of 136 patients between the ages of 18 and 70 years, suspected of having bone tumors on initial radiographic evaluation, was included using a non-probability consecutive sampling technique. However, patients unfit for surgery, having contraindications to MRI, and suffering from claustrophobia were excluded. The sample size was calculated at a 95% confidence level, 60% prevalence, 94% sensitivity, 90% specificity, and

8% precision¹². Informed consent was obtained from the patients, and demographic and clinical details were noted. Magnetic resonance imaging was carried out on all patients. The reference standard was histopathology. Magnetic resonance imaging was performed on a 1.5 Tesla machine. The images obtained were interpreted by a senior radiologist having more than 7 years of experience. The images were interpreted without knowledge of the histopathology results. The lesions were categorized as benign or malignant on the basis of pre-defined criteria such as size, margins, cortical destruction, periosteal reaction, marrow involvement, and soft tissue extension. Histopathological examination of biopsy samples was done by a consultant pathologist who was not aware of MRI results. The target condition was taken as malignancy, and true positives, true negatives, false positives, and false negatives were defined accordingly. The data was analyzed using SPSS version 25.0. Quantitative variables are expressed as means $\pm$ standard deviation or median along with their interquartile range, whereas qualitative variables are expressed as frequencies and percentages. A contingency table was constructed, and sensitivity, specificity, positive predictive value, negative predictive value, and accuracy, along with their confidence intervals

at 95%, were calculated. Stratification was done for all potential confounding variables, and chi-square or Fisher's exact tests were applied, considering $p < 0.05$ statistically significant. The ethical approval for this study was taken from the ethical review board of Bacha Khan Medical College and Mardan Medical Complex, and all procedures were done according to the Helsinki Declaration.

RESULTS

A total of 136 patients were included in this study. The mean age of patients was calculated as 40.29 ± 7.68 years. The majority of patients were male, making up 92 (67.65%) of the cases, while females comprised 44 (32.35%) of the patients. The mean duration of disease was calculated as 5.88 ± 2.73 months. The mean size of the lesions was calculated as 7.36 ± 3.41 cm. Based on the results of the MRI, a total of 81 (59.56%) patients were diagnosed as having malignant lesions, while 55 (40.44%) patients were diagnosed as having benign lesions. The results of the histopathological examination were also consistent, as a total of 81 (59.56%) patients were diagnosed as having malignant lesions, while 55 (40.44%) patients were diagnosed as having benign lesions

Table 1: Baseline Characteristics of Study Population (n = 136)

Variable	Value
Age (years)	40.29 ± 7.68
Duration of disease (months)	5.88 ± 2.73
Lesion size (cm)	7.36 ± 3.41
Gender	
Male	92 (67.65%)
Female	44 (32.35%)
MRI findings	
Malignant	81 (59.56%)
Benign	55 (40.44%)
Histopathology findings	
Malignant	81 (59.56%)
Benign	55 (40.44%)

Comparison of the MRI findings with the histopathology results showed a high degree of agreement between the two. As can be seen from the table below, 74 cases of malignant tumors detected by MRI were confirmed as malignant by histopathology (true positives), and 48 cases of benign tumors detected by MRI were confirmed as

benign by histopathology (true negatives). However, 7 cases were incorrectly diagnosed as malignant by MRI but were benign by histopathology (false positives), and 7 cases were incorrectly diagnosed as benign by MRI but were malignant by histopathology (false negatives).

Table 2: Comparison of MRI Findings with Histopathology

MRI Findings	Histopathology Malignant	Histopathology Benign	Total
Malignant	74 (True Positive)	7 (False Positive)	81
Benign	7 (False Negative)	48 (True Negative)	55
Total	81	55	136

The diagnostic accuracy of MRI was assessed by calculating various indices. The sensitivity of MRI for detecting malignant bone tumors was 91.36%, and the specificity was 87.27%. The positive predictive value of MRI was 91.36%, and the

negative predictive value was 87.27%. The diagnostic accuracy of MRI for differentiating between benign and malignant bone tumors was 89.70%, as shown in Table 3.

Table 3: Diagnostic Performance of MRI

Parameter	Value (%)
Sensitivity	91.36%
Specificity	87.27%
Positive Predictive Value (PPV)	91.36%
Negative Predictive Value (NPV)	87.27%
Diagnostic Accuracy	89.70%

Histopathological assessment indicated osteosarcoma to be the most common malignant tumor, followed by Ewing's sarcoma and chondrosarcoma. Metastatic lesions and plasma cell myeloma were also present; however, the cases were mostly from the older age group. Among the benign tumors, osteochondroma was the most common, followed by enchondroma, giant cell tumor, and cysts. Malignant tumors were found to be larger in size and more aggressive on imaging, compared to benign tumors. Well-defined margins without aggressive features were more commonly observed among the benign tumors compared to the malignant tumors. Well-defined margins without aggressive features were more commonly observed

among the benign tumors compared to the malignant tumors.

DISCUSSION

The present study showed that magnetic resonance imaging (MRI) possessed excellent diagnostic performance for differentiating benign from malignant bone tumors when compared with histopathology, which was taken as a gold standard. The sensitivity of MRI was calculated at 91.36%, specificity at 87.27%, and overall accuracy at 89.70%, showing excellent agreement with histopathology. Although a small percentage of false positives and false negatives were reported, the overall accuracy of MRI was excellent. Moreover, it was also observed that malignant

tumors showed more aggressive features, whereas benign tumors showed more indolent features. The malignant tumors showed larger size, ill-defined margins, cortical destruction, periosteal reaction, and soft tissue extension, whereas benign tumors showed indolent features. This indicates the excellent use of MRI for characterizing tumors at the initial stages.

The overall accuracy of MRI for differentiating benign from malignant bone tumors, as reported in this study, is comparable with previously reported data. Several international studies have reported the sensitivity of MRI for differentiating benign from malignant bone tumors ranging from 85-95%, and specificity ranging from 80-90%¹³⁻¹⁵. Similarly, another research reported excellent sensitivity of MRI but showed relatively lower specificity, which was attributed to overlapping features of certain tumor types¹⁶. Another research reported excellent use of MRI for characterizing tumor lesions but showed relatively lower specificity of MRI, which was attributed to overlapping features of tumor lesions¹⁷. Similarly, studies conducted in South Asian countries have shown comparable diagnostic accuracy, which supports the use of MRI in such healthcare settings¹⁸⁻²⁰. The slightly lower specificity rate could be attributed to false positive cases where benign conditions, such as giant cell tumors or inflammatory conditions, showed aggressive characteristics on imaging. False negative cases could be attributed to well-differentiated malignancies that showed less aggressive characteristics on imaging. These results are comparable with the existing body of knowledge and add regional data for future studies²⁰.

From a clinical point of view, the higher sensitivity rate of MRI is an advantage, as it helps in the early detection of malignant lesions, thus ensuring that a potential case is not missed. Accurate differentiation between benign and malignant bone tumors is an important factor that guides treatment, as appropriate decisions regarding the need for a biopsy, surgical intervention, or oncological referral are necessary. MRI also provides detailed information regarding the extent of the tumor, bone marrow, and soft tissue invasion, which is critical for staging the tumor for

appropriate treatment. MRI is an advanced diagnostic tool that is considered pivotal in settings where access to advanced diagnostic modalities is not readily available, such as in Pakistan. It is a non-invasive diagnostic tool that has a higher diagnostic yield, thus providing an advantage over invasive diagnostic procedures.

The advantages of the present study include the use of histopathology as a gold standard for verifying the diagnosis. In addition, the use of a standard MRI protocol for all the subjects would increase the reliability and reproducibility of the imaging findings. Moreover, the use of 136 subjects would provide a fair sample size for the estimation of the parameters for assessing the diagnostic accuracy. Nevertheless, the present study has a few disadvantages. Firstly, the present study was done at a single center. In addition, the imaging findings were read by a single radiologist. Moreover, the use of advanced MRI techniques such as DWI and ADC would have increased the diagnostic performance.

Future research should be done on a larger sample size and a wider population to increase the generalizability of the study. In addition, the use of advanced imaging techniques would provide more information for the diagnosis of the lesions.

CONCLUSION

Magnetic resonance imaging was observed to have a high diagnostic performance in differentiating between benign and malignant bone tumors, as indicated by a high sensitivity of 91.36%, specificity of 87.27%, and accuracy of 89.70% in comparison with histopathological results. The results of the study indicated the reliability of the use of MRI as a non-invasive diagnostic tool in the early characterization of bone tumors and its importance as a guiding tool in the decision-making process for the management of the conditions. The ability of MRI to characterize the extent of the lesions and the soft tissue involvement of the lesions makes it a vital tool in the management of the conditions. In a resource-scarce environment, MRI plays a vital role as a diagnostic tool in a situation where diagnostic opportunities are scarce, as in the case of Pakistan. Although MRI was observed to have a high

diagnostic accuracy, it could not be used in isolation from histopathological results.

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