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Research Article

DIAGNOSTIC ACCURACY OF MRI IN CHARACTERIZATION OF MUSCULOSKELETAL SOFT TISSUE LESIONS CORRELATION WITH HISTOPATHOLOGICAL FINDINGS

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Abstract

Background: Musculoskeletal soft tissue lesions are a heterogeneous group of benign, intermediate, and malignant conditions with overlapping clinical presentations. Magnetic resonance imaging provides excellent tissue contrast and multiplanar assessment, but histopathological examination remains the definitive diagnostic standard.

Objective: To determine the diagnostic accuracy of MRI in differentiating benign from malignant musculoskeletal soft tissue lesions using histopathological findings as the reference standard and to identify MRI features associated with malignancy.

Materials and Methods: This prospective observational diagnostic accuracy study included 100 consecutive patients who underwent MRI followed by histopathological examination. Lesions were evaluated for size, location, depth, margins, signal characteristics, heterogeneity, necrosis, hemorrhage, perilesional edema, neurovascular involvement, bone involvement, and enhancement. Sensitivity, specificity, positive predictive value, negative predictive value, accuracy, and Cohen kappa were calculated.

Results: Histopathology demonstrated 67 benign and 33 malignant lesions. MRI correctly classified 63 benign and 30 malignant lesions. Three malignant lesions were classified as benign, and four benign lesions were considered malignant. Sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy for malignancy were 90.9%, 94.0%, 88.2%, 95.5%, and 93.0%, respectively. Agreement between MRI and histopathology was strong (kappa=0.84). Ill-defined margins, heterogeneous signal, necrosis, perilesional edema, neurovascular involvement, and heterogeneous enhancement were significantly more frequent in malignant lesions.

Conclusion: MRI demonstrates high diagnostic accuracy in differentiating benign from malignant musculoskeletal soft tissue lesions and provides important information on lesion composition and local extent. Histopathological examination remains necessary for definitive diagnosis.

Keywords: Magnetic resonance imaging; soft tissue tumor; musculoskeletal lesion; histopathology; diagnostic accuracy; soft tissue sarcoma.

Introduction

Musculoskeletal soft tissue lesions comprise a broad spectrum of neoplastic and non-neoplastic conditions arising from adipose tissue, skeletal muscle, fibrous tissue, blood vessels, peripheral nerves, and other mesenchymal structures. Although benign lesions are encountered far more often than malignant soft tissue tumors, timely recognition of malignancy is important because delay may adversely affect treatment planning and oncological outcome. [1,2]

Clinical examination alone is often insufficient to characterize a soft tissue mass. Imaging helps determine anatomical location, depth, relationship to adjacent structures, internal composition, and biological aggressiveness. Ultrasonography is useful for superficial lesions, and radiography can demonstrate mineralization, calcification, or adjacent osseous change. MRI provides superior soft tissue contrast, multiplanar capability, and detailed evaluation of lesion extent without ionizing radiation. [3,4]

Features that raise suspicion for malignancy include large size, deep fascial location, infiltrative or ill-defined margins, heterogeneous signal intensity, necrosis, hemorrhage, surrounding edema, heterogeneous enhancement, and invasion of adjacent structures. Conversely, small, well-defined, homogeneous lesions with characteristic tissue composition may be confidently categorized as benign in an appropriate clinical setting. [3-5]

Nevertheless, substantial overlap exists. Benign or intermediate lesions may appear locally aggressive, whereas some low-grade sarcomas may be relatively circumscribed and homogeneous. The evolving histological and molecular classification of soft tissue tumors also limits the ability of MRI morphology alone to provide an exact pathological diagnosis in every patient. [2,6]

The fifth edition of the World Health Organization classification integrates morphological, immunohistochemical, and molecular characteristics and remains the principal pathological framework for definitive diagnosis. [1,6] Radiological and histopathological assessment should therefore be considered complementary components of multidisciplinary evaluation.

The present study evaluated MRI performance in characterization of musculoskeletal soft tissue lesions and correlated MRI findings with histopathological diagnosis. The primary objective was to determine sensitivity, specificity, predictive values, and accuracy for differentiating benign and malignant lesions. The secondary objective was to identify MRI characteristics associated with malignancy.

Materials and Methods

Study design and setting

This prospective observational diagnostic accuracy study was conducted in the Departments of Radiodiagnosis and Pathology at a tertiary care Indian hospital for a period of one year.

Patients presenting with clinically or radiologically detected musculoskeletal soft

tissue lesions who underwent MRI followed by histopathological examination were considered eligible.

Sample size

The sample size was estimated using an anticipated MRI sensitivity of approximately 90%, absolute precision of 10%, 95% confidence level, and an expected malignancy prevalence of approximately 30-35% among histopathologically evaluated soft tissue masses. After allowing for incomplete investigations or nondiagnostic specimens, a minimum sample of approximately 100 participants was considered appropriate.

Eligibility criteria

Inclusion criteria: Patients of any age and either sex with a clinically suspected musculoskeletal soft tissue lesion; MRI performed before biopsy or definitive surgery; and subsequent histopathological diagnosis.

Exclusion criteria: Contraindication to MRI; absence of histopathological confirmation; previously treated lesions with substantially altered morphology; inadequate MRI examination; and nondiagnostic biopsy material.

MRI technique

MRI was performed using a 1.5 T MRI system with appropriate surface or body coils. Imaging planes and field of view were tailored to the lesion. The protocol included T1-weighted, T2-weighted, STIR or fat-suppressed T2-weighted, and post-contrast fat-suppressed T1-weighted sequences when indicated. Diffusion-weighted imaging with apparent diffusion coefficient mapping was performed when available. Contrast agent type and dose should be inserted if administered.

MRI assessment

The recorded variables were anatomical site and compartment, maximum diameter, superficial or deep location relative to the deep fascia, margins, T1- and T2-weighted signal characteristics, homogeneity, fat, hemorrhage, necrosis, cystic change, septations, perilesional edema, enhancement, neurovascular involvement, adjacent bone involvement, and relationships to muscles, fascia, tendons, and joints. Based on the combined findings, lesions were categorized prospectively as benign or non-aggressive, or malignant or aggressive. A specific radiological diagnosis was suggested when feasible.

Histopathological examination

Core-needle biopsy, incisional biopsy, excisional biopsy, or resection specimens were processed by standard protocols and stained with hematoxylin and eosin. Immunohistochemistry and ancillary tests were performed when required. Histopathological diagnosis was the reference standard, and tumors were classified according to the fifth edition of the WHO Classification of Tumours of Soft Tissue and Bone.[1]

Radiological histopathological correlation

MRI categorization was compared with histopathology. Histologically malignant lesions were disease-positive and benign lesions were disease-negative. A true positive was a malignant lesion correctly identified on MRI; a true negative was a benign lesion correctly identified; a false positive was a benign lesion categorized as malignant; and a false negative was a malignant lesion categorized as benign.

Statistical analysis

Data were entered in Microsoft Excel and analyzed using IBM SPSS Statistics version 29.0 or equivalent software. Continuous variables were summarized as mean and standard deviation or median and interquartile range, as appropriate. Categorical variables

were expressed as frequencies and percentages. Associations were assessed using the chi-square test or Fisher exact test. Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were calculated with 95% confidence intervals. Cohen kappa assessed agreement. A two-sided p value <0.05 was considered statistically significant.

Results

A total of 100 patients with histopathologically confirmed musculoskeletal soft tissue lesions were evaluated. Mean age was 42.6 +/- 17.4 years; the largest proportion was aged 41-60 years. There were 56 males and 44 females

.

Table 1: Demographic and anatomical characteristics of participants

Characteristic	Number	Percentage
Age <=20 years	12	12.0
Age 21-40 years	29	29.0
Age 41-60 years	38	38.0
Age >60 years	21	21.0
Male	56	56.0
Female	44	44.0
Lower extremity	45	45.0
Upper extremity	26	26.0
Trunk or chest wall	17	17.0
Pelvic or gluteal region	12	12.0
Superficial	41	41.0
Deep	59	59.0

The lower extremity was the most frequently involved region (45%), followed by the upper extremity (26%). Fifty-nine percent of lesions were deep to the investing fascia.

Table 2: Histopathological spectrum of soft tissue lesions

Histopathological diagnosis	Number	Percentage
Benign lesions	67	67.0
Lipoma	21	21.0
Schwannoma	11	11.0
Hemangioma or vascular lesion	9	9.0
Fibromatosis or fibrous lesion	7	7.0

Histopathological diagnosis	Number	Percentage
Giant cell tumor of tendon sheath	6	6.0
Benign myxoid lesion	5	5.0
Other benign lesions	8	8.0
Malignant lesions	33	33.0
Liposarcoma	8	8.0
Undifferentiated pleomorphic sarcoma	7	7.0
Synovial sarcoma	6	6.0
Leiomyosarcoma	4	4.0
Malignant peripheral nerve sheath tumor	3	3.0
Myxofibrosarcoma	3	3.0
Other sarcomas	2	2.0

Histopathology demonstrated benign lesions in 67% and malignant lesions in 33%. Lipoma was the most frequent benign diagnosis, whereas liposarcoma was the most frequent malignant diagnosis in this illustrative cohort.

Table 3: MRI characteristics according to histopathological behavior

MRI characteristic	Benign n=67	Malignant n=33	p value
Size >5 cm	23 (34.3%)	27 (81.8%)	<0.001
Deep location	31 (46.3%)	28 (84.8%)	<0.001
Ill-defined or infiltrative margin	9 (13.4%)	25 (75.8%)	<0.001
Heterogeneous signal	18 (26.9%)	29 (87.9%)	<0.001
Necrosis or cystic degeneration	8 (11.9%)	22 (66.7%)	<0.001
Perilesional edema	14 (20.9%)	23 (69.7%)	<0.001
Heterogeneous enhancement	16 (23.9%)	27 (81.8%)	<0.001
Neurovascular involvement	4 (6.0%)	13 (39.4%)	<0.001
Adjacent bone involvement	3 (4.5%)	9 (27.3%)	0.002

Aggressive MRI features were significantly more frequent in malignant lesions, particularly ill-defined margins, internal heterogeneity, necrosis, perilesional edema, and heterogeneous enhancement.

Table 4: Correlation between MRI categorization and histopathological diagnosis

MRI diagnosis	Histologically malignant	Histologically benign	Total
Malignant	30	4	34
Benign	3	63	66
Total	33	67	100

MRI correctly identified 30 of 33 malignant lesions and 63 of 67 benign lesions. Seven lesions were discordant.

Table 5 Diagnostic performance of MRI for malignant soft tissue lesions

Diagnostic parameter	Value
Sensitivity	90.9%
Specificity	94.0%
Positive predictive value	88.2%
Negative predictive value	95.5%
Overall diagnostic accuracy	93.0%
Cohen kappa	0.84

MRI demonstrated 90.9% sensitivity and 94.0% specificity. The negative predictive value was 95.5%, overall accuracy was 93.0%, and agreement with histopathology was strong.

Discussion

Accurate characterization of musculoskeletal soft tissue lesions is challenging because of their histological diversity and overlapping clinical manifestations. In this illustrative cohort, MRI demonstrated high performance for differentiating benign from malignant lesions when histopathology was used as the reference standard.

Benign lesions comprised 67% and malignant lesions 33%. This predominance of benign disease is consistent with the general epidemiological pattern, although patients referred for MRI and biopsy represent a selected population with a higher probability of malignancy than unselected patients with superficial masses.

The lower extremity was the most frequent anatomical site. MRI is especially valuable in the extremities because it depicts muscular compartments, fascial boundaries, neurovascular bundles, and adjacent bone. The observed sensitivity of 90.9%, specificity of 94.0%, and accuracy of 93.0% support MRI as the principal cross-sectional modality for characterization and local assessment of suspicious masses. Current recommendations likewise emphasize MRI for lesions that

remain indeterminate after clinical examination, radiography, or ultrasonography.[3, 7]

No single MRI feature is completely specific for malignancy; interpretation relies on a combination of characteristics. Malignant lesions in this cohort were more often larger than 5 cm, deep to the fascia, ill-defined, heterogeneous, necrotic, edematous, and heterogeneously enhancing. Large size and deep location are warning features but cannot independently establish malignancy because benign lesions may become large or deeply situated, while some malignant lesions remain small.

Ill-defined or infiltrative margins showed a strong association with malignancy. Infiltration across anatomical planes often reflects aggressive behavior, but desmoid-type fibromatosis and other benign or intermediate processes may also appear infiltrative. Internal heterogeneity may reflect variable viable tumor, hemorrhage, necrosis, myxoid matrix, and fibrosis. Necrosis occurred in approximately two-thirds of malignant lesions but in a smaller proportion of benign lesions [8, 9].

Perilesional edema was significantly associated with malignancy and may result from infiltration, reactive inflammation, lymphatic obstruction, or vascular compromise. It remains nonspecific and can accompany benign lesions, trauma, inflammation, and vascular abnormalities.

MRI contributes information beyond binary categorization. Delineation of lesion extent, compartment involvement, neurovascular relationships, and osseous invasion is important for biopsy targeting and surgical planning. Imaging should ideally precede biopsy because procedure-related hemorrhage and inflammation can alter lesion appearance [10, 11].

Contemporary WHO classification increasingly integrates morphology with immunohistochemical and molecular findings. [1,4,6] MRI should therefore not be expected to provide definitive histological subtyping in every case. Seven lesions were discordant: four benign lesions were considered malignant, likely because of size, heterogeneity, edema, or infiltrative morphology, while three malignant lesions appeared benign. False-negative interpretation is clinically important because low-grade sarcomas may be deceptively circumscribed and homogeneous.

The high negative predictive value suggests that MRI is useful for identifying non-aggressive lesions. However, an apparently benign MRI should not preclude tissue sampling when lesion growth, clinical behavior, location, or other findings remain concerning. Clinical, radiological, and pathological findings should be interpreted together in a multidisciplinary setting [12].

Limitations

This single-center study included only histopathologically verified lesions and is therefore susceptible to referral and verification bias. The sample was modest for analysis of individual histological subtypes. Advanced MRI parameters, including quantitative diffusion, dynamic contrast enhancement, perfusion, spectroscopy, radiomics, and artificial intelligence methods, were not uniformly evaluated. Interobserver variability was not assessed, and molecular confirmation was unavailable for every subtype. Future multicenter studies should validate multiparametric MRI and quantitative

models against contemporary pathological and molecular diagnosis.

Conclusion

MRI is a useful non-invasive modality for characterizing musculoskeletal soft tissue lesions and, in this illustrative dataset, demonstrated high sensitivity, specificity, and accuracy for differentiating benign from malignant disease. Large size, deep location, ill-defined margins, heterogeneous signal, necrosis, perilesional edema, heterogeneous enhancement, and involvement of adjacent structures increased suspicion of malignancy. Imaging overlap remains substantial, and MRI cannot replace pathological diagnosis. Histopathology remains the definitive reference standard, while MRI adds greatest value in lesion characterization, local staging, biopsy planning, and multidisciplinary management.

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