Original Article

Diagnostic Accuracy of Diffusion Weighted Magnetic Resonance Imaging in differentiation between Benign and Malignant Soft Tissue Tumors keeping Histopathology as Gold Standard

Zoha Arif Saeed[1], Laiba Khalid[2], Seerat Iqbal[3], Zobia Shahid[4], Maryam Afzal[5]

ABSTRACT

Background & Objective: To determine diagnostic accuracy of Diffusion Weighted Magnetic Resonance Imaging in differentiation between benign and malignant soft tissue tumors keeping histopathology as gold standard.

Methodology: A total of 176 patients meeting inclusion criteria underwent MRI, including DWI sequences at b-values of 0, 50, and 1000 s/mm² and ADC values were calculated from corresponding maps. ROI was placed on the solid tumor component of mass. Post-contrast imaging was also performed. All MRIs were interpreted by blinded, qualified radiologists to ensure unbiased results. Definitive diagnoses were confirmed through histopathological analysis by certified pathologists.

Results: 98 (55.69%) were aged 13–40 years and 78 (44.1%) were 41–75 years, with a mean age of 40.62±10.13 years. There were 94 males (53.5%) and 82 females (46.5%). Tumor sizes ranged from 3.1 cm to 11.5 cm, with a mean size of 6.3 cm. The average ADC value of benign masses (1.50×10^{-3} mm²/s) was higher than that of malignant masses (0.83×10^{-3} mm²/s). A cutoff ADC value of 1.1×10^{-3} mm²/s provided sensitivity of 85.51%, specificity of 86.84%, PPV of 88.89%, NPV of 82.50%, and diagnostic accuracy of 85.88%. Histopathology showed 97 masses (55.3%) were malignant and 79 (44.7%) were benign.

Conclusion: Diffusion-weighted MRI (DWI) is a non-invasive, cost-effective imaging tool with 85.5% sensitivity and 86.8% specificity for evaluating soft tissue masses. It can aid early detection of malignant tumors, improving patient outcomes through timely diagnosis.

KEY WORDS: Diffusion Weighted Imaging (DWI), Magnetic Resonance Imaging (MRI), soft tissue tumor, Restricted Diffusion.

How to cite: *Saeed ZA, Khalid L, Iqbal S, Shahid Z, Afzal M. Diagnostic Accuracy of Diffusion Weighted Magnetic Resonance Imaging in Differentiation Between Benign and Malignant Soft Tissue Tumors Keeping Histopathology as Gold Standard. J Allam Iqbal Med Coll. 2025; 23(4): 119-124.*

INTRODUCTION

Soft tissue tumors exhibit diverse forms, varying by size, location and associated symptoms which may include swelling, pain, tenderness, or restricted mobility. These tumors are categorized based on their tissue of origin, including neural, vascular, muscular, fatty, fibrous, or synovial.[1,2] While they can develop in various areas, the limbs are the most common sites, with the thigh being particularly prevelant.[2] Differentiating between malignant and benign masses, and from non-neoplastic traumatic or inflammatory lesions, remains a significant challenge for surgeons due to their overlapping clinical presentations.[3,4]

Magnetic resonance imaging (MRI) is widely regarded as an ideal method for diagnosing soft tissue masses because of its superior spatial resolution and exceptional contrast compared to other imaging. It accurately determines the extent of soft tissue lesions, offering crucial information for diagnosis and treatment planning[1]. However, MRI alone does not allow reliable differentiation, necessitating complementary conventional methods.[5] Malignant soft tissue masses on MRI show features of bone involvement, surrounding tissues and tendons invasion, surrounding edema, and intense contrast enhancement.6 So techniques like excision biopsy and fine-needle aspiration cytology (FNAC) provide reliable results but are invasive, with potential risks including inadequate sample, haemorrhage and infection. This highlights the need for non-invasive methods to evaluate and characterize soft tissue tumors more safely and effectively.[7]

Diffusion-weighted MRI (DWI) has emerged as a promising technique enhancing the diagnostic capabilities of MRI.[8] Using quantitative values of apparent diffusion coefficient (ADC) provides a more accurate assessment of soft tissue masses and their reaction to therapy over time.[9] DWI evaluates membrane integrity and tissue cellularity by analysing the movement of protons within tissues. Tumors with higher cellular density and reduced extracellular water content show restricted diffusion, resulting in lower ADC values. Conversely, conditions involving cell membrane

Correspondence:
Zoha Arif Saeed[1]
Senior Registrar Department of Diagnostic Radiology
Lahore General Hospital/ PGMI/ AMC, Lahore

* Received: September 9, 2025
* Revised: October10, 2025
* Corrected & Edited: November 28, 2025
* Accepted: December 7, 2025

breakdown and increased extracellular water content lead to higher ADC values.[10] Several factors have impact on the ADC values, including cellularity, composition, stroma, cystic changes and necrosis. In malignant tumors, densely packed cells restrict movement of protons, producing lower ADC values. Any condition that restricts macromolecular diffusion or limits water proton movement similarly reduces ADC values. Romeih et al. determined a threshold of ADC 1.1×10^{-3} mm^2/s for differentiating soft tissue masses, having sensitivity 83.3% and specificity 72.7%.[11]

The rationale of our study was to establish the diagnostic accuracy of Diffusion-Weighted MRI (DWI) as a standalone tool for differentiating benign from malignant soft tissue neoplasm if proven effective, DWI could reduce the reliance on multiphasic MRI protocols, which are time-intensive and require advanced expertise. By incorporating DWI with apparent diffusion coefficient (ADC) maps, we aim to establish a cost-effective and efficient screening and diagnostic method. DWI does not require intravenous contrast, further enhancing its affordability and accessibility while avoiding potential risks associated with contrast agents. Additionally, DWI eliminates radiation exposure, making it a safer imaging option. If its high sensitivity and specificity are established, DWI may serve a crucial function in earlier detection of malignant soft tissue masses, enabling timely and appropriate therapeutic interventions and improve the quality of patient's life.

METHODOLOGY

Following ethics committee approval (No. 181/ RC/KEMU, 25-02-2025) and informed consent, 176 patients meeting the inclusion criteria were enrolled. Sample size (n=176) was calculated using the following parameters: sensitivity of 83.3%, specificity of 72.7%, an absolute precision of 10%, an expected prevalence of 56%, and a 95% confidence level.[12] Confounding variables were controlled through exclusion criteria. Bias was minimized by using a standardized source of information and a well-structured questionnaire

Study design: Descriptive cross-sectional study.

Place and duration of Study: Radiology Department, Mayo Hospital, Lahore from January 2024 to June 2024.

Sample Selection

Inclusion Criteria

- Participants between 13 and 75 years of age, both male and female.
- Patients referred for MRI evaluation of known or clinically suspected soft tissue tumors.
- Individuals with a soft tissue mass either palpable on clinical examination or previously visualized on other imaging modalities (e.g., ultrasound, X-ray).

Exclusion Criteria

- Patients with bone lesions.
- Individuals with a known allergy to Gadolinium-based contrast agents.
- Patients with significantly impaired renal function, defined as a glomerular filtration rate (GFR) of less than 30 ml/min.
- Those with implanted medical devices or metallic hardware (e.g., pacemakers, prosthetic valves, aneurysm clips, plates), as well as individuals suffering from claustrophobia

Variables

Independent Variable

- ***Lesion Type:*** Categorized as benign or malignant, confirmed via histopathological examination.

Dependent Variables

- Age of the patient (in years)
- Gender (male or female)
- Apparent Diffusion Coefficient (ADC) value, stratified as < or > 1.1×10^{-3} mm^2/s
- Presence of calcification on imaging
- Tumor margins (regular or irregular)
- Intralesional hemorrhage or necrosis, identified on T2-weighted and post-contrast sequences
- Regional lymphadenopathy
- Involvement of adjacent neurovascular structures
- Bone involvement
- Fascia penetration
- Post-contrast enhancement patterns (e.g., homogeneous, heterogeneous, peripheral)

All enrolled patients underwent MRI Examination:

- MRI scans were performed after obtaining written, informed consent using a SIGNA VOYAGER 1.5T MRI machine. Following sequences were acquired
- T2WI TSE Axial (TR: 500, TE:132, matrix size of 352 × 224, FOV: 240 mm, and slice thickness: 5 mm),
- T2WI TSE Coronal (TR: 4500, TE: 47, matrix size of 352 × 356, FOV: 240 mm, and slice thickness: 5 mm)
- T1WI Axial (TR: 606, TE: 10, matrix size of 416 × 228, FOV: 240 mm, and slice thickness = 4 mm)
- DWI was obtained by SS-EPI (single shot spin-echo echo-planar imaging) on 0, 50, and 1000 b values (TE: 90, TR: 5500, slice thickness: 4 mm).
- T1WI with contrast in the coronal, sagittal and axial planes were acquired.

Regions of interest (ROI) was drawn in solid part of tumor excluding cystic parts. Radiant DICOM viewer software was utilized for image analysis. Quantitative ADC values were measured using the MRI machine's manufacturer-provided software. All MRI were reported by radiologists blinded to the history. Histopathological analysis of all samples was conducted by a qualified pathologist.

Entry and analysis of data was done by SPSS 20. Calculation of standard deviation and means for quantitative variables like frequency and age along with percentage of qualitative variables was obtained for gender, associated findings in soft tissue tumors on DWI & histopathology. Data was stratified for age and gender. Positive predictive value (PPV), negative predictive value (NPV), Sensitivity, specificity and diagnostic accuracy of DW-MRI were measured by a contingency table. ADC values and area under the curve ware calculated by Receiver operating characteristic (ROC) curve.

RESULTS

This study consisted of 176 patients meeting the inclusion criteria. Of these, males were 94 (53.5%) and females were 82 (46.5%). 98 patients (55.7%) were in aged 13-40 years, while 78(44.3%) were between 41-75 years. The mean age was calculated as 40.62 ± 10.13 years. DWI had sensitivity of 85.51%, specificity was 86.84%, positive predictive value (PPV) of 88.89%, negative predictive value (NPV) of 82.50% and accuracy of 85.88%. (Table No. I). Accuracy was also calculated with respect to two age groups (Table No. II).

Involvement of various adjacent structures in individual patients was also found out in our study. In thirty six patients (20.4%) size of mass was greater than 8cm. Seventy two masses (41.0%) had ill-defined margins. Calcification, Intra-tumoral hemorrhage, fascia penetration and post contrast enhancement was found in thirty (17.0%), thirty eight (21.6%), fifty eight (33%) and one hundred & fifteen (65.3%) patients respectively. Involvement of neurovascular bundle was found in forty three patients (24.4%). Regional lymphadenopathy and bone involvement were seen in ninety one (51.7%) and fifteen subjects (8.5%) respectively (Table No. III).

Table I: Diagnostic accuracy of MRI DWI in differentiating malignant from benign soft tissue tumors keeping histopathology as gold standard. n= 176

		HISTOPATHOLOGY		Total
		Positive	Negative	
DWI (MRI)	Positive for malignancy	81	10	91
	Negative for malignancy	16	69	85
TOTAL		97	79	176

Sensitivity:	a/a+c × 100	85.51%
Specificity:	d/d+b × 100	86.84%
Positive predictive value:	a/a+b × 100	88.89%
Negative predictive value:	d/c+d × 100	82.50%
Accuracy:	a+d/ a+d+b+c × 100	85.88%

Histopathological analysis revealed that 97 masses (55.3%) were malignant, while 79 masses (44.7%) were benign (Table No. IV).

Table III: MRI findings in soft tissue tumors

Sr #	MRI FINDINGS	Percentage
1	Calcification	30 (17.0 %)
2	Intratumoral hemorrhage/ necrosis	38 (21.6%)
3	Regional lymphadenopathy	91 (51.7%)
4	Involvement of bone	15 (8.5%)
5	Neurovascular involvement	43 (24.4%)
6	Size > 8cm	36 (20.4%)
7	Ill-defined margins	72 (41.0%)
8	Fascia penetration	58 (33.0%)
9	Post contrast enhancement	115 (65.3%)

Table IV: Distribution of lesion detected on histopathology n= 176

	Frequency	Percent
Positive for malignant	97	55.3
Negative for malignant	79	44.7
Total	176	100.0

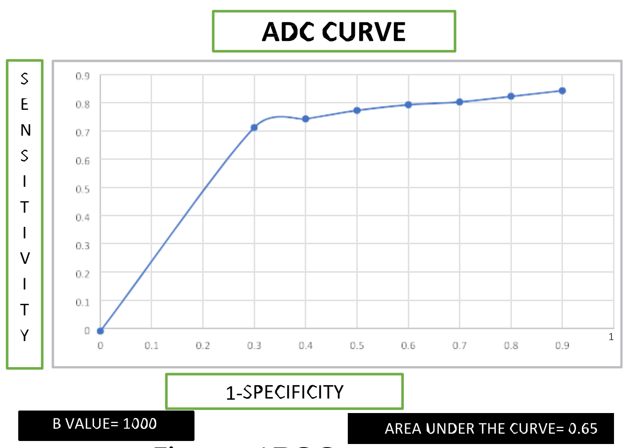

Figure: 1 ADC Curve

Table II: Diagnostic accuracy of MRI DWI in differentiating malignant from benign soft tissue tumors keeping histopathology as gold standard with respect to age n= 176

Age group			Lesion on Histopathology		Total
			Positive for malignant	Negative for malignant	
13-40 years	Lesion on MRI DWI	Positive for malignant	34(85%)	6(15%)	40(23.5%)
		Negative for malignant	7(10.9%)	51(89.1%)	58(32%)
41-75 years	Lesion on MRI DWI	Positive for malignant	47(92%)	4(8%)	51(27%)
		Negative for malignant	9(32%)	18(68%)	27(14%)
Total			97(55%)	79(45%)	176(100%)

Age group	Sensitivity	Specificity	PPV	NPV	Accuracy
13-40 years	85%	89.09%	85%	85.09%	87.37%
41-75 years	85.19%	80.95%	92%	67%	84%

Mean ADC value measuring $1.50\times10^{-3}mm^2s^{-1}$ for benign soft tissue masses was significantly greater than 0.83×10^{-3} mm^2s^{-1} that was for malignant masses. 1.1 x 10^{-3} mm^2s^{-1} was determined to be the Cut off ADC value for discriminating two types of masses11. 0.65 was the calculated area under the ADC curve. Greater the value, better the investigation is in differentiation (Figure: 1)

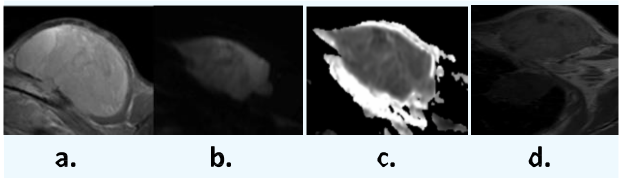

Figure 2: On Axial T2WI multi echo multiplanar spin-echo at 1.5T scanner a heterogeneously hyperintense mass was noted in left pectoralis major muscle with adjacent focal clavicular erosion **(a),** DWI and its correlative ADC at b value of 1000 revealed ADC value of 0.98×10^{-3} mm^2s^{-1} **(b,c),** Axial post contrast T1WI SE showed heterogenous enhancement and a metastatic nodule in apex of left lung **(d).**Histopathology showed spindle cell neoplasm.

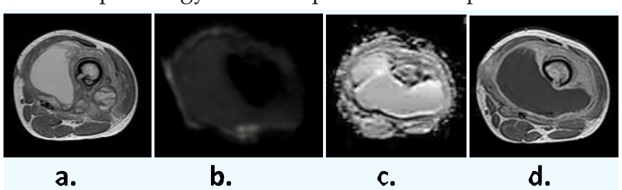

Figure 3: Axial T2WI multi echo multiplanar spin-echo at 1.5T scanner showed a well-defined hyper intense mass in left vastus intermedius and vastus medialis muscle, displacing adjacent muscles and soft tissues with edema signals (a), DWI and its correlative ADC at b value of 1000 revealed ADC value of $1.51\times10^{-3}mm^2s^{-1}$ (b,c), Peripheral enhancement was noted on axial post contrast T1WI SE (d).Histopathology showed myxoma

DISCUSSION

Origin of soft tissue sarcomas is fat, fibrous tissue, muscle, blood vessels, or other supporting tissues of the body. These tumors can occur in any region of body, though they are most commonly found in the upper limbs, lower limbs, arms, thorax or abdomen. A key clinical sign is the presence of a lump or swelling in the soft tissue. Due to the complex nature of these tumors, their management is best undertaken at specialist referral centres, where multidisciplinary teams (MDTs) can ensure comprehensive evaluation and treatment. For accurate diagnosis and effective management, immediate referral of suspicious cases is essential. Surgical treatment is the cornerstone of management, often supplemented by multimodal therapies such as chemotherapy and radiotherapy.[13]

1% of all adult neoplasms are soft tissue sarcomas, which are comparatively uncommon. They are the most common among mesenchymal masses, comprising 80% of all sarcomas. In contrast, Ewing sarcoma, osteosarcoma and chondrosarcomas, represent only 20% of sarcomas.[14] Current study showed that among 176 patients, 55.69% (n=98) were aged 13-40 years and 44.1% (n=78) were in the 41-75 years age group. Mean age was calculated as 40.62±10.13 year. 53.5%(n=94) were male whereas 46.5% (n=82) were females. In this study, our purpose was to determine the diagnostic accuracy of MRI DWI in differentiating benign from malignant soft tissue masses keeping histopathology as gold standard and we found that sensitivity and specificity of MRI DWI is 85.51% and 86.84% respectively. Another study found that the cut off level for ADC value for soft tissue tumors to be $1.1x10^{-3}$ mm^2s^{-1} with sensitivity of 83.3% and specificity of 72.7%.[11]

Soft tissue malignancies are typically painless in their early stages, with pain often only emerging in the later stages when the tumor invades adjacent structures or exerts a mass effect. This characteristic delay in symptom onset is most common factor contributing to the late presentation of patients.[15] If persistent pain is present along with swelling, they seek treatment soon. Time duration and progression of disease are crucial diagnostic factors. A lesion that has remained unchanged for decades is likely to be benign. Conversely, sarcomatous change can be evident from recent change in size. In many cases, patients may report a history of trauma, sometimes attributing their lump to a trivial injury. This can be misleading, as minor trauma may simply draw the patient's attention to a pre-existing lump. Genuine recent trauma should be accompanied by clinical evidence, such as bruising or abrasions. A lack of recovery from past injuries warrants further investigation. Infections, such as abscesses or cellulitis, often present with clear signs of inflammation, which can help differentiate them from tumors. However, a pre-existing mass can sometimes obscure the clinical picture. Aganglion should transilluminate; failure to do so should raise suspicion of an alternative diagnosis. Small, superficial lumps are more unlikely to be malignant, but larger, deep-seated masses require thorough evaluation.[16] Sarcomas are rare malignancies, occurring in approximately 2-4 cases per 100,000 individuals annually. World Health Organization (WHO) Classification of Tumours of Soft Tissue and Bone represent that these tumors encompass more than 50 subtypes categorized into bone sarcomas and soft tissue sarcomas (STS).[17] This classification is component of the “International Classification of Diseases” providing standardized nomenclature for international sarcoma centers.[18]

Soft Tissue Sarcomas account for the larger part of sarcomas, with a soft tissue tumors to bone incidence ratio of 4:1. Male-to-female ratio is 1.4:1as it is more prevalent in males, which increases to 1.9:1 in patients aged 85 years and above where the incidence reaches 230million/year[19]. Age has bimodal distribution peaking in 5th and 8th decade of life and 59 years is the mean age of diagnosis. Most common site for soft tissue tumors is extremities with 40% occurrence in limbs, more common in lower limbs (28%) predominantly thighs and less common in upper limbs (12%).[19,20] Though less common, bone sarcomas follow a similar male predominance.

Unfavourable prognostic factors are high grade mass, advanced age, large size, deep seated lesion, necrotic tumor, metastatic deposits at diagnosis, positive resection margins and local recurrence after incomplete excision.[21-23]

CONCLUSION

In the current study, diagnostic accuracy of Diffusion-Weighted Imaging (DWI-MR) was assessed for differentiation between malignant and benign soft tissue masses comparing it with histopathological findings. The results demonstrated that DWI exhibited sensitivity 85.51%, specificity 86.84%, positive predictive value (PPV) 88.89%, negative predictive value (NPV) 82.50%, and an overall diagnostic accuracy 85.88%. So we concluded that DWI is an effective and cost-efficient screening and diagnostic tool for soft tissue neoplasms. Incorporating DWI for early detection of malignant soft tissue tumors can significantly enhance patient outcomes by facilitating timely diagnosis and guiding appropriate therapeutic management, ultimately improving the quality of patient's life.

Ethical Approval: This study was approved by the Institutional Review Board (IRB) of King Edward Medical University No. 181/ RC/KEMU, dated: 25-02-2025.

Conflict of interest: None

Financial Disclosure: None

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Authors' Contributions:

ZAS & LK: Conceptualization & study design.

SI: Data Collection and manuscript drafting.

ZS: Data Analysis and critical review.

MA: Supervision &Manuscript drafting & proof reading.

All authors have read and approved the final version of the manuscript and are responsible and accountable for the accuracy and integrity of the work.

1. Zoha Arif Saeed
2. Laiba Khalid
3. Seerat Iqbal
4. Zobia Shahid
5. Maryam Afzal

1. Senior Registrar Department of Diagnostic Radiology Lahore General Hospital/ PGMI/ AMC, Lahore

2-5. Post graduate residents Department of Diagnostic Radiology KEMU/Mayo Hospital, Lahore