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ORGINAL ARTICLE

Value of Magnetic Resonance Imaging (MRI) and Diffusion Weighted Imaging (DWI) in Predicting Grade of Soft Tissue Sarcoma

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ABSTRACT

Objectives: To identify the predictive values of MRI features and apparent diffusion coefficient (ADC) measurements that can be used to discriminate high-grade from low grade soft-tissue sarcoma (STS). **Patients and methods:** In this retrospective research, patients with different histologic grades of STS diagnosed between 2018 and 2020 who had undergone MRI examination and DWI before neo-adjuvant treatment or surgery were included. STS grades (grades 1–3) were recorded from the pathologic specimens and images were evaluated for tumour location, depth, size and characteristic MRI features discriminating low-grade lesions (grade 1 and 2) from high-grade ones (grades 3). **Results:** Fifty two patients; 29 (55.7%) men and 23 (44.3 %) women with STS, 24 patients with low-grade and 28 patients with high-grade were included. The commonest pathologic type was undifferentiated pleomorphic sarcoma (n = 14), with the majority of tumors 32/52 (61.5%) were in lower extremities. There were three main MRI findings related more to high grade STS: Presence of area compatible with necrosis, tumor margins < 50 % definition and peri-tumoral enhancement, in addition to the ADC mean which was significantly lower in high-grade (0.921±0.308) than in low-grades tumors (1.24±0.414); (p = 0.0006). **Conclusion**: Our research appraises the conventional MRI findings of tumor margin definitions, amount of necrosis, and peri-tumoral enhancement in addition to ADC measurements in grading of STS with significant reliability to offer predictive data and support clinical decision making.

Keywords: MRI, DWI, ADC, Sarcoma, Tumor grade.

INTRODUCTION

Soft tissue sarcoma (STS) harbors different groups of malignant tumors that are frequently linked to high mortality risk [1,2]. Several prognostic variables have been evaluated for therapy planning and for predicting the outcome. Tumor pathological grade is one of the most significant variables in predicting the prognosis of STS patients [3–6].

In high grade STS treatment protocols, neoadjuvant chemotherapy is commonly used while in low grade tumors it is not usually included [7]. Regarding the decision of subsequent therapeutic action, determining the pathologic grade of the tumor precisely is a crucial step. The standard of care is based on the evaluation of tumor grade by percutaneous or surgical biopsy to plan therapy and decide on chemotherapy preoperatively, which serves as the reference standard for the concluding diagnosis of soft tissue malignancy [8,9].

The imaging technique of choice for assessment of soft tissue masses is MRI. Furthermore, MRI is most useful in discriminating nature of a soft tissue mass either cystic or solid and in recognizing the degree of malignancy for pre-operative arrangement and prognosis [10-12]. For staging of STS, MR-imaging is a well-established modality; primarily for the

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determination of tumour extent [13–15]. Many studies have evaluated specific types of tumours regarding the relationship between radiologic characteristics and pathologic results [16]. However, the link between MR imaging findings and histopathologic grades of STS has not been evaluated thoroughly [17]. Studies have reported that variations in peri-tumoural signal intensity and lesional growth pattern are correlated with tumour pathologic grade [18-20].

Preliminary studies have been conducted using conventional MRI to assess for tumor pathological grades (either low grades or high grades) [21,22]. Various MR imaging results have been shown to be consistent with malignancy, such as aggressive tumor margins, peri-tumoural T2WI high signal intensity, peri-tumoral enhancement, poorly defined tumour margins, larger tumours, and intra-tumoural signal compatible with necrosis [23, 24]. Peri-lesional enhancement was found to be the most reliable variable in previous studies in identifying higher tumor grades [25]. There is, however, a considerable overlap between various tumours and their pathologic grades regarding these findings.

Diffusion-weighted imaging (DWI) is a technique used to assess tumour cellularity in musculoskeletal soft tissue lesions over the past few years. The degree of diffusion of water molecules within tissues is displayed and measured by DW-imaging. Tumours with less free water content, proteinaceous material or much cellularity tend to limit diffusion greatly and vice versa. DW-imaging therefore offers functional information capable of complementing conventional MR-imaging findings [26]. Apparent diffusion coefficient (ADC) is a quantitative method used for assessment of the diffusion degree using mono-exponential or multi-exponential techniques [27]. Simple mono-exponential ADC assessment is reliable and useful in discrimination of benign versus malignant masses [28].

The selected observer-based method of ADC measurement has been shown to be equivalent to the entire measurement technique for tumor volume and has been described as the most realistic and fast method [29,30]. The assessment of such images solely without association with conventional MR images and neglecting inclusion of fibrous, fatty, infarcted, necrotic, myxoid, hemorrhagic and calcified areas in the ADC measurement are major pitfalls of DW-imaging interpretations [31]. For ideal estimation of tumor cellularity, apparently hyperintense areas on DW-imaging and equivalent hypointense areas of ADC maps or vice versa are chosen using the best-fit region of interest (ROI) [32].

The aim of this research was to appraise the MRI features that that permit distinguishing high-grade STS from low-grade ones and to find out the effectiveness of DW-imaging in the initial assessment and differentiation of STS.

PATIENTS AND METHODS

During the period between January 2018 and September 2020, this retrospective research was conducted and of 89 patients' records; 52 patients pathologically proven to be STS were included and assessed by three observers who documented the radiologic characteristics of each tumor. Patients were excluded for having non soft tissue sarcoma pathologically (n = 19), inadequate pathologic findings (n = 7), absence of available MR images prior to treatment (n = 6), and non-diagnostic image quality (n = 5). Overall mean age of patients was 59.5 years, with an age range of 39-80 years. Inclusion criteria included: Both genders, any age group and patients with upper extremity, lower extremity or trunk STS who underwent complete MR-imaging examination including conventional imaging sequences, contrast-enhanced imaging and DW-imaging prior to biopsy and surgery or neoadjuvant treatment. Renal functions tests were revised for all patients before contrast administration regarding creatinine level and GFR.

MRI scanning protocol

MRI was done on 1.5-T MR system (Philips Achieva). A uniform protocol proven for musculoskeletal tumour imaging was used including a flexible phased array body matrix coil. Conventional images (T1W, T2WI & T2W fat-suppressed images in multiple

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planes), contrast-enhanced T1-weighted imaging and DW-imaging were obtained in all cases. Parameters were as follows: T1-weighted (repetition time (TR)/echo time (TE), 580–725/8–16; section thickness, 3 mm; axial and coronal planes), T2WI & T2 fat-suppressed (FS) images (TR/TE,3500–6000/60; section thickness, 3 mm; axial & coronal planes), gadolinium-enhanced T1WI & FST1W sequences (repetition time/echo time (TR/TE), 3.8–6.4/1.2–1.3; section thickness, 1 mm; fat suppression; axial, coronal & sagittal planes; 0.1 ml/kg (0.1 mmol/kg) gadolinium-based contrast agent). Axial DW-imaging was performed prior to contrast administration using a single shot echo-planar imaging (TR/TE, 8000–12,750/68–90; section thickness, 3 mm; b values 0, 50, and 600–800 s/mm^2;flip angle, 90°; matrix, 128 × 128; fat suppression, spectral inversion recovery; time of acquisition, 5 min 10 s). The ADC value was calculated using all b values and the ADC-map was generated.

MR Image Analysis

All examinations were studied by three experienced radiologists. First, lesion location (e.g upper or lower extremity), tissue layer (superficial, deep or mixed) and tumour size (maximum linear measurement of lesion) were recorded. Next, conventional MR-imaging and ADC measurements were performed, where the following characteristics were detected on the non-enhanced scans (T1WI and T2WI): signal intensity (low signal, isointense signal, or high signal in relation to muscle signal), signal intensity heterogeneity (homogeneous or heterogeneous), and tumour margin definitions (well defined > 50 % or definition equal or less than 50 %). Tumour volume with MR-imaging signal compatible with necrosis (no area with necrotic signal, 1%–50% of tumour volume or >50% of tumour volume). The existence or lack of hemorrhagic signal, tail sign, peri-tumoural hyperintensity on T2WI and surroundings invasion, were recorded. On contrast-enhanced imaging; we assessed for the existence or lack of neurovascular encasement or occlusion, tumour enhancement, and for peri-tumoural enhancement.

The mean ADC value measurement was assessed using the best fit ROI including most of the solid compartment on a single most distinctive slice. For analysis, the slice with the lowest (darkest) ADC map was chosen. After excluding any parts of hemorrhage, as correlated with conventional MRI, the darkest area on ADC map (at least 10 mm^2) corresponding to the brightest area on DW-imaging and/or enhancing area on contrast-enhanced imaging was measured using a circular ROI method. Mean representative ADC value was recorded after three measurements.

Histopathologic Analysis

The pathologic diagnosis for each tumour was allocated by a pathologist with 20 years of experience in STS investigation. It was based on pathologic results in surgical samples from our institution in 52 patients. Lesions were categorized in consistence with the French Federation of Cancer Centers Sarcoma Group system into (grades 1–3) [33].

Statistical analysis

Data from history, clinical, laboratory and outcome measurements gathered coded, reordered, evaluated using Microsoft Excel. Data had been subsequently exported into the software for analysis in the Statistical Social Science Package (SPSS version 20.0). Several tests were used as Chi square test (X2), kappa test, t-test, ANOVA, and Pearson's correlation coefficient; P value was established at <0.05 for significant results and <0.001 for high significant outcome. In our study, grade 1 and 2 tumors were considered low-grade STS, and grades 3 were considered high-grade STS.

Ethical consideration

The protocol and informed consent forms used in this study were approved by the Institutional Review Board (IRB) of Zagazig University. All participants signed a written informed consent and filled a written survey including demographic and clinical data. The study was done according to The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

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RESULTS

Fifty two patients with STS were incorporated in the inclusion sample. The baseline features of the population sample and distribution according to analysis of the final tumor grades are illustrated in (Table 1). The final diagnoses were based on percutaneous core biopsy (30/52) and surgical histopathology (22/52). All percutaneous biopsies were image-guided (19/30 ultrasound guided and 11/30 CT guided). All MR-imaging scans were done prior to the start of any neoadjuvant therapy. There were 29/52 (55.7%) men (mean age ± SD = 57.62 ± 10.85 years) and 23/52(44.3 %) women (mean age ± SD = 64.85 ± 9.58 years).

Twenty four patients were with (grade 1-2) STS and 28 patients were with (grade 3). The pathologic types of STS were undifferentiated pleomorphic sarcoma (n = 14, three low grade), myxofibrosarcoma (n = 12, four low grade), dedifferentiated liposarcoma (n = 8, five low grade), leiomyosarcoma (n = 6, three low grade), low grade fibromyxoidsarcoma (n = 5, all low grade), myxoid/round cells liposarcoma (n = 5, three low grade) and malignant peripheralnerve sheath tumour (n = 2, one low grade).

The locations were in the upper limb (n=13), lower limb (n=32) and in the trunk (n=7). Among the 52 malignancies, 33 were located in the deep compartments, 3 in the superficial compartment and 16 were in both deep and superficial compartments and the higher-grade tumours were more likely to be deep (p = 0.27). Regarding tumour size, high-grade extremity-STS (mean size ± SD = 11.85± 3.89cm) and low-grade extremity-STS (mean size ± SD = 7.52 ± 2.14 cm).

The different descriptive statistics of MR-imaging features regard to tumour grades are illustrated in (Table 2). Regarding the tumour volume with MR-imaging signal compatible with necrosis; among the 52 patients, 25 were with no areas with necrotic signal, 18 < 50% and 9 > 50%. Intra-lesional hemorrhage was seen in 14/52 (27 %) tumours; 3 low grade and 11 high grade masses. Tumour margin, high-grade tumours were more likely to have poorly defined margins (< 50 % well defined on all non-enhanced and contrast-enhanced T1WI, P =0.048). Tail sign was seen in 23/52 of tumours (44.2 %), 8 low grade and 15 high grade masses. Peri-tumoural high signal intensity on T2WI, high-grade tumours were more likely to have peri-tumoural hyperintensity, P =0.08, and it was found to be in 40 of 52 patients (16 low grade and 24 high grade masses).

For peri-tumoural contrast enhancement, high-grade tumours displayed peri-tumoural enhancement more frequently, P = 0.14, it was seen in 29 of 52 masses (9 low grade and 20 high grade tumours). Invasion of surrounding structures (e.g. periosteum, cortex, marrow and neurovascular bundles) was more common feature in characterizing a tumor as high-grade, but rarely present, where bone invasion was seen in 4 cases only (2 low grade and 2 high grade) and neurovascular invasion was seen in 11 tumours (4 low grade and 7 high grade).

There were three main MR-imaging characteristics associated more with final grade 3 extremity-STS: peri-tumoural enhancement, presence of area compatible with necrosis and tumour margin definitions on all non-enhanced and contrast-enhanced T1-weighted images less than 50 % definition, P = 0.048).

Among the 52 scans carried out with DW-imaging with b-values of 0, 50, 600 and 800 s/mm^2, the mean ADC value was significantly lower in high-grade tumors (0.921±0.308 x 10^{-3} mm^2/s) compared to low-grade ones (1.24±0.414 x 10^{-3} mm^2/s); (p = 0.0006) on average. The ADC mean cutoff was 0.95 x 10^{-3} mm^2/s for grade 3 versus grade 1 and 2 lesions.

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Table (1): Baseline Characteristics of the Population Study and Distribution according to Final Grde:

Characteristic	Grade 1–2 (*n* = 24)		Grade 3 (*n* = 28)		P value
Age (year)	57.62± 10.85	(39–80)	64.85± 9.58	(46–79)	
Sex	N	%	N	%	0.73
Male	14	58.33%	15	53.57%	
Female	10	41.67%	13	46.43%	
Histologic type					
Undifferentiated pleomorphic sarcoma	3	12.50%	11	39.29%	0.28
Myxofibrosarcoma	4	16.67%	8	28.57%	
Dedifferentiated liposarcoma	5	20.83%	3	10.71%	
Leiomyosarcoma	3	12.50%	3	10.71%	
Myxoid/round cells liposarcoma	3	12.50%	2	7.14%	
Low-grade fibromyxoid sarcoma	5	20.83%	0	0.00%	
Malignant peripheral nerve sheath tumor	1	4.17%	1	3.57%	
Location					
Upper limb	5	20.83%	8	28.57%	0.72
Lower limb	15	62.50%	17	60.71%	
Trunk	4	16.67%	3	10.71%	
Depth					
Deep	18	75.00%	15	53.57%	0.27
Superficial	1	4.17%	2	7.14%	
Deep and superficial	5	20.83%	11	39.29%	
Size (Cm)*	7.52±2. 14	(2-10)	11.85± 3.89	(4-25)	
Biopsy					
Surgical biopsy	10	41.67%	12	42.86%	0.93
Imaging-guided biopsy	14	58.33%	16	57.14%	

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Table (2): Descriptive Statistics and Distribution of MRI Features according to Tumor Grade

Characteristic	Grade 1–2 (N=24)		Grade 3 (N=28)		P Value
Tumor volume with MRI signal compatible with necrosis	N	%	N	%	
No area with necrotic signal	16	66.67%	9	32.14%	0.018*
1%–50% of tumor volume	7	29.17%	11	39.29%	
> 50% of tumor volume	1	4.17%	8	28.57%	
Hemorrhagic signal					
No	21	87.50%	17	60.71%	0.02*
Yes	3	12.50%	11	39.29%	
Margin definitions on T1-weighted imaging					
Well-defined >50.0%	13	54.17%	9	32.14%	0.31
Well-defined ≤ 50.0%	11	45.83%	19	67.86%	
Margin definitions on T2-weighted imaging					
Well-defined >50.0%	11	45.83%	6	21.43%	0.048*
Well-defined ≤ 50.0%	13	54.17%	22	78.57%	
Margin definitions on T1-weighted imaging after gadolinium-based contrast agent injection					
Well-defined >50.0%	11	45.83%	5	17.86%	0.021*
Well-defined ≤ 50.0%	13	54.17%	23	82.14%	
Tail sign					
No	16	66.67%	13	46.43%	0.14
Yes	8	33.33%	15	53.57%	
Peritumoral edema on T2-weighted images					
No	8	33.33%	4	14.29%	0.08
Limited	10	41.67%	9	32.14%	
Extensive	6	25.00%	15	53.57%	
Peritumoral enhancement					
No	15	62.50%	8	28.57%	0.14*
Yes	9	37.50%	20	71.43%	
Bone invasion					
No	22	91.67%	26	92.86%	0.87
Yes	2	8.33%	2	7.14%	
Vessel and/or nerve encasement					
No	20	83.33%	21	75.00%	0.46
Yes	4	16.67%	7	25.00%	
ADC value ($x10^{-3}$ mm^2/s) mean± SD	1.24±0.414		0.921±0.308		0.006*

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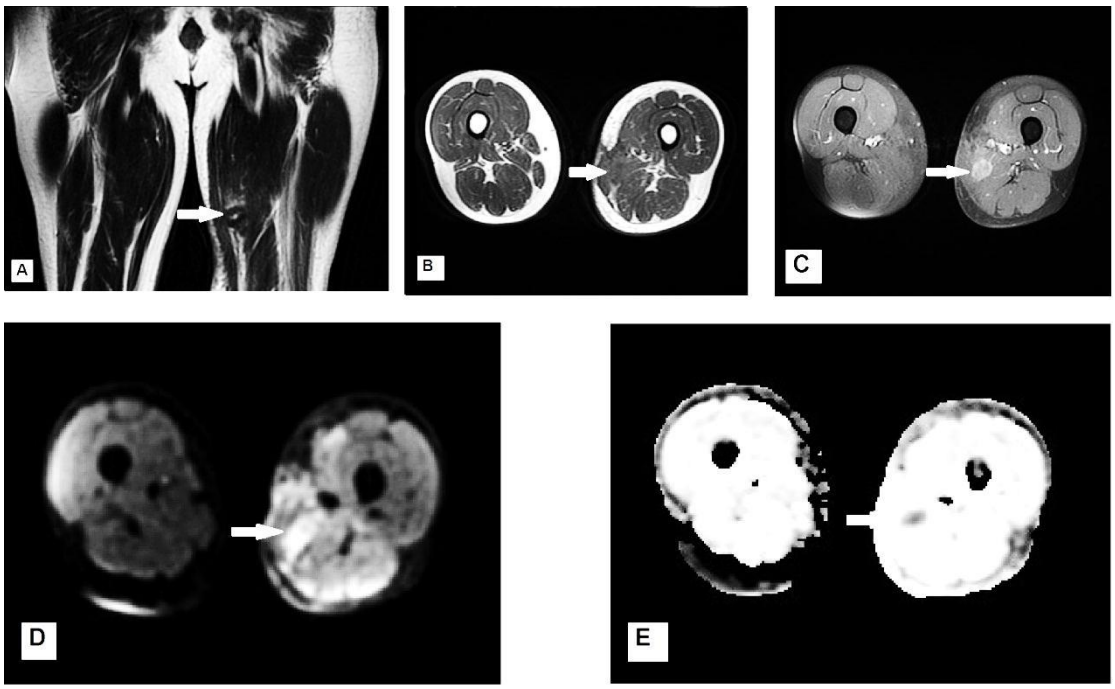

Figure (1): Male patient 43 years old with grade 1 tumor. A- Coronal T2WI shows a 28 x 25 x 24 mm left thigh mass lesion (arrow) of peripheral low signal and central high signal intensity. B- Axial T1WI shows mass of low signal intensity. No intra-tumoral hemorrhage. C- Axial post-contrast T1 fat-suppressed image shows homogenous enhancement more peripherally. No peri-tumoral enhancement. D, E- Axial DWI and ADC map images show diffusion restriction and mean ADC of $1.15x10^{-3}$ mm^2/s. Diagnosis on pathology was leiomyosarcoma after surgical excision.

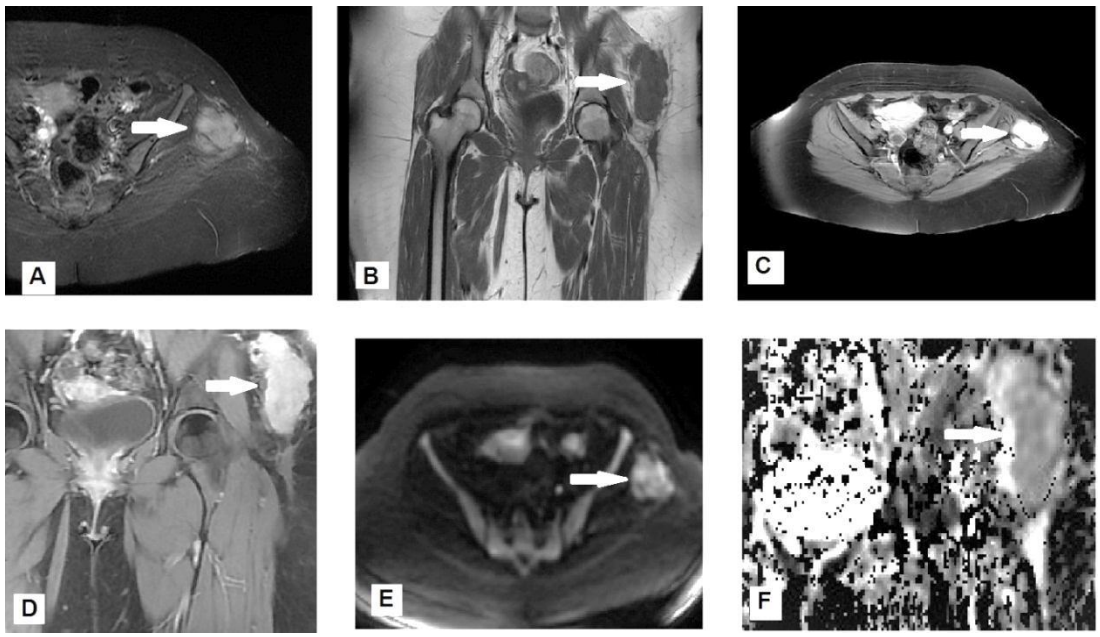

Figure (2): Female patient 48 years old with grade 2 tumor. A- Axial T2 fat-suppressed image shows a 94x54x52 mm heterogeneous left gluteal mass infiltrating left gluteus medius muscle associated with mild peri-tumoral edema. B- Coronal T1WI shows homogeneous intermediate to low signal intensity mass without hemorrhage. C,D- Axial & coronal fat-suppressed post-contrast images shows vivid homogenous enhancement. E,F- DWI and ADC map images show diffusion restriction and mean ADC of $0.9x10^{-3}mm^2/s$. Diagnosis on pathology was aggressive fibromatosis after image guided core-biopsy.

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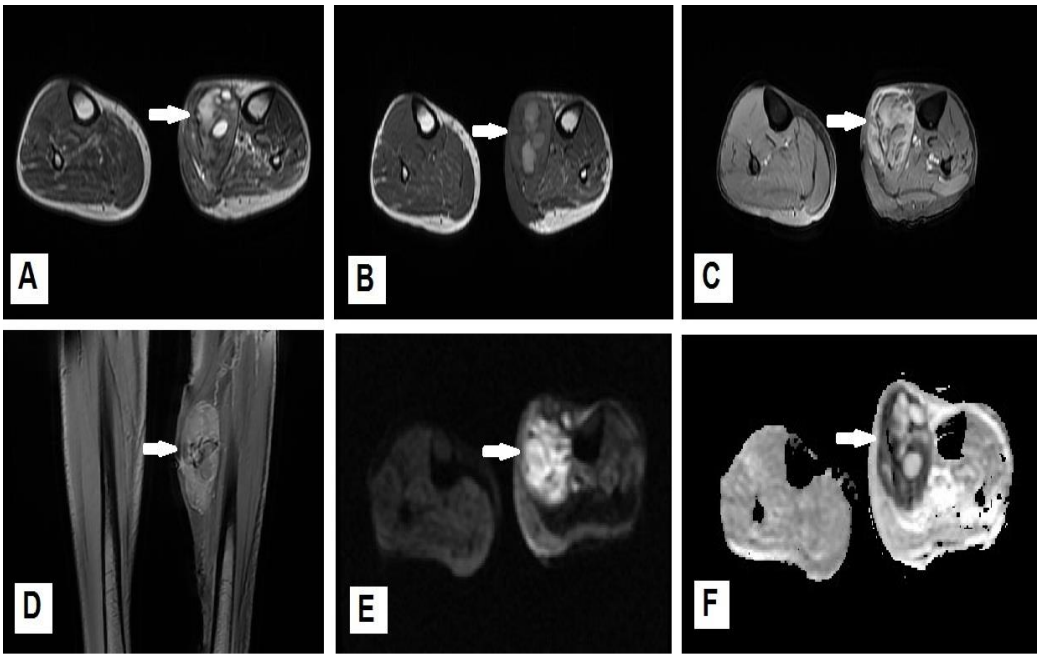

Figure (3): Male patient 51 years old with grade 3 tumor. A- Axial T2WI shows a 85x60x 55 mm heterogeneous left leg mass with mixed intermediate and hyperintense signal intensities. B- Axial T1WI shows internal areas of high signal intensity denoting hemorrhage. C,D- Axial & coronal post-contrast T1-fat suppressed images show vivid heterogeneous enhancement of solid components of the mass and mild peri-tumoral enhancement. E,F- Axial DWI and ADC map images show diffusion restriction and mean ADC of $0.8x10^{-3}mm^2/s$. Diagnosis on pathology was undifferentiated pleomorphic sarcoma (malignant fibrous histocytoma) after image guided core-biopsy.

DISCUSSION

Histopathologic grading is the most significant prognostic factor in soft-tissue sarcoma, since it plays an essential role in planning treatment strategy and is closely linked to patient's risk of metastasis and survival. A significant parameter used for the classification of patients for whom preoperative chemotherapy should be considered is the tumor pathologic grade [6,7]. Neoadjuvant chemotherapy may fit patients with high-grade extremity-STS.

We found that the main MR-imaging characteristics emerged as important predictors of tumour grade are: Tumour margin definitions at non-enhanced and enhanced imaging, a necrotic component of the tumour and peri-tumoural enhancement, in addition to ADC values which decline with rising these malignancies' grades, and it was considerably lower in grade 3 than in grade 1 or 2 masses.

Our study aimed to exhibit a thorough evaluation of the accuracy of all available MR features of STS (on non-enhanced, contrast-enhanced images and DW-imaging) for high-grade tumour prediction and identifying the most reliable predictors of high-grade lesions.

Patients with soft tissue sarcoma usually undergo MR-imaging for tumor extent evaluation at presentation and for identification of MRI features of different histologic types of soft tissue tumors. The features that can be used to discriminate benign from malignant lesions have been recognized. When the findings are indeterminate, a mass biopsy is carried out. The pathologic grade assessment is therefore the next step in determining neoadjuvant therapy when sarcoma is discovered via biopsy results. As the biopsy findings are sometimes inaccurate with respect to tumor grade, imaging characteristics that assist in high grade state prediction can be used as a complement for biopsy outcomes (when indecisive or inconsistent with MRI features) and consequent therapy. The distinguishing features of low and high grade sarcomas have been identified by a few previous investigators [8–10].

In the investigation of 59 STS, Liu et al [18] studied only non-enhanced T1WI &

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T2WI and found that the extremity-STS histologic grade was strongly related to tumor margin definition and peripheral growth pattern; high-grade tumors were found to have poorly-defined margins, while low-grade ones had well-defined margins on non-enhanced sequences. In high-grade sarcomas, peri-tumoural fluid signal intensity was more common in high grade sarcomas. Low grade ones demonstrated a low signal intensity peri-lesional capsule sign.

Our research approves the significance of the delineation of the tumor margin for the recognition of its pathologic grade. Poorly or partly defined tumour margin implies that the surrounding tissues have been infiltrated by lesion cells and demonstrates the invasive aggressive nature of the tumour. The peripheral tumor growth pattern has actually shown to be a significant predictive factor for the development of local recurrence and metastasis.

Fernebro et al [21] studied and compared peri-tumoural signal intensity changes of sarcomas at MR-imaging with pathologic findings, confirming that MRI offers valuable prognostic information about peripheral tumor growth and the risk of metastasis, although the relationship of this feature to tumour grade has not been directly assessed. As for a poorly defined margin, our study reported that peri-tumoural fluid signal intensity was significantly more common in high than in low-grade lesions.

Peri-tumoral enhancement was previously described by Zhao et al [25] as an independent predictor of high-grade sarcoma. However, for multivariable analysis in their series, heterogeneous signal intensity at T2WI, margin definition and peri-tumoural edema were not assessed. The different findings between our research and theirs can be explained by several factors including population size, high-grade tumours margin definitions and the studied MRI features. We classified high grade as grade 3 tumors based on current and published neoadjuvant studies, while they defined high grade as grades 2 and 3. Final grade was clearly defined as assessed on the whole surgical specimen. Patients with neoadjuvant therapy have been excluded because this alters tumor grade estimation. Zhao et al did not evaluate the existence of intra-tumoral necrotic areas, yet this character is now assessed and used in clinical trials.

Administration of intravenous contrast is regularly used for the evaluation of STS, the current research offers new insights that could help in the discrimination between low and high grade sarcomas. Sensitive findings associated with high-grade STS were tumor margin poor definition and peri-tumoural enhancement after contrast administration. The former results support previous studies showing elevated peripheral vascularity of malignant tumours and reveal high grade tumors to have peripheral infiltrative growth pattern [23].

A major indicator for the prognosis and distant metastases development was also found to be tumor depth [16-19]. In current study, both superficial and deep tissue layers were the seat for both low grade and high grade sarcomas. MR imaging properties of high and low-grade superficial STS were found to be not much different when independently studied. One possible explanation for similarities could be the fact that subcutaneous tumours may be identified earlier than deep lesions [14], and thus the ability of detecting high grade subcutaneous tumours earlier than those found in the deeper tissues, and the MR characteristics may not be as developed as those of deep high-grade masses [15,16].

In the study carried by Zhao et al [25], high grade tumors were associated with the following features; margin definition, peri-tumoral edema and enhancement. Other studies have found relations between the radiologic aggressive growth pattern and metastasis-free survival [17]. Moreover, our findings highlight the association between tail sign, peri-tumoural edema, enhancement and margin definitions; all these features probably reveal the tendency to spread into adjacent tissues.

This study supports that DW-imaging can be helpful in the grading of STS with rising grades of these masses, ADC values decline. The ADC mean was found to be significantly low in high-grade STS than in

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low-grade ones. However, no considerable difference detected in ADC mean between grades 1 and grade 2 lesions based on adjusted pairwise comparisons. These outcomes go along with those described for other malignancies as cancer prostate, glioma, and hepatocellular carcinoma, where ADC has been used as a reliable indicator for prediction of tumor grades [21–23]. Thus, as previously shown in literature, DW-imaging is not only valuable in distinguishing benign and malignant musculoskeletal lesions [16, 23] but also offers an insight into tumour grading.

In addition, when administration of intravenous contrast is not allowed as in cases of pregnancy, renal failure or sensitivity to contrast materials, DW-imaging may contribute to the specificity of conventional MR-imaging. DW-imaging is beneficial also in evaluating response of therapy in patients with musculoskeletal tumours that have been successfully treated with neo-adjuvant therapy showing good response and higher ADC values and ratios compared to the non-responsive ones [27, 28].

Our study has some limitations, first all pathologic types were evaluated collectively; there may be discriminating MR features between the different pathologic subtypes of sarcoma that misperceive the outcomes of this research, but a subgroup investigation could not be done with the number of patients that had specific pathologic entities in this research. Second, since tumor grade characterization in patients with known STS was the principle of our study, these research outcomes should not be generalized to all patients with unspecified soft-tissue mass; benign soft-tissue masses with aggressive characteristics, such as myositis ossificans, may share MRI characteristics that resemble high-grade sarcomas, but our research goal was not to differentiate between benign and malignant soft-tissue lesions. Lastly, this research was a single-center study that may have contributed to bias in selection.

In conclusion, our research appraises the conventional MRI findings of tumor margin definitions, amount of necrosis, and peri-tumoral enhancement in addition to ADC measurements in grading of STS with significant reliability to offer predictive data and support clinical decision making.

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