Original Article

JHSMR Journal of Health Science and Medical Research

Correlation of MRI Characteristics with the Histologic Grade of Soft Tissue Sarcoma of the Extremities and Trunk

Teeranan Laohawiriyakamol, M.D.[1], Thunyarat Wiwattnapusit, M.D.[1], Pramot Tanutit, M.D.[1], Wisitsak Pakdee, M.D.[1], Pakjai Tuntarattanapong, M.D.[2], Pattira Boonsri, M.D.[1]

[1]Department of Radiology, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand.
[2]Department of Orthopedics, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand.

Received 25 December 2024 ● Revised 5 June 2025 ● Accepted 10 June 2025 ● Published online 11 September 2025

Abstract:

Objective: The staging and treatment of soft tissue sarcoma depend on the histologic grades, which predicts overall survival. This study aimed to assess magnetic resonance imaging (MRI) characteristics to differentiate between low- and high-grade soft tissue sarcomas of the extremities and trunk.

Material and Methods: This retrospective study included patients with soft tissue sarcomas who underwent preoperative MRI between October 2006 and December 2020. The data obtained included qualitative information (size, depth, MRI signal intensity, hemorrhage signal, margin, fascial tail sign, peritumoral edema/enhancement, and organ involvement) and quantitative information (apparent diffusion coefficient value). Logistic regression was performed to identify the MRI characteristics associated with histologic grades.

Results: A total of 101 patients were included; 76 were diagnosed with histologically high-grade tumors. The final multivariate regression model showed a combination of 4 MRI characteristics: a large area of intratumoral heterogeneity on T2-weighted images (T2W), a large area of non-enhancing hyperintensity on T2W, a fascial tail sign, and peritumoral edema. These characteristics collectively predicted high-grade soft tissue sarcoma with 81% accuracy. The 2 strongest indicators were intratumoral heterogeneity on T2W (adjusted odds ratio (aOR) 3.96, 95% confidence interval (95% CI) 1.16-13.55, p-value=0.028) and a fascial tail sign (aOR 3.34, 95%CI 1.09-10.22, p-value=0.035).

Conclusion: The 2 strongest MRI predictors of high-grade soft tissue sarcoma are marked intratumoral heterogeneity on T2W and a fascial tail sign. Furthermore, the combination of 4 MRI characteristics, including marked intratumoral heterogeneity on T2W, a fascial tail sign, non-enhancing hyperintensity on T2W, and peritumoral edema, can increase the accuracy of histologic grade prediction.

Contact: Pattira Boonsri, M.D.
Department of Radiology, Faculty of Medicine, Prince of Songkla University,
Hat Yai, Songkhla, 90110, Thailand.
E-mail: bpattira@medicine.psu.ac.th

J Health Sci Med Res
doi: 10.31584/jhsmr.20251249
www.jhsmr.org

Keywords: histologic grade, magnetic resonance imaging, soft tissue sarcoma

Introduction

Soft tissue sarcomas originate from mesenchymal cells, which can differentiate into adipose tissue, muscle, vessels, and other connective tissues[1]. Sarcomas are rare, with an incidence of approximately 1% of all adult malignancies. More than 50 types of soft tissue sarcomas occur in the extremities (43%), trunk (10%), viscera (19%), retroperitoneum (15%), and head and neck (9%)[2]. The etiology of sarcomas remains unknown; however, the risk factors for soft tissue sarcoma include genetics (e.g., neurofibromatosis type I and Le Fraumeni syndrome), exposure to chemical substances (e.g., arsenic and vinyl chloride), and radiotherapy.

The diagnostic process for soft tissue sarcoma consists of history-taking, physical examination, magnetic resonance imaging (MRI), and histology from tissue biopsy. Histology is the gold standard for diagnosis and treatment planning[3]. The histologic grading system by Federation Nationale des Centres de Lutte Contre le Cancer (FNCLCC) consists of 3 grades according to histologic type, tumor necrosis, and mitotic activity[4]. The histologic grade is an essential indicator of prognosis and metastatic risk, with a lower grade predictive of a lower rate of metastasis and recurrence than a higher grade[5].

Treatment planning depends on Tumor-Node-Metastasis (TNM) classification staging, which is developed and maintained by the American Joint Committee on Cancer (AJCC) and Union for International Cancer Control (UICC), as well as histologic grading[6]. High-grade soft tissue sarcoma, which is categorized by TNM staging as histologic grades 2 and 3, requires surgery combined with pre-/or post-operative radiotherapy and/or chemotherapy because of the high recurrence rate. The tumor recurrence rate, ranging from approximately 25% to 50%, depends on the tumor size.

A palpable mass and compressive symptoms drive patients to seek medical treatment, so the size of the lesion tends to be quite large by the time it is investigated. Large tumors usually exhibit inhomogeneity with scattered necrotic and hemorrhagic content; thus, the biopsied tissue and its corresponding grade may not necessarily represent the most invasive part of the lesion. The purpose of this study was to investigate significant characteristics on MRI that may predict or correlate with the histologic grade of soft tissue sarcoma.

Material and Methods

Study design

This retrospective, cohort study was conducted at a single center. It was performed in accordance with the Declaration of Helsinki and approved by the Human Research Ethics Committee (HREC) of the Faculty of Medicine, Prince of Songkla University (Approval number REC 63-115-7-4). Informed consent was waived due to the retrospective nature of the study.

The list of patients with soft tissue sarcoma of the trunk and extremities who had available histology and underwent MRI between October 2006 and December 2020 was retrieved from the database. MR imaging was available for interpretation using Synapse. Two musculoskeletal radiologists (13 and 20 years of experience in musculoskeletal expertise) interpreted the images independently.

Patients

The patients were selected from the hospital database according to the following inclusion and exclusion criteria.

The inclusion criteria were (1) first diagnosis of soft tissue sarcoma in the extremities or trunk in patients aged

15 years or older; (2) no history of previous soft tissue sarcoma; (3) non-metastatic stage; (4) available histologic grading by the FNCLCC system; and (5) MRI performed before tissue biopsy. The exclusion criteria were (1) soft tissue sarcoma of the head, neck, or retroperitoneum because of the different treatments and outcomes for these conditions, (2) insufficient imaging data, and (3) preoperative MRI performed more than 3 months before the surgery.

Of the 109 patients with available histology and MRI data, we excluded 4 patients with head and neck soft tissue sarcomas and 4 patients with insufficient imaging data. The information of the included patients was reviewed, including patient characteristics (sex and age), and histologic type and grade (FNCLCC). In our study, the FNCLCC histologic grade was classified as low (grade 1) or high (grade 2-3)[6]. All the soft tissue sarcomas were graded as high or low by 5 pathologists.

Magnetic resonance imaging

As this study was conducted at a referral center, 2 different MR system strengths (1.5 Tesla and 3 Tesla) were used for imaging. Adequate MRI protocols included the following pulse sequences: T1-weighted, T2-weighted, fluid-sensitive sequences, and T1-weighted after gadolinium injection with fat suppression. The ranges of repetition and echo time were 500–800 msec and 10–15 msec for T1-weighted sequences, and 2,400–4,600 msec and 70–130 msec for T2-weighted sequences, respectively. The field of view covered the entire tumor.

All images were independently reviewed by 2 experienced musculoskeletal radiologists. A consensus was reached through discussion in the event of disagreement. Several MRI characteristics were investigated, including tumor size (greatest dimension measuring less than 5 cm, 5–10 cm, or more than 10 cm), depth of tumor (location superficial or deep to muscle fascia), heterogeneous signal intensity on T1-weighted images, T2- weighted images, and T1-weighted images after gadolinium injection (less than 50% and more than 50%), non-enhancing hyperintensity on T2-weighted images (absent, less than 50%, and more than 50%), hemorrhage (absent, less than 50%, and more than 50%), tumor margin (well-defined more than 90%, 50–90%, and less than 50% on T2- weighted images), presence or absence of a fascial tail sign (presence of extensive abnormal signal around soft tissue tumor along the fascial, neurovascular bundle or musculature plane on fluid sensitive sequence or T1-weighted images after gadolinium injection), peritumoral edema (on fluid-sensitive sequence), peritumoral enhancement (on T1-weighted images after gadolinium injection), bone invasion (presence of the contact between tumor with bone and cortical and/or medullary changes on T1- weighted images or T1-weighted images after gadolinium injection), vessel/nerve involvement (the contact between tumor and vessel/nerve circumference exceeds 180 degree on T2- weighted images or T1-weighted images after gadolinium injection). For the evaluation of heterogeneous signal intensity on T1-weighted, T2-weighted, and T1-weighted images following gadolinium injection, the radiologists were allowed to scroll through the entire set of images and used visual estimation to determine if the heterogeneity of the signal was less than or greater than 50%. The quantitative value was the apparent diffusion coefficient (ADC). The ADC value was quantitatively measured in both small and large areas using diffusion-weighted imaging (DWI). The large area was designated by the radiologist by manually drawing the region of interest (ROI) covering the entire tumor on a single axial slice where the tumor seemed to have the most DWI restriction. For the small area, an ROI measuring approximately 50 mm^2 was created in the region of the greatest tumoral DWI restriction, regardless of its relation to the large area of measurement. The DWI protocol included low (~ 50 s/mm^2) and high (~ 800 s/mm^2) b values.

Data were recorded using EpiData3.1. Statistical analyses were performed with R software version 4.4.1. Normally distributed data are presented as mean+/- S.D., and non-normally distributed data as median (interquartile range). Nonparametric tests were used for categorical variables. Continuous variables were compared using the Wilcoxon or Student t-test, depending on the Shapiro-Wilk normality test. The chi-square or Fisher test was used to examine any significant difference in the MRI features of high- and low-grade sarcomas. The bivariate analysis was calculated for each feature. A multivariable binary logistic regression was used to identify independent predictors of high-grade soft tissue sarcoma. The receiver operating characteristics (ROC) curves were constructed for the statistically significant MRI features. The area under the curve (AUC) was calculated. Sensitivity and specificity were reported. The kappa statistics were used to test interrater reliability (less than 0.2 poor, 0.2-0.4 fair, 0.41-0.6 moderate, 0.61-0.8 substantial, greater than 0.8 almost perfect).

Results

Of 101 patients, there were 54 males and 46 females. The average age of the patients was 51.8±28.8 years. The detailed histological types and grades of the soft tissue sarcomas are shown in Table 1. The average time between the MRI and surgery was 41±31 days.

There were 25 patients with grade 1 soft tissue sarcoma, 31 with grade 2 soft tissue sarcoma, and 45 with grade 3 soft tissue sarcoma. The grade 2 and 3 histologic types were grouped as high-grade soft tissue sarcomas (N=76), while the grade 1 histologic type was classified as a low-grade soft tissue sarcoma (N=25). There was no significant difference among the different histologic grade groups for age (p-value=0.763) or sex (p-value=0.104) (Table 2).

Table 3 summarizes the descriptive statistics for MRI characteristics, detailed by tumor grade. In bivariate analysis, 6 MRI characteristics had strong associations (p-value<0.05) with high-grade soft tissue sarcoma, including a large area of intratumoral heterogeneity on T2-weighted images (p-value=0.001), intratumoral hemorrhage (p-value=0.007), poorly defined margin (p-value=0.03), fascial tail sign (p-value=0.004), peritumoral edema (p-value<0.001), and peritumoral enhancement (p-value=0.008).

A crude selection of MRI characteristics from the bivariate analysis (p-value<0.2) was exported for stepwise regression analysis. The final multivariate regression model (Table 4) consisted of 4 MRI characteristics associated with high-grade soft tissue sarcoma, i.e., marked intratumoral heterogeneity on T2-weighted images, a large area of non-enhancing hyperintensity on T2-weighted images, a fascial tail sign, and peritumoral edema. The 2 strongest indicators were intratumoral heterogeneity on T2-weighted images (adjusted odds ratio [OR] 3.96, 95% CI 1.16-13.55, p [Wald's test] 0.028) and the fascial tail sign (adjusted odds ratio [OR] 3.34, 95% CI 1.09-10.22, p [Wald's test] 0.035) (Figures 1.1, 1.2 and 1.3).

To improve the diagnostic accuracy and applicability of MRI in predicting high-grade soft tissue sarcoma, a combination of these 4 MRI features was found to have an accuracy of approximately 81% (AUC=0.814) (Figure 2). If only 2 significant MRI features (heterogeneous signal intensity on T2WI and presence of fascial tail sign) from multivariate analysis were combined, the sensitivity and the specificity were 70% and 76%, respectively.

For quantitative analysis of the ADC values, only 23 of 101 cases (7 cases of grade 1, 6 cases of grade 2, and 10 cases of grade 3) included DWI in the protocol. The average ADC values measured in the large areas of low- and high-grade soft tissue sarcomas were 1637.1±726.7 $x10^{-6}$ mm^2/s

Table 1 Descriptive statistics of histologic type according to tumor grade

Histologic type	Frequency (%)	Low grade (%)	High grade (%)
Liposarcoma	28 (27.7)	12 (48)	16 (21)
Well-differentiated liposarcoma	9		
Dedifferentiated liposarcoma	7		
Pleomorphic liposarcoma	6		
Myxoid liposarcoma	6		
Leiomyosarcoma	6 (5.9)	0 (0)	6 (7.9)
Malignant spindle cell sarcoma	12 (11.9)	2 (8)	10 (13.2)
Undifferentiated pleomorphic sarcoma	13 (12.9)	1 (4)	12 (15.8)
Malignant nerve sheath tumor	10 (9.9)	1 (4)	9 (11.8)
Myxofibrosarcoma	4 (4.0)	2 (8)	2 (2.6)
Myxoid sarcoma	2 (2.0)	1 (4)	1 (1.3)
Myxoid inflammatory fibrosarcoma	1 (1.0)	0 (0)	1 (1.3)
Pleomorphic rhabdomyosarcoma	1 (1.0)	0 (0)	1(1.3)
Pleomorphic spindle cell sarcoma	1 (1.0)	0 (0)	1 (1.3)
Pleomorphic sarcoma	4 (4.0)	0 (0)	4 (5.3)
Synovial sarcoma	11 (10.9)	0 (0)	11 (14.5)
Undifferentiated spindle cell sarcoma	1 (1.0)	0 (0)	1 (1.3)
Alveolar part of sarcoma	1 (1.0)	1 (4)	0 (0.0)
Dermatofibrosarcoma	1 (1.0)	1 (4)	0 (0.0)
Fibromyxoid sarcoma	3 (3.0)	3 (12)	0 (0.0)
Epithelioid sarcoma	1 (1.0)	0 (0)	1 (1.3)
Fibrosarcoma	1 (1.0)	1 (4)	0 (0.0)
Histologic grade	**Frequency (%)**	**Low grade (%)**	**High grade (%)**
Grade 1	25 (24.8)	25 (24.8)	
Grade 2	31 (30.7)		76 (75.2)
Grade 3	45 (44.6)		

Table 2 Descriptive statistics of age and sex according to tumor grade

	Low grade (%)	High grade (%)	p-value
Age (years)*	52.2 (17.6)	51 (16.3)	0.763
Sex			0.104
Male	9 (36.0)	45 (59.2)	
Female	16 (64.0)	31 (40.8)	

*Data are presented as means with standard deviations in parentheses

and 1602.2±543.7 x10^{-6} mm^2/s, respectively. Furthermore, the average ADC values measured in the small areas were 1357.4±752.7 x10^{-6} mm^2/s and 1052.5±399.6 x10^{-6} mm^2/s in low- and high-grade soft tissue sarcomas, respectively (Figure 1.4). There were no significant differences in ADC values between low-grade and high-grade soft tissue sarcomas measured by large (p-value=0.89) or small (p-value=0.21) areas.

The interobserver agreements of the MRI characteristics were slight to substantial, with the range of kappa values varying from 0.10–0.78. The best kappa coefficient corresponded with the location of the soft tissue tumor, and the lowest kappa coefficient was seen for heterogeneous signals on the T1-weighted image after gadolinium injection. Statistical analysis was based on the interpretation of images agreed upon by both radiologists.

Table 3 Bivariate analysis of MRI characteristics of low- and high-grade soft tissue sarcoma

	Low grade (%)	High grade (%)	p-value	Kappa value
Total	**25**	**76**		
Size			0.422	0.785
Less than 5 cm	1 (4)	9 (11.8)		
5–10 cm	10 (40)	23 (30.3)		
More than 5 cm	14 (56)	44 (57.9)		
Depth			0.425	0.812
Superficial	2 (8)	7 (9.2)		
Deep	20 (80)	51 (67.1)		
Superficial and deep	3 (12)	18 (23.7)		
Heterogeneous signal on T1WI			0.072	0.585
Less than 50%	18 (72)	37 (48.7)		
More than 50%	7 (28)	39 (51.3)		
Heterogeneous signal on T2WI			0.001*	0.557
Less than 50%	11 (44)	9 (11.8)		
More than 50%	14 (56)	67 (88.2)		
Heterogeneous signal on T1WI post gadolinium			0.706	0.193
Less than 50%	3 (12)	7 (9.2)		
More than 50%	22 (88)	69 (90.8)		
Non-enhancing hyperintensity on T2-weighted image			0.057	0.462
Absent	14 (56)	31 (40.8)		
Less than 50%	6 (24)	38 (50)		
More than 50%	5 (20)	7 (9.2)		
Hemorrhage			0.007	0.449
Absent	16 (64)	24 (31.6)		
Less than 50%	9 (36)	40 (52.6)		
More than 50%	0 (0)	12 (15.8)		
Well-defined margin			0.030	0.315
More than 90%	16 (64)	26 (34.2)		
50–90%	8 (32)	45 (59.2)		
Less than 50%	1 (4)	5 (6.6)		
Tail sign			0.004	0.375
Absent	14 (56)	17 (22.4)		
Present	11 (44)	59 (77.6)		
Peritumoral edema			<0.001*	0.556
Absent	10 (40)	6 (7.9)		
Present	15 (60)	70 (92.1)		
Peritumoral enhancement			0.008	0.667
Absent	11 (44)	12 (15.8)		
Present	14 (56)	64 (84.2)		
Bone invasion			0.727	0.467
Absent	23 (92)	67 (88.2)		
Present	2 (8)	9 (11.8)		
Vessel and nerve involvement			1	0.457
Absent	15 (60)	47 (62.7)		
Present	10 (40)	28 (37.3)		
ADC (large area)			0.899	NA
Mean (S.D.)	1637.1 (726.7)	1602.2 (543.7)		
ADC (small area)			0.214	NA
Mean (S.D.)	1357.4 (752.7)	1052.5 (399.6)		

*Presence of significant difference, S.D.=standard deviation

Table 4 Multivariate logistic regression analysis of MRI characteristics of low- and high-grade soft tissue sarcoma

	adj. OR (95% CI)	p-value (Wald's test)
Heterogeneous signal on T2WI		
: More than 50% vs. less than 50%	3.96 (1.16, 13.55)	0.028
Non-enhancing hyperintensity on T2-weighted image		
: Absent vs. less than 50%	1.9 (0.56, 6.38)	0.3
: Absent vs. more than 50%	0.29 (0.06, 1.38)	0.122
Tail sign		
Present vs. absent	3.34 (1.09, 10.22)	0.035
Peritumoral edema		
Present vs. absent	3.48 (0.9, 13.44)	0.07

adj. OR=adjusted odds ratio, 95% CI=95% confidence interval

Discussion

The present study assessed the MRI characteristics of soft tissue sarcomas of the extremities and trunk that correlate with, and may potentially predict, histologic grade based on the FNCLCC system. Histologic grade is not only essential for staging soft tissue sarcoma, but it also predicts the risk of metastasis and overall survival, leading to appropriate treatment planning. The AJCC recommendations bifurcate the 3 grades of soft tissue sarcoma in FNCLCC into low- (grade 1) and high-grade (grades 2 and 3). The primary treatment for low-grade soft tissue sarcoma is wide surgical resection because the risk of metastasis is considered low enough that chemotherapy can be avoided. In contrast, the treatment for high-grade soft tissue sarcoma is surgery with an appropriate margin in conjunction with pre- or post-operative radiation therapy with or without adjuvant chemotherapy[6].

The majority of patients in our study had high-grade soft tissue sarcoma, which is a trend also seen in previous studies in the literature (ranging from 83–88%)[7–9]. The most common histological type of soft tissue sarcoma in our study was liposarcoma, similar to that reported by Crombe et al.[7].

Our study comprehensively assessed all available qualitative and quantitative MRI features to identify factors that may help distinguish between low- and high-grade soft tissue sarcomas. We ultimately developed a model that combined 4 MRI characteristics (marked intratumoral heterogeneity on T2-weighted images, a large area of non-enhancing hyperintensity on T2-weighted images, the presence of a fascial tail sign, and peritumoral edema) that best predicted high-grade soft tissue sarcoma, with an accuracy of 81%. The two strongest indicators in this model were marked intratumoral heterogeneity on T2-weighted images and the presence of a fascial tail sign.

According to the most recent studies[7,8,10], which included a variety of histologic grading groups, the MRI feature reportedly associated with histologic high grades in all studies was intratumoral heterogeneity on T2-weighted images. Importantly, this was the strongest predictor in the present study as well. The heterogeneity of soft tissue can be explained by the presence of histologic and cell type variations[7,8,11]. In addition to the solid component of the tumor, necrosis and hemorrhage are responsible for the macroscopic heterogeneity observed on MRI. The rapid growth of malignant tumors outpaces the blood supply, resulting in hypoxia and nutrient imbalance, which leads to central necrosis[12]. Increased necrosis is pathologically proven in high-grade soft tissue sarcoma[13]. Instead of necrosis, our study used the term "non-enhancing hyperintensity on the T2-weighted component" to recognize the limited ability to differentiate tumoral necrosis from cystic or myxoid components without delayed enhanced images. Xiang et al.[9]. quantitatively evaluated intratumoral heterogeneity using an MRI histogram and found different histogram parameters in post-contrast enhancement images (necrosis) corresponding to different soft tissue sarcoma grades. Therefore, quantitative evaluation may provide further information.

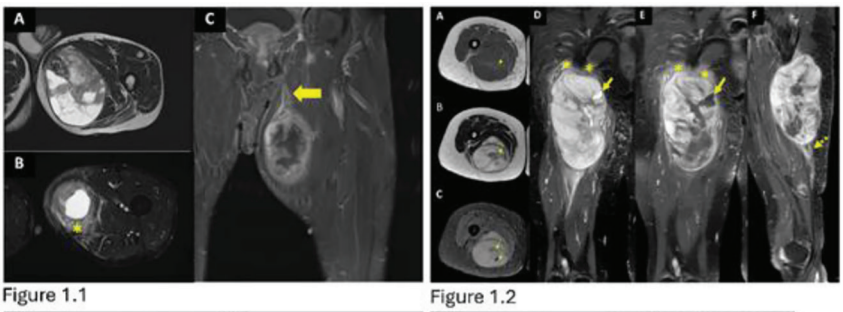

Figure 1.1 Figure 1.2

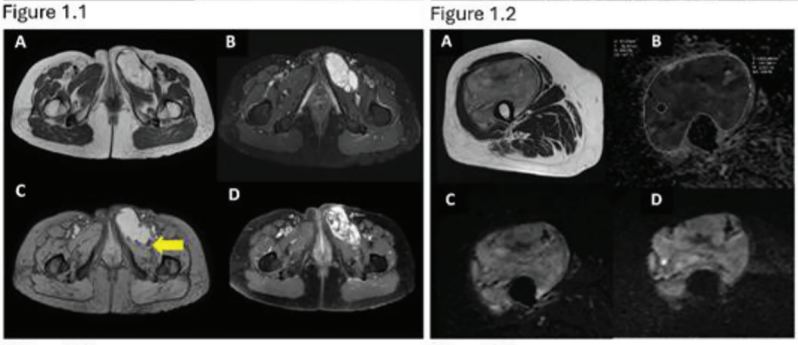

Figure 1.3 Figure 1.4

Figure 1 **Figure 1.1** MRI of high-grade soft tissue sarcoma. Images from a 57-year-old man with grade 3 deep intramuscular sarcoma proven to be leiomyosarcoma. (A) Axial T2-weighted image at the mid-aspect of the tumor shows heterogeneous signal intensity on T2-weighted images of more than 50%. (B) Axial STIR image of the inferior aspect of the tumor showing peritumoral edema (asterisk). (C) Coronal contrast-enhanced T1-weighted image with fat suppression showing fascial tail sign (arrow) and central area of non-enhancing hyperintensity on T2-weighted image, possibly indicating necrosis.; **Figure 1.2** MRI of high-grade soft tissue sarcoma. Images of a 66-year-old female with grade 3 deep intramuscular sarcoma proven as myxofibrosarcoma. These images show rather well-defined heterogeneous signal intensity on T1- and T2-weighted images more than 50%, with internal hemorrhage, necrosis, heterogeneous enhancement, peritumoral edema-enhancement, and fascial tail sign. (A) Axial T1-weighted image (B) Axial T2-weighted image and (C) Axial GRE show a heterogeneous hypo-hypersignal intensity mass with rather circumscribed margin in adductor muscles with internal hemorrhage (thin arrow). (D) Coronal STIR and (E) Coronal contrast-enhanced T1-weighted image with fat suppression shows area of non-enhanced hypersignal intensity on T2-weighted image; possibly necrosis (thick arrow). Peritumoral edema-enhancement is noted at the superior aspect of the mass (asterisk). (F) Sagittal contrast-enhanced T1-weighted image with fat suppression shows fascial tail sign (dash arrow).; **Figure 1.3** MRI of low-grade soft tissue sarcoma. Images from a 66-year-old woman with grade 1 deep intramuscular myxofibrosarcoma. (A) Axial T2-weighted image showing a heterogeneous hyperintensity of less than 50%. (B) Axial T2-weighted image showing fat suppression and no peritumoral edema. (C) Axial GRE showing the area of hemorrhage at the periphery of the tumor (arrow). (D) Axial contrast-enhanced T1-weighted image showing heterogeneous enhancement with fat suppression.; **Figure 1.4** MRI of high-grade soft tissue sarcoma (DWI and ADC). Images from a 54-year-old woman with grade 3 deep intramuscular sarcoma in the right vastus muscles, proven as undifferentiated pleomorphic sarcoma. (A) Axial T2-weighted image showing heterogeneous hyperintensity of >50%. (B) ADC values measured using small and large ROI. (C) Low b-value and (D) high b-value DWI images showing tumor restriction.

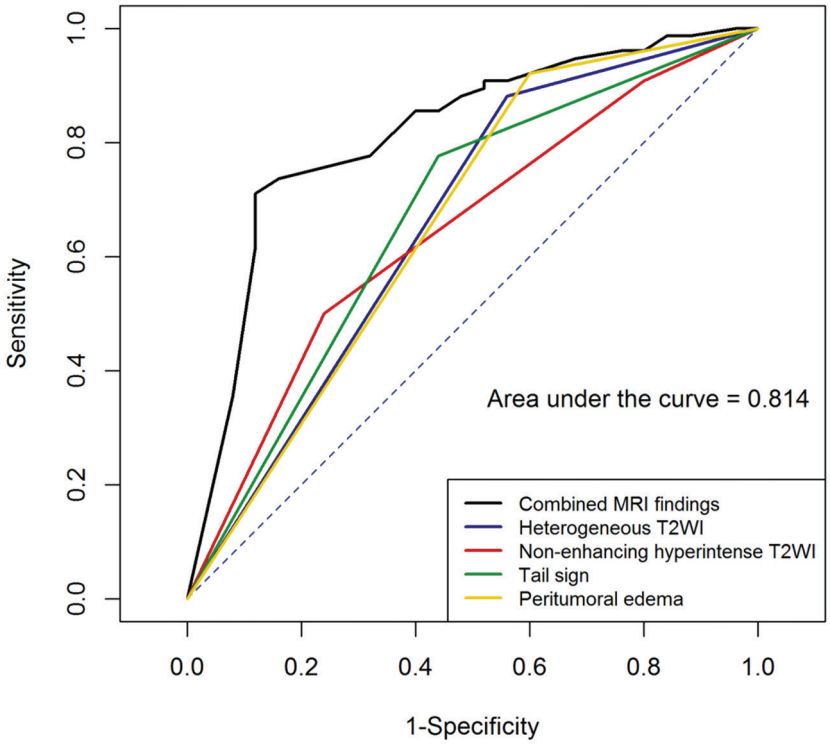

Figure 2 Area under the curve of multivariate logistic regression

Another notable MRI feature in our study was the fascial tail sign, which was also reported by Crombe et al.[7]. The fascial tail sign, characterized by a thick fascial enhancement extending from the tumor, is histologically proven to represent extensive tumor cell infiltration[14,15]. The fascial tail sign can be found in superficial and deep-seated soft tissue sarcomas, and is usually associated with myxofibrosarcoma and undifferentiated pleomorphic sarcoma. However, it has also been associated with other types of sarcoma[15]. The presence of a fascial tail sign is also important in surgical planning because it is associated with a higher risk of local recurrence[10].

In our study, the final model of MRI characteristics related to high-grade soft tissue sarcomas included peritumoral edema. Peritumoral edema was also associated with high-grade soft tissue sarcoma in a univariate analysis by Zhao et al.[8]. Notably, however, Zhao et al. reported that the strongest indicator in their study was peritumoral enhancement, which was found to be significant in the bivariate analysis, but not in the multivariate analysis, in our study. Changes in the peritumoral signal intensity reflect an infiltrative peripheral growth pattern of the tumor[16]. We hypothesize that changes to peritumoral edema are observed before peritumoral enhancement takes place. One possible explanation for this is that the soft tissue mass may compress normal vascular drainage, resulting in regional fluid stasis or bland edema seen on MRI, which initially exhibits no vascular enhancement. However, as the tumor continues to enlarge and becomes vascularized, capillary permeability will be disturbed, inevitably resulting

in peritumoral enhancement. Even though the majority of tumors in our study and the study by Zhao et al.[8]. were high-grade, the exact percentage of high-grade soft tissue sarcoma in our study was slightly lower than that reported by Zhao et al. (75% vs. 83%). Another potential explanation is based on a previous finding that two-thirds of histologically confirmed cases of peripheral tumor infiltration could not be identified by MRI[17]. Thus, some cases with peritumoral edema may have had tumoral infiltration that did not lead to enhancement on MRI.

Corino et al.[18] showed the potential of radiomics analysis based on DWI to differentiate between intermediate- and high-grade soft tissue sarcomas. We tried to extract information on tumoral diffusivity by measuring the ADC value; however, there was no statistical difference between the low and high grades. The available MRI information on the ADC value comprised only 20% of the cases in our study cohort. Previously, the basic soft tissue tumor protocol did not routinely include DWI.

A recent systematic review on the grading of soft tissue sarcoma using MRI by Schmitz and Sedaghat[19] also included several MRI features similar to ours. They found that various MRI characteristics, such as tumor size, necrosis, peritumoral edema/contrast enhancement, and multilobulated tumor configuration, may indicate the malignancy grade of soft tissue sarcoma.

Our study has several limitations. As this was a retrospective study, there was variation in the MRI protocol. Second, there was a relatively small proportion of low-grade soft tissue sarcomas (25% of all cases, and most of them were liposarcomas); however, previous studies showed similar proportions[7–9], reflecting the usual epidemiology. Third, interobserver agreements on the MRI characteristics were slight, with the least agreement observed in interpreting heterogeneous tumoral enhancement. This discrepancy can be explained by the qualitative nature of these features. In the future, this limitation may be resolved by replacing quantitative measurements with machine-learning technology.

Conclusion

The 2 strongest predictors of high-grade soft tissue sarcoma are marked intratumoral heterogeneity on T2-weighted images and the presence of a fascial tail sign. Furthermore, the combination of the 4 MRI characteristics, including marked intratumoral heterogeneity on T2-weighted images, a fascial tail sign, non-enhancing hyperintensity on T2-weighted images, and peritumoral edema, may improve the accurate prediction of histologic grading.

Ethics approval and consent to participate

The Human Research Ethics Committee (HREC) of the Faculty of Medicine, Prince of Songkla University approved the research (Approval number REC 63-115-7-4), and the written informed consent was waived (approved by the same Ethics Committee) because this was a retrospective study and the analysis of anonymous clinical data.

Authors' contributions

Conceptualization, P.T., T.W., T.L., Pa.T., W.P., and P.B.; investigation, T.W., T.L., and P.B.; methodology, P.T., Pa.T., W.P., and P.B.; writing – original draft preparation, T.W. and P.B.; writing – review & editing, P.T., T.W., W.P., and P.B. All authors have read and agreed to the published version of the manuscript.

Acknowledgement

The authors sincerely thank Michelle Chae-min for English proofreading.

Funding sources

This study was not funded.

Conflict of interest

There are no potential conflicts of interest to declare.

References

1. Yang J, Ren Z, Du X, Hao M, Zhou W. The role of mesenchymal stem/progenitor cells in sarcoma: update and dispute. Stem Cell Investig 2014;1:18.
2. Fletcher C, Bridge J, Hogendoorn P, Mertens F. WHO classification of tumours of soft tissue and bone [homepage on the Internet]. Lyon, France: IARC Press; [cited 2024 Dec 21]. Available from: https://publications.iarc.fr/Book-And-Report-Series/Who-Classification-Of-Tumours/WHO-Classification-Of-Tumours-Of-Soft-Tissue-And-Bone-2013
3. Smolle MA, Andreou D, Tunn PU, Szkandera J, Liegl-Atzwanger B, Leithner A. Diagnosis and treatment of soft-tissue sarcomas of the extremities and trunk. EFORT Open Rev 2017;2:421–31.
4. Coindre JM. Grading of soft tissue sarcomas: review and update. Arch Pathol Lab Med 2006;130:1448–53.
5. American Cancer Society medical and editorial content team. Survival rates for soft tissue sarcoma [homepage on the Internet]. Atlanta: American Cancer Society; 2021 [cited 2020 Jan 4]. Available from: https://www.cancer.org/cancer/types/soft-tissue-sarcoma/detection-diagnosis-staging/survival-rates.html
6. von Mehren M, Randall RL, Benjamin RS, Boles S, Bui MM, Ganjoo KN, et al. Soft Tissue Sarcoma, Version 2.2018, NCCN clinical practice guidelines in oncology. J Natl Compr Cancer Netw JNCCN 2018;16:536–63.
7. Crombé A, Marcellin PJ, Buy X, Stoeckle E, Brouste V, Italiano A, et al. Soft-Tissue Sarcomas: assessment of MRI features correlating with histologic grade and patient outcome. Radiology 2019;291:710–21.
8. Zhao F, Ahlawat S, Farahani SJ, Weber KL, Montgomery EA, Carrino JA, et al. Can MR imaging be used to predict tumor grade in soft-tissue sarcoma? Radiology 2014;272:192–201.
9. Xiang P, Zhang X, Liu D, Wang C, Ding L, Wang F, et al. Distinguishing soft tissue sarcomas of different histologic grades based on quantitative MR assessment of intratumoral heterogeneity. Eur J Radiol 2019;118:194–9.
10. Scalas G, Parmeggiani A, Martella C, Tuzzato G, Bianchi G, Facchini G, et al. Magnetic resonance imaging of soft tissue sarcoma: features related to prognosis. Eur J Orthop Surg Traumatol Orthop Traumatol 2021;31:1567–75.
11. Murphey MD, Kransdorf MJ, Smith SE. Imaging of soft tissue neoplasms in the adult: malignant tumors. Semin Musculoskelet Radiol 1999;3:39–58.
12. Lee SY, Ju MK, Jeon HM, Jeong EK, Lee YJ, Kim CH, et al. Regulation of tumor progression by programmed necrosis. Oxid Med Cell Longev 2018;2018:3537471.
13. Guillou L, Coindre JM, Bonichon F, Nguyen BB, Terrier P, Collin F, et al. Comparative study of the National cancer institute and French federation of cancer centers sarcoma group grading systems in a population of 410 adult patients with soft tissue sarcoma. J Clin Oncol Off J Am Soc Clin Oncol 1997;15:350–62.
14. Galant J, Martí-Bonmatí L, Soler R, Saez F, Lafuente J, Bonmatí C, et al. Grading of subcutaneous soft tissue tumors by means of their relationship with the superficial fascia on MR imaging. Skeletal Radiol 1998;27:657–63.
15. Yoo HJ, Hong SH, Kang Y, Choi JY, Moon KC, Kim HS, et al. MR imaging of myxofibrosarcoma and undifferentiated sarcoma with emphasis on tail sign; diagnostic and prognostic value. Eur Radiol 2014;24:1749–57.
16. Engellau J, Bendahl PO, Persson A, Domanski HA, Akerman M, Gustafson P, et al. Improved prognostication in soft tissue sarcoma: independent information from vascular invasion, necrosis, growth pattern, and immunostaining using whole-tumor sections and tissue microarrays. Hum Pathol 2005;36:994–1002.
17. Fernebro J, Wiklund M, Jonsson K, Bendahl PO, Rydholm A, Nilbert M, et al. Focus on the tumour periphery in MRI evaluation of soft tissue sarcoma: infiltrative growth signifies poor prognosis. Sarcoma 2006;2006:21251.
18. Corino VDA, Montin E, Messina A, Casali PG, Gronchi A, Marchianò A, et al. Radiomic analysis of soft tissues sarcomas can distinguish intermediate from high-grade lesions. J Magn Reson Imaging JMRI 2018;47:829–40.
19. Schmitz F, Sedaghat S. Inferring malignancy grade of soft tissue sarcomas from magnetic resonance imaging features. A systematic review. Eur J Radiol 2024;177:111548.