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Prediction of Magnetic Resonance Imaging Scoring System for Differentiating Leiomyomas From Leiomyosarcomas: A Cross-Sectional Study

Manyetik rezonans Görüntüleme Skorlama Sisteminin, Leiomları Leiomyosarkomlardan Ayırt Etmedeki Öngörü Gücü: Kesitsel Bir Çalışma

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ABSTRACT

Aim: The aim of this study was to evaluate the preoperative magnetic resonance imaging (MRI) features that best distinguish uterine leiomyomas (UMs) from leiomyosarcomas (LMSs) and to develop an MRI scoring system for the preoperative prediction of LMS.

Materials and Methods: This cross-sectional study was conducted at a tertiary center between 2013 and 2023. A total of 109 patients who underwent myomectomy or hysterectomy and had pelvic MRI within six months before surgery, with histopathological confirmation of UM or LMS, were included. Cases were classified as Group 1 (UM, n=101; 92.6%) and Group 2 (LMS, n=8; 7.4%). Non-normally distributed variables were analyzed using the Mann–Whitney U test. Categorical variables were assessed using Chi-square or Fisher's exact test. Receiver operating characteristic (ROC) analysis was performed to calculate the cut-off value, sensitivity, and specificity of the MRI scoring system. Logistic regression was used to evaluate MRI features. Statistical significance was set at $p<0.05$.

Results: Six of the 15 MRI features differed significantly between the groups. The total MRI predictive score was significantly higher in the LMS group compared with the UM group (median: 4.5 [range: 3–11] vs 3.0 [range: 0–11], $p<0.01$). A score ≥7 was identified as the optimal cut-off for predicting LMS (sensitivity 98%; specificity 38%; PPV 95.5%; NPV 60%).

Conclusion: This preoperative MRI scoring system demonstrates predictive value in differentiating UMs from LMSs, particularly by identifying patients at risk of LMS

Keywords: Fibroid, leiomyoma, leiomyosarcoma, magnetic resonance imaging, scoring

ÖZ

Amaç: Bu çalışmanın amacı, leiomyom (UM) ve leiomyosarkomları (LMS) en iyi ayırt eden preoperatif manyetik rezonans görüntüleme (MRG) bulgularını değerlendirmek ve LMS'i preoperatif olarak öngörmede kullanılabilecek bir MRG skorlama sistemi geliştirmektir.

Gereç ve Yöntemler: Bu kesitsel çalışma, 2013–2023 yılları arasında üçüncü basamak bir sağlık merkezinde yürütülmüştür. Operasyondan önce altı ay içinde pelvik MRG çekilmiş, myomektomi veya histerektomi uygulanmış ve histopatolojik olarak UM veya LMS tanısı doğrulanmış 109 hasta çalışmaya dahil edilmiştir. Vakalar histopatoloji raporlarına göre Grup 1 (UM; n=101, %92,6) ve Grup 2 (LMS; n=8, %7,4) olarak sınıflandırılmıştır. Normal dağılım göstermeyen değişkenler Mann–Whitney U testi ile, kategorik veriler Ki-kare veya Fisher'ın kesin testi ile analiz edilmiştir. ROC analizi, MRG skorlama sisteminin kesim değerini, duyarlılığını ve özgüllüğünü belirlemek için kullanılmıştır. MRG bulguları lojistik regresyon analizi ile değerlendirilmiş, $p<0.05$ anlamlı kabul edilmiştir.

Bulgular: MRG ile değerlendirilen 15 özelliğin 6'sı gruplar arasında istatistiksel olarak anlamlı farklılık göstermiştir. UM grubunda medyan toplam MRG skoru 3 (0-11), LMS grubunda 4,5 (3-11) bulunmuştur ($p<0.01$). LMS'i öngörmede 7 ve üzeri skor kesim değeri olarak belirlenmiştir (duyarlılık %98; özgüllük %38; PPV %95,5; NPV %60).

Sonuç: Bu preoperatif MRG skorlama sistemi, UM ve LMS ayrımında özellikle LMS riski taşıyan hastaları belirlemede öngörü gücüne sahiptir.

Anahtar Kelimeler: Fibroid, leiomyom, leiomyosarkom, manyetik rezonans görüntüleme, skorlama

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INTRODUCTION

Uterine leiomyomas (UMs) are the most common benign tumors of the uterus. They are detected in approximately 20–40% of women during the reproductive period and in 70–80% during the perimenopausal period (1). These benign tumors may cause symptoms such as pelvic pain, infertility, or abnormal uterine bleeding in 20–50% of affected patients, leading to gynecological hospitalization in about 30% of cases (2).

Within the spectrum of uterine malignancies, sarcomas occur more frequently in older women compared with UMs and account for only 3–7% of all uterine malignancies (3). These sarcomas often present with symptoms similar to UMs, making clinical differentiation unreliable (4–6). Leiomyosarcomas (LMSs) are the most common subtype, with an incidence of 0.5–7 per 100,000 women per year. Endometrial stromal sarcomas are the second most common, occurring in 1–2 per million women annually (7–9).

Because of the significant differences in prognosis and treatment approaches, non-invasive diagnostic imaging modalities are essential for distinguishing UMs from LMSs. Transabdominal or transvaginal ultrasonography, computed tomography (CT), magnetic resonance imaging (MRI), and even positron emission tomography/CT (PET/CT) can be used for diagnosis, staging, and follow-up (10). Among these methods, MRI is the most accurate for identifying, localizing, and characterizing uterine masses. Furthermore, quantitative imaging analysis is increasingly being applied for preoperative prognostic classification (11).

On T2-weighted scans, most UMs appear as well-defined masses with homogeneous low signal intensity (12). However, degenerative changes such as edema, necrosis, or heterogeneous contrast enhancement may complicate differentiation from LMSs. Previous studies have investigated MRI features associated with LMSs, but many were limited by heterogeneous design and small sample sizes (13–17). More recently, quantitative imaging features have been reported to help distinguish LMSs from UMs (11,18,19).

Despite these advances, a widely accepted standardized approach for differentiating UMs from LMSs on MRI is still lacking. Currently, no Reporting and Data Systems (RADS) criteria exist for this purpose. Developing such a system would provide a standardized language for risk evaluation, reporting, and interpretation of imaging findings.

Therefore, the primary aim of this study was to differentiate LMS from leiomyomas by evaluating preoperative MRI features and to assess the predictive value of an MRI scoring system in this context.

MATERIALS AND METHODS

A retrospective cross-sectional study was carried out at a tertiary medical center. All participants provided informed consent. The study was conducted in accordance with the principles of the Declaration of Helsinki and approved by the institutional ethics committee (Date: 14.12.2022, No: 2022/40-17). Between 2013 and 2023, 109 patients who underwent myomectomy or hysterectomy with pelvic MRI performed within six months before surgery, and who had histopathologically confirmed diagnoses of UM or LMS, were included. Uterine mesenchymal tumors other than LMSs and atypical UMs were excluded (n=47). Cases were classified according to histopathology as Group 1 (UM; n=101, 92.6%) and Group 2 (LMS; n=8, 7.4%).

MRI scans of all patients were retrieved from the hospital archives. All examinations were performed on 1.5T scanners. Although minor protocol variations occurred over time, the minimum required sequences included sagittal, coronal, and axial T2-weighted imaging; axial fat-suppressed T1-weighted imaging (FOV: 20–25 cm; slice thickness: 4–5 mm); and contrast-enhanced axial fat-suppressed T1WI. All MR images were reviewed to ensure adequate quality before analysis.

Qualitative MRI features were evaluated by a radiologist with 17 years of experience in gynecological imaging, who was blinded to the pathology reports. For analysis, the dominant lesion was defined as the mass with the largest dimension in any plane or, if masses were of similar size, the most T2-hyperintense lesion. The number of myometrial masses was capped at 20 for recording purposes.

In each dominant lesion, fifteen imaging features were assessed. These included heterogeneity on T2-weighted images, hyperintensity of the solid viable component relative to the myometrium on T2-weighted images, an ill-defined border with the myometrium on T2-weighted or post-contrast T1-weighted images, and the presence of fluid–fluid levels on T2- or T1-weighted sequences. In addition, intra-tumoral hemorrhage (identified as hyperintensity on pre-contrast T1-weighted images), heterogeneous enhancement on post-contrast T1-weighted images, and central non-enhancing pockets consistent with necrosis were evaluated. Morphological features such as enhancing finger-like projections, lobulated margins, and lobulated internal architecture on T2-weighted imaging (described as a T2-hyperintense mass with multiple lobules separated by hypointense septa) were also assessed. Extension of the lesion beyond the uterine serosa and the presence of fluid in the endometrial cavity were recorded. Finally, secondary findings such as adenopathy, ascites, distant metastases, or invasion of adjacent structures were considered.

Statistical analysis was performed using IBM SPSS Statistics version 26.0 (IBM Inc., Chicago, IL, USA). Normality of data distribution was assessed with the Kolmogorov–Smirnov test. Non-normally distributed variables were analyzed with the Mann–Whitney U test, while categorical variables were analyzed with the Chi-square test or Fisher's exact test. Quantitative variables were reported as median (minimum–maximum) [Q1-Q3; interquartile range (IQR)], and categorical variables as counts and percentages (%). Receiver Operating Characteristic (ROC) analysis was conducted to assess the sensitivity and specificity of the MRI scoring system. The area under the curve (AUC) was calculated. The optimal cut-off value was defined by the highest sum of sensitivity and specificity. Logistic regression (univariable and multivariable) was used to evaluate MRI features. Results were presented with 95% confidence intervals (CI), and statistical significance was set at $p<0.05$

RESULTS

The demographic characteristics of the study groups are summarized in Table 1. The median age of all participants was 39 years (range: 21–74). The median age was 39 years (range: 21–57) in Group 1 and 51.5 years (range: 26–74) in Group 2, with a statistically significant difference (p=0.04). The median interval from MRI to surgery was 1 month (range: 1–6) in both groups, and this difference was not statistically significant (p=0.3).

A total of 69 patients (63.3%) underwent myomectomy, including 59 laparotomic and 10 laparoscopic procedures. Thirty-two patients (29.4%) underwent hysterectomy (29 laparotomic, 3 laparoscopic). Radical hysterectomy was performed exclusively in the LMS group (n=8, 7.3%). In all LMS cases, intraoperative frozen section suggested malignancy, which guided the decision to proceed with radical hysterectomy. Bilateral salpingo-oophorectomy was performed in 4 of these postmenopausal patients.

Table 1. Demographic characteristics of patients

Variables	All cases n=109 (100%)	Group 1 n=101 (92.6%)	Group 2 n=8 (7.4%)	p-value
Age (years)	39 (21-74) [34-44; 10]	39 (21-57) [34-43.5; 9.5]	(26-74) [36-57.5;21.5]	0.04
From MRI† to surgery (months)	(1-6) [1-3;2]	(1-6) [1-3;2]	(1-5) [1-1.75;0.75]	0.3
Type of surgery				<0.0001
Myomectomy	63.3% (69/109)	68.3% (69/101)	0% (0/8)	<0.0001
Hysterectomy	29.4% (32/109)	32.7% (32/101)	0% (0/8)	<0.0001
Radical hysterectomyBSO†	7.3% (8/109%)	0% (0/101)	100% (8/8)	<0.0001
Morcellation				0.4
No	90.8% (99/109)	90% (91/101)	0% (0/8)	
Yes	9.2% (10/109)	10% (10/101)	0% (0/8)	
Menopausal status				<0.01
Premenopausal	89.9% (98/109)	93.1% (94/101)	50% (4/8)	
Postmenopausal	10.1% (11/109)	6.9% (7/101)	50% (4/8)	
Initial symptoms				0.001
Premenopausal vaginal bleeding	37.6% (41/109)	38.6% (39/101)	25% (2/8)	0.3
Postmenopausal vaginal bleeding	5.5% (6/109)	3% (3/101)	37.5% (3/8)	<0.01
Pain	21.1% (23/109)	21.8% (22/101)	12.5% (1/8)	0.4
Enlarging pelvic mass	11% (12/109)	11.9% (12/101)	0% (0/8)	0.3
Infertility	11.9% (13/109)	12.9% (13/101)	0% (0/8)	0.3
Incidental	12.8% (14/109)	11.9% (12/101)	25% (2/8)	0.2

†MRI, magnetic resonance imaging; †BSO, bilateral salpingo-oophorectomy
*p<0.05
Quantitative variables were reported as median (minimum–maximum) [Q1-Q3; interquartile range (IQR)], and categorical variables as counts and percentages (%).

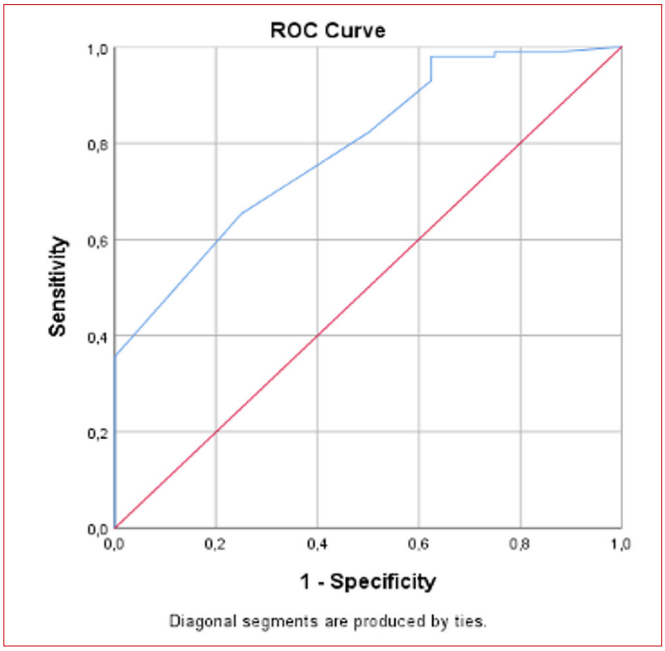

Figure 1. ROC curve for total score of magnetic resonance imaging

Patients with UM were more frequently premenopausal compared with those with LMS (93.1% vs 50.0%, p<0.01). The initial presenting symptom was abnormal uterine bleeding in both groups, but its distribution differed significantly. In the UM group, premenopausal bleeding was the most common form (38.6% vs 25.0%), although this difference was not statistically significant (p=0.3). In contrast, postmenopausal bleeding was the most common form in the LMS group (37.5% vs 3.0%), and this difference was statistically significant (p<0.01).

MRI features of UMs and LMSs are presented in Table 2. The number of myometrial masses did not differ significantly between the groups (median: 2 [range: 1–20] vs 1 [range: 1–10], p=0.2). The largest tumor diameter was slightly greater in Group 1 compared with Group 2 (median: 80 mm [range: 20 mm–150 mm] vs 72.5 mm [range: 35 mm–120 mm]), but this difference was not statistically significant (p=0.9). Six of the 15 MRI features differed significantly between groups: ill-defined border on T2WI (4.0%

Table 2. Magnetic resonance imaging features evaluated in leiomyomas and leiomyosarcomas

Features	All cases n=109 (100%)	Group 1 n=101 (92.6%)	Group 2 n=8 (7.4%)	p-value
Heterogeneity on T2w images	85.3% (93/109)	92.5% (86/101)	87.5% (7/8)	0.6
Hyperintensity[a] of the solid, viable component of the mass	58.7% (64/109)	56.4% (57/101)	87.5% (7/8)	0.08
Ill-defined border[b] on T2WI	6.4% (7/109)	4% (4/101)	37.5% (3/8)	<0.01
Fluid level on T2WI	1.8% (2/109)	1% (1/101)	12.5% (1/8)	0.1
Fluid level on T1WI	2.8% (3/109)	2% (2/101)	12.5% (1/8)	0.2
Hemorrhage: pre-C† T1WI	14.7% (16/109)	11.9% (12/101)	50% (4/8)	0.01
Enhancement: post-C ‡ T1WI Homogenous Heterogenous	 35.7% (39/109) 64.2% (70/109)	 36.6% (37/101) 63.4% (64/101)	 25% (2/8) 75% (6/8)	0.4
Central non-enhancing necrosis	42.2% (46/109)	39.6% (40/101)	75% (6/8)	0.05
Enhancing finger-like projections	3.7% (4/109)	2% (2/101)	25% (2/8)	0.02
Ill-defined border[b] on T1WI	5.5% (6/109)	3% (3/101)	37.5% (3/8)	<0.01
Lobular margins	13.8% (15/109)	11.9% (12/101)	37.5% (3/8)	0.07
Lobular architecture	13.8% (15/109)	11.9% (12/101)	37.5% (3/8)	0.07
Extension beyond uterine serosa	4.6% (5/109)	2% (2/101)	37.5% (3/8)	<0.01
Fluid in endometrial cavity	42.2% (46/109)	43.6% (44/101)	25% (2/8)	0.2
Secondary findings[c]	0% (0/109)	0% (0/101)	0% (0/8)	-
Total score	(0-11) [2-4;2]	(0-11) [2-4;2]	4.5 (3-11) [3.25-9.5;6.25]	<0.01
Number of myometrial masses	(1-20) [1-4;3]	(1-20) [1-4;3]	(1-20) [1-2.75;1.75]	0.2
Largest mass diamater (mm)	(10-200) [59.5-100;31.5]	(10-190) [60-100;40]	(10-200) [46.2-167.5;121.3]	0.9

a. Relative to the myometrium on T2w images
b. With adjacent myometrium
c. Tumor extending into neighboring structures/organs, adenopathy, ascites, or distant metastasis
†Pre-C, pre-contrast; ‡Post-C, post-contrast
*p<0.05
Quantitative variables were reported as median (minimum–maximum) [Q1-Q3; interquartile range (IQR)], and categorical variables as counts and percentages (%).

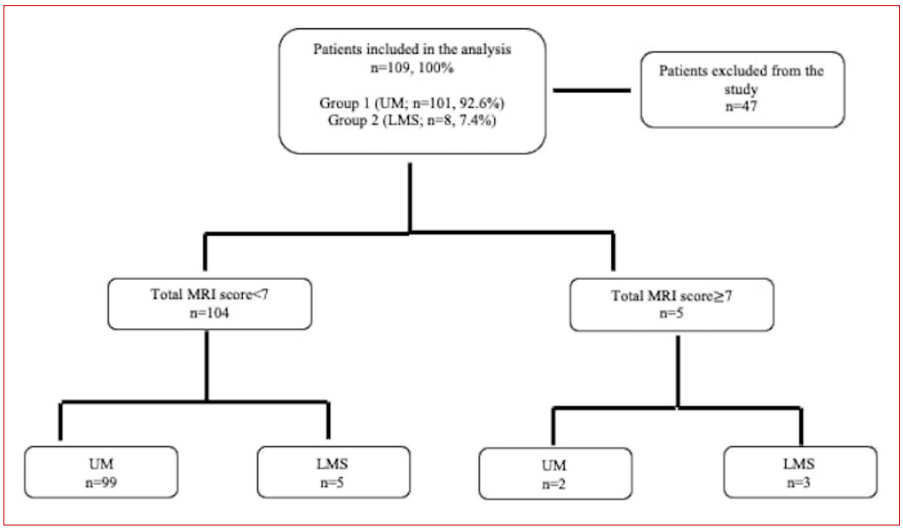

Figure 2. Flowchart of study

Table 3. Diagnostic value of total MRI score for predicting uterine leiomyomas

Variables	Total MRI score<7	Total MRI score7	Total	p-value
Uterine leiomyoma	n=99, 98%	n=2, 2%	n=101 (100%)	p<0.01
Leiomyosarcoma	n=5, 62.5%	n=3, 37.5%	n=8 (100%)	
Total	n=104, 95.4%	n=5, 4.6%	N=109 (100%)	

Table 4. Logistic regression analysis of independent variables in predicting leiomyoma

Variables	Univariable logistic regression					Multivariable logistic regression				
	B	Wald	SE	OR (95% CI)	p value	B	Wald	SE	OR (95% CI)	p value
Ill-defined border on T2WI	-0.418	0.016	3.286	0.658 (0.001 412.169)	0.8	0.418	0.016	3.286	1.519 (0.002-951.358)	0.8
Hemorrhage: pre-C† T1WI	1.570	2.503	0.992	4.807 (0.687-33.612)	0.1	1.570	2.503	0.992	0.208 (0.030-1.455)	0.1
Central non-enhancing necrosis	0.558	0.308	1.005	1.747 (0.244-12.528)	0.5	0.558	0.308	1.005	0.572 (0.080-4.104)	0.5
Enhancing finger-like projections	1.146	0.357	1.920	3.147 (0.073-135.565)	0.5	1.146	0.357	1.920	0.318 (0.007-13.688)	0.5
Ill-defined border on T1WI	0.303	0.008	3.296	1.354 (0.002-868.841)	0.9	0.303	0.008	3.296	0.739 (0.001-471.959)	0.9
Extension beyond uterine serosa	2.827	2.848	1.675	16.897 (0.634-450.591)	0.09	2.827	2.848	1.675	0.59 (0.002-1.578)	0.09
						R^2=0.1 (Cox-Snell), 0.3 (Nagelkerke). Model x^2= 15.607,p=0.01				

†Pre-C, pre-contrast
*p < 0.05. CI; confidence interval, OR; odds ratio, SE; standart error

vs 37.5%, p<0.01), hemorrhage on pre-contrast T1WI (11.9% vs 50.0%, p=0.01), central non-enhancing necrosis (39.6% vs 75.0%, p=0.05), enhancing finger-like projections (2.0% vs 25.0%, p=0.02), ill-defined border on post-contrast T1WI (3.0% vs 37.5%, p<0.01), and extension beyond the uterine serosa (2.0% vs 37.5%, p<0.01).

The total MRI score was evaluated with ROC curve analysis to predict LMS (Figure 3). A total score of ≥7 was identified as the optimal cut-off for predicting LMS, whereas scores below 7 were more likely associated with UM. The ROC analysis demonstrated an AUC of 0.791 (95% CI: 0.645–0.937), with sensitivity of 98%,

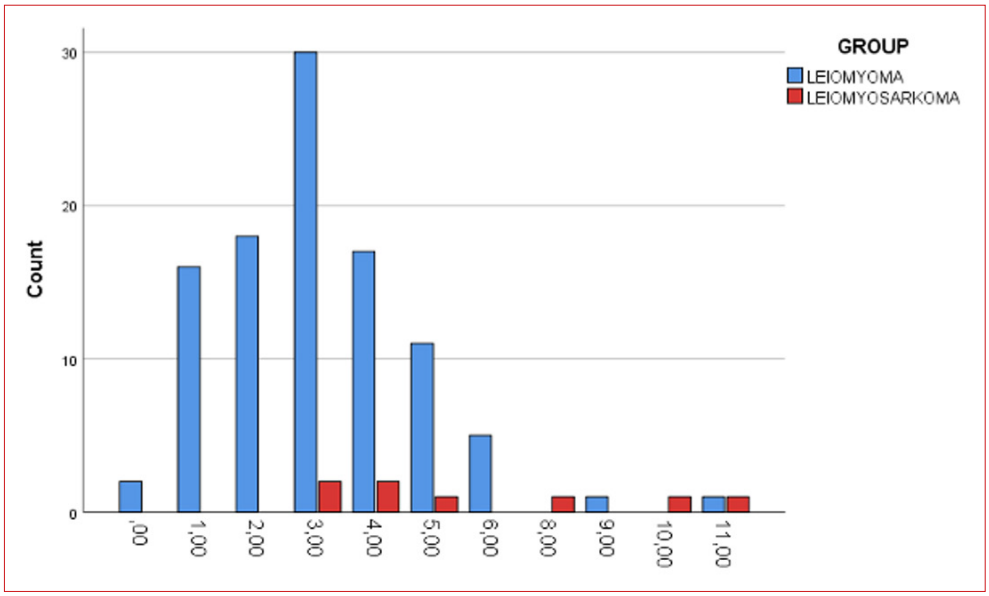

Figure 3. Frequencies of magnetic resonance imaging predictive score, ranging from 0 to 11, in cases of leiomyoma (n=101) and leiomyosarcoma (n=8).

specificity of 38%, positive predictive value (95.5%), negative predictive value (60%), and positive likelihood ratio (1.5) ($p<0.01$).

Logistic regression analysis of MRI features is summarized in Table 4. None of the individual MRI characteristics reached statistical significance (all $p>0.05$). However, the overall multivariable model was statistically significant ($R^2=0.1$ [Cox–Snell], $R^2=0.3$ [Nagelkerke]; model $\chi^2=15.607$, $p=0.01$). This suggests that while no single MRI feature independently predicted LMS, the combined effect of multiple features contributed to the model's ability to differentiate LMS from UM.

DISCUSSION

In this study, we evaluated the predictive value of an MRI scoring system for differentiating uterine leiomyomas (UMs) from leiomyosarcomas (LMSs). Several MRI features showed statistically significant differences between the two groups, and the total MRI score was also significantly higher in LMS cases.

Chantasartrassamee et al. (20) investigated the clinical features of UMs and LMSs and reported that UMs were five times more frequent than LMSs in women younger than 40 years, whereas LMSs were approximately 20 times more prevalent than UMs in postmenopausal women. In our study, LMSs were about seven times more frequent than UMs among postmenopausal patients, and women with UM were younger on average. These findings were statistically significant and consistent with previous reports.

The clinical presentation of UMs and LMSs is often similar, and symptoms alone are not reliable for preoperative differentiation. Tumor growth rate and serum markers such as lactate dehydrogenase and CA-125 have also been shown to be ineffective in distinguishing between benign and malignant disease (21,22). Consistent with Jagannathan et al. (11), we found that premenopausal bleeding was the most common presentation in the UM group, although this difference was not statistically significant. In contrast, postmenopausal bleeding was significantly more frequent in LMS patients, which is in line with previous studies (20).

Jagannathan et al. (11) applied the same MRI scoring system and identified seven features that differentiated LMSs from UMs, including intratumoral hemorrhage, heterogeneous enhancement, finger-like projections, ill-defined borders on post-contrast T1-weighted imaging, central non-enhancing necrosis, and hyperintensity of the solid component on T2-weighted images. They reported that a total MRI score above 6–7 had a 100% positive predictive value for LMS. Similarly, Lakhman et al. and Rio et al. (18,19) found that both atypical UMs and LMSs could show high signal intensity on T2-weighted imaging. In contrast, our study did not find a significant difference regarding T2 hyperintensity of the solid component. Instead, ill-defined borders on post-contrast T1WI and extension beyond the uterine serosa were the most significant features, although they were not independent predictors in logistic regression analysis. Importantly, the overall multivariable model remained statistically significant, suggesting that the combined scoring approach has value even when individual features are not significant.

In our study, a total MRI score of ≥7 was identified as the optimal cut-off for predicting LMS, whereas scores below 7 were more commonly associated with UM. This highlights the clinical

importance of the MRI scoring system as a practical tool for identifying patients at risk of LMS before surgery.

Although the MRI scoring system demonstrated high sensitivity for detecting LMS, its specificity was relatively low. This limitation implies that some patients with benign leiomyomas may be misclassified as LMS, potentially leading to unnecessary aggressive surgical interventions. Therefore, while a high score should raise suspicion for LMS, clinical decision-making should not rely solely on the MRI score. Instead, MRI findings must be interpreted in combination with clinical presentation, intraoperative evaluation, and, when possible, additional diagnostic modalities to minimize false positives and reduce the risk of overtreatment. This study also has several limitations. It was retrospective in design, the number of LMS cases was relatively small, and histological subtypes of UMs were not analyzed separately. Strengths include the relatively large overall sample size and strict exclusion criteria. Moreover, the study emphasizes the potential applicability of the MRI scoring system as a clinically useful tool.

CONCLUSION

In conclusion, a preliminary MRI scoring system for the preoperative evaluation of uterine masses has been described in only a few studies. At present, no standardized reporting systems (such as RADS criteria) exist for differentiating UMs from LMSs. We believe our findings contribute to the growing body of literature and that further large-scale, prospective studies using a similar design will be valuable for establishing broader clinical applicability.

Ethics Approval: This was a retrospective cross-sectional study. The study was performed in line with principles of Declaration of Helsinki. Approval was granted by Ethics Committee of Dokuz Eylul University (Date:14.12.2022, No:2022/40-17).

Consent to Participate: Informed consent was obtained from all individual participants included in ths study.

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Data Sharing Statement: Individual participant data that underlie the results reported in this article, after deidentification (text, tables, figures, and appendices).

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