Original Paper

Diagnostic Performance of Diffusion-Weighted MRI and ADC Values in Differentiating Atypical Leiomyomas from Uterine Sarcomas

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ABSTRACT: Background: Leiomyomas are the most common benign uterine tumors, whereas uterine sarcomas are rare malignant neoplasms associated with high morbidity and mortality. Differentiation using imaging remains challenging because of overlapping radiologic features. Purpose: To evaluate magnetic resonance imaging (MRI) characteristics of atypical leiomyomas and uterine sarcomas, with emphasis on diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) values. Materials and Methods: In this retrospective study, 22 patients with histopathologically confirmed uterine leiomyoma or sarcoma underwent MRI for atypical or suspicious uterine lesions. MRI assessment included T2-weighted imaging, DWI with ADC maps, and fat-suppressed T1-weighted sequences before and after gadolinium administration. Results: Thirteen atypical leiomyomas (59%) and nine sarcomas (41%) were analyzed. Mean patient age was similar between groups. Abnormal vaginal bleeding was more frequent in sarcomas (89% vs. 38%). Sarcomas more commonly showed irregular margins (89% vs. 69%) and T2 hyperintensity (89% vs. 15%). Heterogeneous enhancement and cystic or hemorrhagic changes occurred in both tumor types, while extrauterine disease was observed only in sarcomas. All sarcomas demonstrated high DWI signal intensity exceeding that of the endometrium, whereas most leiomyomas showed intermediate signal intensity. Mean ADC values were significantly lower in sarcomas (0.813×10^{-3}mm²/s) than in leiomyomas (1.050×10^{-3} mm²/s), with an optimal cutoff of 0.892×10^{-3}mm²/s. Conclusion: MRI, particularly DWI and ADC analysis, provides valuable differentiation between atypical leiomyomas and uterine sarcomas, with sarcomas demonstrating higher DWI signal intensity and significantly lower ADC values.

KEYWORDS: *Uterine sarcomas, atypical leiomyoma, diffusion-weighted imaging (DWI), apparent diffusion coefficient (ADC).*

Introduction

Uterine leiomyomas are among the most common benign tumors in women, occurring in approximately 40% of individuals during their reproductive years [1].

Although many cases are detected incidentally and remain asymptomatic, nearly one-third of affected patients develop symptoms such as pelvic pain, a palpable pelvic mass, or abnormal vaginal bleeding [2].

In contrast, uterine sarcomas are rare malignant tumors, accounting for only 2-7% of uterine malignancies [3].

Despite their low incidence, these tumors frequently present with clinical manifestations similar to those of leiomyomas, making accurate preoperative differentiation difficult in routine clinical practice.

Uterine sarcomas originate from the uterine mesenchyme and include several histologic subtypes, the most common being leiomyosarcoma, followed by endometrial stromal sarcoma, adenosarcoma, and undifferentiated uterine sarcoma [4].

Although leiomyomas and uterine sarcomas may appear similar on imaging, they differ substantially in biological behavior and clinical prognosis. Uterine sarcomas are characterized by rapid progression, a high risk of metastatic spread, and poor overall outcomes.

Consequently, establishing an accurate diagnosis before treatment is essential in order to ensure appropriate surgical management and to avoid uterus-preserving therapies such as gonadotropin-releasing hormone analog treatment or uterine artery embolization, which are contraindicated in the presence of malignancy.

Typical leiomyomas generally demonstrate low signal intensity on T2-weighted and diffusion-weighted MRI sequences.

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However, approximately 65% of leiomyomas exhibit degenerative changes that produce atypical imaging features, complicating the differentiation from malignant tumors [5].

As a result, reliable preoperative discrimination between leiomyomas and uterine sarcomas remains challenging. Postoperative histopathologic analysis reveals leiomyosarcoma in approximately 0.01-0.5% of cases initially diagnosed as leiomyomas[6].

From a therapeutic perspective, hysterectomy is often considered an appropriate treatment for leiomyomas in postmenopausal women, whereas uterine-sparing approaches are generally preferred in premenopausal patients. However, uterine sarcoma must be confidently excluded before conservative management is pursued [7].

Performing myomectomy on an unrecognized sarcoma, particularly when power morcellation is used, may result in tumor dissemination. Conversely, unnecessary hysterectomy should be avoided in patients with atypical but benign leiomyomas.

Objective

Therefore, the purpose of this study was to evaluate the MRI characteristics of atypical leiomyomas and uterine sarcomas and to assess the role of diffusion-weighted imaging and quantitative ADC measurements in their differentiation.

Materials and Methods

Patient selection

A retrospective study of the oncologic database of our institution, from January 2019 to December 2025 included 22 women that underwent MRI examinations that showed uterine lesions with atypical or malignant characteristics, while histopathological analysis of the tumors showed sarcomas or leiomyomas.

Clinical, pathologic, and imaging data were extracted from electronic medical records.

All patient information was anonymized and stored in a centralized database using Microsoft Excel©. Statistical analyses were performed using IBM SPSS Statistics version 29.0 (IBM Corp., Armonk, NY, USA).

Continuous variables were tested for normality using the D'Agostino-Pearson normality test. Normally distributed variables were compared using the independent-samples t-test. Categorical variables were compared using Pearson's chi-square test. Receiver operating characteristic (ROC) curve analysis was performed to evaluate the diagnostic performance of ADC values and to determine the optimal cutoff using the Youden index. A two-sided P value <0.05 was considered statistically significant.

Imaging protocol

All examinations were performed with patients in supine position using phased-array abdominal coils on 1.5 T MRI system under free-breathing conditions. Serum creatinine levels were verified before imaging to minimize the risk of contrast-related renal impairment.

The imaging protocol comprised high-resolution sagittal T2-weighted fast spin-echo sequences, as well as coronal and axial T2-weighted acquisitions oriented to the long axis of the uterus. Diffusion-weighted imaging was obtained in the axial and sagittal planes using b values of 0 and 800 s/mm², with apparent diffusion coefficient maps automatically generated by the scanner software. Pre- and post-contrast T1-weighted fat-suppressed images were acquired following intravenous administration of 10mL of gadolinium, followed by a 20mL saline flush.

Image analysis

The following clinical, pathologic, and imaging parameters were evaluated in the patients included in the study: age, menopausal status, abnormal vaginal bleeding, pelvic pain, histologic diagnosis, size, tumor margins, homogeneity on T2-weighted images, visual analysis of diffusion weighted imaging signal intensity and ADC values, presence of intratumoral bleeding and cystic alterations, enhancement, presence of infiltrated lymph nodes and pelvic masses.

Signal intensity on diffusion-weighted imaging was evaluated qualitatively and divided into three categories based on the area demonstrating the greatest intensity within the lesion. Lesions were classified as having low signal intensity when their signal was comparable to or lower than that of the myometrium. Intermediate intensity was assigned when the signal exceeded that of the myometrium but did not surpass the intensity observed in the endometrium and/or lymph nodes. Lesions exhibiting signal intensity greater than that of the endometrium and/or lymph nodes were categorized as high intensity.

For quantitative analysis, apparent diffusion coefficient measurements were obtained from

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ADC maps by positioning circular regions of interest in regions showing the most restricted diffusion. Care was taken to exclude haemorrhagic, necrotic and cystic components by correlating with T1-weighted, T2-weighted, and contrast-enhanced images. Multiple regions of interest were analyzed for each lesion, and the minimum mean ADC value was selected for statistical evaluation.

Lymph nodes were considered infiltrated when the short-axis diameter measured at least 10mm.

Results

The study included 22 patients with pathologically confirmed uterine tumors, consisting of atypical leiomyomas in 13 cases (59%) and uterine sarcomas in 9 cases (41%) (Figure 1, Figure 2).

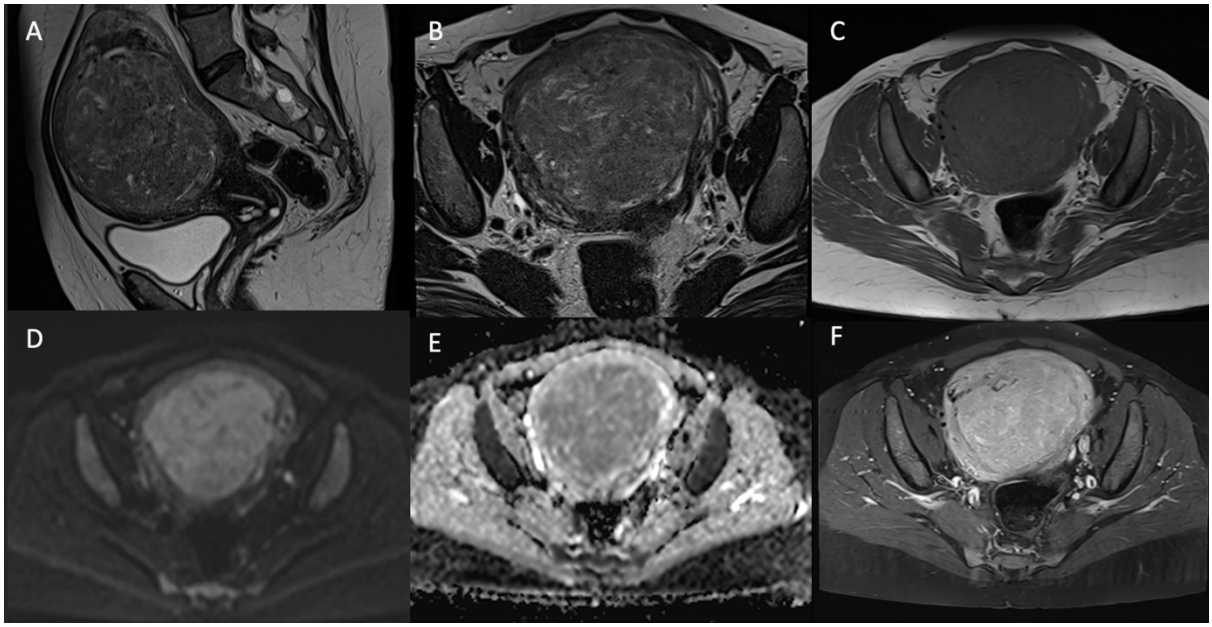


Figure 1. Forty-five-year-old female patient complaining of abnormal vaginal bleeding. A B Sagittal and axial T2WI showed a heterogenous hyperintense lesion; C Axial T1WI revealed isointense lesion; D E Intermediate signal on DWI, lower than the endometrium and low signal on the ADC map. ADC mean value was (1.054×10^{-3} mm^2/s). F T1 FS postcontrast axial image with heterogeneous enhancement. Pathology revealed atypical leiomyoma.

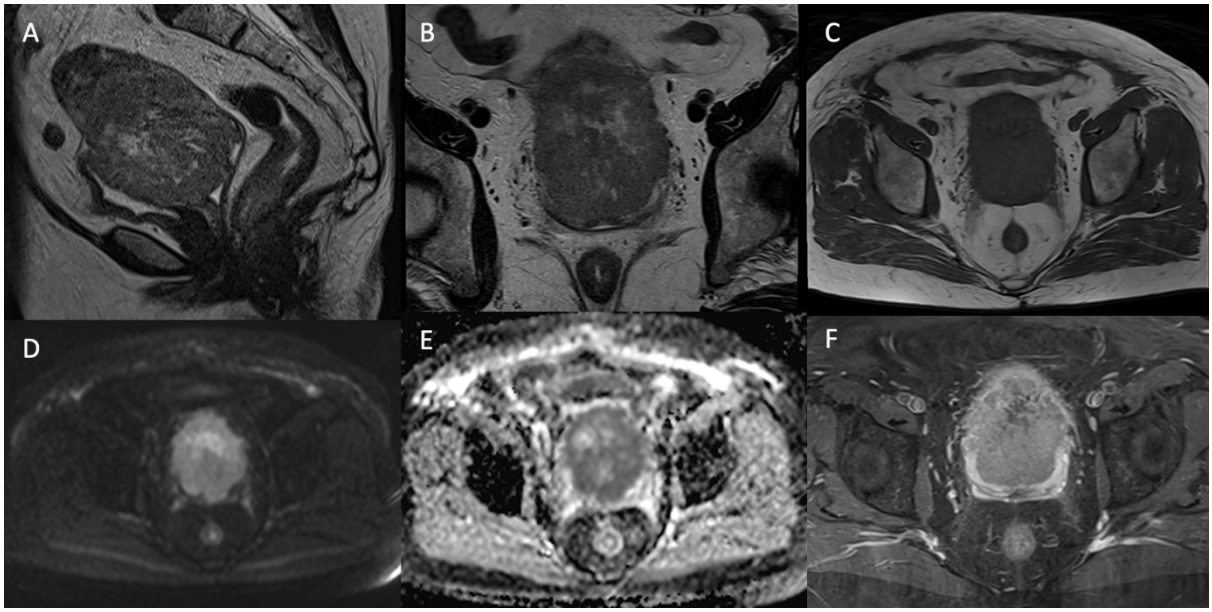


Figure 2. Sixty-seven-year-old female patient with no clinical manifestations, with a lesion discovered in a routine checkup. A B Sagittal and axial T2WI showed a heterogenous hyperintense lesion; C Axial T1WI revealed isointense lesion; D E High signal on DWI, higher than the endometrium and low signal on the ADC map. ADC mean value was (0.806×10^{-3} mm^2/s). F T1 FS postcontrast axial image with heterogeneous low enhancement. Pathology revealed leiomyosarcoma.

Clinical and MRI features were evaluated in all cases in order to identify potential differences between the two entities (Table 1).

Patients with atypical leiomyomas ranged in age from 39 to 74 years (mean, 51 years), whereas patients with uterine sarcomas ranged from 41 to 78 years (mean, 55 years). The menopausal status of the patients did not differ significantly between the two groups, as seven patients with leiomyomas (54%) and five patients with sarcoma (54%) attained menopause at the time of the diagnosis.

Abnormal vaginal bleeding was the main symptom the patients presented with, being noted in 5 cases of atypical leiomyoma (38%) and 8 cases of sarcoma (89%). Pelvic pain was more frequent in patients with sarcoma, being present in three cases (33%) versus two cases (15%) of leiomyoma.

The size of the lesions varied in both groups, ranging from 9mm to 120mm in atypical leiomyomas (with a mean of 59mm) and from 29mm to 110 mm in sarcomas (with a mean of 63mm) (Figure 3).

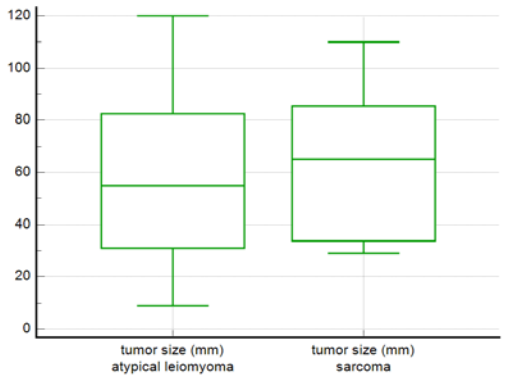
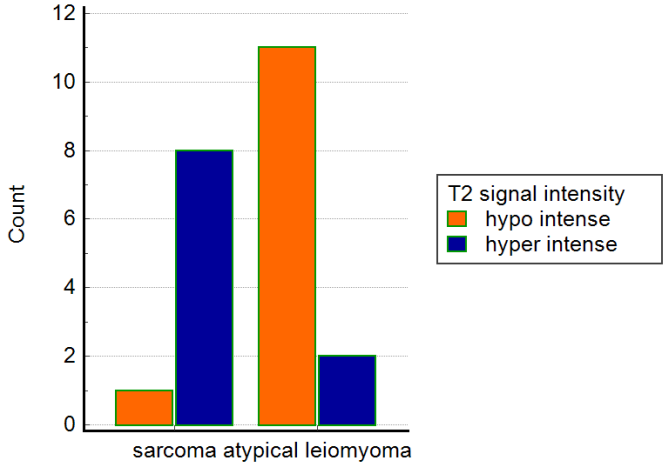


Figure 3. Distribution of tumor size in patients with atypical leiomyomas and uterine sarcomas. The mean tumor size was 59 mm for atypical leiomyomas and 63 mm for uterine sarcomas. No statistically significant difference in lesion size was observed between the two groups.

Irregular borders of the tumors were observed in nine cases of leiomyoma (69%) and eight cases of sarcoma (89%).

On T2 weighted imaging, when compared to the surrounding myometrium, Lesions were classified as hypointense in 11 of 13 leiomyomas (85%), while in eight out of the nine cases of sarcoma were hyperintense (89%) (Figure 4).

Postcontrast images were similar for both pathologies, as the main aspect described was heterogenous enhancement (77% of cases in each group).



	T2-weighted signal intensity		
	hypointense	hyperintense	
sarcoma	1	8	9 (40.9%)
atypical leiomyoma	11	2	13 (59.1%)
	12 (54.5%)	10 (45.5%)	22
Chi-squared	11.062		
DF	1		
Significance level	P=0.0009		

Figure 4. Distribution of T2-weighted signal intensity according to histopathological diagnosis. Hyperintense lesions on T2-weighted imaging were significantly more frequent in uterine sarcomas than in atypical leiomyomas (χ^2=11.06, df=1, P=0.0009).

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We further evaluated lesions demonstrating heterogeneous morphology and evaluated the presence of cystic or hemorrhagic areas.

Seven cases (54%) of leiomyomas presented cystic degeneration, while five patients with sarcomas had lesions with cystic areas (56%).

Hemorrhagic areas were described in three patients (23%) with leiomyoma and four patients (44%) with sarcoma.

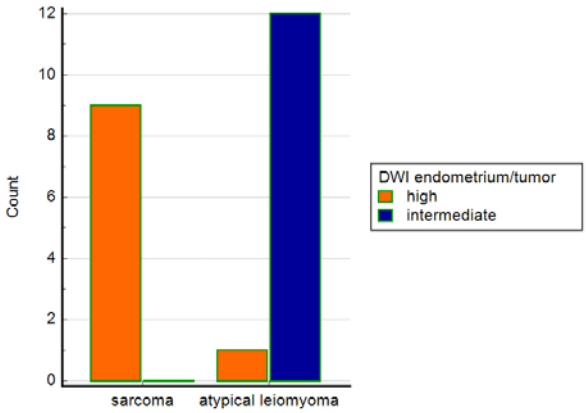
Free pelvic fluid was present in 6 cases of leiomyoma (46%) and 6 patients with sarcoma (67%).

No infiltrated lymph nodes, peritoneal implants, or ovarian nodules were identified in any patient with leiomyoma. In contrast, four patients with sarcoma (44%) had infiltrated pelvic lymph nodes, four (44%) had peritoneal metastases, and one (11%) had ovarian metastases.

All sarcomas demonstrated at least a focal area of DWI signal intensity exceeding that of the endometrium, while 12 of 13 leiomyomas presented intermediate DWI signal intensity (Figure 5).

Table 1. Clinical and MRI aspect of the lesions.

Characteristics	Atypical leiomyoma	Sarcoma
Age	51 [39;74]	55 [41;78]
Menopausal status	7/13 (54%)	5/9 (56%)
Abnormal bleeding	5/13 (38%)	8/9 (89%)
Pelvic pain	2/13 (15%)	3/9 (33%)
Tumour size	59mm [9;120]	63mm [29;110]
Lesion borders		
- regular	4/13 (31%)	1/9 (11%)
- irregular	9/13 (69%)	8/9 (89%)
T2-weighted signal intensity		
- hyperintense	2/13 (15%)	8/9 (89%)
- hypointense	11/13 (85%)	1/9 (11%)
Contrast		
- heterogenous	10/13 (77%)	7/9 (77%)
- low	3/13 (23%)	2/9 (22%)
Cystic areas	7/13 (54%)	5/9 (56%)
Haemorrhagic areas	3/13 (23%)	4/9 (44%)
Infiltrated lymph nodes	0/13 (0%)	4/9 (44%)
Ovarian metastases	0/13 (0%)	1/9 (11%)
Peritoneal metastases	0/13 (0%)	4/9 (44%)
Pelvic free fluid	6/13 (46%)	6/9 (67%)



	DWI endometrium/tumor		
	high	intermediate	
sarcoma	9	0	9 (40.9%)
Atypical leiomyoma	1	12	13 (59.1%)
	10 (45.5%)	12 (54.5%)	22
Chi-squared	17.446		
DF	1		
Significance level	P<0.0001		

Figure 5. Distribution of diffusion-weighted imaging signal intensity according to histopathological diagnosis. High DWI signal intensity exceeding that of the endometrium was significantly associated with uterine sarcomas (χ^2=17.45, df=1, P<0.0001).

We measured the ADC values of the lesions, that ranged between 1.013×10^{-3} mm^2/s and 1.214×10^{-3}mm^2/s (mean 1.050) for atypical leiomyomas and 0.698×10^{-3}mm^2/s and 0.892×10^{-3}mm^2/s (mean 0.813) for sarcomas (Figure 6).

Statistical analysis was performed to compare ADC values between atypical leiomyomas and uterine sarcomas. The D'Agostino-Pearson test indicated that the data were normally distributed (P=0.0564).

An F-test for equal variances showed no significant difference between the groups (P=0.153), supporting the use of a t-test assuming equal variances (Table 2).

The mean ADC value was significantly lower in uterine sarcomas compared with atypical leiomyomas ($0.813 \times 10^{-3}mm^2/s$ vs $1.050 \times 10^{-3}mm^2/s$; mean difference $-0.237 \times 10^{-3}mm^2/s$; 95% CI -0.328 to -0.146; *P* <0.0001).

These results indicate that ADC values are significantly lower in uterine sarcomas compared with atypical leiomyomas.

Table 2. Comparison of ADC values between atypical leiomyoma and sarcoma.

	Atypical leiomyoma	**Sarcoma**
Sample size	13	9
Arithmetic mean ADC value	1.0502	0.8137
95% CI for the mean	0.9797 to 1.1207	0.7600 to 0.8673
Variance	0.01361	0.004873
Standard deviation	0.1167	0.06980
Standard error of the mean	0.03236	0.02327

F-test for equal variances	P=0.153

T-test (assuming equal variances)	
Difference	-0.2366
Pooled Standard Deviation	0.1006
Standard Error	0.04361
95% CI of difference	-0.3275 to -0.1456
Test statistic t	-5.424
Degrees of Freedom (DF)	20
Two-tailed probability	P < 0.0001

D'Agostino-Pearson test for Normal distribution	accept Normality (P=0.0564)

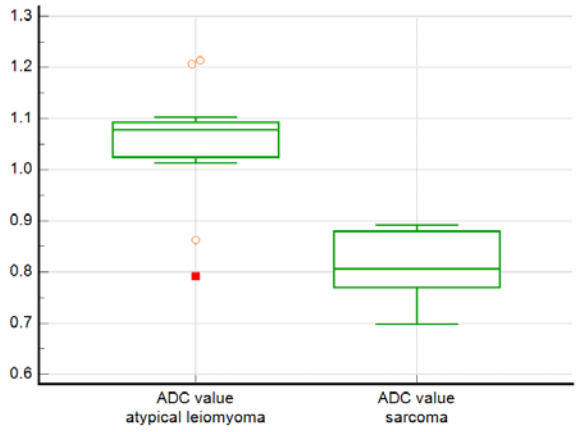


Figure 6. Distribution of ADC value in patients with atypical leiomyomas and uterine sarcomas.

ROC curve analysis was performed to evaluate the diagnostic performance of ADC values in differentiating uterine sarcomas from atypical leiomyomas (Figure 7).

The study included 22 patients, of whom 9 (40.9%) had sarcomas and 13 (59.1%) had atypical leiomyomas.

The area under the ROC curve (AUC) was 0.923 (standard error=0.0597; 95% CI, 0.727-0.993; z=7.090; P <0.0001), indicating excellent discrimination. Using the Youden index, an optimal cutoff ADC value of $\leq 0.892 \times 10^{-3}mm^2/s$ was identified, yielding a sensitivity of 100% and specificity of 84.6% (Youden index J=0.8462).

Table 3 presents additional ADC thresholds, corresponding sensitivity, specificity, 95% confidence intervals, and positive/negative likelihood ratios (+LR, -LR).

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Table 3. Diagnostic performance of ADC values for differentiating uterine sarcomas from atypical leiomyomas (Legend: ADC=apparent diffusion coefficient; CI=confidence interval; +LR=positive likelihood ratio; -LR=negative likelihood ratio.)

Criterion ($\times 10^{-3}$ mm²/s)	Sensitivity (%)	95% CI	Specificity (%)	95% CI	+LR	-LR
<0.698	0.0	0.0-33.6	100.0	75.3-100.0	-	1.00
≤0.783	33.3	7.5-70.1	100.0	75.3-100.0	-	0.67
≤0.791	33.3	7.5-70.1	92.3	64.0-99.8	4.33	0.72
≤0.860	66.7	29.9-92.5	92.3	64.0-99.8	8.67	0.36
≤0.863	66.7	29.9-92.5	84.6	54.6-98.1	4.33	0.39
≤0.892	100.0	66.4-100.0	84.6	54.6-98.1	6.50	0.00
≤1.214	100.0	66.4-100.0	0.0	0.0-24.7	1.00	-

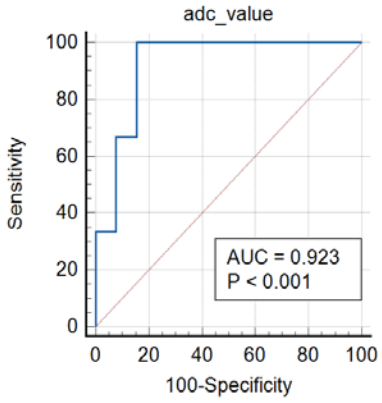

Figure 7. Receiver operating characteristic (ROC) curve for ADC values in differentiating uterine sarcomas from atypical leiomyomas. The area under the curve (AUC) was 0.923 (95% CI: 0.727-0.993; P<0.0001), indicating excellent diagnostic performance. The optimal ADC cutoff value determined using the Youden index was ≤0.892 × 10 $^{-3}$ mm²/s, corresponding to 100% sensitivity and 84.6% specificity.

Discussion

The present study demonstrates that magnetic resonance imaging, particularly diffusion-weighted imaging and quantitative ADC analysis, provides valuable information for differentiating atypical leiomyomas from uterine sarcomas.

Although several conventional MRI features showed partial overlap between the two entities, diffusion parameters demonstrated the highest discriminatory performance in our cohort.

Clinically, abnormal vaginal bleeding and pelvic pain were more frequently observed in patients with uterine sarcoma, consistent with the more aggressive biological behavior of these tumors.

However, clinical presentation alone was not sufficient for reliable differentiation, as both benign and malignant uterine tumors may present with similar symptoms.

Conventional MRI features provided useful but limited diagnostic information. In our cohort, irregular tumor margins and hyperintense signal on T2-weighted imaging were more frequently observed in uterine sarcomas, whereas atypical leiomyomas were predominantly hypointense relative to the myometrium.

Nevertheless, considerable overlap was observed between the two groups. Degenerative leiomyomas may exhibit heterogeneous signal intensity, cystic degeneration, or hemorrhage, all of which can mimic malignant lesions and reduce the specificity of morphological MRI criteria.

Our findings are in agreement with those reported by Tanaka et al. [8], who demonstrated that irregular tumor margins, high T2 signal intensity, and intratumoral hemorrhage were associated with uterine sarcoma.

Similarly, in our cohort, T2 hyperintensity and irregular margins were observed more frequently in malignant lesions, although considerable overlap remained with atypical leiomyomas.

Cornfeld et al.[9] tested previously proposed MRI criteria in an independent population and demonstrated a marked reduction in sensitivity (17% compared with 73% in the original training set), emphasizing the limited reproducibility of purely qualitative imaging features.

Our findings are consistent with this limitation: although T2 hyperintensity and irregular borders were more common in sarcomas, these features were not exclusive.

This reinforces the notion that conventional MRI characteristics lack robustness when applied across different cohorts.

The presence of extrauterine disease strongly favored malignancy.

Pelvic lymph node involvement, peritoneal metastases, and ovarian metastases were exclusively identified in sarcoma cases, underscoring the importance of careful evaluation for locoregional and distant spread when malignancy is suspected.

Among all evaluated parameters, diffusion-weighted imaging provided the most reliable differentiation between atypical leiomyomas and uterine sarcomas.

All sarcomas in our cohort demonstrated at least focal high signal intensity on DWI exceeding that of the endometrium, whereas the majority of atypical leiomyomas exhibited intermediate signal intensity.

This finding likely reflects the increased cellular density and reduced extracellular space characteristic of malignant tumors, which restricts water molecule diffusion and results in higher DWI signal intensity.

Quantitative analysis using ADC measurements further strengthened this distinction.

In our study, uterine sarcomas demonstrated significantly lower ADC values compared with atypical leiomyomas (mean 0.813×10^{-3} mm²/s versus 1.050×10^{-3} mm²/s, respectively). ROC curve analysis in our cohort demonstrated excellent diagnostic performance of ADC values, with an area under the curve (AUC) of 0.923.

Using the Youden index, the optimal ADC cutoff value for differentiating uterine sarcomas from atypical leiomyomas was 0.892×10^{-3} mm²/s, which yielded a sensitivity of 100% and specificity of 84.6%.

This threshold is comparable to values reported in previous studies, which have proposed cutoff values ranging between approximately 0.9 and 1.2×10^{-3} mm²/s depending on imaging protocols and patient populations.

Earlier studies[10-12] have proposed ADC cutoff values ranging from 1.06 to 1.23×10^{-3} mm²/s (using b values of 800-1000 s/mm²), with the primary aim of safely excluding sarcoma. In those studies, an ADC value above the proposed threshold yielded a negative predictive value of 100%, meaning that no sarcomas were missed.

While this strategy maximizes sensitivity and patient safety, it inevitably reduces specificity, as a subset of benign leiomyomas, particularly cellular or atypical variants, may demonstrate relatively low ADC values and thus be misclassified as suspicious.

This may lead to overtreatment, including unnecessary hysterectomy.

Recent studies have further emphasized the role of diffusion-weighted imaging in the evaluation of uterine tumors.

In a large cohort study [13] including 156 women (median age 50 years), MRI findings predictive of malignancy included enlarged lymph nodes or peritoneal implants, high DWI signal intensity exceeding that of the endometrium, and ADC values $\leq 0.905 \times 10^{-3}$ mm²/s.

Conversely, lesions demonstrating low T2 signal intensity and low-to-intermediate DWI signal relative to the endometrium were strongly associated with benign leiomyomas.

Additionally, both studies confirm the utility of conventional morphologic features: in our cohort, extrauterine disease such as pelvic lymph node involvement or peritoneal implants was observed exclusively in sarcomas, mirroring the prior study's predictive value of these findings.

However, overlapping features such as heterogeneous enhancement and irregular margins remained common in both benign and malignant lesions, highlighting that diffusion metrics offer superior discriminatory power when combined with morphologic assessment.

Several limitations should be acknowledged.

The study cohort was relatively small (22 patients), which may limit the generalizability of the findings and the statistical power to detect subtle differences between atypical leiomyomas and sarcomas.

The study was retrospective, and imaging assessments were performed without external validation, which may introduce selection and interpretation biases.

Quantitative diffusion-weighted imaging (ADC) measurements were performed using a single MRI protocol and field strength, which may reduce comparability with studies using different scanners, b-values, or imaging parameters.

Finally, while morphologic MRI features and diffusion metrics were assessed, advanced techniques such as perfusion imaging or radiomic analysis were not included, which may provide additional discriminatory value in differentiating uterine masses.

Despite these limitations, our findings support the growing evidence that diffusion-weighted MRI provides clinically relevant information for differentiating atypical leiomyomas from uterine sarcomas.

Combining conventional morphologic MRI features with quantitative diffusion parameters may improve diagnostic confidence and facilitate appropriate surgical planning while reducing unnecessary radical treatment for benign disease.

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Conclusions

MRI plays a central role in the preoperative evaluation of atypical uterine smooth muscle tumors.

While conventional morphologic MRI findings may overlap between atypical leiomyomas and uterine sarcomas, diffusion-weighted imaging and quantitative ADC measurements significantly improve diagnostic confidence.

In our cohort, an ADC cutoff value of ≤0.892 ×10-3 mm²/s demonstrated excellent diagnostic performance, supporting the use of diffusion MRI as a valuable imaging biomarker for differentiating benign from malignant uterine mesenchymal tumors.

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None to declare.

Author Contributions

Conceptualization, A.M.B.; Methodology, G.I.; Data analysis, Alexandre Ionescu; Manuscript writing and initial draft preparation R.A.R.; Manuscript review and editing I.A.S.; Supervision, I.A.G. All authors read and approved the final manuscript.

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Conflicts of interest

The authors declare no competing interests.

Institutional Review Board

The study was conducted according to the guidelines of the Declaration of Helsinki; the study and the protocols utilized therein were approved by the Institutional Ethics Committee of University of Medicine and Pharmacy Craiova, 283/11.09.2024.

Consent Statement

All human subjects involved in this study provided a written informed consent prior to participation, including the consent of publishing their anonymized data.

Data availability

All data presented in the manuscript are available from the authors upon request.

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