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ORIGINAL RESEARCH ARTICLE

A scoring method for differentiating incidental ovarian endometriotic cysts from ovarian cystadenomas based on CT and clinical features

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Abstract

Detecting and distinguishing between ovarian endometriotic cysts and ovarian cystadenomas using computed tomography (CT) scans is a clinical challenge due to their similar CT characteristics. This study aims to identify key CT and clinical features that can effectively differentiate these two diseases and to develop a simple and practical scoring system. We conducted a retrospective analysis of 202 patients who underwent pre-operative contrast-enhanced CT at two medical centers. The subjects were divided into training cohort (*n*=151) and validation cohort (*n*=51). Utilizing univariate analyses and binary logistic regression, predictive factors for ovarian endometriotic cysts and ovarian cystadenomas were identified to construct an initial model. Subsequently, a scoring system was developed by assigning weights to each feature based on the initial model. The accuracy of both models (the initial model and the scoring system) was quantified by calculating the area under the receiver operating characteristic curve (AUC). We further determined the optimal cutoff point for the scoring system (0 – 15 points) and established three predictive ranges based on the probabilities of ovarian endometriotic cyst occurrence (<7 points; 7 – 8 points; >8 points). The initial model, which incorporated two clinical factors (age and CA125 level) and three CT characteristics (wall thickness, density heterogeneity, and edge adhesion), demonstrated an AUC of 0.993. In the training cohort, the proportions of patients correctly diagnosed with ovarian endometriotic cysts within these three score ranges were 0%, 38.89%, and 96.83%, respectively, while in the validation cohort, they were 0%, 33.33%, and 95.00%. Thus, having a refined scoring range can help improve diagnostic accuracy, with a higher score indicating a diagnosis with ovarian endometriosis cysts, and assist with differentiating patients with different risk levels.

Keywords: Contrast-enhanced CT; Differential diagnosis; Endometrioma; Ovarian cystadenoma; Scoring system

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1. Introduction

Endometriosis, a chronic inflammatory condition influenced by estrogen, significantly diminishes the quality of life for many women.[1-3] It is marked by common symptoms such as infertility and pelvic pain, with 30 – 50% of those affected experiencing infertility and an increased risk of early miscarriage.[3-6] Post-surgical recurrence rates are high, reaching 21.5% within 2 years and 40 – 50% within 5 years.[7] The condition presents in three primary forms: Peritoneal endometriosis, ovarian endometriotic cysts, and deep infiltrating endometriosis.[8,9] Ovarian endometriotic cysts, the most prevalent type, are characterized by cystic masses on the ovaries.[10] However, ovarian cystic masses can also include benign cystadenomas, which are the most frequent type.[11,12] The imaging features of these lesions often overlap, complicating diagnosis due to their distinct treatment protocols. Ovarian endometriotic cysts typically require comprehensive, age- and stage-specific management, including early empirical drug therapy and long-term post-operative medication to prevent recurrence.[9] In contrast, ovarian cystadenomas are primarily managed through surgical excision to alleviate symptoms caused by the masses.[12] Endometriosis often presents with atypical symptoms, and its definitive diagnosis relies on laparoscopic examination, which is invasive and frequently delayed. Early diagnosis, therefore, hinges on imaging examinations, presenting a significant challenge for radiologists.

Ultrasound is the preferred diagnostic method for ovarian endometriotic cysts but can be limited by gastrointestinal gas and operator expertise, which potentially impact the imaging accuracy.[13,14] Magnetic resonance imaging (MRI), known for its excellent soft tissue resolution, is also widely used but is costly and time-consuming. High signal intensity on T1-weighted MRI is a key indicator of ovarian endometriotic cysts.[10,13,15] However, this can also result from hemorrhages or mucoid fluid, leading to potential misdiagnoses with mucinous cystadenomas, which have a misdiagnosis rate of nearly 22%.[16] With rapid scanning and broad coverage, computed tomography (CT) is often the first choice of imaging modality for patients presenting with abdominal pain, enabling detection of ovarian cystic lesions. However, radiologists often face challenges in differentiating ovarian endometriotic cysts from ovarian cystadenomas on CT, resulting in delayed diagnoses and treatment. Although studies have explored CT features of benign ovarian cystic lesions, such as the utility of CT texture analysis in distinguishing benign ovarian cysts[12] and the multi-slice spiral CT manifestations of benign adnexal lesions,[11] the findings are overly complex and lack quantifiable feature assessment.

To solve this problem, this study proposed an innovative solution: To construct a scoring system based on CT imaging features and clinical features. By selecting imaging and clinical factors that are important for differential diagnosis, and assigning corresponding scores to these factors, the system can achieve quantitative evaluation of the two diseases. This approach is designed to simplify and optimize the diagnostic process, allowing doctors to stratify risks more quickly and accurately, reducing subjectivity and uncertainty in the diagnostic process.

This study aims to develop and validate a scoring system based on CT and clinical features, to provide a powerful tool for improving diagnostic efficiency and accuracy by simplifying and optimizing the clinical diagnostic process of ovarian endometriotic cysts and ovarian cystadenomas. Through this study, we hope to provide clinicians with a more convenient and reliable diagnosis method, thereby improving the diagnosis and treatment experience of patients.

2. Methods

2.1. Research sample

A retrospective analysis was performed on a cohort comprising 151 patients from the Second Affiliated Hospital of Zhejiang University School of Medicine (referred to as Hospital 1), pathologically confirmed to have either ovarian endometriotic cysts (n = 68) or ovarian cystadenomas (n = 83) between March 2012 and June 2021. This group served as the training cohort. The inclusion criteria for this study were as follows: (1) patients with pathologically confirmed of ovarian endometriotic cysts or ovarian cystadenomas, (2) patients whose image quality meets diagnostic requirements, (3) patients with no history of malignant tumors, and (4) patients who did not experience cyst rupture. Due to incomplete clinical data, nine patients were excluded from the analysis (Figure 1). To validate our findings, a separate cohort was assembled from 51 patients at the Affiliated Jinhua Hospital of Wenzhou Medical University (Hospital 2), confirmed to have ovarian endometriotic cysts (n = 20) or ovarian cystadenomas (n = 31) between January 2019 and August 2023.

2.2. CT acquisition

Routine plain scans were performed on all subjects in the supine position using multi-slice spiral CT scanners, including the SOMATOM Definition Flash (Siemens Healthcare) and the Philips Medical Systeme 64 (Philips Healthcare). Scanning parameters were as follows: tube voltage 120 kV, tube current 180 mAs, slice thickness

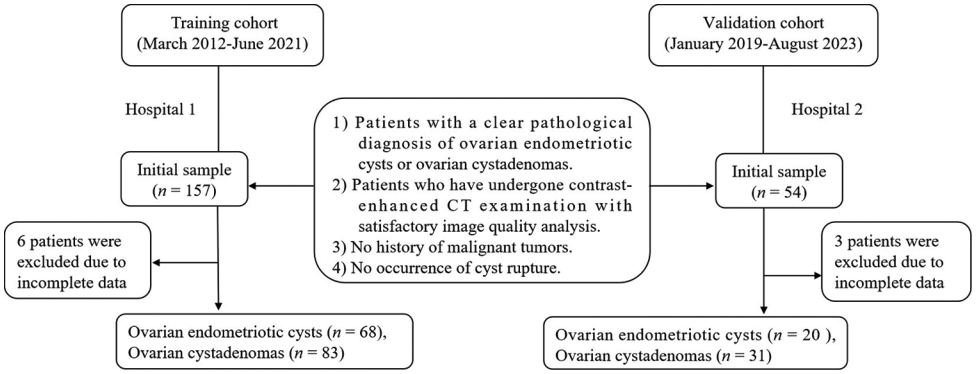


Figure 1. Flowchart depicting the process of patient selection.
Note: Hospital 1: Second Affiliated Hospital of Zhejiang University School of Medicine; Hospital 2: Affiliated Jinhua Hospital of Wenzhou Medical University

and spacing 5 mm, and reconstruction interval 1 mm. A high-pressure syringe was used to inject a contrast agent into the antecubital vein at a rate of 5 mL/s. Images were collected during the arterial phase (40 s), portal venous phase (100 s), and delayed phase (150 s) after the contrast medium injection.

2.3. Image analysis

Two experienced radiologists, each with over a decade of expertise in abdominal imaging, independently reviewed the CT plain and enhanced scans without access to the pathological outcomes. Discrepancies in their assessments were resolved through collaborative discussion. The CT features evaluated included the number of cysts (single or multiple), contour (regular or irregular), presence of marginal adhesions (absent or present), intra-cystic density heterogeneity (<10 hounsfield unit [HU], 10 – 40 HU, ≥40 HU), wall thickness (<2 mm or ≥2 mm), longitudinal diameter (LD) (<5 cm, 5 – 10 cm, ≥10 cm), calcification, presence of solid components, and pelvic fluid. Density homogeneity was defined as a difference of <10 HU, mild to moderate heterogeneity as 10 – 40 HU, and severe heterogeneity as 40 HU or greater.

A 20 mm² region of interest (ROI) was consistently outlined.[17,18] The ROI was centered at the midpoint of the cyst's short axis, from which a circle was drawn with a radius equal to half the length of the short axis. Four symmetric points on the circle, along with the origin, were used to measure CT values. This methodology allowed for the determination of five CT values, from which the maximum, minimum, and range of values were derived.[19,20] Quantitative parameters were measured thrice by both physicians, with the final value being the average of these six measurements. Clinical characteristics, such as age, clinical symptoms, CA125 levels, and hemoglobin values, were also documented for analysis.

2.4. Statistical analysis

Continuous variables were presented as medians and interquartile ranges for data that did not follow a normal distribution, while categorical variables were expressed as frequencies (*n*, %). For group comparisons, we utilized the Student's *t*-test for continuous variables, Chi-square or Fisher's exact test for categorical variables, and the rank-sum test for ordinal variables. After ensuring the absence of multicollinearity, variables that showed significant differences in univariate analysis were included in a logistic regression model (an initial model) to determine independent predictors of endometriotic cysts. A $p<0.05$ was considered statistically significant.

To derive an optimal integer scoring system suitable for clinical use, we employed the formula β/(1/2 β min), where β represents the regression coefficient of each variable, and β min is the smallest value of the regression coefficient.[21] This calculation was rounded to the nearest whole number to assign scores to each independent predictor. The total score for each case was calculated by summing the scores of all independent predictors. The receiver operating characteristic (ROC) curve and the area under the ROC curve (AUC) value were employed to assess the model's discriminative power. The Delong non-parametric method was applied to compare the AUC of different models.[22] For clinical convenience, the scoring system was divided into three ranges to estimate the diagnostic probability of ovarian endometriotic cysts.[17,18] Further validation was performed using an independent cohort of 51 patients.

All statistical analyses, with the exception of AUC comparisons, were conducted using Statistical Packages for the Social Sciences version 23.0 (IBM Corp, Armonk, NY). AUC comparisons were carried out using MedCalc version 19.0 (MedCalc Software bvba). A $p<0.05$ was considered statistically significant.

3. Results

3.1. Clinical characteristics and CT values

In the training cohort, a total of 151 patients were enrolled, with 68 diagnosed with ovarian endometriotic cysts and 83 with ovarian cystadenomas. For group comparisons, Table 1 revealed significant differences between the two groups for the following factors: Age ($p < 0.001$), clinical symptoms ($p = 0.010$), CA125 levels ($p < 0.001$), number of cysts ($p = 0.006$), contour ($p < 0.001$), LD ($p < 0.001$), density heterogeneity ($p < 0.001$), presence of marginal adhesions ($p < 0.001$), wall thickness ($p < 0.001$), and pelvic fluid ($p < 0.001$).

3.2. Predictors for the initial model

Univariate analysis revealed that patient age, clinical symptoms, CA125 levels, cyst number, contour, LD, density heterogeneity, marginal adhesions, wall thickness, and pelvic fluid are significant factors in distinguishing between ovarian endometriotic cysts and other types of cysts. Following a multicollinearity analysis with a tolerance threshold >0.1 and a variance inflation factor below 5, binary logistic regression identified five independent predictive factors: Elevated CA125 levels, age within the 21 – 50 years range, mild to moderate density heterogeneity, wall thickness of 2 mm or greater, and the presence of marginal adhesions (Table 2). The initial model demonstrated an AUC of 0.993 (95% confidence interval [CI], 0.985 – 1.000; $p < 0.001$), indicating excellent discriminative ability. With a Youden index of 0.896 and a cutoff value of 2.0485, the model achieved a sensitivity of 95.6% and a specificity of 94.0%.

3.3. Establishment of a scoring model

The integer scores for the predictor are derived by rounding the ratio of each predictor's regression coefficient to half of the minimum regression coefficient (Table 2). Specifically, elevated CA125 levels are allocated 4 points, age between 21 and 50 years merits 4 points, mild to moderate density heterogeneity earns 2 points, wall thickness of 2 mm or more is awarded 3 points, and marginal adhesions receive 2 points (Figures 2 and 3). Cystadenomas are characterized by lower CA125 elevations, a higher prevalence in both adolescents and older adults, thinner walls with smoother margins, and a more uniform density (Figure 4). The total score for each case in the model is calculated by summing the scores of the relevant predictors, yielding a score range from 0 to 15 points. An ROC curve was plotted to assess the model's performance across various thresholds, with the AUC of the scoring system reaching 0.992 (95% CI, 0.983 – 1.000; $p < 0.001$). When the Youden index was 0.896 and the cutoff value was 7.5 points, the sensitivity was 95.6% and the specificity was 94.0%. A comparison of the two AUCs revealed no statistically significant difference between the initial model and the scoring model ($p>0.05$, Figure 5), suggesting that the discriminative scoring system effectively utilized the primary predictive model.

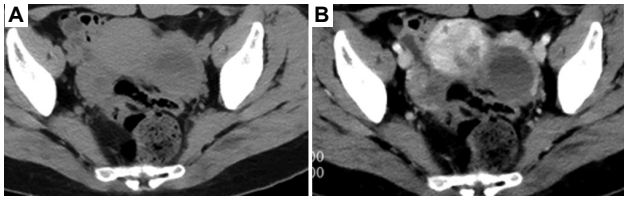


Figure 2. A representative female case of 44 years old (4 points), with a CA125 value of 82.60 (4 points) and abdominal pain for 2 days. (A) Abdominal CT plain scan shows the left ovary with a cystic tumor measuring approximately 4 cm × 5 cm × 5 cm (anteroposterior × transverse × craniocaudal) in size. The CT value is approximately 39 HU in larger regions and around 6.9 HU in smaller regions, with a CT value difference of 32.1 HU (2 points). (B) The contrast-enhanced CT scan shows a cystic lesion with a wall thickness is approximately 4.1 mm (3 points), with a blurry margin and evident adhesion to the left adnexa (2 points). The total score for this case is 15 points, alluding to a diagnosis of ovarian endometriotic cysts.
Abbreviation: CT: Computed tomography

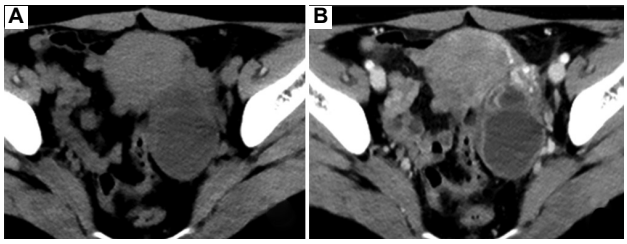


Figure 3. A representative female case of 37 years old (4 points), with a pelvic mass discovered for 1 month and a CA125 value of 26.64 (0 points). (A) Abdominal CT plain scan reveals left ovarian cystic enlargement with a cystic mass measuring approximately 5 cm × 7 cm × 4 cm (anteroposterior × transverse × craniocaudal) in size. The cyst in the left adnexal area demonstrates heterogeneous density, with a CT value of approximately 22 HU in larger regions and around 4.3 HU in smaller regions, with a CT value difference of 17.7 HU (0 points). (B) The contrast-enhanced CT scan shows a cystic lesion with a wall thickness of approximately 3.1 mm (3 points), a blurry margin, and adhesion to the left adnexa (2 points). The total score for this case is 9 points, alluding to a diagnosis of ovarian endometriotic cysts.
Abbreviation: CT: Computed tomography

For clinical application, patients' final scores were categorized into three ranges: 0 – <7 points, 7 – 8 points, and >8 points, There were 0, 7, and 61 patients with ovarian endometriotic cysts in the three ranges in the training cohort, and 0, 1, and 19 patients in the validation cohort, respectively, with a notable increase in the prevalence of ovarian endometriomas as scores increased (Table 3). The proportion of patients in the

Table 1. Characteristics of patients with ovarian endometriomas and ovarian cystadenomas

Characteristics	Training cohort			Validation cohort		
	Cystadenomas (*n*=83)	Endometriotic cysts (*n*=68)	*p*	Cystadenomas (*n*=31)	Endometriotic cysts (*n*=20)	*p*
CA125, (%)			<0.001			0.009
Normal	74 (89.2)	13 (19.1)		26 (83.9)	9 (45)	
Elevated	9 (10.8)	55 (80.9)		5 (16.1)	11 (55)	
Age (years), (%)			<0.001			
≤20	6 (7.2)	1 (1.5)				<0.001
21 – 50	31 (37.3)	66 (97.1)		19 (61.3)	1 (5)	
>50	46 (55.4)	1 (1.5)		11 (35.5)	19 (95)	
Wall thickness, (%)			<0.001	1 (3.2)	0 (0)	<0.001
<2 mm	61 (73.5)	7 (10.3)		31 (100)	1 (5)	
≥2 mm	22 (26.5)	61 (89.7)		0 (0)	19 (95)	
Marginal adhesions, (%)			<0.001			<0.001
Absent	78 (94)	18 (26.5)		31 (100)	6 (30)	
Present	5 (6)	50 (73.5)		0 (0)	14 (70)	
Density heterogeneity, (%)			<0.001			0.002
Uniform	69 (83.1)	22 (32.4)		23 (74.2)	5 (25)	
Mild to moderate	11 (13.3)	43 (63.2)		8 (25.8)	15 (75)	
Severe	3 (3.6)	3 (4.4)		0 (0)	0 (0)	
Contour, (%)			<0.001			
Regular	67 (80.7)	15 (22.1)				
Irregular	16 (19.3)	53 (77.9)				
Pelvic fluid, (%)			<0.001			
Absent	71 (85.5)	41 (60.3)				
Present	12 (14.5)	27 (39.7)				
Longitudinal diameter, (%)			<0.001			
<5 cm	8 (9.6)	18 (26.5)				
5 – 10 cm	30 (36.1)	43 (63.2)				
≥10 cm	45 (54.2)	7 (10.3)				
Clinical symptoms, (%)			0.010			
Asymptomatic	37 (44.6)	34 (50)				
Dysmenorrhea, infertility	10 (12)	18 (26.5)				
Abdominal pain, bloating	35 (42.2)	14 (20.6)				
Others	1 (1.2)	2 (2.9)				
Cyst number, (%)			0.006			
Single	75 (90.4)	50 (73.5)				
Multiple	8 (9.6)	18 (26.5)				
Hemoglobin	124 (116 – 132)	124 (117 – 130)	0.809			
Calcification, (%)			0.058			
Absent	74 (89.2)	66 (97.1)				
Present	9 (10.8)	2 (2.9)				
Solid component, (%)			0.611			
Absent	81 (97.6)	66 (97.1)				
Present	2 (2.4)	2 (2.9)				

Table 2. Multivariate regression analysis for ovarian endometriotic cysts diagnosis and the weighted score of independent predictors

Variables	Weighted score	B	Standard error	*p*	OR	95% CI for OR
Elevated CA125	4	6.472	2.170	0.003	28.47	5.11 – 158.55
20 < Age ≤ 50	4	7.339	3.282	0.025	0.17	0.04 – 0.72
Wall thickness ≥2 mm	3	5.365	2.027	0.008	7.45	1.59 – 34.82
Marginal adhesions	2	3.725	1.640	0.023	6.97	1.16 – 41.7
Mild to moderate density heterogeneity	2	3.298	1.524	0.030	0.23	0.06 – 0.86

CI: Confidence interval; OR: Odds ratio.

Table 3. Diagnostic probability of ovarian endometriotic cysts classified in different score ranges

Score range	Number of patients with ovarian endometriotic cysts		Total number		Diagnostic probability of ovarian endometriotic cysts	
	Training cohort	Validation cohort	Training cohort	Validation cohort	Training cohort (%)	Validation cohort (%)
0 – 6 points	0	0	70	28	0	0
7 – 8 points	7	1	18	3	38.89	33.33
>8 – ≤15 points	61	19	63	20	96.83	95.00

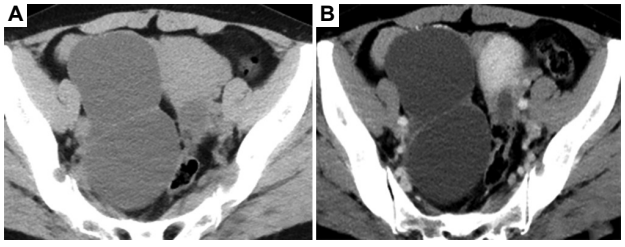


Figure 4. A representative female case of 54 years old (0 points), who had reported irregular menstruation for 3 months and irregular vaginal bleeding for 20 days, with a CA125 value of 13.93 (0 points). (A) Abdominal CT plain scan shows a cystic lesion on the right side of the pelvis, measuring approximately 7 cm × 15 cm × 12 cm (anteroposterior × transverse × craniocaudal) in size, with uniform density. The CT value is approximately 7.7 HU in larger regions and around 2.9 HU in smaller regions, with a CT value difference of 4.8 HU (0 points). (B) The contrast-enhanced CT scan reveals a cystic lesion with clear boundaries (0 points) and a thin wall (0 points). The total score for this case is 0 points, indicating a diagnosis of ovarian cystadenoma.
Abbreviation: CT: Computed tomography.

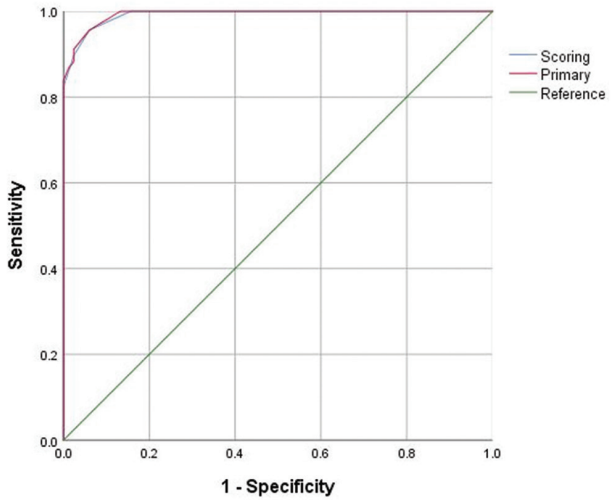


Figure 5. ROC curve of the primary and scoring models
Abbreviation: ROC: Receiver operating characteristic.

training cohort who were correctly diagnosed with ovarian endometriomas was as follows: 0 out of 28 (0%) in the first range (0 – <7 points), 1 out of 3 (33.33%) in the second range (7 – 8 points), and 19 out of 20 (95.00%) in the final range (>8 – ≤15 points), respectively, compared with 0%, 33.33% and 95.00% in the validation cohort. In the training and validation cohorts, the probability of diagnosis in the three scoring ranges also increased significantly with the increase of the scoring range. While the specific percentages in the validation cohort differed slightly from the training cohort, the overall trend was consistent, namely that patients in the high-scoring range were more likely to be correctly diagnosed with ovarian endometriosis cysts. This suggests that the scoring system may be somewhat effective in differentiating patients with different risk levels.

Furthermore, a ROC curve was plotted to evaluate the performance of the scoring model in the validation cohort, with an AUC of the scoring system at 0.991 (95% CI, 0.975 – 1.000, $p < 0.001$; Figure 6), indicating a strong discriminative ability for ovarian endometriomas. The Youden index was 0.918, with a cutoff value of 8.5 points, with a sensitivity of 95.0% and a specificity of 96.8%.

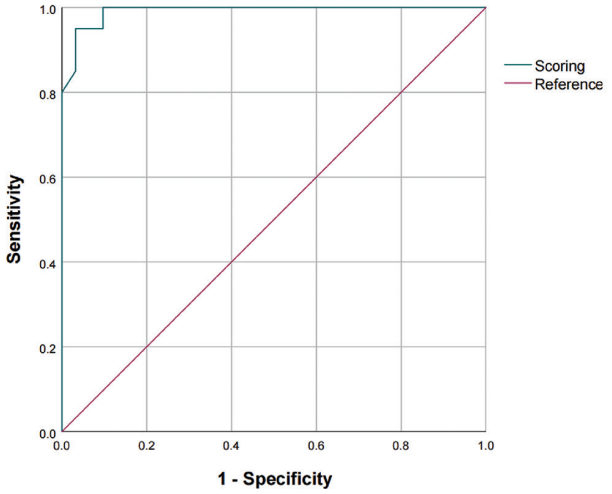


Figure 6. ROC curve of the scoring model in the validation cohort
Abbreviation: ROC: Receiver operating characteristic.

4. Discussion

Endometriosis has a high clinical incidence, affecting approximately 5 – 10% of women of reproductive age worldwide, and is a major contributor to infertility.[31] The presence of endometriotic lesions can disrupt the normal pelvic anatomy, cause adhesions, and affect ovarian function, tubal motility, and embryo implantation, all of which can lead to reduced fertility potential.[32] A recent systematic review and meta-analysis explored the impact of endometriosis on embryo quality in *in vitro* fertilization/intracytoplasmic sperm injection.[33] The findings revealed that endometriosis significantly impacts embryo quality, further highlighting the importance of early and accurate diagnosis of ovarian endometriotic cysts, which are a form of endometriosis. Our scoring system, by enabling precise differentiation between ovarian endometriotic cysts and ovarian cystadenomas, can assist clinicians in promptly identifying endometriotic cases. This allows for timely intervention, potentially reducing the negative impact on embryo quality and fertility in affected patients.

Accurate pre-operative diagnosis of endometriosis is crucial in determining appropriate treatment strategies. Present management of endometriosis follows a patient-centered, multimodal, and interdisciplinary approach tailored to the individual, focusing on pain and inflammation relief. Long-term management is often required. In cases where family planning is a priority, conservative surgery may be considered to excise endometriotic lesions, thus preserving fertility. In contrast, ovarian cystadenomas are typically managed through surgical removal to alleviate the mass effect.

With the widespread use of CT in clinical practice, patients presenting with abdominal pain, bloating, or other symptoms frequently undergo CT scans, which can reveal ovarian cystic masses. However, there is limited literature specifically detailing the CT characteristics of ovarian cystic lesions, contributing to diagnostic uncertainty among radiologists. Previous studies have highlighted imaging features that may differentiate ovarian endometriotic cysts from ovarian cystadenomas. Foti *et al.*[8] emphasized changes in pelvic organ and structural morphology due to adhesions. Tsili *et al.*[11] suggested that the CT features of endometriotic cysts are variable, while cystadenomas typically have smooth and thin walls. Seo *et al.*[12] used CT texture analysis to differentiate mucinous cystadenomas from other benign ovarian tumors, stating that mucinous cystadenomas exhibit more mucin and septations, while endometriotic cysts show bleeding and blood clots, resulting in a more heterogeneous density within the cyst. Buy *et al.*[23] studied high-density foci within endometriotic cysts, highlighting the diagnostic value of blood clots. However, these methods are somewhat subjective, focusing on partial features, and do not provide a comprehensive analysis of multiple features.

Our developed scoring system, which integrates five predictive factors (elevated CA125 levels, age between 21 and 50 years, wall thickness ≥2 mm, mild-to-moderate density heterogeneity, and marginal adhesions), assists with the efforts in fertility preservation by identifying patients of various risk levels to enable formulation of more tailored treatment management. Accurate differentiation of ovarian endometriotic cysts from ovarian cystadenomas pre-operatively contributes considerably to making more informed clinical decisions. For patients with a high risk for endometriotic cysts determined using the scoring system and who desire fertility preservation, conservative surgical options should be considered, avoiding unnecessary radical surgeries that might damage the ovarian function and further reduce fertility potential.[34] In the context of assisted reproductive techniques, understanding the impact of endometriosis-related ovarian conditions is essential. A study on fresh versus frozen embryo transfer in assisted reproductive techniques[35] can offer insights into the best reproductive strategies for patients with ovarian endometriotic cysts who may require such interventions. Our scoring system can potentially guide the selection of appropriate treatment paths, including whether to consider assisted reproduction and which approach might be more suitable based on the accurate diagnosis of the ovarian cyst type.

However, these diagnostic methods are somewhat subjective, focusing on partial features, and fail to provide

a comprehensive evaluation of multiple characteristics. Consequently, radiologists continue to rely heavily on their experience when assessing ovarian cystic masses. In this study, we aimed to develop a reliable and highly accurate scoring system for differentiating ovarian endometriotic cysts from ovarian cystadenomas based on a combination of clinical and CT features. Our scoring system, which integrates five predictive factors, enhances diagnostic accuracy, particularly for less experienced radiologists and clinicians. The scoring system categorizes patients into three groups based on their scores, with corresponding diagnostic probabilities for ovarian endometriotic cysts in both the training and validation cohorts. In the first group (0 – <7 points), the probability of ovarian endometriotic cysts was 0% in both cohorts. In the second group (7 – 8 points), the probabilities were 38.89% in the training cohort and 33.33% in the validation cohort. In the final group (>8 – ≤15 points), the probabilities were 96.83% and 95.0%, respectively.

The five independent risk factors in the model are: (1) Elevated CA125 levels, (2) age between 21 and 50 years, (3) wall thickness ≥2 mm, (4) mild to moderate density heterogeneity, and (5) marginal adhesions. In addition, we found that ovarian endometriotic cysts are more likely to occur bilaterally, which is consistent with previous studies. Previous literature[12] suggested that mucinous cystadenomas exhibit more septations. However, since our study included both serous and mucinous cystadenomas in the analysis, intra-cystic septations did not show significant specificity. According to Seo *et al.*'s study,[12] cyst diameter helps in differential diagnosis of ovarian endometriotic cysts and cystadenomas. However, our multivariate analysis did not demonstrate statistical differences. Nevertheless, Lee *et al.*[24] found that ovarian endometrioma cysts >5.5 cm in diameter were significantly associated with post-operative recurrence.

Of the five factors, radiological factors include wall thickness ≥2 mm, mild to moderate density heterogeneity, and marginal adhesions. The growth of endometriotic cysts is associated with angiogenesis, inflammation, immune factors, and fibrosis, leading to pelvic adhesions and anatomical deformities.[3,6] Compared to cystadenomas, there is increased fibrosis in the surrounding tissues of endometriotic cysts,[25] and they lack a true capsule. The wall between the endometriotic cysts and adjacent ovarian tissue is formed by the ovarian parenchyma or surrounding inflammatory response tissue.[26] Therefore, the wall of endometriotic cysts is thick and surrounded by adhesions, while the wall of cystadenomas is generally smooth and thin. Endometriosis involves periodic bleeding, and bleeding at different stages causes uneven density within endometriotic cysts. The average, standard deviation, and entropy values of endometriotic cysts are often higher than those of mucinous cystadenomas.[12,27] Our experimental results also confirm that ovarian endometriotic cysts are more likely to exhibit density heterogeneity compared to cystadenomas.

Clinical factors include age and CA125. Women aged 21 – 50 have higher estrogen levels, which can promote the growth of ectopic endometrial tissue, leading to a higher incidence of endometriosis. There is a general increase of the serum CA125 levels in patients with endometriotic cysts, and the degree of elevation is related to the American Fertility Society (r-AFS) stage of endometriosis, with a higher r-AFS stage potentially raising the likelihood and degree of CA125 elevation, which may be associated with inflammation and adhesions.[28,29] It has also been revealed that the amount of CA125 secreted by endometriosis patient-derived endometrial tissue cultured *in situ* is 2 – 4 times that of patients without endometriosis, establishing CA125 concentration as a marker to predict the prognosis and recurrence of endometriosis.[28,30]

Gynecological diseases, including ovarian endometriotic cysts and ovarian cystadenomas, have not only physical but also psychological impacts on patients. A study emphasizing the psychological impact of gynecological diseases and the importance of a multidisciplinary approach[36] can be paralleled with our research. On the grounds of its accuracy, the scoring system we constructed can contribute to multidisciplinary management. By providing a clear diagnosis, it helps with streamlining communication with patients, reducing their anxiety caused by diagnostic uncertainty resulted from conventional method. This, in turn, can have a positive impact on the overall well-being of patients during the treatment process.

Moreover, lifestyle and diet can influence the development and progression of endometriosis. A study exploring the impact of lifestyle and diet on endometriosis suggests that appropriate lifestyle modifications should be supplementary to the management of endometriosis-related ovarian conditions.[37] Upon making an accurate diagnosis of ovarian endometriotic cysts, our scoring system can also guide clinicians to provide more personalized lifestyle advice to patients, so as to improve long-term management of the disease.

In the field of diagnostic imaging, while our study focuses on CT-based features, understanding advanced MRI techniques for endometriosis can offer a broader perspective. Comparing the capabilities of CT and MRI in diagnosing ovarian endometriotic cysts and ovarian cystadenomas can help in further validating

the uniqueness and effectiveness of our CT and clinical feature-based scoring system. This comparison can also provide insights into how different imaging modalities can be complementary in the accurate diagnosis of these ovarian cystic lesions.

In clinical practice, the scoring system can streamline the diagnostic process. For patients with suspected ovarian cystic masses, instead of relying solely on the radiologist's experience, the scoring system can provide a more objective and standardized assessment. This can lead to more timely and accurate diagnosis, reducing the time to appropriate treatment. It also helps in communication between different departments, such as radiology and gynecology, as the scoring system provides a unified and standardized system for simplifying the nature and classification of cystic lesions.[38]

Moreover, findings from advanced MRI techniques in endometriosis can potentially offer a comparative perspective to the CT-based approach. Specifically, comparing MRI and CT might help in further validating the utility and uniqueness of our scoring system for differentiating ovarian endometriotic cysts and ovarian cystadenomas.[37] In addition, considering relevant research findings, offering comprehensive reproductive counseling for patients with ovarian endometriotic cysts has grown in importance. Our scoring system, by enabling accurate diagnosis, can better inform such counseling sessions.[39]

This study has several limitations. First, the retrospective design may introduce selection bias. For example, patients with more severe symptoms or more complex cases may be more likely to be included in the study, while milder cases may be under-represented. This can lead to an over - or under-estimation of the scoring system's performance. Second, despite the use of multicenter data, the sample size was relatively small, which may have led to overfitting. In addition, the validation cohort showed slightly lower predictive accuracy than the training cohort, potentially due to its smaller size, which increases variability and bias. Future studies should focus on conducting prospective, multicenter, large-scale studies to confirm the robustness and generalizability of the scoring system. Moreover, incorporating more diverse patient populations, including different ethnic groups and those with comorbidities, can further improve the scoring system's applicability.[40]

5. Conclusion

In summary, we developed a CT feature-based scoring system for the differential diagnosis of ovarian endometriotic cysts and ovarian cystadenomas. The system integrates five key variables: elevated CA125 levels, age (21 – 50 years), wall thickness ≥2 mm, mild to moderate density heterogeneity, and marginal adhesions. This scoring system demonstrates strong predictive ability, enhancing the diagnostic confidence of radiologists and clinicians, and holds substantial clinical value in distinguishing between these two types of ovarian cystic lesions.

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Conflict of interest

The authors declare no conflict of interest.

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Ethics approval and consent to participate

This study was approved by the Medical Ethics Committee (ky-2023-0827) and the requirement for patient consent was waived.

Consent for publication

Not applicable.

Availability of data

The data and materials supporting the conclusion of this article can be provided by the author upon reasonable request.

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