(Research Article)

Comparative evaluation of the diagnostic performance of radiomics-based ultrasound analysis in the differential diagnosis of ovarian cysts

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Abstract

Ovarian cysts are among the most common gynecological conditions in women of reproductive age. Ultrasound examination remains the primary imaging modality for evaluating adnexal masses; however, conventional ultrasound interpretation is often dependent on the subjective assessment of the examiner. In recent years, radiomics-based image analysis has emerged as a promising approach for extracting quantitative imaging biomarkers that may improve diagnostic accuracy. This study aimed to comparatively evaluate the diagnostic performance of radiomics-based ultrasound analysis and conventional ultrasound examination in the differential diagnosis of ovarian cysts. Methods. A prospective observational study included 24 female patients aged 19–45 years with sonographically confirmed ovarian cysts. All patients underwent clinical evaluation, gynecological examination, and transvaginal ultrasound with Doppler assessment. Ultrasound images were processed using MATLAB and Simulink, followed by radiomics feature extraction with the PyRadiomics platform after manual segmentation of the region of interest (ROI). Results. Functional cysts (follicular and corpus luteum) accounted for 66.7% (16/24) of cases, while neoplastic cysts (dermoid and endometriotic) represented 33.3% (8/24). A statistically significant difference in cyst distribution was observed (χ^2=4.03; p=0.045). Radiomics analysis revealed characteristic imaging patterns for functional cysts, including anechoic content, smooth margins, and high internal homogeneity, which corresponded with histopathological findings. Neoplastic cysts demonstrated higher entropy values and heterogeneous texture patterns. Conclusion. The integration of radiomics into routine ultrasound imaging may enhance diagnostic precision, reduce subjectivity in image interpretation, and support more accurate clinical decision-making in gynecological practice.

Keywords: Ovarian cysts; Radiomics; Ultrasound imaging; Texture analysis; Differential diagnosis; Adnexal masses

1. Introduction

Ovarian cysts represent one of the most common gynecological conditions affecting women of reproductive age. In many cases, these cystic lesions are benign and functional in nature, such as follicular or corpus luteum cysts; however, some ovarian cysts may represent neoplastic processes that require careful diagnostic evaluation and appropriate clinical management. Accurate differentiation between functional and neoplastic ovarian cysts is therefore essential in order to avoid unnecessary surgical interventions while ensuring timely identification of potentially malignant lesions [4].

Ultrasound examination remains the primary imaging modality for the evaluation of ovarian masses due to its accessibility, cost-effectiveness, and high diagnostic value in gynecological practice. Transvaginal ultrasonography provides detailed visualization of ovarian morphology and allows assessment of lesion size, internal structure, vascularization, and wall characteristics. Several standardized diagnostic approaches have been developed to improve ultrasound interpretation, including simple ultrasound rules and structured reporting systems such as the Ovarian-

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Adnexal Reporting and Data System (O-RADS), which aim to enhance risk stratification and improve diagnostic consistency [5,6]. Despite these advances, conventional ultrasound assessment remains partially dependent on the subjective interpretation of the examiner. Interobserver variability and limited ability to detect subtle microstructural differences within lesions may lead to diagnostic uncertainty, particularly in cases of complex ovarian cysts [4,10]. For this reason, there is a growing interest in quantitative imaging techniques that may provide more objective diagnostic information.

Radiomics has emerged as a promising approach in medical imaging analysis. This technique involves the extraction of large numbers of quantitative features from medical images, transforming imaging data into high-dimensional measurable information that reflects tissue heterogeneity and morphological characteristics [1,2]. Radiomic features can capture subtle patterns within medical images that are not readily detectable through conventional visual assessment.

Previous studies have demonstrated that radiomics-based approaches can be used to characterize tumor phenotypes and improve diagnostic performance in various oncological applications [3]. Texture analysis and other radiomic features derived from medical images have shown potential in identifying structural heterogeneity and differentiating between benign and malignant lesions [8]. Furthermore, the integration of machine learning techniques with radiomics features has opened new opportunities for the development of predictive diagnostic models in medical imaging [7].

In recent years, radiomics has increasingly been applied to gynecological imaging, particularly in the evaluation of ovarian tumors. Studies have suggested that quantitative radiomics features extracted from ultrasound images may improve the differentiation between different types of ovarian lesions, providing additional information beyond conventional imaging parameters [9]. Combined imaging approaches incorporating ultrasound characteristics, laboratory markers such as CA-125, and advanced analytical methods may further enhance diagnostic accuracy in ovarian pathology [11,12]. Therefore, the application of radiomics-based ultrasound analysis may represent an important step toward improving the differential diagnosis of ovarian cysts and supporting more objective clinical decision-making.

2. Materials and methods

This prospective observational study was conducted to evaluate the diagnostic performance of radiomics-based ultrasound analysis in the differential diagnosis of ovarian cysts. The study included 24 female patients aged 19–45 years, who were referred to the gynecology department for evaluation of ovarian cystic lesions. The mean age of the participants was 32.8±5.4 years, representing women of reproductive age. Patients were recruited consecutively during routine clinical practice after the detection of ovarian cysts during ultrasound examination. All participants underwent a comprehensive clinical and instrumental evaluation according to the study protocol.

The inclusion criteria were: women of reproductive age with sonographically confirmed ovarian cysts, availability of complete ultrasound imaging suitable for radiomics analysis, agreement to undergo further diagnostic procedures including surgical treatment if clinically indicated. The exclusion criteria included: previous ovarian surgery that could alter ovarian anatomical structure, pregnancy, inflammatory pelvic diseases affecting ovarian morphology, incomplete imaging data or images of insufficient quality for radiomics processing.

All patients underwent a detailed clinical assessment, including evaluation of medical history, gynecological complaints, reproductive history, and previous gynecological conditions. A standard gynecological examination was performed for each patient. The primary imaging modality used in the study was transvaginal ultrasonography, which represents the most widely used and informative method for evaluating adnexal masses. Ultrasound examination included evaluation of the following parameters: cyst localization and size, internal echogenicity, presence of septations, detection of solid components, wall thickness and irregularity, internal structural characteristics. Additionally, color Doppler ultrasound was performed to assess vascularization of the cystic lesions. Doppler assessment allowed evaluation of blood flow patterns, which may indicate increased vascular activity in certain pathological processes. These conventional ultrasound parameters served as the baseline diagnostic indicators and were further compared with radiomics-derived imaging features.

To improve the diagnostic accuracy of ultrasound imaging, a radiomics-based quantitative image analysis approach was applied. Ultrasound images were exported from the imaging system in standardized digital format and subsequently processed using MATLAB and Simulink environments for image acquisition, preprocessing, and data standardization. Image preprocessing included: image normalization, noise reduction, intensity standardization, spatial resolution harmonization. These steps were necessary to minimize technical variability and ensure reproducibility of radiomic

feature extraction. The Region of Interest (ROI) corresponding to the cystic lesion was manually segmented on ultrasound images by experienced specialists. Accurate segmentation is essential for reliable extraction of radiomic features. After ROI segmentation, quantitative radiomic features were extracted using the PyRadiomics platform, which enables automated calculation of a large number of imaging features describing tissue characteristics.

Histopathological examination served as the reference standard for final diagnosis. Tissue samples were obtained after surgical excision or biopsy of the ovarian cysts. All samples were processed according to standard histological protocols and evaluated by experienced pathologists using microscopic examination.

Statistical analysis was performed using SPSS v.26. A p-value <0.05 was considered statistically significant.

3. Results

A total of 24 ovarian cyst cases were analyzed in this study based on ultrasound examination and subsequent histopathological verification. According to ultrasound findings, functional cysts represented the majority of cases. These included follicular cysts and corpus luteum cysts, which together accounted for 66.7% (16 out of 24 cases) of all detected lesions. In contrast, neoplastic cysts, including dermoid cysts and endometriotic cysts, were identified in 33.3% (8 out of 24 cases).

Statistical analysis demonstrated a significant difference in the distribution of functional and neoplastic cysts within the study population (χ^2=4.03; p=0.045), indicating that functional cysts were significantly more prevalent among the examined patients. These findings are consistent with epidemiological data indicating that functional ovarian cysts represent the most common cystic lesions in women of reproductive age.

Radiomics-based ultrasound analysis allowed the extraction of multiple quantitative imaging parameters describing the internal structure and morphology of ovarian cysts. Analysis of first-order intensity features revealed a mean intensity value of 35.5, which is characteristic of anechoic or low-density fluid content typically observed in functional ovarian cysts.

The entropy value was 5.12, indicating a moderate level of image homogeneity within the cystic structures. Lower entropy values generally correspond to more uniform internal structures, which is typical for simple fluid-filled cysts. Morphological analysis demonstrated that most cysts had well-defined round or oval contours. The average lesion area measured 135,079 pixels, reflecting moderate cyst size within the studied cohort. The circularity coefficient was 0.143, suggesting that the majority of lesions were relatively regular and smooth in shape, without significant irregular projections or complex structures. Texture analysis based on Gray Level Co-occurrence Matrix (GLCM) parameters provided additional information about the internal heterogeneity of the cystic lesions. The following average values were observed: Contrast: 51.2, Homogeneity: 0.594, Correlation: 0.980. The high correlation value (0.980) and moderate homogeneity indicated substantial internal uniformity, which is typical for benign functional cysts containing homogeneous fluid.

Radiomics-based ultrasound profiles of functional cysts consistently demonstrated characteristic imaging features, including: anechoic internal content, smooth and well-defined borders, high internal homogeneity, absence of solid components or internal septations. These imaging characteristics showed strong concordance with histopathological findings, which confirmed the presence of follicular cysts and corpus luteum cysts.

In contrast, neoplastic cysts demonstrated markedly different radiomic patterns. These lesions exhibited: higher entropy values, indicating increased internal complexity, irregular margins, heterogeneous texture patterns, suggesting mixed internal structures. Radiomics analysis was particularly helpful in the early identification of dermoid cysts, which demonstrated distinctive heterogeneous radiomic signatures. These findings were subsequently confirmed by histopathological examination.

The diagnostic performance of conventional ultrasound and radiomics-based ultrasound analysis in the differential diagnosis of ovarian cysts is presented in Table 1.

Table 1 Diagnostic performance of conventional ultrasound and radiomics-based analysis in the differential diagnosis of ovarian cysts

Diagnostic method	Sensitivity (%)	Specificity (%)	Accuracy (%)
Conventional ultrasound assessment	75.0	81.3	77.1
Radiomics-based ultrasound analysis	87.5	93.8	89.6

The results presented in Table 1 demonstrate a clear improvement in diagnostic performance when radiomics-based ultrasound analysis was applied. Conventional ultrasound assessment showed a sensitivity of 75.0%, specificity of 81.3%, and overall diagnostic accuracy of 77.1% in differentiating functional and neoplastic ovarian cysts. In contrast, radiomics-based ultrasound analysis demonstrated higher diagnostic indicators, with a sensitivity of 87.5%, specificity of 93.8%, and overall accuracy of 89.6%. The increase in sensitivity indicates that radiomics analysis improved the detection of neoplastic cysts, while the higher specificity reflects a reduced rate of false-positive diagnoses. These findings suggest that the incorporation of quantitative radiomic features into ultrasound evaluation can significantly enhance diagnostic precision by providing objective imaging biomarkers that reflect the internal structure and heterogeneity of ovarian lesions. Consequently, radiomics-based analysis may serve as a valuable adjunct to conventional ultrasound in the differential diagnosis of ovarian cysts.

These findings highlight the potential advantages of radiomics-based ultrasound analysis and provide a basis for further discussion regarding its role in improving the differential diagnosis of ovarian cysts.

4. Discussion

The results of the present study demonstrate the potential diagnostic value of radiomics-based ultrasound analysis in the differential diagnosis of ovarian cysts. Traditional ultrasound assessment remains the primary imaging modality for evaluating adnexal masses; however, its interpretation largely depends on the subjective experience of the examiner. Radiomics provides a quantitative approach to image analysis, enabling extraction of objective imaging biomarkers that reflect the underlying morphological structure of ovarian lesions.

Our findings showed that functional ovarian cysts were the most frequently observed lesions in the study population, accounting for 66.7% of cases. This observation is consistent with previously reported clinical data indicating that functional cysts are commonly encountered in women of reproductive age and often resolve spontaneously.

Radiomics analysis revealed that functional cysts are characterized by low intensity variability, smooth contours, and high internal homogeneity, which correspond to their fluid-filled structure. These features were reflected in the relatively low entropy values and high correlation coefficients observed in our analysis. In contrast, neoplastic cysts, including dermoid and endometriotic cysts, demonstrated significantly higher structural complexity. Radiomic parameters such as increased entropy and heterogeneous texture patterns reflect the presence of mixed tissue components, fat inclusions, or blood products, which are typical for these lesions. An important finding of this study is the ability of radiomics to identify subtle structural heterogeneity that may not be easily detected by visual assessment alone. This capability may improve early diagnostic differentiation between benign functional cysts and more complex neoplastic lesions. Furthermore, the use of quantitative imaging biomarkers may help reduce interobserver variability, which remains a major limitation of conventional ultrasound interpretation.

The results of this study suggest that radiomics-based ultrasound analysis can significantly enhance the diagnostic accuracy of ovarian cyst evaluation. By providing objective quantitative parameters, radiomics may: improve the differential diagnosis of ovarian cysts, reduce reliance on subjective visual interpretation, assist clinicians in making more informed management decisions, potentially reduce unnecessary surgical interventions.

Importantly, radiomics analysis can be implemented using standard ultrasound images, making it particularly valuable in resource-limited clinical settings where access to advanced imaging modalities such as MRI may be limited. Integration of radiomics into routine gynecological imaging workflows may therefore represent a promising step toward more precise and personalized diagnostic strategies in the management of ovarian cysts.

5. Conclusion

The present study demonstrates the potential value of radiomics-based ultrasound analysis in the differential diagnosis of ovarian cysts. Quantitative radiomic features extracted from ultrasound images provided additional objective information about the internal structure and morphological characteristics of cystic ovarian lesions. The results showed that functional cysts were the most common lesions, accounting for 66.7% of cases, while neoplastic cysts represented 33.3% of the examined cohort. Radiomics analysis revealed distinct imaging patterns between these groups. Functional cysts were characterized by anechoic content, smooth and well-defined borders, and high internal homogeneity, which corresponded with histologically confirmed follicular and corpus luteum cysts. In contrast, neoplastic cysts demonstrated higher entropy values, heterogeneous texture patterns, and irregular margins, reflecting their more complex internal structure.

Comparative analysis indicated that radiomics-based ultrasound evaluation showed higher diagnostic performance compared with conventional ultrasound assessment, demonstrating improved sensitivity, specificity, and overall diagnostic accuracy. These findings suggest that radiomics can enhance the diagnostic capabilities of ultrasound imaging by providing quantitative imaging biomarkers that reduce subjectivity in image interpretation.

Overall, the integration of radiomics into routine ultrasound examination may contribute to more accurate differentiation between functional and neoplastic ovarian cysts, facilitating more appropriate clinical decision-making and potentially reducing unnecessary surgical interventions. Further studies with larger patient populations and multicenter validation are required to confirm the clinical applicability and reproducibility of radiomics-based diagnostic models in gynecological imaging.

Compliance with ethical standards

Disclosure of conflict of interest

There was no conflict of interest.

Statement of ethical approval

Ethical approval for this study was obtained from the Ethics Committee of Tashkent State Medical University.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study prior to their participation.

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