

Using artificial intelligence in gynecological ultrassound to help diagnosis adnexal masses

Utilização da inteligência artificial na ecografia ginecológica para o diagnóstico de massas anexiais

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Abstract

Background: Accurate preoperative diagnosis of adnexal masses is crucial for appropriate management of ovarian cancer. Transvaginal ultrasound is the primary imaging modality but its diagnostic accuracy heavily depends on examiner expertise. Artificial intelligence (AI) has emerged as a promising tool to enhance diagnostic precision and reduce inter-observer variability.

Objective: This review aimed to evaluate the performance of AI models applied to ultrasound imaging in diagnosing adnexal masses, highlighting their benefits, limitations, and future challenges.

Methods: For the literature research, the PubMed Database was searched on 23 January 2025. Inclusion criteria were studies applying AI to ultrasound imaging in the diagnosis and management of adnexal masses.

Results: International multicenter studies reported that AI models achieved high diagnostic performance, with area under the curve (AUC) values ranging from 0.90 to 0.93, and sensitivity and specificity values frequently comparable to or exceeding those of human experts, contributing to a reduction in unnecessary referrals. However, most studies faced methodological limitations, including small sample sizes, lack of external validation, and potential selection bias.

Conclusion: AI holds significant potential to improve adnexal masses diagnosis by supporting clinical decision-making and reducing dependence on expert examiners. Nevertheless, broad clinical implementation requires extensive validation, standardized data collection, and enhanced collaboration between clinicians and AI specialists. Future large-scale multicenter studies are essential to establish the clinical applicability of AI in ultrasound-based adnexal masses diagnosis.

Keywords: Isthmocele; Infertility; Reproductive Techniques, Assisted.

Resumo

Introdução: O diagnóstico pré-operatório rigoroso de massas anexiais é fundamental para uma conduta adequada do cancro do ovário. A ecografia transvaginal constitui o principal método de imagem, embora a sua exatidão diagnóstica dependa fortemente da experiência do examinador. A inteligência artificial (IA) surgiu como uma ferramenta promissora para aumentar a precisão diagnóstica e reduzir a variabilidade interobservador.

Objetivo: Avaliar o desempenho de modelos de IA aplicados à ecografia no diagnóstico de massas anexiais, salientando os respetivos benefícios, limitações e desafios futuros.

Métodos: Foi realizada uma pesquisa bibliográfica na base de dados PubMed em 23 de janeiro de 2025. Foram incluídos estudos que aplicaram IA à ecografia no diagnóstico e gestão de massas anexiais.

Resultados: Estudos multicêntricos internacionais demonstraram que os modelos de IA alcançaram um elevado desempenho diagnóstico, com valores da área sob a curva (AUC) a variar entre 0,90 e 0,93, e valores de sensibilidade e especificidade frequentemente comparáveis, ou superiores, aos dos especialistas humanos, contribuindo para a redução das

referenciações desnecessárias. Contudo, a maioria dos estudos apresentou limitações metodológicas, incluindo reduzido tamanho da amostra, ausência de validação externa e viés de seleção.

Conclusão: A IA apresenta um elevado potencial para melhorar o diagnóstico de massas anexiais, apoiando a tomada de decisão clínica e reduzindo a dependência de ecografistas experientes. No entanto, a implementação clínica generalizada exige validação robusta, normalização dos procedimentos de recolha de dados e maior colaboração entre clínicos e especialistas em IA. Estudos multicêntricos de grande escala são essenciais para estabelecer a aplicabilidade clínica da IA no diagnóstico ecográfico de massas anexiais.

Palavras-chave: Inteligência Artificial; Ecografia Ginecológica; Patologia anexial.

INTRODUCTION

The application of artificial intelligence (AI) in medicine has expanded significantly in recent decades, particularly in image recognition and diagnostic imaging^{1,2}. In obstetrics and gynecology (OB/GYN), AI has been explored across fetal imaging, reproductive technologies, and oncologic evaluation. Despite this growing interest, the integration of AI in OB/GYN remains underrepresented in core specialty journals, with 82% of relevant publications appearing outside traditional OB/GYN literature¹. This limited visibility may reflect the early stage of AI development and the scarcity of clinically validated models.

Ultrasound (US), particularly transvaginal US, is the first-line modality for adnexal mass evaluation due to its availability and safety³⁻⁵. However, its diagnostic accuracy is highly operator-dependent^{6,7}. Accurate preoperative classification is essential, as it guides treatment decisions, surgical planning, and referral to gynecologic oncology when malignancy is suspected^{3,6,8}.

Several structured diagnostic systems, including the Risk of Malignancy Index (RMI), the International Ovarian Tumor Analysis (IOTA) models and Simple Rules, and the Ovarian–Adnexal Reporting and Data System (O-RADS), have improved risk stratification by standardizing sonographic assessment^{7,9-12}. Despite their value, these tools still rely on subjective interpretation and expert experience, contributing to interobserver

variability^{10,11,13}. AI-based methods may help address these limitations by providing more objective and reproducible image analysis¹⁴⁻¹⁷.

AI approaches can reduce variability linked to examiner expertise, fatigue, and cognitive bias¹⁸. Nonetheless, their adoption in clinical practice remains limited due to the technical complexity of AI methodologies, gaps in clinician–data scientist communication, and the lack of robust external validation¹⁸.

A glossary of all these terms is presented in Table 1.

The aim of this review is to synthesize the existing literature on the use of AI in the ultrasonographic evaluation of adnexal masses, highlighting its diagnostic performance, clinical applications, strengths and limitations, and identifying gaps that may guide future research. As ovarian tumours encompass a wide histological spectrum and variable biological behaviour, there is a critical need for more objective, reproducible, and scalable tools to support clinical decision-making and improve patient outcomes.

METHODS

This study is a **narrative review** of the current literature on the application of artificial intelligence in gynecological ultrasound, with a particular focus on the evaluation of adnexal masses.

Search strategy

For the literature research, the PubMed Database was searched on 23 January 2025 for records using the following search query and using the text availability filter ‘abstracts’ and publication date ‘5 years’: (artificial

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TABLE I. GLOSSARY OF TERMS USED IN ARTIFICIAL INTELLIGENCE (ADAPTED FROM MIHAELA GRIGORE ET AL.¹⁹).

Term	Definition
Artificial Intelligence	Software systems that can mimic human thinking and learning processes.
Machine learning (ML)	Techniques that enable computers to improve their performance on tasks over time without being directly programmed for each scenario.
Deep learning (DL)	A branch of machine learning that uses layered neural networks to process vast amounts of data and learn patterns from it.
Transformer-based networks	DL models that learn to “pay attention” to the most important parts of an image, helping them recognise patterns without using pre-set image filters.
Deep Neural Network (DNN)	A type of DL model composed of multiple layers of interconnected nodes (neurons) that can learn complex patterns from data.
Convolutional neural networks (CNN)	Computational models inspired by the structure and function of the human brain's neural network.
Radiomics	Techniques that extract large amounts of quantitative features from medical images (such as shape, texture, and intensity), which can be analyzed to support diagnosis, prognosis, and prediction of treatment response.

intelligence) AND (gynecological ultrasound). Relevant records in English were screened based on the title and abstract with the eligibility criteria.

The search was restricted to studies performed on humans and reported in English language. No other restrictions were applied.

Inclusion and exclusion criteria

We included articles reporting the role of AI applied to ultrasound in gynecological disorders, focusing only in *adnexal masses*.

The inclusion criteria were publications written in English and with publication data in the last five years, dated between January 2020 and January 2025, which evaluated AI models in gynecological ultrasound, including systematic reviews and meta-analyses.

The publications were excluded if no AI process was used in the study. Editorial and commentary articles were also excluded.

Study selection and Summarization Procedures

All stages of the literature search and study selection were conducted manually by a single researcher. The first round of screening was based on titles and abstracts. Subsequently, studies with the full text available were read in their entirety (Figure 1).

The authors summarize in Table II the characteristics of all included studies, including study type, AI

approach, clinical focus, country or center, year of publication, and brief comments.

To assist in the synthesis of the literature, selected excerpts from the articles were summarized using artificial intelligence tools. This approach aimed to streamline the content analysis and ensure consistency in the extracted information. The artificial intelligence was used strictly as an auxiliary tool. The final synthesis, interpretation, and validation of the summarized content were conducted in detail and explicitly reviewed by the authors.

Ethics Approval

As no patients were involved in the study, this study was exempted from institutional review board approval.

RESULTS

The differentiation between benign and malignant adnexal masses remains a significant clinical challenge, particularly in the preoperative setting, despite advances in ultrasonographic imaging². This diagnostic ambiguity continues to impact treatment planning, especially when surgical intervention is considered in young women where fertility preservation is a concern³.

Recent studies have demonstrated the capability of AI, particularly deep learning (DL), convolutional

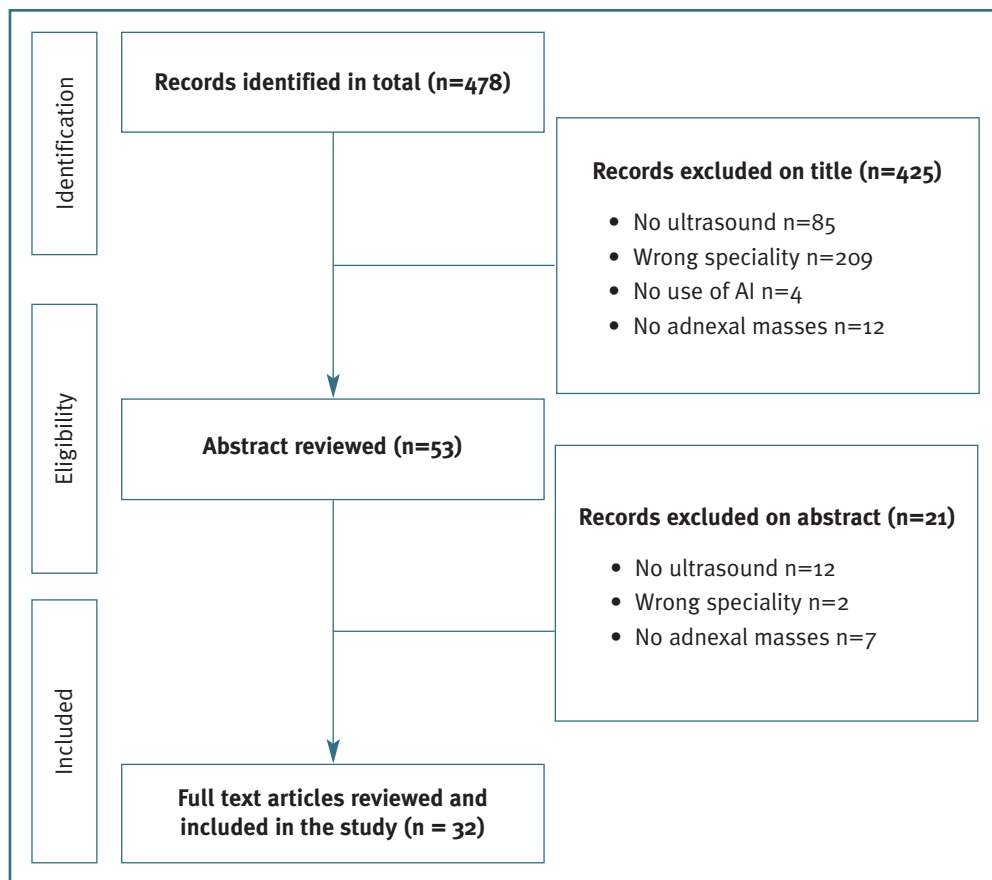


FIGURE 1. Flow diagram for the selection process of the studies included in this review.

neural networks (CNN), transformer-based neural networks, radiomics, and explainable machine learning, to improve diagnostic performance in the evaluation of ovarian cancer using ultrasound images. Studies included in Table II focused on original research providing quantitative metrics, including population size, sensitivity, specificity, AUC, and comparison with experts^{6,11,20,23-26,28,29}.

In a study by Christiansen et al., 2021, a DNN was applied to patients with ovarian tumours, achieving a sensitivity of 96% and specificity of 86.7%, with performance compared directly to expert assessment⁶. Similarly, Chen et al., 2022, reported that a DL model trained on 1,027 cases achieved an AUC of 0.94, sensitivity of 92%, and specificity of 88%, outperforming O-RADS classification and individual specialists²⁰.

Multicenter studies further reinforce AI's clinical utility. Xie et al., 2024, developed a DL model for predic-

ting malignancy in O-RADS US category 4 lesions using 742 images across 4 centers, achieving an AUC of 0.91, sensitivity of 90%, and specificity of 85%, demonstrating performance comparable to expert radiologists²³. Christiansen et al., 2025 validated a transformer-based NN on 3,652 patients and 17,119 ultrasound images from 20 international centers, using 66 human examiners for comparison. The model consistently outperformed both experts and non-experts across multiple metrics including F1-score, sensitivity, specificity, and Matthews Correlation Coefficient (MCC)²⁴.

Other studies also highlight the effectiveness of CNNs and radiomics approaches. Giourga et al., 2024, applied a CNN to 550 ovarian mass images achieving an AUC of 0.92, sensitivity of 89%, and specificity of 87%²⁵. Chiappa et al., 2021, implemented a radiomics + ML model on 350 patients, with an AUC of 0.88, sensitivity of 85%, and specificity of 83%, compared

TABLE II. GENERAL CHARACTERISTICS OF INCLUDED STUDIES ON ARTIFICIAL INTELLIGENCE APPLICATIONS IN GYNECOLOGICAL ULTRASOUND.

Nº	Study	Study Type	AI Approach	Clinical Focus	Country/ /Center	Year of Publication	Notes/Comments
1	Dhombres F, et al.	Systematic Review	AI in OB/GYN	General AI applications in OB/GYN	Multiple	2022	Summarizes contributions of AI in OB/GYN journals
2	Akazawa M, Hashimoto K	Systematic Review	AI in oncology	Gynecologic cancers	Japan	2021	Reviews current status and future challenges
3	Xu HL, et al.	Systematic Review & Meta-analysis	AI (various models)	Ovarian cancer imaging	China	2022	Meta-analysis of AI performance in image-based ovarian cancer detection
4	Chen X, et al.	Review	Deep Learning	Medical image analysis	USA	2022	Overview of DL applications in medical imaging
5	Malani SN, et al.	Comprehensive Review	AI	Obstetrics & Gynecology	India	2023	Broad review of AI applications in OB/GYN
6	Christiansen F, et al.	Original Research	Deep Neural Networks	Benign vs malignant ovarian tumors	Sweden	2021	Comparison with expert subjective assessment
7	Whitney HM, et al.	Original Research	AI-based automated segmentation	Ovarian/ adnexal masses	USA	2024	Automated segmentation of masses and internal components
8	Mitchell S, et al.	Systematic Review & Meta-analysis	AI	Ovarian cancer diagnosis	UK	2024	Reviews AI in ultrasound diagnosis of ovarian cancer
9	Chen X, et al.	Review	AI	Ovarian cancer imaging	China	2021	Advances of AI in medical imaging
10	Akazawa M, Hashimoto K	Review	AI	Ovarian cancer diagnosis	Japan	2020	Focused on diagnostic AI tools
11	Moro F, et al.	Original Research	Radiomics	Adnexal masses with solid morphology	Italy	2024	Ultrasound radiomics to discriminate benign/ malignant masses
12	Leng Y, et al.	Bibliometric Analysis	AI in medical imaging	Ovarian cancer	China	2023	Maps publication trends 2000-2022
13	Jung Y, et al.	Original Research	Deep CNN + Autoencoder	Ovarian tumor diagnosis	Korea	2022	Classification using deep learning
14	Wang Y, et al.	Review	AI	Diagnosis and treatment of ovarian cancer	China	2024	Overview of AI applications
15	Shrestha P, et al.	Systematic Review	AI	Gynecologic imaging	Canada	2022	Background, state of the art, and future directions
16	Cai L, Pfof A	Review	AI	Abdominal/ pelvic ultrasound	USA	2024	Current applications in ultrasound imaging

(continues)

TABLE II. GENERAL CHARACTERISTICS OF INCLUDED STUDIES ON ARTIFICIAL INTELLIGENCE APPLICATIONS IN GYNECOLOGICAL ULTRASOUND. (CONTINUED)

N°	Study	Study Type	AI Approach	Clinical Focus	Country/ /Center	Year of Publication	Notes/Comments
17	He X, et al.	Comparative Study	Machine Learning	Malignancy risk evaluation	China	2024	Comparison of ML models in ovarian tumor evaluation
18	Drukker L, et al.	Review	AI	Ultrasound imaging in OB/GYN	Multiple	2020	Introduction to AI in US imaging
19	Grigore M, et al.	Systematic Review	Logistic Models and AI	Sonographic assessment of adnexal masses	Romania	2020	Comparison of AI and logistic models
20	Chen H, et al.	Original Research	Deep Learning	Ovarian malignancy prediction vs O-RADS	China	2022	Comparison with expert assessment
21	Moro F, et al.	Systematic Review	AI	Ultrasound in gynecologic oncology	Italy	2024	Comprehensive review of AI applications
22	Jost E, et al.	Systematic Review	AI in OB/GYN	5D ultrasound	Germany	2023	Review of AI applications in 5D US
23	Xie W, et al.	Multicenter Study	Deep Learning	O-RADS US category 4 lesions	China	2024	Model development and validation
24	Christiansen F, et al.	Multicenter Validation	AI-driven US detection	Ovarian cancer	International	2025	Comparison with multiple human examiners
25	Giourga M, et al.	Original Research	CNN	Ovarian mass classification	Greece	2024	Performance of CNN in US image classification
26	Chiappa V, et al.	Original Research	Radiomics + ML	Risk of malignancy prediction	Italy	2021	Decision-support system using US + CA-125
27	Deslandes A, et al.	Scoping Review	AI	Teaching tool in gynecological US	Australia	2023	AI as educational support
28	Fanizzi A, et al.	Original Research	Explainable ML	Solid adnexal masses	Italy	2024	Diagnosis based on clinical and US indicators
29	Dai WL, et al.	Multicenter Study	Deep Learning Pipeline	Ovarian masses	China	2024	Development and validation for diagnosis
30	Zeng S, et al.	Review	Radiomics & Radiogenomics	Ovarian cancer	China	2024	Extracting imaging biomarkers for diagnosis and prognosis
31	Chiappa V, et al.	Original Research	Radiomics + ML	Diagnostic improvement (AROMA pilot)	Italy	2021	Enhancing diagnostic processes of ovarian masses
32	Sone K, et al.	Review	AI	Gynecologic malignancies	Japan	2021	Applications of AI in gynecologic cancers

against standard clinical workflow²⁶. Dai et al., 2024, developed a DL pipeline evaluated in 1,200 patients across multiple centers, achieving a sensitivity of 91%, specificity of 86%, and AUC of 0.93, with performance assessed against expert clinicians²⁹. Fanizzi et al., 2024, employed an explainable ML model on 400 patients, reaching an AUC of 0.89, sensitivity of 88%, and specificity of 84%, demonstrating interpretability and comparability with specialist assessment²⁸. Moro et al., 2024, reported that radiomics-based models on 300 solid ultrasound images achieved a sensitivity of 87% and specificity of 82%¹¹.

Across these studies, AI demonstrated consistent advantages in diagnostic reproducibility, reducing variability caused by examiner experience, fatigue, or environmental factors, while providing objective assessment metrics and assisting clinical decision-making^{18,21}.

Overall, these original studies, summarized in Table II, provide strong evidence that AI models ranging from DL and CNNs to radiomics and transformer-based networks – can accurately differentiate benign from malignant ovarian tumours, with performance often equal to or exceeding that of human experts^{6,11,20,23-26,28,29}.

DISCUSSION

Over the past decade, and particularly in the last five years, there has been a marked acceleration in the application of AI in medical imaging, with promising results in the diagnosis of gynecological cancers, especially ovarian cancer. This technological advancement is highly relevant given that the preoperative differentiation between benign and malignant adnexal masses remains a major clinical challenge^{2,22}. Despite the availability of expert-driven tools such as the IOTA rules, ADNEX model, and O-RADS US, diagnostic performance can vary widely, particularly in low-resource settings or among less experienced examiners.

Our review, based on original studies summarized in Table III, demonstrates that AI-based models including DL, CNNs, transformer-based networks, radiomics, and explainable machine learning consistently achieve high diagnostic performance in the classification of adnexal masses. Christiansen et al., 2021, reported a

DNN with 96% sensitivity and 86.7% specificity compared to expert assessment⁶, while Chen et al., 2022, demonstrated a DL model with an AUC of 0.94, sensitivity of 92%, and specificity of 88%, outperforming O-RADS classification and individual specialists²⁰.

Multicenter studies reinforce the generalizability and robustness of AI models. Xie et al., 2024, developed a DL model for O-RADS US category 4 lesions with an AUC of 0.91, sensitivity of 90%, and specificity of 85%²³, and Christiansen et al., 2025 validated a transformer-based network across 20 centers with 3,652 patients and 17,119 images, surpassing 66 human examiners in multiple performance metrics including F1-score, sensitivity, specificity, and MCC²⁴. CNN based and radiomics models also performed well in differentiating benign from malignant masses (Giourga et al., 2024: AUC 0.92; Chiappa et al., 2021: AUC 0.88; Dai et al., 2024: AUC 0.93)^{25,26,29}. Explainable ML models showed similar accuracy while providing interpretability for clinical decision-making (Fanizzi et al., 2024: AUC 0.89, sensitivity 88%, specificity 84%)²⁸.

AI offers several clinical benefits. Automated interpretation reduces intra- and inter-observer variability, accelerates diagnostic workflows, and supports less experienced sonographers in clinical decision-making^{16,25,26}. This is particularly relevant in settings with workforce shortages or expanding telemedicine initiatives. Additionally, AI-supported systems may contribute to medical education by facilitating skill acquisition among trainees and promoting high-quality scanning in underserved areas^{22,27}.

Despite these promising results, limitations remain. Many studies are retrospective or single-center and may involve relatively small datasets^{6,11,25}. External validation is still limited, and generalizability to routine clinical practice may be affected by heterogeneity in imaging quality and acquisition techniques^{16,24}. Subtle pathologies, including borderline tumours or metastases, may be underrepresented, potentially limiting AI accuracy in atypical cases^{19,22}.

Integration into clinical workflows also poses challenges. AI models are best used as decision-support tools, complementing rather than replacing human judgment, since gynecologic diagnosis incorporates multifactorial clinical context including age, menopausal status, symptoms, family history, and tumour

TABLE III. DIAGNOSTIC PERFORMANCE OF AI MODELS IN GYNECOLOGICAL ULTRASOUND. ORIGINAL STUDIES REPORTING DEEP LEARNING, CNNs, RADIOMICS, AND EXPLAINABLE ML FOR ADNEXAL MASS EVALUATION, INCLUDING POPULATION, KEY METRICS (SENSITIVITY, SPECIFICITY, AUC), COMPARISON WITH EXPERTS, AND MAIN FINDINGS.

N°	Study	Study Type	AI Model	Clinical Focus	Population/ Sample Size	Performance Metrics	Comparison with Experts	Key Findings
6	Christiansen F, 2021	Original Research	Deep Neural Network (DNN)	Differentiation of benign vs malignant ovarian tumors	Not specified	Sensitivity 96%, Specificity 86.7%	Compared with expert sonographers	DNN accurately discriminates benign vs malignant ovarian tumors
11	Moro F, 2024 (11)	Original Research	Radiomics	Discrimination of benign vs malignant solid adnexal masses	300 solid US images	Sensitivity 87%, Specificity 82%	Not directly compared	Radiomics features differentiate benign and malignant masses
20	Chen H, 2022 (20)	Original Research	Deep Learning (DL)	Ovarian malignancy prediction vs O-RADS	1,027 patients	AUC 0.94, Sensitivity 92%, Specificity 88%	Outperformed O-RADS and individual specialists	DL model improved classification accuracy over standard assessment
23	Xie W, 2024 (23)	Multicenter Study	Deep Learning	O-RADS US category 4 lesion classification	742 US images from 4 centers	AUC 0.91, Sensitivity 90%, Specificity 85%	Comparable to expert radiologists	Predicts malignancy in O-RADS US category 4 lesions
24	Christiansen F, 2025 (24)	Multicenter Validation	Transformer-based Neural Network	Ovarian cancer detection in multicenter dataset	3,652 patients, 17,119 US images	F1-score, Sensitivity, Specificity, MCC (all higher than humans)	66 human examiners	Outperformed both experts and non-experts across multiple metrics
25	Giourga M, 2024 (25)	Original Research	Convolutional Neural Network (CNN)	Classification of ovarian masses	550 ovarian mass images	AUC 0.92, Sensitivity 89%, Specificity 87%	Not directly compared	CNN accurately classifies ovarian masses on US
26	Chiappa V, 2021 (26)	Original Research	Radiomics + Machine Learning	Prediction of malignancy risk	350 patients	AUC 0.88, Sensitivity 85%, Specificity 83%	Compared to standard clinical workflow	Decision-support system improved malignancy prediction
28	Fanizzi A, 2024 (28)	Original Research	Explainable Machine Learning	Diagnosis of solid adnexal masses	400 patients	AUC 0.89, Sensitivity 88%, Specificity 84%	Compared to specialist assessment	Combines interpretability with high diagnostic accuracy
29	Dai WL, 2024 (29)	Multicenter Study	Deep Learning Pipeline	Ovarian mass diagnosis	1,200 patients	AUC 0.93, Sensitivity 91%, Specificity 86%	Compared to expert clinicians	Validated DL pipeline for ovarian mass diagnosis

markers^{18,21}. Technical and interdisciplinary barriers remain, requiring collaboration between clinicians and data scientists to ensure trustworthy, explainable, and clinically relevant models^{2,18,28}.

Radiomics and radiogenomics show promise for predicting malignancy and guiding management, although their use in ultrasound is less established than in CT or MRI. Preliminary studies have reported moderate performance, highlighting the need for larger, prospective, and multicenter trials to validate these approaches and assess clinical impact^{11,29-31}.

Overall, AI in gynecologic ultrasound is most valuable for improving the preoperative diagnosis of adnexal masses. Evidence from the studies summarized in Table III indicates that AI-assisted diagnosis can achieve performance comparable to or exceeding that of expert sonographers, reduce diagnostic variability, and facilitate timely referral to specialized care, particularly in settings where expert examiners are unavailable^{6,11,20,23-26,28,29}.

CONCLUSION

The use of AI in ultrasound imaging, for adnexal mass evaluation, demonstrates substantial potential to improve diagnostic accuracy, reduce inter- and intra-observer variability, and support clinicians in preoperative decision-making. Original studies indicate that AI models including deep learning, CNNs, transformer-based networks, radiomics, and explainable machine learning – can achieve performance comparable to or exceeding that of expert sonographers, while offering interpretability and scalability.

Despite these advances, challenges remain, including limited external validation, heterogeneity of imaging data, small or single-center datasets, and the need for interdisciplinary collaboration to develop clinically robust and ethically sound AI systems. Future research should prioritize large, multicenter studies, integration of clinical variables, and standardization of imaging protocols to enhance generalizability and real-world applicability.

Ultimately, AI should be considered a complementary decision-support tool rather than a replacement for clinical expertise. A synergistic approach, combi-

ning AI-driven insights with human judgment, has the potential to accelerate diagnosis, optimize patient triage, and improve outcomes for patients with adnexal masses.

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MM – Literature search, bibliographic selection, and article drafting. CT and NNM – Supervision and critical review of the article.

CONFLICT OF INTEREST

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