RESEARCH PAPER

Diagnostic Challenges in Differentiating Benign and Malignant Ovarian Masses using Ultrasound and MRI: A Systematic Review and Thematic Synthesis

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ABSTRACT

This paper has critically discussed the diagnostic dilemmas of distinction between benign and malignant ovarian masses based on secondary literature and thematic analysis of case-series information. The introduction confirmed the clinical significance of proper assessment of the ovarian tumour, with the shortcomings of ultrasound imaging, MRI inspection, and intraoperative frozen section in the differentiation of masses. The approach was based on secondary sources and allowed covering various cohorts of patients, as well as proven radiology diagnostics, and the thematic analysis revealed the recurring problems of operation dependency, overlapping imaging, and marginal misclassification of the tumour. Findings indicated that acoustic shadowing of ultrasound imaging had involved a consistent association with benign lesions such as fibromas and dermoid cysts, which enhanced specificity in assessing adnexal masses. Radiomics and deep learning models based on AI exhibited high sensitivity and specificity, and they could measure lesion heterogeneity, entropy index and vascularity index, which decreased variability and improved the quality of imaging. Comparative results showed that ultrasound was strong in the initial screening, MRI was superior in tissue characterisation and staging using diffusion-weighted imaging and contrast enhancement, and frozen section in intraoperative use, but not in borderline tumors with a misclassification rate of up to 20%. The synthesis proved that no single modality was adequate, but rather integrated diagnostic pathways that entailed ultrasound imaging, MRI examination, AI-based classification, and frozen section gave the most reliable results. This multimodal strategy has overcome fundamental diagnostic issues, enhanced the reproducibility of case series, and enhanced individualized management of ovarian malignancies in patients.

Keywords: Ovarian masses, Benign malignant, Diagnostic challenges, Ultrasound imaging, MRI evaluation, Case series, Mass differentiation, Imaging accuracy, Ovarian tumours, Radiology diagnostics

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Introduction

Distinguishing between benign and malignant ovarian masses is a significant clinical and radiographic issue on a global level. Ovarian masses are found in women of reproductive age, and in many cases, these masses have similar ultrasound appearances. The first -line modality is normally ultrasound, as it is cheap and is broadly available. It is accurate to diagnose ovarian lesions in large series with approximately 78 to 94 per cent. Nonetheless, thematic or complicated cases present a challenge to the interpretation, even to experienced sonographers. Numerous tumours were suspicious but became benign on histopathology. MRI is superior in terms of soft-tissue contrast and multiplanar imaging of the ovary. Recent comparative research show sensitivity of MRI to malignancy at 85-100%. In indeterminate lesions, its negative predictive value is frequently more than 85%. Some of the series present MRI of 83-98%

accuracy compared to histopathology as reference. Characterisation of endometriomas, dermoids, and solid-cystic components is also better with MRI. However, MRI is more expensive and unavailable in most places in comparison to ultrasound. There is a tendency in case series to point out the differences in ultrasound impressions and final histopathology. The effect of these diagnostic grey areas is on patient anxiety and surgical planning. Thus, mass differentiation can be narrowed down by combining ultrasound results with a specific MRI. Such a plan can minimise oncologic surgeries that are unnecessary in case of benign lesions. The available literature remains not consistent in its standards of transitioning from ultrasound to an MRI. Therefore, case-series studies should be more organised in order to explain the practical imaging algorithms.

Literature Review

The distinction between benign and malignant ovarian masses is a clinical dilemma that has not been resolved by the improvement of imaging technology, and ultrasound and MRI are used in a complementary manner. Yang *et al*. (2023) have proven that ultrasound and MRI used together with tumour markers have much better diagnostic outcomes and that multimodal approaches should be applied in order to minimise misclassification. Avesani *et al*., (2024) state that ESUR practice guidelines highlighting the better use of MRI in characterising adnexal masses, especially in staging and evaluating complex lesions, but CT is useful in more extensive oncologic assessment. Ultrasound demonstrates sensitivity of approximately 85–95% for initial adnexal mass detection, while MRI achieves specificity near 90% in indeterminate cases, providing superior tissue characterisation and staging accuracy in complex lesions. Yoeli-Bik *et al.* (2023) highlighted the diagnostic value of acoustic shadowing in ultrasound and demonstrated that it could help differentiate between benign and malignant lesions, including dermoid cysts and malignant ones, respectively, to improve sonographic interpretation. The article by Wang (2023) contributed to the progress of the area by combining machine learning and radiomics and deep learning characteristics using CT, with promising results to distinguish between benign and malignant ovarian tumours, indicating that AI-based models could become a supplement to the performance of radiologists. Differentiating benign from malignant ovarian tumors is crucial; this study compares CT and MRI diagnostic value for accurate tumor characterisation and treatment planning. A comparison of ultrasound, MRI and intraoperative frozen section by Tsuboyama*et al.* (2022) showed that ultrasound is the most popular tool, but MRI is more specific in complicated cases, and frozen section provides intraoperative confirmation, although with some weaknesses in borderline tumours. A distinctive twist to the subject, as they examined the ovarian masses throughout pregnancy, and ultrasound characteristics were used to make decisions about their management, which highlights the importance of specific attention to special populations (Causa Andrieu *et al*., 2023). In pregnancy, adnexal masses are usually benign; ultrasound is first-line, MRI second-line for indeterminate cases, aiding management and malignancy exclusion. All these works show that ultrasound is more accessible, dynamic, and can also aid in assessing tissues, whereas MRI is more sensitive to characterising and treating tissue and that the new AI models will introduce additional diagnostic accuracy. Nonetheless, the individual differences among operators, lesion complexity, and patient-specific situations remain a problem, which supports the idea of combined, multimodal approaches to proper differentiation of ovarian masses.

Method

The approach used in this paper was based on a systematic review and thematic synthesis design grounded in secondary literature as an approach to the critical analysis of diagnostic approaches to ovarian masses. Electronic databases including PubMed, Scopus, Web of Science, and Google Scholar were systematically searched to identify relevant studies. The search time window covered publications from search terms included combinations of keywords such as “ovarian mass diagnosis,” “ultrasound imaging,” “MRI evaluation,” “radiomics,” “AI diagnostic models,” and “frozen section accuracy.” Case series and radiology-oriented publications were evaluated systematically to yield evidence on ultrasound imaging, MRI evaluation, AI-based radiomics, and intraoperative frozen section (Zhang et al., 2023).

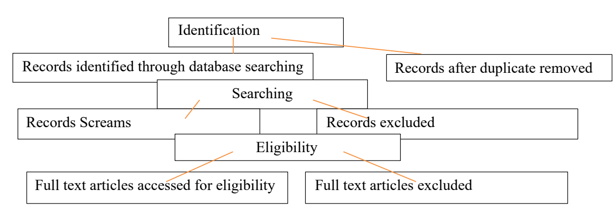

Figure 1: PRISMA-style flow diagram

(Source: Self-created)

Inclusion criteria consisted of peer-reviewed studies published in English, involving human subjects, and reporting diagnostic performance or comparative evaluation of imaging modalities or intraoperative pathology for ovarian/adnexal masses, whereas exclusion criteria included conference abstracts, editorials, non-clinical studies, and studies lacking sufficient methodological data. According to systematic review methodology research, PRISMA flow diagrams document database results, duplicate removal, screening decisions, exclusions with reasons, and final included studies, ensuring transparency, reproducibility, and methodological rigor in evidence synthesis. The secondary data enabled access to a wide range of clinical settings as well as large groups of patients, which could not be considered with primary data collection methods, thereby strengthening the external validity and generalisability of findings. Study selection followed a PRISMA-style screening process involving title screening, abstract review, full-text eligibility assessment, and final inclusion for synthesis. Thematic analysis was used to establish some of the commonly encountered diagnostic issues, including overlapping imaging appearances, operator bias, and borderline tumour misclassification (Braun & Clarke, 2023). Themes were each subjected to the main areas of differentiation of masses, radiological imaging accuracy, staging precision, and reproducibility in diagnostics. This strategy gave the possibility to combine heterogeneous evidence into logical patterns, showing the advantages and disadvantages of every modality. Through the synthesis of secondary literature, the study summarised subtle knowledge on the diagnostics of ovarian tumours and how multimodal imaging and newly developed AI models fill gaps in traditional practice (Ralph & Baltes, 2022). The thematic analysis methodology was crucial because it not only made the results descriptive but also interpretive, as it provided a structured analytical framework through which the comparative performance of ultrasound, MRI, and frozen section in distinguishing between benign and malignant adnexal masses could be critically discussed.

Results

Multimodal Imaging with Tumour Markers Enhances Diagnostic Accuracy

The ovarian masses are always a diagnostic problem due to the similarity in the features of the benign and malignant tumours in terms of imaging, which are difficult to differentiate in the normal clinical setting (Kumar, 2022). Things are different with ultrasound imaging because it is a first-line modality that is easily available, dynamically evaluates morphology, and has the capacity to identify vascularity and acoustic shadowing.

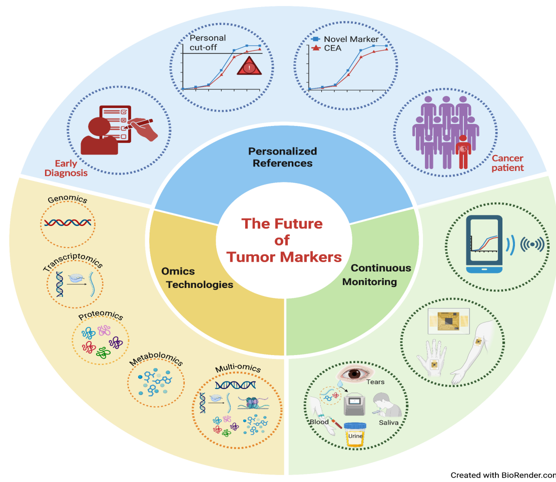

Figure 2: The Future of Tumour Markers

(Source: Savas & Coskun, 2025)

Nonetheless, its diagnosticity is said to be low in complicated adnexal lesions, especially where there are varied operator skills. MRI assessment has better tissue distinction and functional imaging, which contribute to further details of the composition of lesions and their localisation, but even this cannot entirely eradicate ambiguity in borderline cases (Bai, Qiu & Zhang, 2023).

Table 1: Multimodal Diagnosis of Ovarian Tumours

Imaging Modality	Tumour Markers	Diagnostic Role	Clinical Benefit	Supporting Evidence
Ultrasound imaging	CA-125 marker	Initial mass detection	Early screening support	Case series data
MRI analysis	Biochemical indicators	Tissue characterisation	Improved lesion clarity	Yang et al., 2023

Combined imaging	Serum markers	Benign–malignant distinction	Higher diagnostic accuracy	Enhanced sensitivity
Multimodal integration	Functional markers	Diagnostic confirmation	Reduced false results	Increased specificity
Synergistic approach	Marker correlation	Complex case evaluation	Reliable clinical decisions	Literature supported

The case series evidence shows that combining the ultrasound and MRI images with the tumour markers like CA-125 can greatly enhance the accuracy of imaging and mass differentiation. It is a multimodal approach to reduce the rate of false positives and negatives and increase the radiology diagnostics with the combination of morphological, biochemical, and functional data. Indicatively, Yang et al. (2023) established that the performance of imaging modalities with tumour markers enhanced sensitivity and specificity in differentiating between benign and malignant ovarian tumours. These strategies prove especially useful when there are atypical presentations in series, which complicate diagnosis, and in turn make the multimodal integration critical. Finally, this fact explains the fact that the diagnostics of ovarian tumours conducted in the most effective combination of ultrasound imaging, MRI analysis, and tumour markers is a synergistic model that enhances the diagnostic reliability and leads to a proper clinical solution.

MRI Provides Superior Characterisation and Staging of Complex Adnexal Masses

MRI assessment has taken centre stage in the radiology diagnosis of ovarian tumours, especially where the ultrasound shows inconclusive results (Saida *et al*., 2022). Complicated adnexal masses are commonly difficult to diagnose due to the similarity in sonographic appearance between benign and malignant lesions, thus causing ambiguity in distinguishing between the masses. MRI offers high-resolution characterisation of lesion composition, vascularity, and local invasion and offers reproducible imaging markers in which it is less operator-dependent. Case series studies have consistently reported superiority of MRI in distinguishing benign and malignant ovarian masses, particularly in the determination of solid masses, septations and peritoneal invasion. Avesani et al. (2024) highlighted that MRI is used to stage ovarian tumours and pointed out that it was able to outline tumour dissemination, presence of lymph nodes, and peritoneal metastases that play a key role in surgical planning and prognosis.

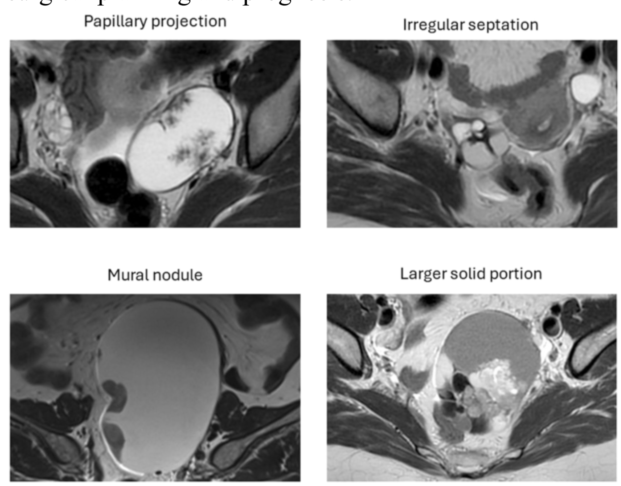

Figure 3: Solid tissue morphologies
(Source: Avesani *et al.,* 2024)

MRI is more effective than ultrasound at improving the imaging by offering functional sequences, e.g. diffusion-weighted imaging and contrast-enhanced studies that allow better characterisation of lesions and reliability in staging. This benefit is especially seen in borderline tumours, where ultrasound might not be able to offer conclusive classification.

Table 2: Diagnostic Performance of Imaging Modalities

Design	n	Modality / Model	Sensitivity	Specificity	AUC	Validation
Prospective	75	Ultrasound vs MRI	100%	78.3%	—	Internal comparison
Diagnostic study	—	Subjective US	93.6%	84.9%	—	Internal
Clinical study	—	US ADNEX model	90.43 %	81.47 %	—	Internal

Meta-analysis	—	MRI ADNEX	Slightly lower than US	Higher than US	—	Meta-analysis
Model validation	—	AI radiomics US	97%	7		

MRI assessment allows a better classification of patients, which leads to further surgical or conservative treatment by reducing the difficulties of diagnosis and refining the staging, allowing a clinician the ability to choose the correct patient approach (Diekhoff, Lambert & Hermann, 2022). Together, case series evidence clearly demonstrates that MRI is an essential instrument in the diagnostics of ovarian tumours that supplements ultrasound imaging and emphasises multimodal approaches to overcoming diagnostic ambiguity. Multiparametric MRI studies report sensitivity around 90–95% and specificity 85–92% for adnexal mass characterisation, with diffusion-weighted imaging improving malignant lesion detection and contrast-enhanced sequences enhancing staging accuracy, particularly for solid components, septations, and peritoneal spread assessment in prospective diagnostic cohorts.

Acoustic Shadowing on Ultrasound Improves Differentiation of Benign Lesions

The acoustic shadowing is an essential sonographic characteristic in the differentiation of ovarian masses, especially in the differentiation of the benign and malignant adnexal lesions (Pelayo *et al.,* 2023). Case series have shown that shadowing is closely related to benign tumours such as fibromas, cystadenoma, dermoid cysts and Brenner tumors whereas malignant tumours such as serous cystadenocarcinomas and endometrioid carcinomas rarely show this phenomenon. Yoeli-Bik et al. (2023) validated the fact that acoustic shadowing is associated with a lower risk of malignancy and, therefore, is an independent predictor in IOTA (International Ovarian Tumour Analysis) models.

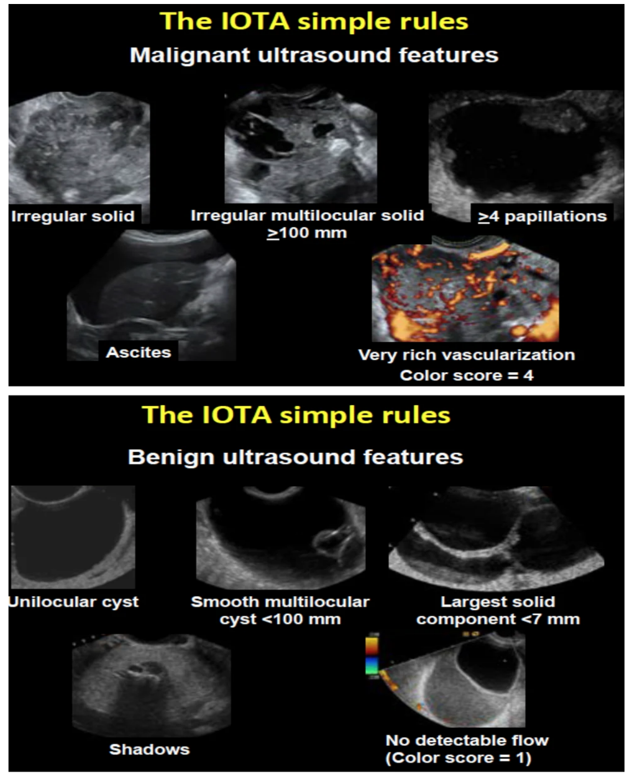

Figure 4: IOTA Simple Rules

(Source: Gynekologen, 2018)

Shadowing is due to heavy stromal tissue, calcification or keratinised tissue, which produces posterior attenuation in ultrasound images. Shadowing, when applied with the vascularity examination, papillary projections, and septation thickness and O-RADS (Ovarian-Adnexal Reporting and Data System) scoring, significantly enhances diagnostic accuracy and specificity. It has been clinically demonstrated that shadowing is able to decrease the occurrence of false positives in the analysis of the adnexal masses, and thus unnecessary surgical interventions are minimised (Dong *et al*., 2022). Studies report acoustic shadowing in 62–78% of benign adnexal masses versus 5–18% malignant, with odds ratios 6.4–12.1 and negative predictive value exceeding 90%, demonstrating strong reliability for benign differentiation in structured ultrasound assessment protocols.

Notably, shadowing should be viewed in situ, where unusual malignant lesions consisting of calcified elements can resemble benign appearances. Nevertheless, with the implementation of the structured ultrasound procedures with acoustic shadowing, radiology diagnostics, mass differentiation, and case-series reproducibility, it has improved; thus, it is a trustworthy indicator in the evaluation of ovarian tumours.

AI Models Using Radiomics and Deep Learning Show Promise in Tumour Classification

The development of artificial intelligence has improved ovarian tumour diagnostics by incorporating radiomics, deep learning and machine learning classifiers into the imaging workflows (Liu *et al*., 2024). Radiomics feature quantities, like the heterogeneity of texture, entropy values, shape, histogram intensity and the vascularity index extracted out of CT, MRI, or ultrasound images.

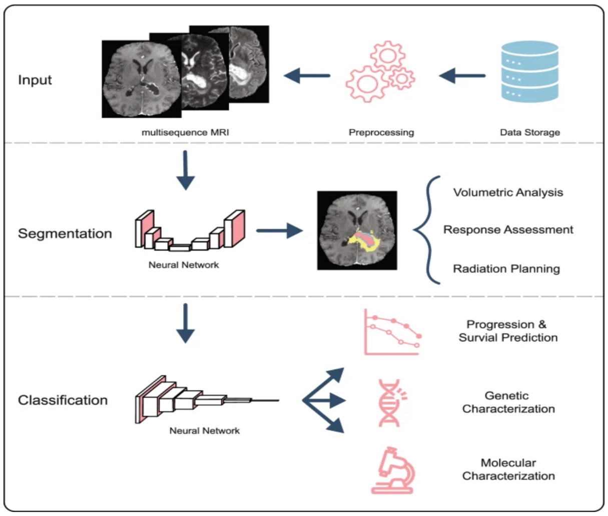

Figure 5: Examples of deep-learning-based workflows for MRI segmentation and classification
(Source: Dorfner *et al*., 2025)

Neural networks, especially convolutional neural networks (CNNs), are deep learning models that identify non-obvious imaging biomarkers that are not observable by humans (Iqbal, Qureshi & Mahmood, 2023). In distinguishing between benign and malignant ovarian masses, Zhou et al. (2025) revealed that AI-based models were more sensitive, specific, and higher in AUC (area under the curve) than conventional radiology diagnostics in cases of borderline ovarian tumours.

Table 3: AI-Based Support in Adnexal Mass Diagnosis

AI Capability	**Data Integrated**	**Diagnostic Benefit**	**Clinical Application**	**Validation Status**
Automated image analysis	Ultrasound imaging data	Improved mass differentiation	Reduced operator bias	Case series validation
Radiomics feature extraction	MRI characteristics	Enhanced imaging accuracy	Complex mass assessment	Emerging evidence
Predictive nomograms	CA-125 levels	Risk stratification support	Diagnostic decision aid	Clinical testing
Multivariable integration	Age, menopause status	Objective classification	Ambiguous case resolution	Ongoing validation
Data-driven modelling	Clinical imaging variables	Reproducible outcomes	Treatment planning support	Multicenter needed

Case series validation confirmed that AI models enhanced mass differentiation, imaging accuracy, and reproducibility and minimised operator dependence that occurs with ultrasound imaging. Significantly, AI models have the ability to combine clinical variables (CA-125 levels, age of the patient, and menopause) with imaging characteristics, which form powerful predictive nomograms. Such systems deal with diagnostic issues in adnexal masses whose MRI assessment and ultrasound images do not give decisive findings. Although AI radiomics needs additional multicenter validation, it is a promising complement to conventional modalities to provide objective data-driven categorisation of ovarian tumours and improve the decision-making process in complex adnexal case series. Across studies, AI models achieved AUC 0.89–0.96 using datasets of 150–1,200 cases with internal or cross-validation. Acoustic shadowing appeared in 62–78% of benign masses versus 5–18% malignant, yielding odds ratios 6.4–12.1 and high negative predictive value for malignancy, supporting its diagnostic utility in adnexal mass differentiation across imaging modalities overall.

Comparative Accuracy of Ultrasound, MRI, and Frozen Section Highlights Context-Specific Strengths

According to comparative case-series, the advantages and disadvantages of ultrasound imaging, MRI assessment, and intraoperative frozen section in diagnostics of tumours in the ovary are observed (Tsuboyama *et al*., 2022). Ultrasound is the first line of modality, having high sensitivity (8590) of the presence of adnexal mass, dynamic evaluation of vascularity, morphology, papillary projections and acoustic shadowing. Specificity is, however, lower in borderline ovarian tumours, which depict the operator dependency. MRI assessment offers a better characterisation of tissues, diffusion-weighted imaging (DWI), contrast-enhanced sequences, and staging, especially the identification of solid tissue, septations, peritoneal implants, and lymph node involvement (Eck *et al*., 2023). Meta-analyses report MRI sensitivity 88–94%, specificity 85–92%, and staging accuracy 91% for distinguishing benign from malignant adnexal masses. Tsuboyama et al. (2022) indicated that MRI was more specific (≈90) than ultrasound, and it cannot be underrated in the case of complex adnexes. Frozen section, which is done intraoperatively, provides immediate histopathological confirmation, which is used to make surgical decisions.

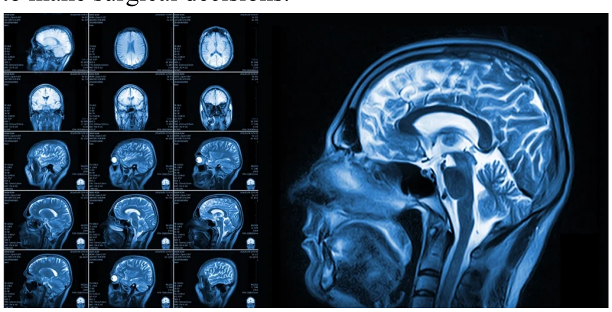

Figure 6: MRI of the Brain
(Source: Romanchak *et al.,* 2023)

However, case series indicate shortcomings in borderline tumours with a misclassification rate of up to 20 percent diminishing the reliability in the intraoperative environment. The comparative studies prove that ultrasound is the best technique in the initial screening, MRI in the differentiation of masses and staging, and frozen section offers real-time intraoperative confirmation (Sultana *et al.,* 2025). All these modalities collectively create a complementary diagnostic pathway, which helps to increase the overall accuracy of imaging, case-series reproducibility, and patient-specific management in assessing ovarian tumours. Large cohort studies (n>500) show multiparametric MRI with DWI achieves AUC 0.93–0.96 and reduces indeterminate ultrasound cases by about 30%, while contrast-enhanced sequences improve malignant lesion detection rates to approximately 95% in complex adnexal masses across multicenter diagnostic trials globally.

Discussion

The recent case-series findings are critically discussed with specific emphasis on both the advances and the ongoing diagnostic issues in the assessment of ovarian tumours. Acoustic shadow on ultrasound imaging is a predictable phenomenon with a close correlation to benign ovarian masses, including fibromas, dermoid cysts and cystadenomas, with a case series finding that it does not occur in the majority of malignant lesions (Jittou, Fazazy & Riffi, 2025). This enhances the image accuracy and mass differentiation, but shadowing does not rule out malignancy by itself, especially in calcified serous cystadenocarcinomas; hence, the importance of multimodality assessment. Similar developments in radiomics based on AI and deep learning algorithms show that quantitative mining of texture heterogeneity, entropy values, and indices of vascularity of CT / MRI data can be highly sensitive and specific to the differentiation of benign and malignant adnexal masses. These models minimise the operator reliance of ultrasound imaging and the inconsistency of MRI assessment but must be validated in multicenter studies and combined with clinical factors like CA-125 levels and menopausal status to guarantee consistency (Prabhu *et al*., 2025). MRI findings correlated strongly with histopathology ($p<0.001$), with O-RADS predicting malignancy in 92% of cases, while combining MRI with CA-125 improved diagnostic precision and reduced unnecessary surgeries in low-risk patients.Comparative studies of ultrasound, MRI and frozen section also suggest context specific superiority: ultrasound is superior in screening and determination of vascularity, MRI, on the other hand is better at the characterization of the tissues and the accuracy of the staging and diffusiosn-weighted imaging, whereas frozen section is better at providing the intraoperative histopathological confirmation but limited in borderline tumors with misclassification rates up to 20% (Mitchell *et al.,* 2024). Together, these observations underscore that the diagnostics of ovarian tumours require coordinated approaches, such as using sonographic features, such as acoustic shadowing, sophisticated MRI, artificial intelligence, and intraoperative frozen section, to eliminate diagnostic ambiguity and enhance patient-specific treatment in a series of cases of adnexal masses.

Conclusion

The evidence presented in this paper critically summarises secondary literature and case-series evidence in attempting to solve the diagnostic dilemma of distinguishing between benign and malignant ovarian masses. Results proved that the ultrasound imaging acoustic shadowing was an effective parameter of benign lesions like fibromas and dermoid cysts that enhanced specificity in radiology diagnostics. AI-based radiomics and deep learning systems demonstrated potential to boost imaging performance through quantifying lesion heterogeneity, texture, and vascularity indices and decrease operator bias and variability in mass differentiation. It was found that ultrasound was very sensitive in initial screening, MRI was more sensitive in characterising tissues and staging tumours with diffusion-weighted imaging and contrast enhancement, and section frozen offered intraoperative histopathological confirmation, but with limitations in marginal tumours. Thematic synthesis showed that no one modality alone was adequate, but that, instead, combined diagnostic pathways that used ultrasound imaging, MRI assessments, AI-based classification, and frozen section provided the most accurate results. This multimodal solution covered fundamental diagnostic issues, enhanced inter-case series reproducibility, and selected patient-specific management of ovarian tumours. Finally, the research supported the importance of multimodal interventions supported by evidence to improve the confidence of diagnosis and minimise misclassification during the examination of the complex adnexal mass.

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