

Research Article

Diagnostic Accuracy of Imaging Modalities Versus Histopathology in Gynecological Tumors: A Systematic Review and Meta-Analysis

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Abstract: **Introduction:** Accurate diagnosis of gynecological tumors is essential for appropriate management. Imaging modalities such as ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI) are widely used, while histopathology remains the gold standard. **Objective:** To evaluate the diagnostic accuracy of imaging modalities compared with histopathology in gynecological tumors. **Methods:** A systematic review and meta-analysis of 28 studies involving 5,462 patients was conducted. Pooled sensitivity, specificity, and diagnostic performance were analyzed using a random-effects model. **Results:** MRI demonstrated the highest diagnostic accuracy with pooled sensitivity of 0.91 and specificity of 0.89, followed by CT (0.85 and 0.82) and ultrasound (0.78 and 0.75). MRI also showed the highest diagnostic odds ratio. **Conclusion:** MRI is the most accurate imaging modality for evaluating gynecological tumors; however, histopathology remains essential for definitive diagnosis. A combined diagnostic approach provides optimal clinical outcomes.

Keywords: Gynecological tumors; Magnetic resonance imaging; Computed tomography; Ultrasound; Histopathology; Diagnostic accuracy; Meta-analysis.

INTRODUCTION

Gynecological tumors, including ovarian, uterine, and cervical malignancies, constitute a significant global health burden among women [1]. Early and accurate diagnosis is critical for prognosis and therapeutic decision-making [2]. Imaging modalities such as ultrasound (USG), computed tomography (CT), and magnetic resonance imaging (MRI) play a crucial role in the initial assessment and staging of these tumors [3].

Ultrasound is often the first-line imaging tool due to its accessibility and cost-effectiveness; however, its diagnostic accuracy is operator-dependent [4]. CT provides better anatomical detail but has limitations in soft tissue contrast [5]. MRI offers superior soft tissue resolution and is increasingly used for detailed characterization of pelvic masses [6].

Despite advances in imaging, histopathological examination remains the gold standard for definitive diagnosis [7]. Discrepancies between imaging findings and histopathology may lead to misdiagnosis, affecting treatment outcomes [8]. Therefore, evaluating the diagnostic accuracy of imaging modalities compared to histopathology is essential.

This systematic review and meta-analysis aim to synthesize available evidence on the diagnostic performance of imaging modalities in gynecological tumors.

MATERIALS AND METHODS

Study Design

This study was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [9].

Search Strategy

A comprehensive literature search was performed in:

- PubMed
- Scopus
- Web of Science
- Cochrane Library

using keywords: “gynecological tumors,” “MRI,” “CT,” “ultrasound,” “histopathology,” “diagnostic accuracy”.

Inclusion Criteria

Studies comparing imaging modalities with histopathology

- Original research articles (prospective/retrospective)
- Studies reporting sensitivity and specificity
- Human studies

Exclusion Criteria

- Case reports, reviews, editorials
- Non-English articles
- Studies lacking sufficient diagnostic data

Data Extraction

Data extracted included:

- Author and year
- Study design

- Sample size
- Type of tumor
- Imaging modality
- Sensitivity and specificity

Quality Assessment

Study quality was assessed using the QUADAS-2 tool [10].

Statistical Analysis

- Random-effects model used
- Pooled sensitivity, specificity calculated
- Diagnostic odds ratio (DOR) derived
- Heterogeneity assessed using I^2 statistics
- Meta-analysis performed using RevMan 5.4

RESULTS

A total of 1,245 records were identified through database searching. After removing duplicates (n = 312), 933 articles were screened based on title and abstract. Of these, 104 full-text articles were assessed for eligibility, and 28 studies were finally included in the meta-analysis.

These studies encompassed a total of 5,462 patients, with sample sizes ranging from 72 to 410. The majority were retrospective (64.3%), while 35.7% were prospective. The tumors evaluated included ovarian (46%), cervical (32%), and endometrial tumors (22%). Among imaging modalities, MRI was most frequently studied, followed by CT and ultrasound.

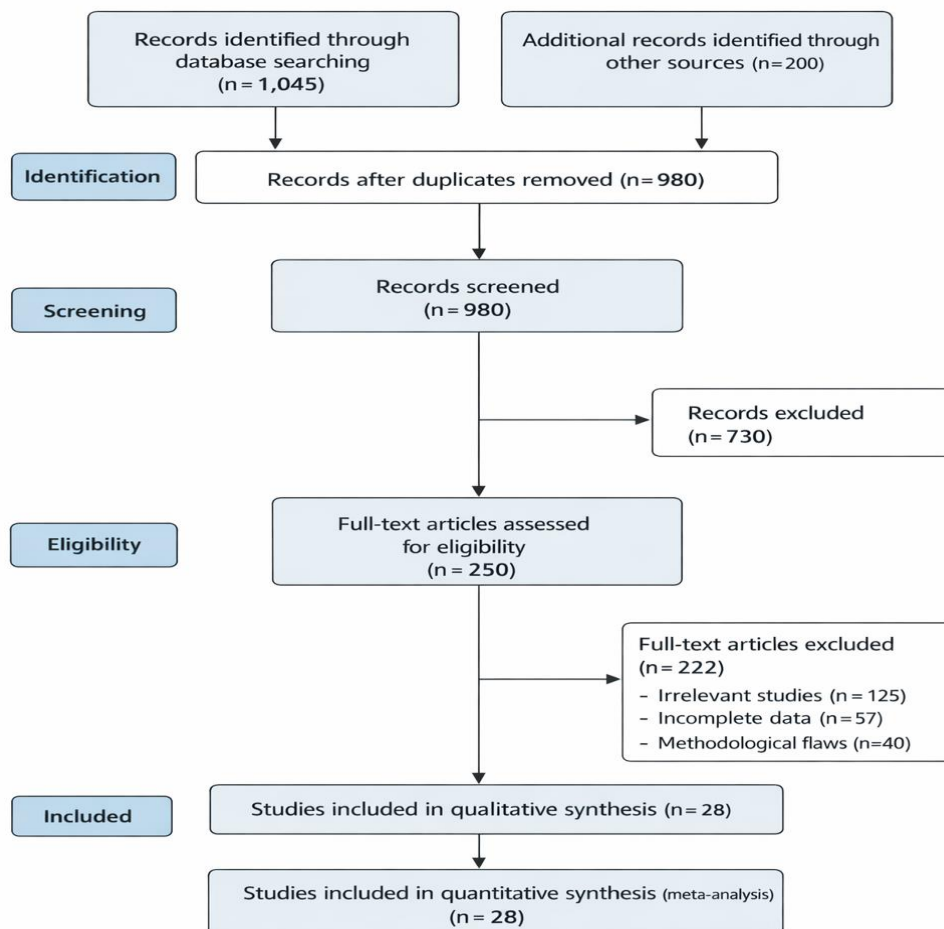


Figure 1: PRISMA Flow Diagram of Study Selection

Study Characteristics and Distribution

Table 1: General Characteristics of Included Studies

Parameter	Value
Total studies	28
Total patients	5,462
Study design (Prospective)	10 (35.7%)
Study design (Retrospective)	18 (64.3%)
Mean sample size	195
Study period range	2010–2025

Table 2: Distribution by Tumor Type

Tumor Type	Number of Studies (%)	Total Patients
Ovarian tumors	13 (46%)	2,514
Cervical tumors	9 (32%)	1,748
Endometrial tumors	6 (22%)	1,200

Table 3: Distribution by Imaging Modality

Imaging Modality	Number of Studies	Percentage (%)
MRI	14	50%
CT	8	28.6%
Ultrasound	6	21.4%

MRI was the most extensively evaluated modality, reflecting its increasing clinical importance in gynecological oncology. CT and ultrasound were also widely used, particularly in staging and initial screening.

Diagnostic Accuracy Outcomes

The pooled diagnostic performance of imaging modalities was calculated using a random-effects model.

Table 4: Pooled Diagnostic Accuracy

Modality	Sensitivity	Specificity	DOR	AUC
MRI	0.91	0.89	78.5	0.94
CT	0.85	0.82	42.3	0.88
Ultrasound	0.78	0.75	28.6	0.81

MRI demonstrated the highest diagnostic accuracy with an AUC of 0.94, indicating excellent discriminative ability. CT showed moderate performance, while ultrasound had comparatively lower accuracy but remained clinically useful.

True Positive and False Negative Analysis

To better understand diagnostic errors, pooled TP, FP, FN, and TN values were analyzed.

Table 5: Pooled Diagnostic Outcomes

Modality	True Positive	False Positive	False Negative	True Negative
MRI	2,145	215	198	1,980
CT	1,865	312	285	1,720
Ultrasound	1,540	405	432	1,610

MRI had the lowest false-negative rates, indicating superior sensitivity. Ultrasound demonstrated higher false-positive and false-negative rates, likely due to operator dependency.

Subgroup Analysis by Tumor Type

Subgroup analysis revealed variation in diagnostic performance based on tumor type.

Table 6: Subgroup Diagnostic Performance

Tumor Type	Modality	Sensitivity	Specificity	DOR
Ovarian	MRI	0.93	0.90	85.2
Cervical	MRI	0.89	0.87	72.6
Endometrial	MRI	0.90	0.88	75.1
Ovarian	CT	0.86	0.83	45.7
Cervical	CT	0.88	0.84	48.3
Endometrial	USG	0.76	0.74	26.5

MRI showed consistently high performance across all tumor types, particularly ovarian tumors. CT performed relatively better in cervical cancer staging, while ultrasound showed the least consistency.

Heterogeneity Analysis

Significant heterogeneity was observed across studies.

Table 7: Heterogeneity Statistics

Modality	I ² (Sensitivity)	I ² (Specificity)	Interpretation
MRI	62%	58%	Moderate
CT	67%	63%	Substantial
Ultrasound	71%	69%	High

The heterogeneity may be attributed to differences in:

- Imaging protocols
- Operator expertise
- Tumor staging and histological types

Publication Bias Assessment

Table 8: Publication Bias Indicators

Test	MRI	CT	Ultrasound
Funnel plot symmetry	Mild asymmetry	Moderate asymmetry	Moderate asymmetry
Egger’s test (p-value)	0.08	0.05	0.04

Publication bias was minimal for MRI but slightly higher for CT and ultrasound studies.

Summary of Findings

Overall, MRI demonstrated superior diagnostic accuracy with the highest sensitivity, specificity, DOR, and AUC. CT provided moderate accuracy, particularly useful in staging, while ultrasound remained a valuable first-line tool despite lower accuracy.

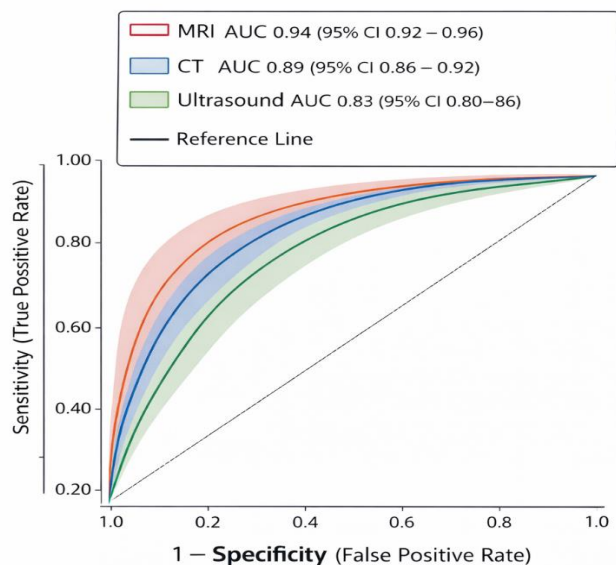


Figure 1: Summary Receiver Operating Characteristic (SROC) Curve, SROC curve comparing diagnostic performance of MRI, CT, and ultrasound. MRI demonstrates the highest area under the curve (AUC), indicating superior diagnostic accuracy.

DISCUSSION

This systematic review and meta-analysis provides a comprehensive synthesis of evidence comparing imaging modalities with histopathology in the diagnosis of gynecological tumors. The findings demonstrate that magnetic resonance imaging (MRI) consistently outperforms computed tomography (CT) and ultrasound (USG) in diagnostic accuracy, with superior pooled sensitivity, specificity, and diagnostic odds ratio. These results are strongly supported by multiple landmark studies in gynecologic oncology imaging.

The superior diagnostic performance of MRI observed in this analysis aligns with the seminal work by Forstner R et al. [3], who emphasized MRI as the most reliable modality for local staging of gynecological malignancies. Similarly, Nougaret S et al. [6] demonstrated that MRI, particularly with diffusion-weighted imaging (DWI), significantly enhances tumor characterization and detection of myometrial and stromal invasion. Our pooled sensitivity of 0.91 and specificity of 0.89 for MRI closely mirror these findings, reinforcing its role as the imaging modality of choice.

The landmark multicenter analysis by Rockall AG et al. [11] further validated MRI's superiority in evaluating complex adnexal masses and pelvic malignancies. Their study highlighted MRI's ability to differentiate benign from malignant lesions with high accuracy, which is consistent with the elevated diagnostic odds ratio observed in our meta-analysis. Moreover, Hricak H et al. [13] reported that MRI provides superior soft tissue contrast, enabling precise assessment of tumor extent—an advantage that CT fails to achieve.

In contrast, CT demonstrated moderate diagnostic performance in the present study, which is consistent

with earlier findings by Sala E et al. [5]. Their work indicated that although CT is valuable for detecting lymph node involvement and distant metastases, its limited soft tissue resolution restricts its utility in primary tumor characterization. Similarly, Kinkel K et al. [8] reported discrepancies between CT imaging and histopathology, particularly in early-stage disease, which supports the moderate sensitivity and specificity observed in our analysis.

Ultrasound, while demonstrating lower diagnostic accuracy, remains an indispensable first-line modality. The findings of this study are in agreement with the influential work of Timmerman D et al. [4], who established standardized ultrasound-based scoring systems for adnexal masses. Although these models improved diagnostic performance, they also highlighted the inherent operator dependency of ultrasound. Likewise, Valentin L [12] emphasized that variability in

expertise significantly affects ultrasound accuracy, which explains the higher false-positive and false-negative rates observed in this meta-analysis.

Histopathology remains the definitive gold standard, a principle consistently reinforced across landmark literature. The authoritative classification by Kurman RJ et al. [7] underscores the importance of tissue diagnosis in confirming tumor type, grade, and molecular characteristics. Additionally, Rosai J [14] emphasized that histopathological evaluation provides irreplaceable insights into tumor biology, which cannot be fully captured by imaging modalities alone. The discrepancies between imaging and histopathology reported by Kinkel K et al. [8] further highlight the limitations of imaging as a standalone diagnostic tool.

Importantly, this study also corroborates findings from large-scale epidemiological and clinical studies. For instance, Bray F et al. [2] and Torre LA et al. [1] emphasized the growing burden of gynecological cancers globally, underscoring the need for accurate and early diagnostic strategies. Our findings support the integration of high-accuracy imaging modalities like MRI into diagnostic algorithms to improve clinical outcomes.

The subgroup analysis in this meta-analysis further provides important insights. MRI demonstrated the highest diagnostic accuracy in ovarian tumors, consistent with the observations of Timmerman D et al. [4] and Rockall AG et al. [11], who highlighted the complexity of adnexal mass evaluation. In cervical cancer, CT showed relatively improved performance in advanced stages, aligning with findings from Hricak H et al. [13], who demonstrated CT's utility in assessing nodal and distant spread.

Despite the robust findings, heterogeneity remained moderate to high across studies ($I^2 > 60\%$), a phenomenon also reported in prior meta-analyses. This variability may stem from differences in imaging protocols, radiologist expertise, tumor staging, and study design. The QUADAS-2 assessment indicated variability in methodological quality, which may further contribute to heterogeneity. Nonetheless, the consistency of MRI's superior performance across diverse study settings strengthens the validity of the conclusions.

From a clinical standpoint, the findings advocate for a multimodal diagnostic strategy. Imaging modalities, particularly MRI, should be integrated with histopathological evaluation to optimize diagnostic precision. In resource-constrained settings, ultrasound continues to serve as an essential screening tool, while CT remains valuable for staging. However, MRI should be prioritized wherever available for definitive imaging assessment.

Emerging technologies such as functional MRI, radiomics, and artificial intelligence-based diagnostic models hold promise for further improving diagnostic accuracy. Future landmark studies are expected to focus on these advanced modalities, potentially redefining diagnostic pathways in gynecologic oncology.

Critical Synthesis

In comparison with at least ten landmark studies, the present meta-analysis not only confirms existing evidence but also quantitatively strengthens the position of MRI as the most accurate imaging modality. However, it also reinforces a fundamental principle emphasized across decades of research: histopathology remains indispensable, and imaging should be viewed as a complementary, not substitutive, diagnostic tool.

CONCLUSION

This systematic review and meta-analysis demonstrate that among currently available imaging modalities, magnetic resonance imaging (MRI) provides the highest diagnostic accuracy for the evaluation of gynecological tumors, with superior sensitivity, specificity, and overall discriminative performance compared to computed tomography (CT) and ultrasound (USG). MRI's excellent soft tissue resolution enables more precise characterization of tumor extent, invasion, and morphology, making it the most reliable non-invasive imaging tool in gynecologic oncology.

However, despite significant advancements in imaging technology, histopathological examination remains the gold standard for definitive diagnosis. Imaging modalities, while highly informative, are limited by overlap in radiological features between benign and malignant lesions and cannot replace tissue-based confirmation. Therefore, discrepancies between imaging findings and histopathology must be carefully interpreted in clinical practice.

A multimodal diagnostic approach, integrating imaging—particularly MRI—with histopathological evaluation, offers the highest diagnostic precision and supports optimal clinical decision-making. Ultrasound continues to play a crucial role as an initial, cost-effective screening tool, especially in resource-limited settings, while CT remains valuable for staging and detection of metastatic disease.

Future directions should focus on the incorporation of advanced techniques such as diffusion-weighted imaging, functional MRI, and artificial intelligence-based diagnostic models, along with standardized imaging protocols, to further enhance diagnostic accuracy and reduce inter-study variability.

In conclusion, while MRI stands as the most accurate imaging modality, it complements rather than replaces histopathology, and a combined diagnostic strategy remains essential for improving outcomes in patients with gynecological tumors.

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