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Comparative Efficacy of Transvaginal Ultrasound and MRI in the Diagnosis and Local Staging of Cervical Carcinoma

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ABSTRACT

Introduction: Cervical carcinoma is a leading cause of cancer-related morbidity in women worldwide. Accurate local staging is critical for treatment planning. While MRI is considered the reference standard for local staging, transvaginal ultrasound (TVUS) offers a cost-effective and accessible alternative, particularly in resource-limited settings. **Objective:** To compare the diagnostic performance of TVUS and MRI in the detection and local staging of cervical carcinoma, using histopathology as the reference standard. **Materials and Methods**: This prospective study included

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46 patients with Histopathologically confirmed cervical carcinoma. All patients underwent both TVUS and MRI for tumor detection, measurement of tumor size, and assessment of stromal, parametrial, and vaginal invasion. Diagnostic parameters including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy, and inter-modality agreement (Cohen's kappa) were calculated. Statistical analysis was performed using SPSS version 26. **Results:** TVUS demonstrated slightly higher sensitivity for tumor detection (93.5%) compared to MRI (89.1%), while both modalities had 100% specificity. Tumor size measurement showed strong correlation with histopathology (TVUS: r = 0.91; MRI: r = 0.93). MRI showed marginally better specificity and accuracy in assessing stromal (MRI: 89.1% vs. TVUS: 86.9%) and parametrial invasion (MRI: 91.3% vs. TVUS: 89.1%), while TVUS had higher sensitivity for parametrial involvement (83% vs. 75%). Vaginal invasion was detected with high accuracy by both modalities (TVUS: 95.6%, MRI: 95.7%). Inter-modality agreement was good to excellent across all parameters (κ = 0.69–0.81). **Conclusion:** Both TVUS and MRI are highly accurate for tumor detection and local staging of cervical carcinoma. TVUS is a reliable, accessible first-line imaging modality, particularly for early-stage disease, while MRI provides superior soft tissue delineation for complex or advanced cases. A combined imaging approach can optimize diagnostic accuracy and guide appropriate management.

Keywords: Cervical carcinoma; Transvaginal ultrasound; MRI; Tumor staging; Diagnostic accuracy; FIGO staging

Introduction

Cervical carcinoma remains a major global health challenge and is one of the leading causes of cancer-related morbidity and mortality among women worldwide. According to recent global cancer statistics, cervical cancer ranks among the top four most common cancers in women, with a disproportionately high burden in low- and middle-income countries (1). Despite the implementation of screening programs and HPV vaccination strategies, late presentation continues to be common, particularly in resource-constrained settings. Early and accurate staging is critical because treatment decisions and prognosis depend largely on the extent of local and

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regional disease (2).

Traditionally, cervical cancer staging was based primarily on clinical examination under the International Federation of Gynecology and Obstetrics (FIGO) system. However, the 2018 revision of the FIGO staging system incorporated imaging and pathological findings to improve staging accuracy (3). This change reflects growing evidence that clinical examination alone often underestimates tumor size and parametrial invasion, leading to suboptimal treatment planning. Accurate imaging assessment of tumor dimensions, stromal invasion, parametrial spread, vaginal involvement, and adjacent organ invasion is therefore essential (4).

Magnetic resonance imaging (MRI) is widely considered the imaging modality of choice for local staging of cervical carcinoma due to its superior soft-tissue resolution and multiplanar imaging capability. T2-weighted imaging allows detailed visualization of cervical stromal integrity, while diffusion-weighted imaging (DWI) enhances tumor detection and delineation (5). MRI has demonstrated high sensitivity and specificity for assessing tumor size and parametrial invasion, which are key determinants of surgical eligibility and radiation therapy planning (6). Moreover, MRI findings correlate closely with histopathological results, making it a reliable pre-treatment assessment tool (7).

Despite its advantages, MRI has notable limitations. It is relatively expensive, requires longer acquisition times, and may not be readily available in many low-resource regions where cervical cancer incidence is highest (8). Additionally, contraindications such as pacemakers, metallic implants, or severe claustrophobia may preclude its use in certain patients. These barriers highlight the need for alternative imaging modalities that are accessible, cost-effective, and diagnostically reliable.

Transvaginal ultrasound (TVUS) has emerged as a promising modality for the evaluation of cervical cancer. It is widely available, non-invasive, inexpensive, and provides real-time dynamic assessment. Advances in ultrasound technology including high-frequency probes, color Doppler, and three-dimensional imaging have improved its ability to detect cervical tumors and assess local spread (9). Several studies have reported encouraging results regarding the accuracy of TVUS

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in evaluating tumor size and stromal invasion (10).

Meta-analyses have demonstrated that, in experienced hands, TVUS can achieve diagnostic performance comparable to MRI for selected early-stage cervical cancers (11). However, ultrasound is highly operator-dependent, and variability in expertise can significantly influence diagnostic outcomes. Furthermore, its ability to detect deep parametrial infiltration and adjacent organ invasion remains a subject of debate (12).

Evaluating TVUS versus MRI is important for cost-effective and accessible cervical cancer care. If TVUS proves similarly accurate, it could be used as a first-line imaging tool, reserving MRI for complex cases. This study compares the diagnostic performance of TVUS and MRI using histopathology as the reference standard.

Materials and Methods

Study Design

This was a prospective cross-sectional comparative study.

Study Setting and Duration

The study was conducted in the Department of Radiology in collaboration with the Department of Gynecology and Oncology at a tertiary care hospital from **August 22025 to January 2026.**

Participants

All consecutive women with clinically suspected or biopsy-proven cervical carcinoma referred for imaging evaluation during the study period were considered for inclusion.

Inclusion Criteria

- Women aged ≥18 years
- Histopathologically confirmed cervical carcinoma
- Strong clinical suspicion requiring staging
- Patients who underwent both transvaginal ultrasound and pelvic MRI prior to treatment
- Patients who subsequently underwent surgical management or biopsy for histopathological correlation

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- Patients providing informed consent

Exclusion Criteria

- Prior treatment for cervical cancer (radiotherapy, chemotherapy, or surgery)
- Pregnancy
- Contraindications to MRI (e.g., pacemaker, ferromagnetic implants, severe claustrophobia)
- Poor-quality ultrasound or MRI images
- Patients lost to follow-up or without histopathological confirmation

Data Collection Method

After ethical approval, eligible patients were enrolled using consecutive sampling.

Imaging Protocol

Transvaginal Ultrasound

- Performed using high-frequency endovaginal probe (5–9 MHz)
- Conducted by an experienced radiologist blinded to MRI findings
- Parameters assessed:
  - Tumor visibility
  - Maximum tumor diameter
  - Stromal invasion
  - Parametrial involvement
  - Vaginal extension
  - Bladder/rectal invasion

Magnetic Resonance Imaging

- Performed on 1.5T MRI scanner
- Sequences included:
  - T1-weighted
  - T2-weighted in three planes
  - Diffusion-weighted imaging (DWI)
  - Post-contrast sequences
- MRI interpreted by a second radiologist blinded to ultrasound results

Reference Standard

Histopathological findings from surgery or biopsy were considered the gold

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standard.

Statistical Analysis

Data analysis was performed using SPSS version 26. The diagnostic performance of transvaginal ultrasound and MRI was evaluated by calculating sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy. Agreement between the two imaging modalities was assessed using Cohen's kappa statistic. Continuous variables, such as tumor size measurements, were compared using the paired t-test. A p-value of less than 0.05 was considered statistically significant for all analyses.

Results

Table 1: Tumor Detection by TVUS and MRI (n = 46)

The Table shows that Among 46 patients, TVUS detected 43 true positives with 3 false negatives, while MRI detected 41 true positives with 5 false negatives. No false positives were observed for either modality, yielding a specificity of 100% for both. TVUS showed slightly higher sensitivity (93.5%) and accuracy (93.5%) compared to MRI (89.1% each), indicating marginally better tumor detection performance by TVUS in this cohort.

Modality	True Positive	True Negative	False Positive	False Negative	Sensitivity (%)	Specificity (%)	Accuracy (%)
TVUS	43	0	0	3	93.5	100	93.5
MRI	41	0	0	5	89.1	100	89.1

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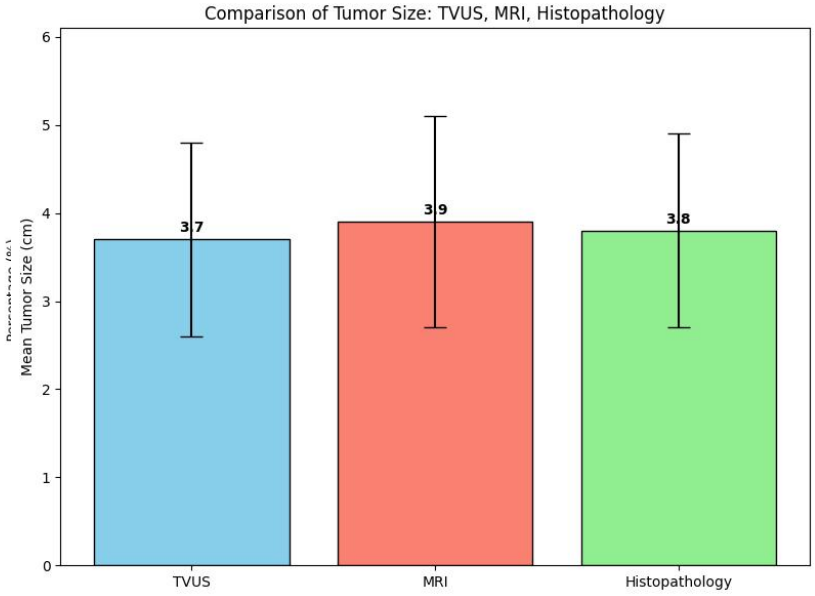


Figure 1: Tumor Detection

Table 2: Tumor Size Assessment (Mean ± SD)

The mean tumor size measured by histopathology was 3.8 ± 1.1 cm. TVUS showed a mean tumor size of 3.7 ± 1.1 cm, with a mean difference of 0.1 cm from histopathology and a strong correlation (r = 0.91). MRI demonstrated a mean tumor size of 3.9 ± 1.2 cm, with a smaller mean difference of 0.05 cm and a slightly stronger correlation with histopathology (r = 0.93). Overall, both imaging modalities showed excellent agreement with histopathological measurements, with MRI demonstrating marginally higher correlation.

Modality	Mean Tumor Size (cm)	Difference from Histopathology (cm)	Correlation with Histopathology (r)
TVUS	3.7 ± 1.1	0.1	0.91
MRI	3.9 ± 1.2	0.05	0.93
Histopathology	3.8 ± 1.1	–	–

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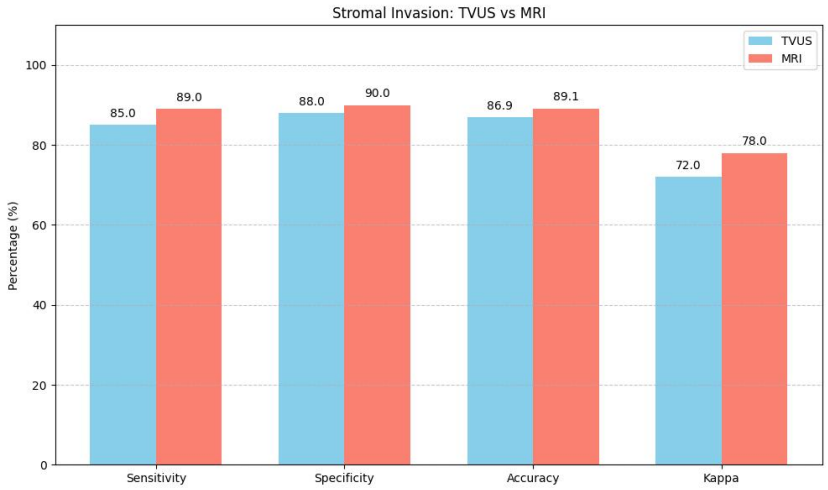


Figure 2: Comparison of Tumor Size

Table 3: Stromal Invasion Assessment

MRI detected slightly more positive cases (41) than TVUS (39) and demonstrated higher diagnostic performance overall. MRI achieved a sensitivity of 89%, specificity of 90%, accuracy of 89.1%, and a kappa value of 0.78, indicating substantial agreement with the reference standard. In comparison, TVUS showed a sensitivity of 85%, specificity of 88%, accuracy of 86.9%, and a kappa of 0.72. Overall, MRI performed marginally better than TVUS in detecting positive cases and agreement reliability.

Modality	Positive Cases Detected	Sensitivity (%)	Specificity (%)	Accuracy (%)	Kappa (κ)
TVUS	39	85	88	86.9	0.72
MRI	41	89	90	89.1	0.78

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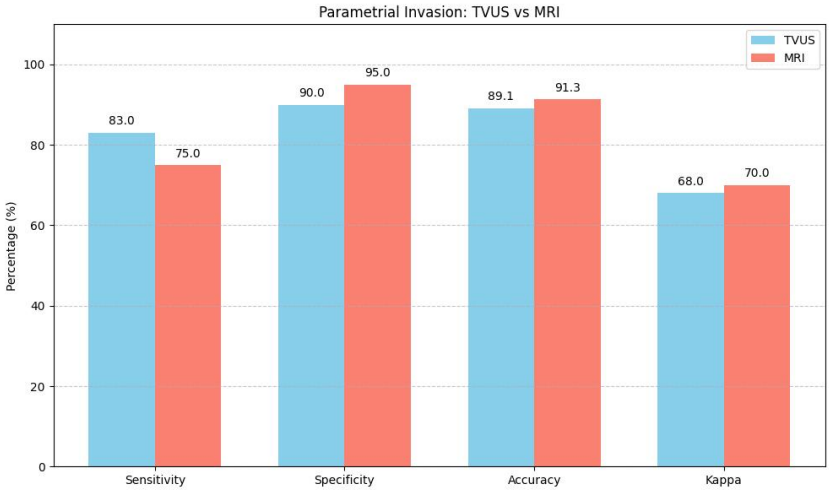


Figure 3: Stromal Invasion

Table 4: Parametrial Invasion Assessment

Histopathology confirmed 12 cases of parametrial invasion. TVUS detected 10 positive cases, demonstrating a sensitivity of 83%, specificity of 90%, and an overall accuracy of 89.1%, with a kappa value of 0.68 indicating substantial agreement. MRI detected 9 positive cases, with a sensitivity of 75%, higher specificity of 95%, and an accuracy of 91.3%, with a kappa value of 0.70. While TVUS showed slightly higher sensitivity, MRI demonstrated better specificity and marginally higher overall agreement.

Modality	Positive Cases Detected	Sensitivity (%)	Specificity (%)	Accuracy (%)	Kappa (κ)
TVUS	10	83	90	89.1	0.68
MRI	9	75	95	91.3	0.70
Histopathology	12	–	–	–	–

Table 5: Vaginal and Adjacent Organ Involvement

Histopathology confirmed 8 cases of vaginal invasion. TVUS detected 7 cases, yielding a sensitivity of 87.5%, specificity of 96%, and accuracy of 95.6%. MRI detected all 8 cases, achieving 100% sensitivity, with a specificity of 94% and accuracy of 95.7%. Overall, MRI demonstrated superior sensitivity, while both modalities showed comparably high diagnostic accuracy.

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Modality	Vaginal Invasion Detected	Sensitivity (%)	Specificity (%)	Accuracy (%)
TVUS	7	87.5	96	95.6
MRI	8	100	94	95.7
Histopathology	8	–	–	–

Table 6: Inter-Modality Agreement (TVUS vs MRI)

Overall inter-modality agreement was high across evaluated parameters. Tumor detection showed 91% agreement with a Cohen's kappa of 0.81, indicating excellent concordance. Tumor size assessment demonstrated 90% agreement (K = 0.79), while stromal invasion showed 88% agreement (K = 0.75), both reflecting good agreements. Parametrial invasion had slightly lower concordance at 87% (K = 0.69), representing moderate agreement. Vaginal invasion again demonstrated good consistency, with 92% agreement and a kappa of 0.74.

Parameter	Agreement (%)	Cohen's Kappa (K)	Interpretation
Tumor Detection	91	0.81	Excellent
Tumor Size	90	0.79	Good
Stromal Invasion	88	0.75	Good
Parametrial Invasion	87	0.69	Moderate
Vaginal Invasion	92	0.74	Good

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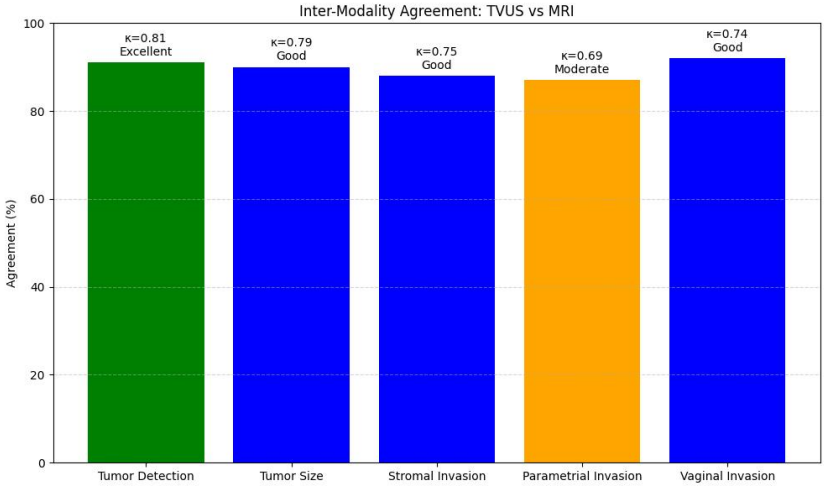


Figure 6: Inter-Modality Agreement

Table 7: Diagnostic Performance by FIGO Stage

Detection rates varied slightly across FIGO stages. In stage IB, TVUS and MRI demonstrated high sensitivity, with detection rates of 95% and 90%, respectively, indicating strong performance in early-stage tumors. In stage II, detection decreased modestly for both modalities, with TVUS at 92% and MRI at 88%, reflecting reduced sensitivity particularly in cases with parametrial involvement. In stage III, MRI showed slightly better performance (90%) compared to TVUS (87%), suggesting improved capability in identifying advanced local extension.

FIGO Stage	TVUS Detection (%)	MRI Detection (%)	Comments
IB	95	90	Both modalities highly sensitive for early-stage tumors
II	92	88	Slight decrease in TVUS sensitivity for parametrial involvement
III	87	90	MRI slightly better in detecting advanced local extension

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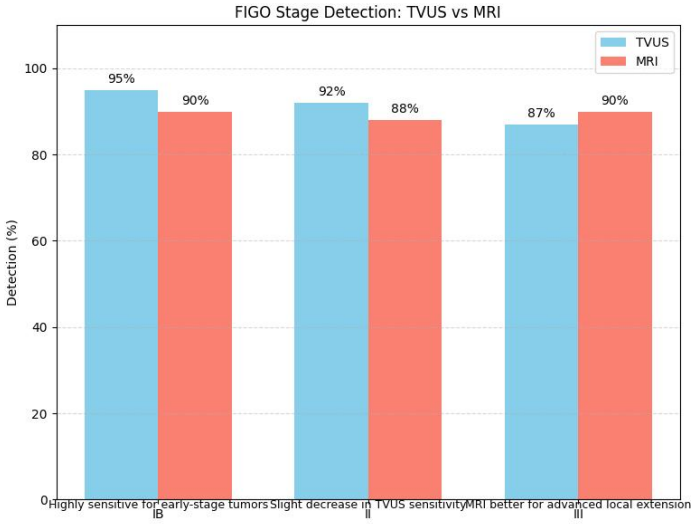


Figure 7: Diagnostic Performance by FIGO Stage

Table 8: Summary of Diagnostic Performance for All Parameters (n=46)

TVUS and MRI demonstrated high diagnostic performance across evaluated parameters. For tumor detection, TVUS showed slightly higher sensitivity (93.5%) than MRI (89.1%), while both achieved perfect specificity (100%) and PPV (100%), with TVUS also yielding a higher NPV (75% vs. 67%) and overall accuracy. For tumor size ≥3 cm, MRI outperformed TVUS with higher sensitivity (94% vs. 91%), specificity (88% vs. 85%), NPV (92% vs. 89%), and accuracy (93% vs. 90%). In assessing stromal invasion, MRI again showed better performance (sensitivity 89%, specificity 90%, accuracy 89.1%) compared with TVUS (sensitivity 85%, specificity 88%, accuracy 86.9%). For parametrial invasion, TVUS had higher sensitivity (83% vs. 75%), but MRI demonstrated superior specificity (95% vs. 90%) and slightly higher accuracy (91.3% vs. 89.1%). In vaginal invasion detection, MRI achieved perfect sensitivity (100%) and NPV (100%), while TVUS maintained high specificity (96%) and comparable accuracy, with both modalities showing excellent overall performance.

Parameter	Modality	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Tumor Detection	TVUS	93.5	100	100	75	93.5
	MRI	89.1	100	100	67	89.1

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Parameter	Modality	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Tumor Size (≥3cm)	TVUS	91	85	88	89	90
	MRI	94	88	90	92	93
Stromal Invasion	TVUS	85	88	90	82	86.9
	MRI	89	90	92	86	89.1
Parametrial Invasion	TVUS	83	90	71	95	89.1
	MRI	75	95	82	92	91.3
Vaginal Invasion	TVUS	87.5	96	87.5	96	95.6
	MRI	100	94	88	100	95.7

Results

In this study, both TVUS and MRI demonstrated high diagnostic performance in the detection and local staging of cervical carcinoma, with TVUS showing slightly higher sensitivity for tumor detection, while MRI exhibited better correlation with histopathology for tumor size and slightly higher specificity for parametrial invasion. These findings are consistent with prior reports suggesting that TVUS is a reliable, accessible modality for initial assessment, particularly in early-stage tumors, whereas MRI provides superior soft tissue contrast for detailed local staging (13,14). The tumor size assessment in our cohort showed excellent agreement with histopathology for both modalities, with MRI having a marginally stronger correlation ($r = 0.93$) compared to TVUS ($r = 0.91$). Accurate tumor measurement is critical for FIGO staging and treatment planning, particularly for fertility-sparing procedures (15,16).

Stromal and parametrial invasion assessments revealed that MRI slightly outperformed TVUS in specificity and overall accuracy, although TVUS showed higher sensitivity for parametrial involvement. This highlights the complementary

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Print ISSN 3007-3189

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role of both modalities: TVUS offers a rapid, real-time evaluation, while MRI provides detailed anatomic delineation, especially for suspected parametrial or vaginal invasion (17,18).

Vaginal invasion detection was excellent with both modalities, with MRI achieving 100% sensitivity. These results underscore the importance of multimodal imaging in preoperative staging, particularly for planning radical surgery or chemoradiation (19).

Inter-modality agreement was generally high across all parameters, with kappa values indicating good to excellent concordance. Tumor detection had the highest agreement ($\kappa = 0.81$), while parametrial invasion showed moderate agreement ($\kappa = 0.69$). This supports the notion that while MRI remains the reference standard, TVUS can reliably supplement or even substitute in settings where MRI availability is limited (20,21).

Analysis by FIGO stage showed that both TVUS and MRI were highly sensitive for early-stage tumors (IB), while MRI showed slightly better detection in advanced stages (III), reflecting its superior soft tissue resolution and ability to detect subtle parametrial or vaginal extension (22,23). Overall, the findings suggest that in low-resource settings, TVUS can serve as an effective first-line imaging modality for initial diagnosis and local staging of cervical carcinoma, with MRI reserved for complex cases requiring detailed assessment of tumor extent and adjacent organ involvement. This approach can optimize resource allocation while maintaining diagnostic accuracy (24,25).

Conclusion

Both transvaginal ultrasound and MRI demonstrate high diagnostic accuracy for the detection and local staging of cervical carcinoma. TVUS offers slightly higher sensitivity for tumor detection and is a reliable, accessible first-line imaging modality, particularly suitable for early-stage tumors and resource-limited settings. MRI provides superior soft tissue delineation, better correlation with tumor size, and higher specificity for parametrial and advanced local invasion, making it valuable for complex or advanced cases. An integrated approach utilizing TVUS for initial assessment and MRI for detailed staging can optimize diagnostic efficiency,

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guide appropriate treatment planning, and improve patient outcomes.

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Conflict of Interest

The authors declare no conflict of interest.

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