Cureus
Part of SPRINGER NATURE

Open Access Original Article

Diagnostic Accuracy of Transvaginal Ultrasound Versus Magnetic Resonance Imaging for Deep Infiltrating Endometriosis: A Histopathologically Correlated Prospective Study

Review began 10/17/2026
Review ended 10/28/2026
Published 10/31/2026

© Copyright 2026
Ahmed et al. This is an open access article distributed under the terms of the Creative Commons Attribution License CC-BY 4.0., which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

DOI: 10.7759/cureus.118898

Doaa Ahmed [1], Amina Iqbal [2], Gauri Sreeram [3], Urooj Anwar [4], Nida Waqas [5], Titilayo Olawunmi [6], Gyanendra KC [7], Vanessa Colaco [8], Rachel Marsha Manoj Stanley [9], Nazia Sumbul Mahir [10], Saadia Hassan [11]

1. Obstetrics and Gynaecology, Guy's and St Thomas' NHS Foundation Trust, London, GBR 2. Radiology, Cheema Heart Complex Gujranwala, Gujranwala, PAK 3. Radiology, Mallige Hospital, Bengaluru, IND 4. Obstetrics and Gynaecology, Akhtar Saeed Medical and Dental College, Lahore, PAK 5. Obstetrics and Gynaecology, Khokhar Hospital, Mandi Bahauddin, PAK 6. Medicine, Ekiti State University, Ekiti, NGA 7. Radiology, KIST Medical College and Teaching Hospital, Imadol, NPL 8. Obstetrics and Gynaecology, Oxford University Hospitals NHS Foundation Trust, Oxford, GBR 9. Emergency, Glenfield Hospital, Leicester, GBR 10. Obstetrics and Gynaecology, Luhansk State Medical University, Luhansk, UKR 11. Gynaecology, Rawalpindi Medical University, Rawalpind, PAK

Corresponding author: Saadia Hassan, hassansaadia695@gmail.com

Abstract

Background

Deep infiltrating endometriosis (DIE) requires accurate anatomical assessment. This study prospectively compared transvaginal ultrasound (TVUS) and magnetic resonance imaging (MRI) with histopathology as the reference standard.

Methods

In this prospective paired diagnostic-accuracy study, 350 women with clinically suspected DIE underwent standardized TVUS and pelvic MRI, followed by laparoscopy and histopathological assessment. We computed overall and anatomical site-specific sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy, and likelihood ratios. We compared paired classifications using McNemar's test.

Results

Histopathology confirmed DIE in 213 (60.9%) participants. TVUS demonstrated 89.2% sensitivity, 86.9% specificity, 91.3% PPV, 83.8% NPV, and 88.3% accuracy. Corresponding MRI estimates were 91.5%, 92.7%, 95.1%, 87.6%, and 92.0%, respectively. TVUS showed higher sensitivity for ureteric disease, whereas MRI showed higher specificity and accuracy for several other anatomical sites. Paired classifications showed no significant differences (McNemar's $\chi^2 = 0.066$, $P = 0.798$), although the counts differed. Interobserver agreement was substantial to near-perfect for most sites.

Conclusion

Both standardized TVUS and MRI demonstrated high diagnostic accuracy for DIE. MRI performed better numerically for several measurements, but the paired analysis did not show statistically significant differences in overall classification. Expert TVUS may serve as an effective first-line examination, with MRI providing complementary information for complex, extensive, or equivocal disease and preoperative mapping.

Categories: Obstetrics/Gynecology, Radiology
Keywords: deep infiltrating endometriosis, diagnostic accuracy, histopathology, magnetic resonance imaging, transvaginal ultrasound

Introduction

Endometriosis is a chronic inflammatory gynecologic disorder that affects 2-10% of the general female population, reduces quality of life, and is associated with dysmenorrhea, dyspareunia, pelvic pain, and infertility [1]. Deep infiltrating endometriosis (DIE) is defined by lesions that penetrate deeply into pelvic tissues, including the uterosacral ligaments, rectovaginal area, bowel, bladder, and other pelvic organs. The location and extent of disease matter for preoperative evaluation, surgical complexity, and treatment planning [2,3]. Accurate preoperative identification and anatomical classification of DIE are therefore important for patient assessment and appropriate planning of surgical treatment strategies [4].

Noninvasive imaging may be used as part of the initial diagnostic approach for patients with suspected endometriosis, as surgical evaluation with histopathological examination is not necessary to make the diagnosis [5]. Noninvasive imaging has thus become the key factor in the assessment of patients with suspected DIE [4]. Transvaginal ultrasound (TVUS) is widely available, relatively inexpensive, and can be performed using a systematic, endometriosis-specific protocol that provides detailed assessment of pelvic structures [6]. Magnetic resonance imaging (MRI), however, allows excellent soft-tissue characterization and comprehensive multiplanar evaluation of the pelvis, with special benefits for extensive, multicompartment, or anatomically complex disease [7,8]. Nevertheless, reported diagnostic efficacy varies widely across modalities, depending on lesion localization, imaging protocols, operator experience, and patient selection [9].

Despite growing evidence supporting both TVUS and MRI, an important clinical question remains unresolved: does MRI provide superior diagnostic accuracy to appropriately performed TVUS for detecting DIE, and are any differences in diagnostic performance modality- or site-specific? [10]. Previous investigations have used diverse imaging modalities and methods to define and assess anatomical DIE, with varied study designs and reference standards for diagnostic confirmation ranging from surgical to histological [8,9]. Moreover, overall diagnostic assessment may mask clinically relevant differences between pelvic compartments [11]. Within each patient, direct prospective comparison using a uniform imaging strategy and histopathology as the reference standard can provide a more meaningful assessment of each modality's relative diagnostic value [11].

Therefore, this prospective paired diagnostic-accuracy study aimed to compare the diagnostic performance of TVUS and MRI for detecting DIE, using histopathological examination as the reference standard. The primary objective was to evaluate and compare the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy of both modalities for detecting histopathologically confirmed DIE. Secondary objectives were to compare their diagnostic performance across predefined anatomical sites and assess interobserver agreement in site-specific disease detection. Rather than presuming the superiority of either imaging modality, this study sought to characterize their comparative diagnostic performance and identify potential differences in their strengths across anatomical sites. The findings may help inform the selection and complementary use of these modalities to optimize preoperative imaging assessment and surgical planning in women with suspected DIE.

Materials And Methods

Study design and setting

We conducted a prospective paired diagnostic-accuracy study to compare the diagnostic performance of TVUS and MRI for detecting and anatomically mapping DIE. The paired design allowed each participant to undergo both index imaging examinations (TVUS and MRI) before the same surgical and histopathological reference-standard assessment, enabling direct within-participant comparison of the two imaging modalities. The study was conducted in the gynecology unit of Holy Family Hospital, Rawalpindi, Pakistan, with dedicated gynecological ultrasound units, pelvic MRI, laparoscopic surgery for gynecological conditions, and histopathology facilities. We recruited participants consecutively between January 2026 and August 2026.

Study population

The study population comprised adult women with clinically suspected endometriosis or DIE who were scheduled for laparoscopic surgical evaluation. We screened women presenting to the gynecology/endometriosis service during the recruitment period for eligibility. To limit selection and spectrum bias, we recruited women with suspected disease rather than only those with a diagnosis, providing a clinically enriched population of women referred for specialist evaluation of suspected endometriosis.

During the study period, we assessed 412 women for eligibility. Of these, 62 were ineligible: 34 did not meet the inclusion criteria, 16 refused to participate, and 12 had incomplete data. The remaining 350 women were selected for the study and underwent both TVUS and MRI, followed by laparoscopy and histopathological examination. All 350 participants completed the diagnostic pathway and constituted the final analytic cohort. Figure *1* presents the participant flow.

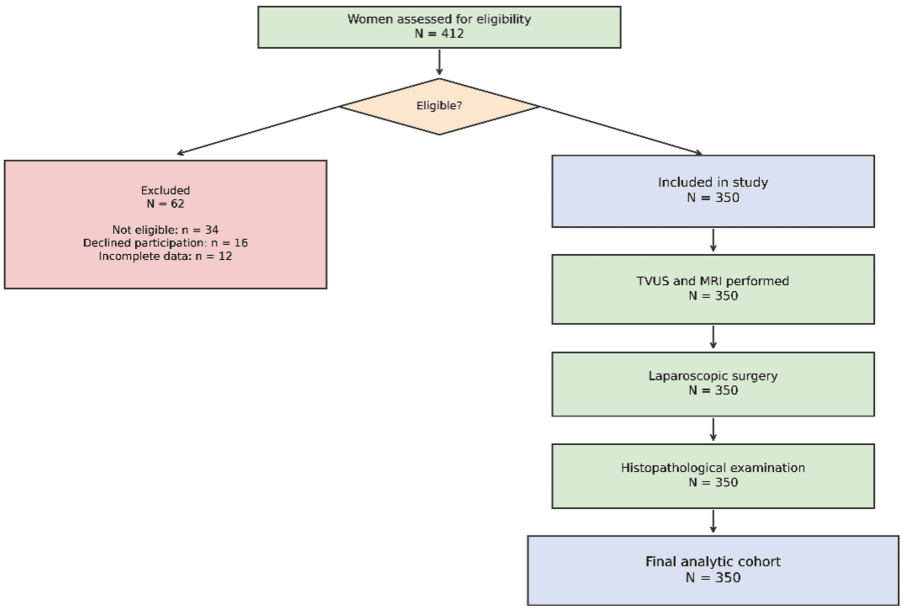


FIGURE 1: Participant flow diagram for the prospective paired diagnostic-accuracy study

Inclusion and exclusion criteria

Women were eligible if they were aged 18 years or older, had clinical suspicion of endometriosis or DIE, were scheduled for definitive surgical evaluation, and underwent both preoperative TVUS and MRI before surgery. Clinical suspicion was based on compatible symptoms, including dysmenorrhea, chronic pelvic pain, deep dyspareunia, dyschezia, dysuria or cyclical urinary symptoms, infertility, or cyclical bowel symptoms. All participants underwent surgical evaluation and provided written informed consent. All participants underwent laparoscopic surgical assessment with tissue sampling for histopathological examination.

Women were excluded if they were pregnant, had known pelvic malignancy, had undergone previous hysterectomy, had a contraindication to MRI, had an incomplete MRI examination or inadequate TVUS examination, underwent surgery before completion of both imaging examinations, had missing essential imaging information, were unable to undergo the planned surgical evaluation, or lacked relevant histopathological assessment required for the primary lesion-based analysis. Women who refused to participate were also excluded. Previous endometriosis surgery was not an automatic exclusion criterion; instead, it was recorded as a clinical characteristic for subsequent secondary or sensitivity analyses.

Recruitment and study procedures

We recruited eligible women sequentially and conducted a standardized clinical assessment before imaging. We documented demographic characteristics, anthropometric measurements, gynecological history, symptom profile, previous endometriosis diagnosis or surgery, previous pelvic surgery, hormonal treatment, and relevant gynecological conditions using a standardized data collection form.

All participants underwent both TVUS and MRI before surgical intervention. We performed the two imaging examinations within a predefined interval, preferably within four weeks of each another, and completed both before surgery. We documented any deviation from the predefined interval and considered it in sensitivity analyses, where appropriate.

Index tests

The two index tests were standardized TVUS and pelvic MRI. We compared the modalities in terms of their ability to detect histopathologically confirmed DIE. Both examinations involved systematic anatomical assessment rather than evaluation restricted to a single suspected lesion.

TVUS

We performed TVUS using a GE Voluson E10 ultrasound system equipped with an RIC5-9-D 5-9 MHz endovaginal probe (Wipro GE Medical Device Manufacturing Private Limited, Bengaluru, India). An experienced gynecological sonologist with at least three years of experience in gynecological ultrasound and specialized experience in endometriosis imaging performed the examination. The examiner was trained in

the International Deep Endometriosis Analysis (IDEA) approach. The TVUS examiner independently interpreted and recorded the ultrasound findings and was blinded to the MRI findings during image interpretation. The examiner systematically assessed pelvic anatomy using a standardized, IDEA-based examination.

The examination first assessed uterine position, uterine dimensions, adenomyosis, myometrial abnormalities, and endometrial appearance. The ovaries were then examined for abnormalities and endometriomas, assessing laterality, number, and largest dimensions. We evaluated pelvic organ mobility using the sliding sign and assessed uterine mobility relative to the bladder and rectum, categorizing it as positive or negative. We categorized the pouch of Douglas as not obliterated, partially obliterated, or completely obliterated.

We systematically examined the posterior compartment, including the uterosacral ligaments, torus uterinus, rectovaginal septum, vagina, rectum, rectosigmoid, and pouch of Douglas. We examined the anterior compartment for abnormalities involving the urinary bladder, vesicouterine space, and distal ureters.

For each suspected DIE lesion, we recorded its presence or absence, anatomical site, laterality, number, and dimensions. We documented lesion dimensions as length × width × depth in millimeters. Additionally, where possible, we recorded the number of nodules, lesion length, and distance from the anal verge in rectosigmoid lesions. We also documented associated organ involvement.

MRI

Pelvic MRI was performed on a 3-T Siemens MAGNETOM Skyra MRI system (Siemens Healthineers, Forchheim, Germany) with a pelvic phased-array coil. All patients underwent the same preimaging preparation: fasting, bowel preparation, moderate bladder filling, and administration of an antiperistaltic agent before imaging. MRI acquisitions comprised high-resolution, multiplanar T2-weighted sequences in the sagittal, axial, and oblique planes, along with T1-weighted and fat-suppressed T1-weighted sequences. Diffusion-weighted images were obtained using b-values of 50, 400, and 800 s/mm^2. Images were acquired with a slice thickness of approximately 3-4 mm and a field of view of approximately 20-24 cm, with small interslice gaps where applicable. Gadolinium contrast was not routinely used to assess DIE. Additional renal imaging was performed to evaluate possible urinary tract involvement.

An experienced pelvic radiologist with more than three years of experience in pelvic MRI, including expertise in gynecological imaging and endometriosis, interpreted the MRI examinations. The radiologist systematically assessed the predefined anatomical sites according to the study protocol and was blinded to the TVUS findings during image interpretation. The MRI evaluation was systematic and included the anterior, central, posterior, and lateral pelvic compartments. The bladder, vesicouterine space, and distal ureters were included in the anterior compartment. The central compartment comprised the cervix, vagina, and rectovaginal septum. The posterior compartment included the pouch of Douglas, rectosigmoid, rectum, torus uterinus, and uterosacral ligaments. The lateral compartment comprised the parametrial structures, ureters, and the pelvis sidewalls. The ovaries, endometriomas, appendix, cecum, small bowel, sigmoid colon, and upper abdominal and diaphragmatic regions were also evaluated when clinically indicated.

For each suspected lesion, the radiologist recorded its presence or absence, anatomical location, laterality, number, size, depth or extent, associated organ involvement, and evidence of obstruction, where applicable. When measurable, the lesion size and length, distance from the anal verge, and circumferential involvement were recorded for rectosigmoid lesions. The MRI protocol followed European Society of Urogenital Radiology guidelines for MRI evaluation of pelvic endometriosis [12].

Definition of DIE

DIE was defined as endometriotic disease affecting the subperitoneal tissues, with infiltration of underlying tissues, typically presenting as fibrotic or nodular lesions. Imaging appearances were not used as the definitive diagnostic criterion for the primary analysis. Diagnostic classification was based on the prespecified histopathological reference standard.

For both TVUS and MRI, findings were recorded according to the presence or absence of suspected DIE, the anatomical site involved, and lesion dimensions, where available. The predefined anatomical sites included the rectosigmoid, rectum, uterosacral ligaments, rectovaginal septum, vagina, bladder, and ureters. Histopathological examination served as the reference standard for diagnostic-accuracy analyses. Histopathology variables were coded as binary outcomes, with 1 indicating histopathological confirmation of DIE and 0 indicating that DIE was not recorded as histopathologically confirmed at the corresponding site. Site-specific imaging findings were compared with the corresponding histopathology classifications. The anatomical sites and imaging classification approach were defined according to the study protocol, and no additional site-specific imaging classification criteria were introduced retrospectively.

Surgical assessment

Experienced gynecologic surgeons with expertise in endometriosis surgery performed all surgical procedures. All patients underwent laparoscopic surgery or surgery with laparoscopic assistance, depending on the clinical situation. The operating surgeon carefully examined the pelvis and documented the location, number, and size of suspected lesions and the organs involved. Particular attention was paid to the uterosacral ligaments, pouch of Douglas, rectovaginal region, rectum and rectosigmoid, urinary bladder, and ureters. The presence and extent of adhesions and obliteration of the pouch of Douglas were also documented. The operating surgeon was not blinded to the clinical and imaging findings available before surgery. We recorded operative findings independently at the time of surgical assessment.

Histopathological reference standard

Histopathological examination of surgically obtained tissue specimens served as the reference standard for the diagnostic-accuracy analysis. All 350 patients underwent laparoscopic surgery following TVUS and MRI, and tissue specimens were submitted for histopathological examination. Histological assessment focused on the presence of endometrial-type glands and endometrial-type stroma, with fibrosis and hemosiderin-laden macrophages considered supportive findings. DIE was classified as histopathologically confirmed when endometrial-type glands or stroma were identified in the examined tissue, according to the prespecified diagnostic criteria. We identified the anatomical site of each specimen from the corresponding surgical and histopathological records and linked site-specific findings to the relevant imaging findings for diagnostic-accuracy analysis. Site-specific imaging findings were compared with the corresponding histopathological classifications. The pathologist was blinded to the TVUS and MRI findings during histopathological assessment.

Blinding and bias control

To reduce interpretation and review bias, the TVUS examiner was blinded to the MRI findings, and the MRI radiologist was blinded to TVUS findings during image interpretation. The pathologist was blinded to the TVUS and MRI findings during histopathological assessment. Imaging readers recorded their findings before accessing the corresponding results from the other imaging modality. Participants received coded identification numbers, and statistical analyses were conducted using the coded dataset.

Consecutive recruitment was used to reduce selection bias, while the inclusion of women with suspected rather than already confirmed DIE reduced spectrum bias. Imaging examinations were performed before surgery to avoid affecting image interpretation. To minimize timing-related bias, the interval between imaging and surgery was defined before the study. All participants underwent the index imaging examinations within four weeks before laparoscopic surgery and histopathological assessment. Participants underwent the same reference-standard surgical and histopathological evaluation, where possible, to minimize verification bias.

Sample size and final study cohort

The final analytic cohort included 350 participants. In total, we assessed 412 women for eligibility and excluded 62 because of ineligibility (n = 34), unwillingness to participate (n = 16), or missing data (n = 12). The remaining 350 participants underwent both TVUS and MRI, followed by laparoscopic surgery and histopathological examination, and were included in the final diagnostic-accuracy analysis. No formal a priori sample-size calculation was performed. The absence of a formal a priori sample-size calculation should be considered when interpreting the precision of the diagnostic-accuracy estimates, particularly for anatomical sites with relatively few histopathologically confirmed cases. The final sample size was based on the number of consecutive eligible participants who completed the prespecified diagnostic pathway during the study recruitment period. All 350 participants underwent both index tests and the same histopathological reference-standard assessment; therefore, a paired design was used to compare the diagnostic performance of TVUS and MRI.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics, version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize the study variables. Diagnostic performance was evaluated using 2 × 2 contingency tables, with histopathology serving as the reference standard. Sensitivity, specificity, PPV, NPV, overall diagnostic accuracy, positive and negative likelihood ratios, and the diagnostic odds ratio were calculated for TVUS and MRI. Corresponding 95% confidence intervals were reported for the diagnostic performance estimates. McNemar's test was used to compare paired diagnostic classifications between the two imaging modalities. Interobserver agreement was assessed using Cohen's kappa coefficient. Multivariable logistic regression was performed for the secondary analyses, with model fit indices assessed and variance inflation factors examined for multicollinearity. All statistical tests were two-sided, and a P-value of <0.05 was considered statistically significant.

Ethical considerations

The study followed ethical principles applicable to research involving human participants. Before recruiting participants, the study obtained institutional ethical approval from Rawalpindi Medical College, Rawalpindi,

Pakistan (EC-RMU-331-26). We informed all eligible participants about study procedures, potential risks, benefits, confidentiality, and the voluntary nature of participation, and obtained written informed consent before enrollment. We coded participant information and treated it confidentially, and used study data only for research purposes.

Reporting standards

The study methodology and reporting followed diagnostic-accuracy research standards, with special emphasis on participant selection, index-test procedures, reference-standard assessment, blinding, timing, and diagnostic performance estimates. The final study flow was documented from eligibility assessment through completion of TVUS and MRI, laparoscopic surgical assessment, histopathological examination, and inclusion in the final analytic cohort.

Results

As shown in Table *1*, the study population comprised 350 women with a mean age of 35.67 ± 7.51 years and a mean BMI of 25.91 ± 4.06 kg/m². Median gravidity was 2 (IQR, 2), median parity was 1 (IQR, 2), and median symptom duration was 4.7 years (IQR, 4.0). A total of 123 (35.1%) women reported a previous diagnosis of endometriosis, and 49 (14.0%) had previously undergone surgery for endometriosis; 41 (11.7%) having had a history of previous pelvic surgery. Hormonal therapy was reported by 151 (43.1%) women. The most common presenting symptoms were dysmenorrhea (246, 70.3%), chronic pelvic pain (185, 52.9%), and deep dyspareunia (118, 33.7%). Dyschezia was reported by 82 (23.4%) participants, while cyclical bowel symptoms occurred in 86 (24.6%). Infertility was present in 74 (21.1%) women. Dysuria and cyclical urinary symptoms were less frequently reported, occurring in 26 (7.4%) and 30 (8.6%) participants, respectively. The cohort was representative of a clinical population with a substantial history of endometriosis, and predominantly pain-centered presentations.

Characteristic	Overall (N = 350)
Age (years)	35.67 ± 7.51
BMI (kg/m²)	25.91 ± 4.06
Gravidity, median (IQR)	2 (2)
Parity, median (IQR)	1 (2)
Symptom duration (years), median (IQR)	4.7 (4.0)
Previous endometriosis diagnosis, n (%)	123 (35.1)
Previous endometriosis surgery, n (%)	49 (14.0)
Previous pelvic surgery, n (%)	41 (11.7)
Hormonal therapy, n (%)	151 (43.1)
Dysmenorrhea, n (%)	246 (70.3)
Chronic pelvic pain, n (%)	185 (52.9)
Deep dyspareunia, n (%)	118 (33.7)
Dyschezia, n (%)	82 (23.4)
Dysuria, n (%)	26 (7.4)
Cyclical bowel symptoms, n (%)	86 (24.6)
Cyclical urinary symptoms, n (%)	30 (8.6)
Infertility, n (%)	74 (21.1)

TABLE 1: Baseline demographic and clinical characteristics of the study population (N = 350)

Continuous variables are presented as mean ± SD or median (IQR), as appropriate; categorical variables are presented as frequency and percentage. No variables included in this table had missing values.

SD, standard deviation; IQR, interquartile range

The overall number of participants with DIE confirmed by histopathology was 213 (60.9%), compared with 211 (60.3%) at surgery, as shown in Table 2. Anatomically, uterosacral ligament DIE was identified in 102 (29.1%) cases by histopathology and 104 (29.7%) by surgical evaluation, followed by rectosigmoid DIE in 83 (23.7%) and 85 (24.3%) cases, respectively. Both evaluations identified rectal DIE in 50 (14.3%) participants, and rectovaginal septum involvement in 37 (10.6%) and 38 (10.9%) participants, respectively. Vaginal, bladder, and ureteric DIE were identified in 32 (9.1%), 21 (6.0%), and 16 (4.6%) participants, respectively, by both evaluations. Surgical evaluation also revealed obliteration of the pouch of Douglas in 112 (32.0%) participants. Histopathologically, 205 (58.6%) participants had endometrial glands, 203 (58.0%) had endometrial stroma, 174 (49.7%) had fibrosis, and 148 (42.3%) had hemosiderin-laden macrophages.

Finding	Histopathology, n (%)	Surgery, n (%)
Anatomical distribution of DIE	-	-
Overall DIE	213 (60.9)	211 (60.3)
Rectosigmoid DIE	83 (23.7)	85 (24.3)
Rectal DIE	50 (14.3)	50 (14.3)
Uterosacral ligament DIE	102 (29.1)	104 (29.7)
Rectovaginal septum DIE	37 (10.6)	38 (10.9)
Vaginal DIE	32 (9.1)	32 (9.1)
Bladder DIE	21 (6.0)	21 (6.0)
Ureteric DIE	16 (4.6)	16 (4.6)
Additional surgical finding	-	-
Pouch of Douglas obliteration	-	112 (32.0)
Histopathological characteristics	-	-
Endometrial glands present	205 (58.6)	-
Endometrial stroma present	203 (58.0)	-
Fibrosis present	174 (49.7)	-
Hemosiderin-laden macrophages present	148 (42.3)	-

TABLE 2: Histopathological and surgical findings in the study population (N = 350)

Values are presented as n (%). Histopathology was considered the reference standard. Anatomical site percentages are calculated using the total study population (N = 350); therefore, categories are not mutually exclusive. Of the 213 participants with histopathologically confirmed DIE, 207 were also classified as having DIE at surgery, whereas six were not identified as having DIE intraoperatively. Conversely, four participants without histopathologically confirmed DIE had a positive surgical assessment. Thus, the surgical assessment identified 211 cases overall, compared with 213 cases confirmed by histopathology.

DIE, deep infiltrating endometriosis; POD, pouch of Douglas

Table 3 shows that 208 (59.4%) and 205 (58.6%) participants were identified as having DIE on TVUS and MRI, respectively. The most common site of DIE was the uterosacral ligament, with 88 (25.1%) cases identified by both modalities, followed by the rectosigmoid region, with 83 (23.7%) cases identified on TVUS and 76 (21.7%) on MRI. Rectal DIE was detected in 49 (14.0%) and 48 (13.7%) participants on TVUS and MRI, respectively, while rectovaginal septum involvement was found in 36 (10.3%) and 32 (9.1%), respectively. Endometriomas were identified in 68 (19.4%) participants on TVUS and 64 (18.3%) on MRI. Other findings included pouch of Douglas obliteration (123, 35.1%) and a positive sliding sign (196, 56.0%) on TVUS. Adenomyosis was detected in 99 (28.3%) cases on TVUS and 106 (30.3%) on MRI. Quantitative uterine measurements were similar between the modalities.

Imaging finding	TVUS, n (%)/mean ± SD	MRI, n (%)/mean ± SD
DIE by anatomical site	-	-
Rectosigmoid DIE	83 (23.7)	76 (21.7)
Rectal DIE	49 (14.0)	48 (13.7)
Uterosacral ligament DIE	88 (25.1)	88 (25.1)
Rectovaginal septum DIE	36 (10.3)	32 (9.1)
Vaginal DIE	27 (7.7)	31 (8.9)
Bladder DIE	21 (6.0)	20 (5.7)
Ureteric DIE	13 (3.7)	12 (3.4)
Overall DIE	208 (59.4)	205 (58.6)
Other imaging findings	-	-
Endometrioma	68 (19.4)	64 (18.3)
Pouch of Douglas obliteration	123 (35.1)	-
Positive sliding sign	196 (56.0)	-
Adenomyosis	99 (28.3)	106 (30.3)
Myometrial abnormality	62 (17.7)	62 (17.7)
Quantitative imaging measurements	-	-
Uterine length (mm)	74.64 ± 9.27	74.62 ± 9.36
Uterine AP diameter (mm)	41.95 ± 5.82	41.98 ± 5.89
Uterine width (mm)	48.94 ± 6.66	48.85 ± 6.85
Endometrial thickness (mm)	8.60 ± 2.89	8.64 ± 3.01
Maximum endometrioma diameter (mm)†	43.27 ± 13.45	40.66 ± 14.43

TABLE 3: TVUS and MRI Imaging Findings in the Study Population (N = 350)

Values are presented as n (%) or mean ± SD. Quantitative measurements were available for all 350 participants except maximum endometrioma diameter, which was assessed among participants with an endometrioma detected by the respective modality (TVUS, n = 68; MRI, n = 64).

AP, anteroposterior; DIE, deep infiltrating endometriosis; MRI, magnetic resonance imaging; TVUS, transvaginal ultrasound; SD, standard deviation

As shown in Table 4, TVUS demonstrated a sensitivity of 89.2% (95% CI, 84.2-93.0) and a specificity of 86.9% (95% CI, 80.0-92.0), with a PPV of 91.3% (95% CI, 86.7-94.8), an NPV of 83.8% (95% CI, 76.7-89.4), and an overall accuracy of 88.3% (84.4-91.5). MRI showed slightly higher diagnostic performance, with a sensitivity of 91.5% (95% CI, 87.0-94.9), a specificity of 92.7% (95% CI, 87.0-96.4), a PPV of 95.1% (95% CI, 91.2-97.6), an NPV of 87.6% (95% CI, 81.1-92.5), and an accuracy of 92.0% (95% CI, 88.6-94.6). MRI also demonstrated a higher LR+ (12.54 vs. 6.79) and a lower LR− (0.091 vs. 0.124), resulting in a substantially higher DOR (137.58 vs. 54.61). Overall, both modalities had high diagnostic performance, with MRI showing numerically higher sensitivity, specificity, and overall accuracy.

Diagnostic measure	TVUS	MRI
Sensitivity, % (95% CI)	89.2 (84.2-93.0)	89.2 (84.2-93.0)
Specificity, % (95% CI)	86.9 (80.0-92.0)	92.7 (87.0-96.4)
Positive predictive value, % (95% CI)	91.3 (86.7-94.8)	95.1 (91.2-97.6)
Negative predictive value, % (95% CI)	83.8 (76.7-89.4)	87.6 (81.1-92.5)
Accuracy, % (95% CI)	88.3 (84.4-91.5)	92.0 (88.6-94.6)
Positive likelihood ratio, LR+ (95% CI)	6.79 (4.40-10.47)	12.54 (6.90-22.81)
Negative likelihood ratio, LR− (95% CI)	0.124 (0.084-0.184)	0.091 (0.058-0.142)
Diagnostic odds ratio, DOR (95% CI)	54.61 (28.28-105.45)	137.58 (61.53-307.64)

TABLE 4: Overall diagnostic performance of TVUS and MRI for detection of DIE

Histopathology was used as the reference standard. All diagnostic performance estimates are presented with 95% confidence intervals.

TP, true positive; FP, false positive; FN, false negative; TN, true negative; PPV, positive predictive value; NPV, negative predictive value; LR+, positive likelihood ratio; LR−, negative likelihood ratio; DOR, diagnostic odds ratio; DIE, deep infiltrating endometriosis; MRI, magnetic resonance imaging; TVUS, transvaginal ultrasound

Figure 2 illustrates the overall diagnostic performance of TVUS and MRI for detecting DIE. MRI showed numerically higher sensitivity, specificity, PPV, and NPV than TVUS. However, the overall paired comparison did not demonstrate a statistically significant difference in diagnostic classifications between the two modalities (McNemar's $\chi^2 = 0.066$, $P = 0.798$). Therefore, the numerical differences should not be interpreted as evidence of the statistical superiority of either modality.

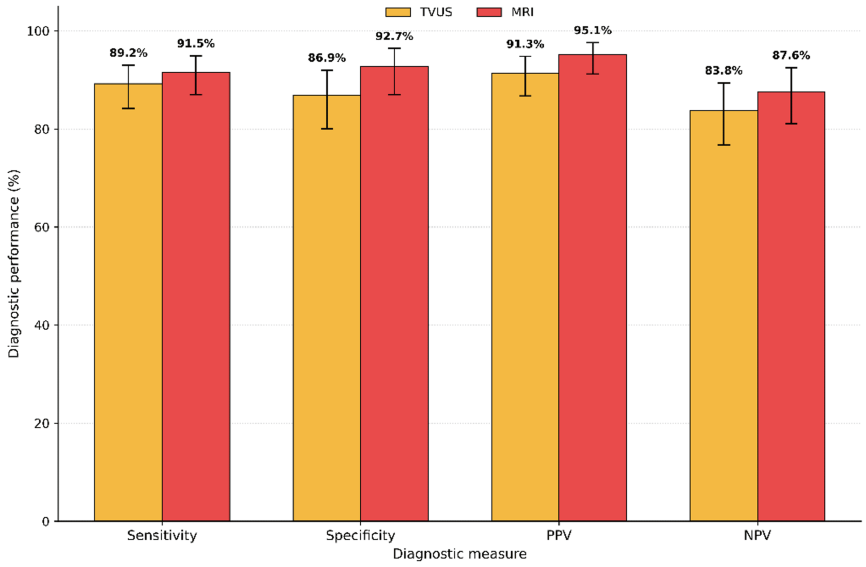


FIGURE 2: Overall diagnostic performance of TVUS and MRI for detection of DIE

DIE, deep infiltrating endometriosis; MRI, magnetic resonance imaging; TVUS, transvaginal ultrasound

TVUS and MRI were both high-performing modalities across the assessed anatomic sites, as shown in Table 5. For rectosigmoid DIE, MRI showed higher sensitivity and specificity than TVUS (88.0% vs. 86.7% and 98.9% vs. 95.9%, respectively), with higher accuracy (96.3% vs. 93.7%). Similar patterns were observed for rectal, uterosacral ligament, rectovaginal septum, and bladder DIE, where MRI yielded numerically higher sensitivity, specificity, and accuracy across several anatomical sites. However, these descriptive differences should be interpreted cautiously because formal paired statistical comparisons were not performed for every

site. For vaginal DIE, TVUS had a sensitivity of 75.0%, compared with 78.1% for MRI; PPV was 88.9% for TVUS and 80.6% for MRI. For ureteric DIE, TVUS had higher sensitivity (81.3% vs. 68.8%) and perfect specificity (100.0%), although its LR+ and DOR were not estimable because no false-positive cases occurred. Overall, both modalities showed excellent diagnostic performance, with MRI generally more specific and accurate across most anatomical sites.

Anatomical site	Modality	Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV, % (95% CI)	NPV, % (95% CI)	Accuracy, % (95% CI)	LR+	LR−	DOR
Rectosigmoid	TVUS	86.7 (77.5-93.2)	95.9 (92.7-97.9)	86.7 (77.5-93.2)	95.9 (92.7-97.9)	93.7 (90.6-96.0)	21.06	0.138	152.33
	MRI	88.0 (79.0-94.1)	98.9 (96.8-99.8)	96.1 (88.9-99.2)	96.4 (93.4-98.2)	96.3 (93.7-98.0)	78.28	0.122	642.4
Rectal	TVUS	86.0 (73.3-94.2)	98.0 (95.7-99.3)	87.8 (75.2-95.4)	97.7 (95.3-99.1)	96.3 (93.7-98.0)	43	0.143	301
	MRI	90.0 (78.2-96.7)	99.0 (97.1-99.8)	93.8 (82.8-98.7)	98.3 (96.2-99.5)	97.7 (95.5-99.0)	90	0.101	891
Uterosacral ligament	TVUS	81.4 (72.4-88.4)	98.0 (95.4-99.3)	94.3 (87.2-98.1)	92.7 (88.9-95.6)	90.0 (78.2-96.7)	40.36	0.19	212.31
	MRI	84.3 (75.8-90.8)	99.2 (97.1-99.9)	97.7 (92.0-99.7)	93.9 (90.3-96.5)	94.9 (92.0-96.9)	104.55	0.158	661.13
Rectovaginal septum	TVUS	78.4 (61.8-90.2)	97.8 (95.4-99.1)	80.6 (64.0-91.8)	97.5 (95.0-98.9)	95.7 (93.0-97.6)	35.05	0.221	158.46
	MRI	83.8 (68.0-93.8)	99.7 (98.2-100.0)	96.9 (83.8-99.9)	98.1 (95.9-99.3)	98.0 (95.9-99.2)	262.24	0.163	1612
Vaginal	TVUS	75.0 (56.6-88.5)	99.1 (97.3-99.8)	88.9 (70.8-97.6)	97.5 (95.2-98.9)	96.9 (94.4-98.4)	79.5	0.252	315
	MRI	78.1 (60.0-90.7)	98.1 (95.9-99.3)	80.6 (62.5-92.5)	97.8 (95.5-99.1)	96.3 (93.7-98.0)	41.41	0.223	185.71
Bladder	TVUS	76.2 (52.8-91.8)	98.5 (96.5-99.5)	76.2 (52.8-91.8)	98.5 (96.5-99.5)	97.1 (94.8-98.6)	50.13	0.242	207.36
	MRI	81.0 (58.1-94.6)	99.1 (97.4-99.8)	85.0 (62.1-96.8)	98.8 (96.9-99.7)	98.0 (95.9-99.2)	88.78	0.192	461.83
Ureteric	TVUS	81.3 (54.4-96.0)	100.0 (98.9-100.0)	100.0 (75.3-100.0)	99.1 (97.4-99.8)	99.1 (97.5-99.8)	NE	0.188	NE
	MRI	68.8 (41.3-89.0)	99.7 (98.3-100.0)	91.7 (61.5-99.8)	98.5 (96.6-99.5)	98.3 (96.3-99.4)	229.63	0.313	732.6

TABLE 5: Site-specific diagnostic performance of TVUS and MRI for detection of DIE

Histopathology as the reference standard for each anatomical site. Values are based on 350 participants with no missing observations. Confidence intervals for sensitivity, specificity, PPV, NPV, and accuracy were calculated using exact binomial methods; likelihood-ratio and DOR confidence intervals were calculated on the log scale. For ureteric TVUS, no false-positive cases were observed; therefore, LR+ or DOR could not be estimated. Site-specific percentages are not mutually exclusive. The underlying site-specific crosstabs confirm, for example, rectosigmoid TVUS (72 TP, 11 FP, 11 FN, 256 TN) and MRI (73 TP, 3 FP, 10 FN, 264 TN), as well as the corresponding rectal, USL, RVS, vaginal, bladder, and ureteric comparisons.

CI, confidence interval; DOR, diagnostic odds ratio; DIE, deep infiltrating endometriosis; LR+, positive likelihood ratio; LR−, negative likelihood ratio; MRI, magnetic resonance imaging; NE, not estimable; NPV, negative predictive value; PPV, positive predictive value; TVUS, transvaginal ultrasound

Table 6 shows high agreement between TVUS and MRI in the overall classification of DIE. In 113 (32.3%) participants, both modalities were negative; in 176 (50.3%) participants, both modalities were positive; and in 29 (8.3%) participants, TVUS was negative and MRI was positive, and in 32 (9.1%) participants, TVUS was positive and MRI was negative. Overall, TVUS was positive in 208 (59.4%) patients, and MRI was positive in 205 (58.6%) patients. MRI sensitivity was numerically higher than that of TVUS (91.5% vs. 89.2%), and specificity was also higher (92.7% vs. 86.9%). However, there was no statistically significant difference in sensitivity (McNemar's P = 0.500) or specificity (McNemar's P = 0.169) between the two methods. The overall

paired comparison of diagnostic classifications was also not statistically significant (McNemar's $\chi^2 = 0.066$, P = 0.798).

TVUS result	MRI negative, n (%)	MRI positive, n (%)	Total, n (%)
TVUS negative	113 (32.3)	29 (8.3)	142 (40.6)
TVUS positive	32 (9.1)	176 (50.3)	208 (59.4)
Total	145 (41.4)	205 (58.6)	350 (100.0)

TABLE 6: Paired comparison of TVUS and MRI for detection of overall DIE

McNemar's test was used for paired comparisons. Sensitivity was compared among participants with histopathology-confirmed DIE, whereas specificity was compared among participants without histopathology-confirmed DIE. The paired difference in sensitivity was not statistically significant (P = .500), nor was the paired difference in specificity (P = .169). For the overall paired classification, McNemar's $\chi^2 = 0.066$, P = 0.798.

DIE, deep infiltrating endometriosis; MRI, magnetic resonance imaging; TVUS, transvaginal ultrasound

As shown in Table 7, interobserver agreement was generally strong to near-perfect for both TVUS and MRI across the assessed anatomical sites. The highest agreement was observed for rectosigmoid DIE, with Cohen's κ values of 0.935 for TVUS and 0.898 for MRI, followed by uterosacral ligament involvement (0.875 and 0.859, respectively). Agreement remained substantial for rectal, rectovaginal septum, vaginal, and bladder involvement, with κ values ranging from 0.677 to 0.863. Agreement was lowest for ureteric DIE (κ = 0.557) in both modalities. All κ values were statistically significant (P < 0.001), indicating good interobserver agreement in the predefined subset of 88 (25.1%) participants.

Anatomical site	TVUS Cohen's κ (95% CI)	MRI Cohen's κ (95% CI)
Rectosigmoid	0.935 (0.847-1.000)	0.898 (0.784-1.000)
Rectal	0.783 (0.603-0.963)	0.750 (0.540-0.960)
Uterosacral ligament	0.875 (0.755-0.995)	0.859 (0.739-0.979)
Rectovaginal septum	0.823 (0.629-1.000)	0.727 (0.476-0.978)
Vaginal	0.863 (0.677-1.000)	0.677 (0.416-0.938)
Bladder	0.822 (0.581-1.000)	0.692 (0.412-0.972)
Ureteric	0.557 (0.116-0.998)	0.557 (0.116-0.998)

TABLE 7: Interobserver agreement for TVUS and MRI detection of deep infiltrating endometriosis by anatomical site

We assessed interobserver agreement in a predefined second-reader subset of 88 participants (25.1% of the study population) using Cohen's κ. Values are presented as Cohen's κ with approximate 95% confidence intervals. Higher κ values indicate greater interobserver agreement.

As indicated in Table 8, a previous diagnosis of endometriosis, a history of prior pelvic surgery, hormonal therapy, dysmenorrhea, chronic pelvic pain, dyschezia, cyclical bowel symptoms, and infertility were independently associated with histopathology-confirmed DIE. Longer symptom duration was associated with lower odds of DIE (aOR, 0.877; 95% CI, 0.805-0.956; P = 0.003), whereas a previous diagnosis of endometriosis (aOR, 2.298; 95% CI, 1.309-4.033; P = 0.004), previous pelvic surgery (aOR, 4.563; 95% CI, 1.650-12.619; P = 0.003), hormonal therapy (aOR, 2.286; 95% CI, 1.342-3.897; P = 0.002), dysmenorrhea (aOR, 3.102; 95% CI, 1.757-5.476; P < 0.001), chronic pelvic pain (aOR, 2.438; 95% CI, 1.461-4.066; P = 0.001), dyschezia (aOR, 2.886; 95% CI, 1.448-5.754; P = 0.003), cyclical bowel symptoms (aOR, 1.923; 95% CI, 1.027-3.601; P = 0.041), and infertility (aOR, 2.342; 95% CI, 1.200-4.569; P = 0.013) were associated with higher odds of DIE. Age, BMI, previous endometriosis surgery, deep dyspareunia, dysuria, and cyclical urinary symptoms were not independently associated with histopathology-confirmed DIE in the multivariable model. The overall model was significant ($\chi^2 = 108.943$, P < 0.001) and correctly classified 74.9% of cases.

Predictor	Adjusted OR	95% CI	P-value
Age, per year	0.974	0.942-1.006	0.131
BMI, per kg/m²	0.989	0.928-1.052	0.742
Symptom duration, per year	0.877	0.805-0.956	0.003
Previous endometriosis diagnosis	2.298	0.805-0.956	0.004
Previous endometriosis surgery	2.278	0.988-5.251	0.053
Previous pelvic surgery	4.563	1.650-12.619	0.003
Hormonal therapy	2.286	1.342-3.897	0.002
Dysmenorrhea	3.102	1.757-5.476	<0.001
Chronic pelvic pain	2.438	1.461-4.066	0.001
Deep dyspareunia	1.615	0.941-2.773	0.083
Dyschezia	2.886	1.448-5.754	0.003
Dysuria	1.859	0.619-5.584	0.268
Cyclical bowel symptoms	1.923	1.027-3.601	0.041
Cyclical urinary symptoms	1.815	0.672-4.904	0.24
Infertility	2.342	1.200-4.569	0.013

TABLE 8: Multivariable analysis of clinical factors associated with histopathology-confirmed DIE

Model statistics: likelihood-ratio $\chi^2(15) = 108.943$, $P < 0.001$; −2 log likelihood = 359.625; Cox and Snell $R^2 = 0.267$; Nagelkerke $R^2 = 0.363$; Hosmer-Lemeshow $\chi^2(8) = 12.113$, $P = 0.146$; overall classification accuracy = 74.9%. We derived adjusted ORs from multivariable binary logistic regression. The outcome was histopathology-confirmed DIE (0 = no, 1 = yes). We entered continuous variables as continuous predictors; binary clinical variables were coded 0 = no and 1 = yes, with absence/no as the reference category. OR > 1 indicates higher odds of histopathology-confirmed DIE, whereas OR < 1 indicates lower odds.

CI, confidence interval; DIE, deep infiltrating endometriosis; OR, odds ratio

Discussion

Principal findings and overall diagnostic performance

This prospective paired study on diagnostic accuracy found that both TVUS and MRI were highly accurate in diagnosing DIE compared with histopathology. TVUS sensitivity, specificity, and overall accuracy were 89.2%, 86.9%, and 88.3%, respectively, while MRI values were 91.5%, 92.7%, and 92.0%, respectively. MRI also showed a modest numerical advantage in PPV, NPV, positive likelihood ratio, and diagnostic odds ratio, indicating numerically higher diagnostic performance for MRI across several measures in this cohort. These results align with past studies showing that both TVUS and MRI have high diagnostic accuracy for DIE. A systematic review and meta-analysis of 30 studies with 4,565 subjects showed pooled sensitivities of 76% and 82% for TVUS and MRI, respectively, and specificities of 94% for TVUS and 87% for MRI, with high diagnostic accuracy for both modalities [13]. Likewise, a prospective paired comparison study of TVUS with contrast-enhanced MR colonography demonstrated good diagnostic accuracy for both imaging modalities (TVUS, 89.2%; MRI, 87.2%) [14]. The results suggest that both modalities can serve as reliable preoperative tools for detecting DIE [13,15] and that MRI had a slight numerical advantage in overall diagnostic performance in this study. Although MRI demonstrated numerically higher values for several diagnostic performance measures, the overall paired comparison did not show a statistically significant difference between TVUS and MRI classifications (McNemar's $\chi^2 = 0.066$, $P = 0.798$). Therefore, these findings do not establish the superiority of MRI over TVUS, and the numerical differences should be interpreted cautiously.

Diagnostic performance of standardized TVUS

TVUS's high diagnostic accuracy is important, as it demonstrates the added value of a standardized, expertly performed ultrasound examination in the perioperative evaluation of DIE [16]. In this study, TVUS was carried out using a systematic IDEA-based approach, including evaluation of the uterosacral ligaments, rectovaginal septum, vagina, rectum, rectosigmoid, bladder, ureters, pouch of Douglas, and pelvic organ mobility. This extensive evaluation may have helped achieve the improved diagnostic performance

observed, as recent validation studies show increasing sensitivity and overall accuracy as the IDEA protocol steps were added [17]. Current approaches to endometriosis imaging emphasize systematic anatomical assessment and examination by adequately trained operators rather than relying on nonspecific pelvic ultrasonography alone [4].

Diagnostic performance and clinical role of MRI

MRI demonstrated a modest numerical advantage in diagnostic performance in the present cohort, particularly for specificity and positive likelihood ratio. The higher specificity (92.7%) and LR+ (12.54) indicate a strong ability to exclude disease and significantly increase the probability of DIE with MRI positivity. This aligns with previous head-to-head evidence that MRI can be more specific and have higher likelihood ratios than TVUS in some anatomical locations. In a systematic review and meta-analysis of paired studies, MRI showed higher specificity (93% vs. 86%) and LR+ (10.4 vs. 4.8) than TVUS for uterosacral ligament DIE. However, the diagnostic performance of the two modalities was broadly similar for rectosigmoid and rectovaginal septal disease [14]. This could be especially useful in extensive or more complex disease, where multiplanar MRI and compartment-based evaluation allow thorough mapping and provide additional data for preoperative surgical planning [18]. The standardized MRI protocol used in this study incorporated multiplanar T2-weighted sequences, T1-weighted/fat-suppressed imaging, and systematic evaluation of multiple pelvic compartments, consistent with established ESUR recommendations [12]. An experienced pelvic radiologist interpreted all MRI examinations.

Site-specific diagnostic performance

Site-specific findings further show that diagnostic performance varied by anatomical compartment. MRI showed a numerical advantage in accuracy for several compartments in the present cohort, including rectosigmoid, rectal, uterosacral ligament, rectovaginal septal, and bladder DIE. For instance, MRI had 96.3% accuracy versus 93.7% for rectosigmoid disease and 97.7% versus 96.3% for rectal disease. MRI diagnosed rectovaginal septal disease with 98.0% accuracy, whereas TVUS achieved 95.7%. These results suggest that MRI may add value when more precise delineation of disease distribution is needed. Nevertheless, the advantage was not universal. TVUS was more sensitive than MRI for ureteric DIE (81.3% vs. 68.8%) and had perfect specificity (100.0%). This is consistent with recent comparative data showing that the diagnostic performance of MRI and TVUS is site-dependent. A recent meta-analysis of rectosigmoid DIE identified that both MRI and TVUS had high diagnostic accuracy and were comparable with respect to specificity and sensitivity, with slightly higher specificity for MRI than for TVUS (95% vs. 92%), but with no significant difference between them in terms of specificity or sensitivity [19]. Likewise, a recent systematic review found that TVUS and MRI are complementary procedures, with TVUS being highly accurate for posterior-compartment disease and MRI providing greater body coverage and higher sensitivity for anterior and multicompartmental lesions [9]. Thus, the choice of imaging modality should consider the suspected anatomical distribution rather than assuming that one modality is uniformly superior. However, because formal paired statistical comparisons were not performed for each anatomical site, the observed differences should be interpreted descriptively and should not be considered evidence of statistically significant superiority of either modality at individual sites.

Paired comparison and complementary role of TVUS and MRI

The paired analysis showed that both modalities classified 113 (32.3%) participants as negative and 176 (50.3%) as positive. Discordant classifications occurred in 29 (8.3%) participants who were TVUS-negative/MRI-positive and 32 (9.1%) who were TVUS-positive/MRI-negative. The lack of a statistically significant difference in the paired classifications indicates that this cohort did not show a statistically significant difference in marginal paired classifications. Earlier comparative analyses support this view, showing similar diagnostic accuracy for TVUS and MRI across different anatomic sites, with MRI superior at some sites and TVUS at others [15,20]. TVUS may serve as an effective first-line imaging and mapping examination when performed by appropriately trained operators. At the same time, MRI can provide complementary anatomical characterization when more extensive or anatomically complex disease requires further delineation [4].

Interobserver agreement and reproducibility

The reproducibility analysis also confirms the reliability of the imaging results. Interobserver agreement was high for most anatomical sites, with the highest agreement for rectosigmoid DIE (0.935 for TVUS and 0.898 for MRI) and uterosacral ligament disease (0.875 for TVUS and 0.859 for MRI). Agreement was lower for ureteric disease ($\kappa = 0.557$ for both modalities), indicating that urinary tract disease might be harder to diagnose consistently in this cohort. These results support previous work showing good-to-high interobserver agreement between TVUS and MRI in diagnosing deep endometriosis and suggest site- and examiner-dependent variations in reproducibility [21,22]. The results thus highlight the need for specialist training and standardization of imaging assessment and reporting, especially for less common or more complex locations.

Clinical predictors of histopathology-confirmed DIE

The secondary clinical analysis identified several factors independently associated with histopathologically confirmed DIE, including a previous diagnosis of endometriosis, previous pelvic surgery, hormonal therapy, dysmenorrhea, chronic pelvic pain, dyschezia, cyclical bowel symptoms, and infertility. Previous pelvic surgery (aOR 4.563) and dyschezia (aOR 2.886) were among the clinical factors independently associated with histopathology-confirmed DIE. Dysmenorrhea showed the strongest association among the symptom variables examined (aOR 3.102). These results corroborate previous evidence showing that deep endometriosis was associated with severe dysmenorrhea, dyschezia, and infertility, and that the association was stronger when more than one pelvic compartment was affected [23]. Detailed clinical assessment has also been shown to predict DIE in the preoperative setting, with combinations of clinical symptoms helping make this prediction [24]. However, clinical symptoms should be considered supporting predictors rather than substitutes for anatomical imaging, and MRI can provide complementary information about the location and extent of deep disease and can confirm the diagnosis of clinically suspected DIE when appropriate diagnostic criteria are used [25].

Strengths of the study

A major strength of this study was its prospective paired design, in which all 350 participants underwent both imaging modalities before laparoscopic assessment and histopathological evaluation. The within-participant design reduced variability across patient populations in the different imaging groups and allowed direct comparisons between TVUS and MRI. Consecutive recruitment, predefined imaging protocols, blinded interpretation between modalities, systematic anatomical assessment, and histopathology as the reference standard further strengthened the study's methodological rigor.

Limitations

This study had several limitations. The relatively high prevalence of DIE in the participants may limit generalizability to lower-risk or primary care populations since participants were already scheduled for laparoscopic evaluation. Also, no formal a priori sample size calculation was performed, as the final cohort comprised consecutive eligible participants recruited during the study period. Consequently, the precision of some diagnostic-accuracy estimates, particularly for less frequently affected anatomical sites such as the ureters and bladder, may be limited by the relatively small number of histopathologically confirmed cases. The findings for these sites should therefore be interpreted cautiously. Second, experts conducted the examinations in a standardized fashion, and diagnostic performance may be higher in more specialized settings. Third, histopathology was used as the reference standard; however, histopathological findings are limited to the tissue sampled and may not fully capture the overall anatomical extent of disease across the pelvis. Consequently, lesions in unsampled areas may not be represented in the histopathological assessment, potentially affecting site-specific diagnostic comparisons. Fourth, interobserver agreement was examined in only 88 participants, which reduced the generalizability of reproducibility estimates. Lastly, the study did not assess downstream clinical outcomes. Therefore, it cannot be concluded whether the absolute differences between MRI and TVUS lead to better surgical planning, fewer surgical complications, more cost-effective care, or better patient outcomes.

Conclusions

In this prospective paired diagnostic-accuracy study, both standardized TVUS and MRI had high diagnostic performance when compared with the study reference standard for DIE. Although MRI showed numerically higher diagnostic performance for several anatomical sites, the paired analysis revealed no statistically significant difference between the modalities in overall positive/negative classification. MRI showed numerically higher sensitivity, specificity, and overall accuracy. The results confirm that expert, standardized TVUS is an appropriate first-line imaging examination, and MRI can provide additional anatomical data for women with large, complex, or indeterminate disease and those who need detailed preoperative mapping. The results should be interpreted in the context of the specialist referral population and the limitations of tissue-based reference-standard assessment.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Saadia Hassan, Amina Iqbal, Urooj Anwar, Nida Waqas, Titilayo Olawunmi , Gyanendra KC, Rachel Marsha Manoj Stanley

Acquisition, analysis, or interpretation of data: Saadia Hassan, Doaa Ahmed, Amina Iqbal, Gauri Sreeram, Urooj Anwar, Nida Waqas, Gyanendra KC, Vanessa Colaco, Rachel Marsha Manoj Stanley, Nazia Sumbul Mahir

Drafting of the manuscript: Saadia Hassan, Doaa Ahmed, Amina Iqbal, Gauri Sreeram, Urooj Anwar, Nida Waqas, Titilayo Olawunmi , Gyanendra KC, Vanessa Colaco, Rachel Marsha Manoj Stanley, Nazia Sumbul

Mahir

Critical review of the manuscript for important intellectual content: Doaa Ahmed, Gauri Sreeram, Titilayo Olawunmi , Vanessa Colaco, Nazia Sumbul Mahir

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Rawalpindi Medical College, Rawalpindi, Pakistan issued approval EC-RMU-331-26. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

Acknowledgements

Doaa Ahmed and Gauri Sreeram contributed equally to this manuscript and should be considered co-first authors.

References

1. Becker CM, Bokor A, Heikinheimo O, et al.: ESHRE guideline: endometriosis. Hum Reprod Open. 2022, 2022:hoac009. 10.1093/hropen/hoac009
2. Thomassin-Naggara I, Dolciami M, Chamie LP, et al.: ESUR consensus MRI for endometriosis: indications, reporting, and classifications. Eur Radiol. 2025, 35:7260-8. 10.1007/s00330-025-11579-0
3. Abike F, Tanoglu FB, Sidar G: Deep pelvic endometriosis: clinical features, diagnosis, and treatment - a comprehensive review. Arch Gynecol Obstet. 2025, 312:1857-69. 10.1007/s00404-025-08187-0
4. Condous G, Gerges B, Thomassin-Naggara I, et al.: Non-invasive imaging techniques for diagnosis of pelvic deep endometriosis and endometriosis classification systems: an International Consensus Statement. Eur J Radiol. 2024, 176:111450. 10.1016/j.ejrad.2024.111450
5. Singh SS, Allaire C, Al-Nourhji O, et al.: Guideline No. 449: diagnosis and impact of endometriosis - a Canadian guideline. J Obstet Gynaecol Can. 2024, 46:102450. 10.1016/j.jogc.2024.102450
6. Daniilidis A, Grigoriadis G, Dalakoura D, D'Alterio MN, Angioni S, Roman H: Transvaginal ultrasound in the diagnosis and assessment of endometriosis-an overview: how, why, and when. Diagnostics (Basel). 2022, 12:2912. 10.3390/diagnostics12122912
7. Tang X, Ling R, Gong J, et al.: Deep infiltrating endometriosis MR imaging with surgical correlation . Quant Imaging Med Surg. 2018, 8:187-95. 10.21037/qims.2018.01.10
8. VanBuren W, Feldman M, Shenoy-Bhangle AS, et al.: Radiology state-of-the-art review: endometriosis imaging interpretation and reporting. Radiology. 2024, 312:e233482. 10.1148/radiol.233482
9. O'Leary M, Neary C, Lawrence E: The diagnostic accuracy of magnetic resonance imaging versus transvaginal ultrasound in deep infiltrating endometriosis and their impact on surgical decision-making: a systematic review. Diagnostics (Basel). 2025, 15:2856. 10.3390/diagnostics15222856
10. Tong A, Cope AG, Waters TL, McDonald JS, VanBuren WM: Best practices: ultrasound versus MRI in the assessment of pelvic endometriosis. AJR Am J Roentgenol. 2024, 223:e2431085. 10.2214/AJR.24.31085
11. Indrielle-Kelly T, Frühauf F, Fanta M, et al.: Diagnostic accuracy of ultrasound and MRI in the mapping of deep pelvic endometriosis using the International Deep Endometriosis Analysis (IDEA) consensus. Biomed Res Int. 2020, 2020:3583989. 10.1155/2020/3583989
12. Bazot M, Bharwani N, Huchon C, et al.: European society of urogenital radiology (ESUR) guidelines: MR imaging of pelvic endometriosis. Eur Radiol. 2017, 27:2765-75. 10.1007/s00330-016-4673-z
13. Zhang X, He T, Shen W: Comparison of physical examination, ultrasound techniques and magnetic resonance imaging for the diagnosis of deep infiltrating endometriosis: a systematic review and meta-analysis of diagnostic accuracy studies. Exp Ther Med. 2020, 20:3208-20. 10.3892/etm.2020.9043
14. Vimercati A, Achilarre MT, Scardapane A, et al.: Accuracy of transvaginal sonography and contrast-enhanced magnetic resonance-colonography for the presurgical staging of deep infiltrating endometriosis. Ultrasound Obstet Gynecol. 2012, 40:592-603. 10.1002/uog.11179
15. Guerriero S, Saba L, Pascual MA, Ajossa S, Rodriguez I, Mais V, Alcazar JL: Transvaginal ultrasound vs magnetic resonance imaging for diagnosing deep infiltrating endometriosis: systematic review and meta-analysis. Ultrasound Obstet Gynecol. 2018, 51:586-95. 10.1002/uog.18961
16. Leonardi M, Uzuner C, Mestdagh W, et al.: Diagnostic accuracy of transvaginal ultrasound for detection of endometriosis using International Deep Endometriosis Analysis (IDEA) approach: prospective international pilot study. Ultrasound Obstet Gynecol. 2022, 60:404-13. 10.1002/uog.24936
17. McClenahan P, Mak J, Uzuner C, Espada Vaquero M, Reid S, Eathorne A, Condous G: Diagnostic test accuracy of each of the four IDEA ultrasound steps in predicting presence of deep endometriosis. Ultrasound Obstet Gynecol. 2026, 67:679-83. 10.1002/uog.70208
18. Thomassin-Naggara I, Dolciami M, Chamie LP, et al.: ESUR consensus MRI for endometriosis: protocol, lexicon, and compartment-based analysis. Eur Radiol. 2025, 35:7272-86. 10.1007/s00330-025-11611-3
19. Xu Z, Li Y, Wang Y, Wan Y, Chen J: Transvaginal ultrasound and magnetic resonance imaging in detecting rectosigmoid deep infiltrating endometriosis: a comparative meta-analysis. Front Med (Lausanne). 2025, 12:1552185. 10.3389/fmed.2025.1552185
20. Guerriero S, Alcázar JL, Pascual MA, et al.: Deep infiltrating endometriosis: comparison between 2-

dimensional ultrasonography (US), 3-dimensional US, and magnetic resonance imaging. J Ultrasound Med. 2018, 37:1511-21. 10.1002/jum.14496

21. Guerriero S, Pascual M, Ajossa S, et al.: The reproducibility of ultrasonographic findings of rectosigmoid endometriosis among examiners with different level of expertise. J Ultrasound Med. 2022, 41:403-8. 10.1002/jum.15717
22. Harth S, Kaya HE, Zeppernick F, et al.: Application of the #Enzian classification for endometriosis on MRI: prospective evaluation of inter- and intraobserver agreement. Front Med (Lausanne). 2023, 10:1303593. 10.3389/fmed.2023.1303593
23. Rocha TP, Andres MP, Carmona F, Baracat EC, Abrão MS: Deep endometriosis: the involvement of multiple pelvic compartments is associated with more severe pain symptoms and infertility. Reprod Sci. 2023, 30:1668-75. 10.1007/s43032-022-01104-9
24. Stratton P: The association of clinical symptoms with deep infiltrating endometriosis: the importance of the preoperative clinical assessment. Hum Reprod. 2014, 29:1627-8. 10.1093/humrep/deu131
25. Harth S, Roller FC, Zeppernick F, Meinhold-Heerlein I, Krombach GA: Deep infiltrating endometriosis: diagnostic accuracy of preoperative magnetic resonance imaging with respect to morphological criteria. Diagnostics (Basel). 2023, 13:1794. 10.3390/diagnostics13101794