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Diagnosis of deep infiltrating endometriosis: accuracy of magnetic resonance imaging and transvaginal 3D ultrasonography

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Abstract

Purpose: To compare two different imaging modalities, magnetic resonance (MR), and three-dimensional sonography (3DUS), in order to evaluate the specific role in preoperative work-up of deep infiltrating endometriosis.
Materials and methods: 33 women with endometriosis underwent 3DUS and MR followed by surgical and histopathological investigations. Investigators described the disease extension in the following sites: torus uterinus and uterosacral ligaments (USL), vagina, rectovaginal-septum, rectosigmoid, bladder, ovaries. Results were compared with surgical and histopathological findings.
Results: Ovarian and deep pelvic endometriosis were found by surgery and histology in, respectively, 24 (72.7%) and 22 (66.6%) of the 33 patients. Sensitivity and specificity values of 3DUS for the diagnosis of endometrial cysts were 87.5% and 100%, respectively; those of MRI were 96.8% and 91.1%, respectively. Sensitivity and specificity of 3DUS for the diagnosis of deep infiltrating endometriosis in specific sites were: USL 50% and 94.7%; vagina 84% and 80%; rectovaginal-septum 76.9% and 100%; rectosigmoid 33.3% and 100%; bladder 25% and 100%. Those of MR were: USL 69.2% and 94.3%; vagina 83.3% and 88.8%; rectovaginal-septum 76.4% and 100%; restosigmoid 75% and 100%; bladder 83.3% and 100%.
Conclusions: MR accurately diagnoses deep infiltrating endometriosis; 3DUS accurately diagnoses deep infiltrating endometriosis in specific locations.

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Key words: Deep endometriosis—MR—3DUS—Infiltrating endometriosis—Ultrasonography

Endometriosis is a common gynecological disorder defined by the presence of ectopic endometrial glands and stroma outside the uterus. It represents a common and important clinical problem in women of childbearing age, manifesting with pain and infertility [1].

The exact prevalence of endometriosis is not well-defined, as the standard of reference for diagnosis remains laparoscopy or laparotomy; it is, however, estimated to be found in about 5–10% of women, including both symptomatic and asymptomatic women [2].

The most common locations of endometriosis are the ovaries and the pelvic peritoneum, followed by deep lesions of the pelvic subperitoneal space, the intestinal system, and the urinary system [1].

Deeply infiltrating endometriosis is a specific entity: deep endometriotic lesions penetrate under the surface of peritoneum (infiltration >5 mm) in the uterosacral ligaments (USL), rectum, rectovaginal septum, vagina or bladder, inducing a fibromuscular hyperplasia that surrounds endometriosis foci [3].

Transvaginal sonography (TVUS) is a good cost-effective imaging method in the evaluation of pelvic pain and it has proven to be quite accurate in the diagnosis of endometriomas and bladder endometriosis. There have been only a few reports studying its role in the prediction of the extension of deeply infiltrating pelvic endometriosis [4–6].

In a recent study magnetic resonance (MR) demonstrated high sensitivity, specificity, positive and negative predictive values, and accuracy in the prediction of the

locations of extension of the disease in patients with deep pelvic endometriosis (sensitivity 90.3%, specificity 91%, positive predictive value 92.1%, negative predictive value 89%) [7].

To our knowledge no studies have evaluated the potential role of three-dimensional sonography (3DUS) in the preoperative work-up of deeply infiltrating pelvic endometriosis. Seow et al. [8] reported that transvaginal three-dimensional sonography (3DTVUS) was suitable for evaluating pelvic adhesions in women with surgically proven pelvic adhesions; they also found that sensitivity increased when sonographic findings were combined with Ca125 serum level abnormalities.

The aim of our study was to compare two different imaging modalities: 3DTVUS and MR, in order to evaluate their contribution in defining preoperatively the extension of deeply infiltrating pelvic endometriosis.

Laparoscopy is to be considered the benchmark.

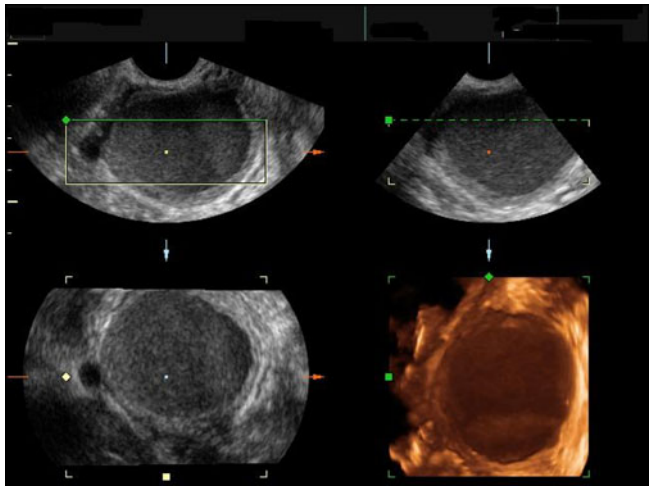

Fig. 1. 3D study of an endometrial cyst.

Materials and methods

Patients

Between June 2006 and June 2008, 33 patients (mean age 35; range 22–53) with clinical suspicion of pelvic endometriosis were recruited. They presented signs of pelvic pain ($n = 18$; dysmenorrhea, dyspareunia, chronic pelvic pain), infertility ($n = 5$), adnexal masses and/or tenderness at physical examination ($n = 10$). Thirty-three of the patients underwent MR, while TVUS was performed in 24 of the patients because nine of the patients were referred to other institutions.

All the patients underwent laparoscopy and histopathological examination of resected lesions. The MR images and TVUS images were analyzed prospectively by two investigators in a double-blinded fashion. The mean interval between these two examinations was 2 weeks (range 1–4 weeks).

Transvaginal sonography technique

All scans were performed by a gynecologist with 20 years experience of endometriosis and gynecologic ultrasound. The investigator was blinded to the patient's clinical history, symptoms, and MR results.

Transvaginal ultrasonography was performed using 3D scan (SONOACE 9900 PRIME Medison, Seoul, Korea and a wide-band 5–9 MHz volume transducer).

The examination did not require any bowel preparation.

The region-of-interest (ROI) was identified in 3D sonography using a B-mode scan and a transvaginal volume transducer; the investigator opened the volume-box (in B-mode scans it appears as a ''truncated cone'' when using the transvaginal transducer) that determines the limits of the volumetric scan region. During the volumetric scan the transducer carries out a series of parallel scans of varying speeds focusing on the ROI. The anatomical ROI was finally visualized on the monitor as a graphic containing the three orthogonal planes (Fig. 1). During the volumetric scans the investigator adopted some expedients such as positioning the probe near the anatomical ROI and reducing or eliminating patient's movements.

Ultrasonographic analysis of deep infiltrating endometriosis

The study of the patient's pelvis by 3DTVUS started from the evaluation of the position, morphology, size, and echogenicity of the uterus and adnexa.

The diagnosis of pelvic endometriosis was based on different morphological criteria that varied for each anatomical location of the disease and included thickening or echogenic nodules or masses with regular or irregular outlines.

Endometriomas were diagnosed when adnexal cystic lesions with a homogeneous hyperechoic ''carpet'' of low level echoes, unilocular or multilocular pattern and hyperechogenic mural foci were seen. 3D scans were useful because they clearly showed blood clots and the mural regular profile. For example, the surface-rendering mode allowed recognition of benign lesion features showing endometriomas' surface ''regularity''. Transparent maximum/minimum mode was adopted in differential diagnosis with tumors or dermoid cysts because of a better visualization of intratumoral calcifications and bone abnormalities (typical of dermoid cysts).

The power and color Doppler supported diagnosis of endometriomas in showing a typical vascular location: regularly separated pericystic vessels with low to moderate vascular resistance.

The USL were considered involved when in 3D scans they appeared thickened or they showed a regular or irregular hypoechogenic nodule near their insertion on the cervix.

Posterior vaginal fornix involvement was seen as a cystic or a thickened area.

Such abnormalities were seen also in the rectovaginal septum under a horizontal plane passing through the posterior lip of the cervix, under the peritoneum.

Sigmoid colon involvement was diagnosed when a hypoechogenic area with irregular margins penetrated into bowel's walls.

Deep bladder endometriosis was noted as iso or hypoechogenic nodules or cystic lesions into bladder walls and was differentiated from superficial endometriosis foci located in the uterovesical fold.

The investigator also recorded the presence of adhesions and the obliteration of the pouch of Douglas; fluid collection was another criterion of pelvic adhesions.

The presence of an associated adenomyosis was also recorded.

Magnetic resonance technique

MR images were acquired with a 1.5 T MR imaging device (Magnetom Simphony; Siemens, Erlangen, Germany) and a "phased array" coil.

About 45 min before the examination, patients were asked to drink 1.5 L of water in order to fill the bladder to correct the angle of the anteflexed uterus. All the patients also received an antispasmodic drug, Buscopan® (*n*-butilbromuro di Joscina 20 mg/mL), 1 mL dilute in 10 mL saline intravenously at the onset of the examination to decrease peristalsis.

The protocol always included a coronal T2-weighted HASTE sequence (half-Fourier single shot turbo spin echo: TR 700; TE 89; section thickness 6.0 mm; field of view 350 × 450 mm; matrix 320; time of acquisition 21 s), transverse T1-weighted turbo spin echo sequences from the iliac crest to the pubic sinfisis (TR 771; TE 9.7; section thickness 4.0 mm; field of view 400 × 219 mm; matrix 512 × 512; time of acquisition 2:46), transverse, sagittal and coronal T2-weighted turbo spin echo sequences. These sequences allowed an initial complete analysis of the pelvic region and a preliminary evaluation of endometriotic lesions, which appear as hyperintense lesions in T1-weighted sequences and mildly hypointense or hyperintense in T2-weighted sequences. The FLASH T1-weighted sequences with fat suppression in transverse, coronal, and sagittal plane (Fast Low-Angle Shot 2D: TR 357; TE 4.76; FA 70°; section thickness 4.5 mm; field of view 300 × 300 mm; matrix 256 × 256; time of acquisition 1:31) (T1 flash 2D fat sat) were performed to evaluate adnexal masses because they allow a distinction between a fatty content lesion (for example a teratoma, which appears hypointense in fat-suppressed T1-weighted sequences) and endometriomal cyst (that exhibits a typical hyperintense signal in such sequences) (Fig. 2A, B). Fat-suppressed MR imaging was useful in enhancing the contrast between hemorrhagic implants and normal tissue.

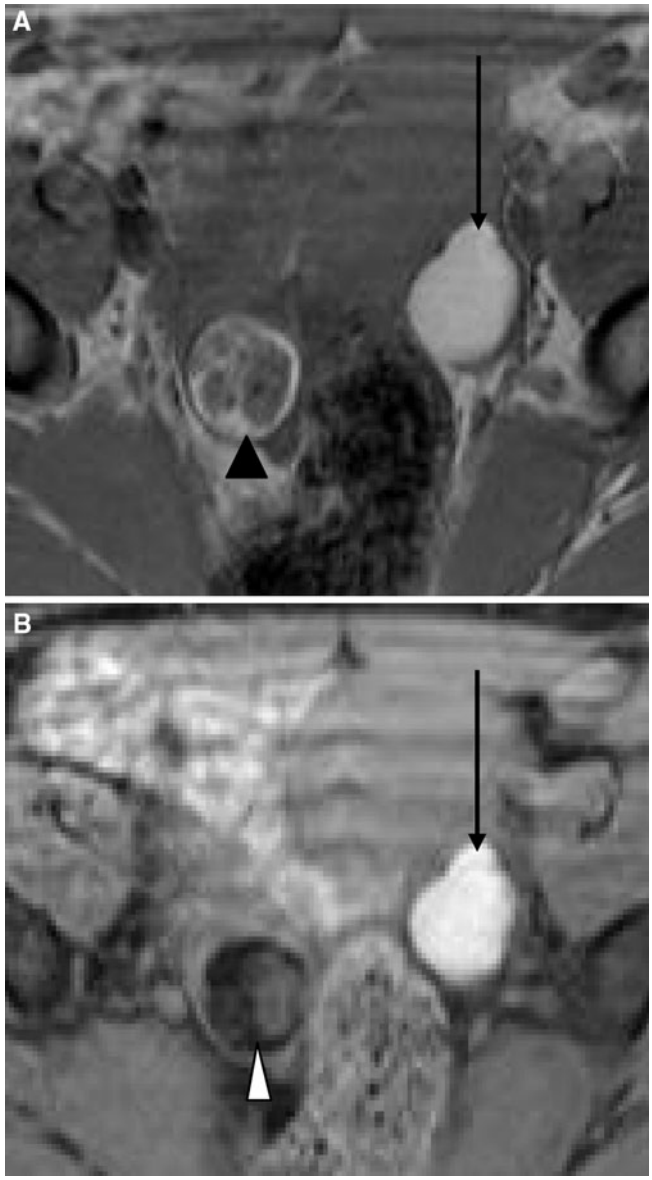

Fig. 2. 30-year-old patient. **A** Transverse T1-weighted flash 2D image. Homogeneous hyperintense cystic lesion in the left ovary (*arrow*) and heterogeneously hyperintense lesion in the right ovary (*arrow head*). **B** Transverse T1-weighted flash 2D image with fat suppression. This sequence allows differentiation of the fatty content in the dermoid cyst in the right ovary, which appears hypointense (*white arrowhead*) from blood content in the endometrial cyst in the left ovary that appears hyperintense (*black arrow*).

Contrast-enhanced FLASH T1-weighted sequences (gadolinium Gd-DTPA 0.1 mmol/kg was administrated intravenously) were performed in selected cases, especially when a mural nodule within a hyperintense

endometrioma was observed; in such cases the absence of contrast-enhancement was the diagnostic clue to its benignity. Finally, the contrast agent was administrated when the initial images hinted towards ureteral infiltration. The investigator performed FLASH 3D T1-weighted sequences in the coronal plane with MIP reconstructions (1 mm) (TR: 2.96; TE 1.21; section thickness 1.40 mm; field of view 350 × 490 mm; matrix 384; time of acquisition 20 s).

The MR images were analyzed prospectively by one radiologist of our department who was blinded to clinical and sonographic findings: he was asked to determine whether endometriosis was present in the ovaries, the superficial peritoneum at specific locations such as the ovarian fossa, uterine serosa, broad ligaments, pouch of Douglas, and vesicouterine fold. The radiologist was asked to describe the subperitoneal implants in the USL, vagina, rectovaginal septum and the deep infiltration of bowel, bladder and ureters. He was asked to identify adenomyosis according to previously described criteria.

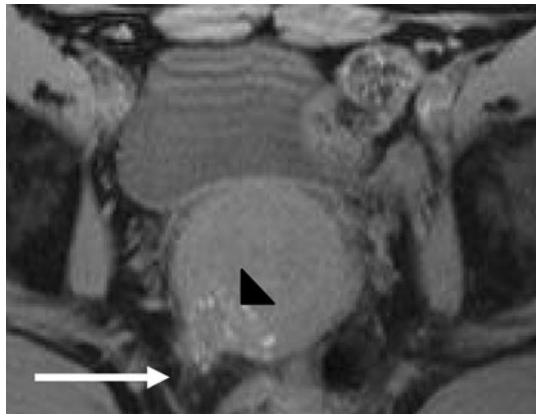

Fig. 3. 38-year-old patient. Transverse T1-weighted flash 2D image with fat suppression. Thickening of the right uterosacral ligament (*white arrow*) adjacent to posterior adenomyosis of the uterine isthmus (*black arrowhead*).

Magnetic resonance analysis of deep pelvic endometriosis

Pelvic endometriosis was diagnosed by MR when at least one site of involvement (ovarian or deep pelvic endometriosis) was seen. Deeply infiltrating pelvic endometriosis was defined by the presence of endometriosis in one of the following areas: torus uterinus and USL, vagina, rectovaginal septum, sigmoid colon, ureters, and bladder.

Endometrial cysts were diagnosed at MR when an endometrial cyst had high signal intensity at both T1- and T2-weighted sequences, persisting at subsequent fat-suppressed T1-weighted images. Gradual variation of signal intensity at T2-weighted images has been described as ''shading'' and is another specific feature. Interovarian adhesion was described as ''kissing ovaries''.

Uterosacral ligaments endometriosis was diagnosed when a small or large hypointense nodule at the upper posterior cervix in axial T2-weighted images was seen. In T2-weighted images these lesions are identified as iso- or hypointense to myometrium. On T1-weighted fat suppressed images it was characterized by asymmetric nodular irregularity of USL associated with hyperintense spots (Fig. 3).

Magnetic resonance presentation of vaginal and rectovaginal septum endometriosis was T2-hypointensity (Fig. 4) and variable signal intensity at T1-weighted images associated with hyperintense spots on fat-suppressed T1-weighted images.

Diagnostic criteria of sigmoid invasion at MR was an asymmetric thickening of the lower surface of the sigmoid wall showing contrast-enhancement on T1-weighted MR images.

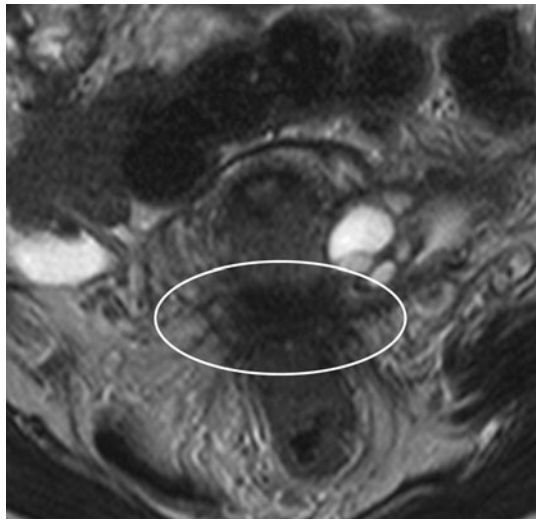

Fig. 4. 30-year-old patient. Transverse T2-weighted turbo spin echo image. Thickening of anterior rectal wall with a fibrotic area that exhibits a signal intensity close to that of the pelvic muscle.

The presence of partial or complete obliteration of the pouch of Douglas or fluid collection was recorded.

Localized bladder wall thickening occasionally protruding inside the bladder lumen represented the main diagnostic criterion of anterior compartment endometriosis. It appears isointense on T2-weighted images and with hyperintense spots on T1-weighted sequences (Fig. 5).

Ureteral endometriosis was detected at T2-weighted sequences as hypointense nodule associated with hyperintense foci close to the ureter at both T1- and T2-weighted sequences.

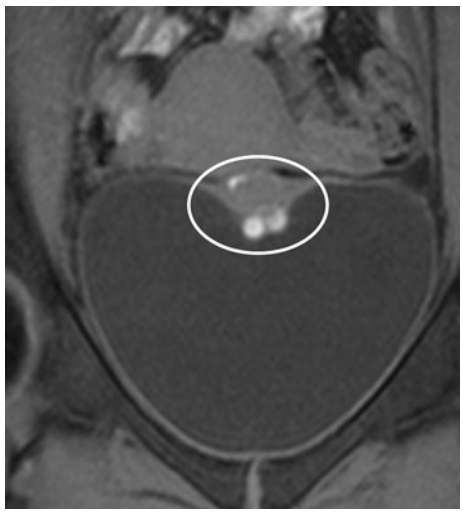

Fig. 5. 32-year-old patient. Coronal T1-weighted flash 2D image with fat suppression. Hypointense lesion inside the bladder wall with hyperintense spots suggesting hemosiderin content.

Surgical and pathologic findings

All patients underwent laparoscopy for diagnosis and treatment of pelvic endometriosis.

The surgeons recorded all the superficial lesions of the peritoneum (making a distinction between superficial and deep infiltration), the presence of adhesion, of a complete obliteration of the pouch of Douglas (it was always resectable), the involvement of Fallopian tubes and for each localization of pelvic endometriosis they recorded if the involvement was superficial or deep. All resected lesions were analyzed.

Some lesions were treated intraoperatively. Two different pathologists analyzed the first 20 patients and the last 13 patients, respectively. All resected lesions were analyzed to exclude malignant transformation.

For a surgeons' choice the adenomyosis seen at previous diagnostic studies was not treated.

Statistical analysis

The sensitivity, specificity, positive and negative predictive values, and accuracy of MR imaging and 3DTVUS were evaluated for ovarian involvement and each site of deep pelvic endometriosis. The standard of reference were surgical and pathologic findings. The kappa Cohen values and statistical significance were calculated in order to evaluate the agreement between 3DTVUS and laparoscopy, MR and laparoscopy and between 3DTVUS and MR. A P value <0.05 was considered statistically significant.

Results

Surgical and pathologic findings

Pelvic endometriosis was confirmed at surgery and in at least one site of biopsy (ovary, peritoneal surface, and subperitoneal space) in 33 patients.

The anatomical distribution of lesions, the site of biopsy, and the presence or absence of endometriosis at pathologic examination are shown in Table 1.

Among 33 patients, 24 (72.7%) had endometriomas and 26 (78.7%) had involvement of at least one site of deep pelvic endometriosis. Among those with deeply infiltrating pelvic endometriosis lesions were distributed as follows:

1. posterior compartment alone—USL, vagina, bowel, sigmoid colon, rectovaginal septum, obliteration of the pouch of Douglas, ureters—was involved in 20 of 26 patients (76.9%);
2. anterior compartment alone—bladder—was involved in 3 of 26 patients (11.5%);
3. posterior and anterior compartments were both involved in 3 of 26 patients (11.5%).

Among 26 patients with deep pelvic endometriosis, 7 (26.9%) had deep endometriosis without adnexal involvement (endometrial cysts or superficial lesions).

Umbilical endometriosis was seen in one patient.

There were no cases of bowel involvement in sites other than rectum or sigmoid colon.

Concomitant diseases were fibroleiomyomas (3 patients), endometrial polyps (2 patients), and dermoid cyst (1 patient).

3DTVUS results

Pelvic endometriosis was diagnosed at TVUS in 23 of the 24 patients (23/24; 95.8%). Endometrial cysts were diagnosed with a sensitivity of 87.5% and a specificity of 100%. Deeply infiltrating pelvic endometriosis was diagnosed in 15 of the 19 patients with surgically proven deeply infiltrating endometriosis (15/19; 78.9%). There were two false positives. In such cases the investigator made an incorrect diagnosis of USL infiltration.

Sensitivity, specificity, positive and negative predictive value, and accuracy of TVUS for diagnosis of deep pelvic endometriosis are reported in Table 2.

Sensitivity and specificity of TVUS for uterosacral involvement were 50% and 94.7%, respectively. Sensitivity and specificity for posterior vaginal fornix infiltration were, respectively, 84% and 80%. Rectovaginal septum endometriosis and sigmoid colon endometriosis were diagnosed with a sensibility of 76.9% and 33.3%, respectively. Specificity was 100% in both cases. For bladder endometriosis sensitivity was 25% and specificity

Table 1. Anatomical distribution of lesions, site of biopsy, and presence or absence of endometriosis

Location of pelvic endometriosis	Surgical diagnosis of endometriosis	Biopsy	Confirmation at pathologic examination
Right ovary—superficial lesions	1		
Right ovary—endometrial cysts	14	14	14
Left ovary—superficial lesions	5		
Left ovary—endometriomal cysts	17	18	18
Right fallopian tube	2	3	2
Left fallopian tube	2	3	3
Right USL—superficial lesions	6		
Right USL—deep infiltration	8	8	8
Left USL—superficial lesions	3		
Left USL—deep infiltration	5	5	5
Right broad ligament	15	10	10
Left broad ligament	20	12	12
Vagina—no deep infiltration	3	3	3
Vagina—posterior fornix infiltration	6		
Obliteration of the pouch of Douglas	2		
Endometriosis of rectovaginal septum (septum nodule—infiltration of the serosa of rectum)	17	17	17
Sigmoid colon	4	4	4
Bowel: cecum, appendix, etc.	0		
Bladder—superficial lesions of uterovesical fold	5	1	1
Bladder—deep endometriosis (prevesical nodule—nodule projecting into the lumen)	6	6	6
Ureters—periureteral fibrosis	4		

Table 2. Sensitivity, specificity, positive and negative predictive value and accuracy of TVUS for diagnosis of deep pelvic endometriosis

Location of pelvic endometriosis	Sensitivity 3DTVUS (%)	Specificity 3DTVUS (%)	PPV 3DTVUS (%)	NPV 3DTVUS (%)	Accuracy 3DTVUS (%)
Deep infiltrating endometriosis	78.9	70	86.6	44.4	77.7

Table 3. Results of TVUS

Location of deep pelvic endometriosis	Sensitivity 3DTVUS (%)	Specificity 3DTVUS (%)	PPV 3DTVUS (%)	NPV 3DTVUS (%)	Accuracy 3DTVUS (%)
USL	50	94.7	71,4	87.8	85.4
Posterior vaginal fornix	84	80	70	83	83
Rectovaginal septum	76.9	100	100	78.5	87.5
Sigmoid colon	33.3	100	100	91.3	91.6
Ureters	NA	NA	NA	NA	NA
Bladder	25	100	100	86.9	87.5

100%. Ureteral involvement was not evaluated. Results of TVUS are reported in Table 3.

MR imaging results

Pelvic endometriosis was diagnosed at MR imaging in all the patients (33/33; 100%). Sensitivity and specificity of MR for diagnosis of endometrial cysts were 96.8% and 91.1%. Contrast-enhanced T1-weighted sequences were employed in 4 cases in which there was a suspicion of malignant transformation.

Deeply infiltrating endometriosis was diagnosed at MR in 25 of 26 patients with surgically proven deeply infiltrating endometriosis (25/26; 96.1%). Sensitivity, specificity, positive and negative predictive value, and accuracy of MR for diagnosis of deep pelvic endometriosis are reported in Table 4.

Sensitivity and specificity of MR in diagnosing deep infiltration of USL were 69.2% and 94.3%, respectively (Fig. 6).

Posterior vaginal fornix involvement was diagnosed with sensitivity of 83.3% and specificity of 88.8%.

In diagnosing endometriosis of the rectovaginal septum (Fig. 7), MR showed a sensitivity of 76.4% and a specificity of 100%. Sensitivity and specificity of MR for sigmoid colon involvement was 75–100%.

The infiltration of ureters was seen by MR with a sensitivity of 66.6% and a specificity of 100%.

Table 4. Sensitivity, specificity, positive and negative predictive value and accuracy of MR for diagnosis of deep pelvic endometriosis

Location of pelvic endometriosis	Sensitivity MR (%)	Specificity MR (%)	PPV MR (%)	NPV MR (%)	Accuracy MR (%)
Deep infiltrating endometriosis	96.1	85.7	96.1	85.7	93.9

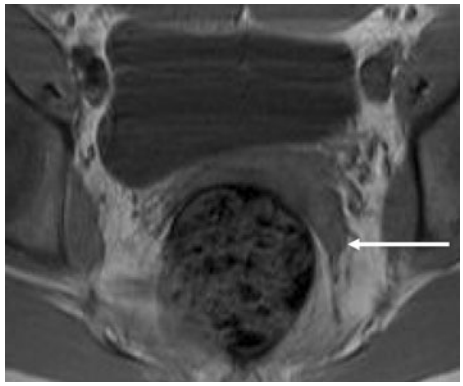

Fig. 6. 30-year-old patient. Transverse T1-weighted flash 2D image. True positive diagnosis of nodular USL involvement with endometriosis was determined at MR imaging (*white arrow*).

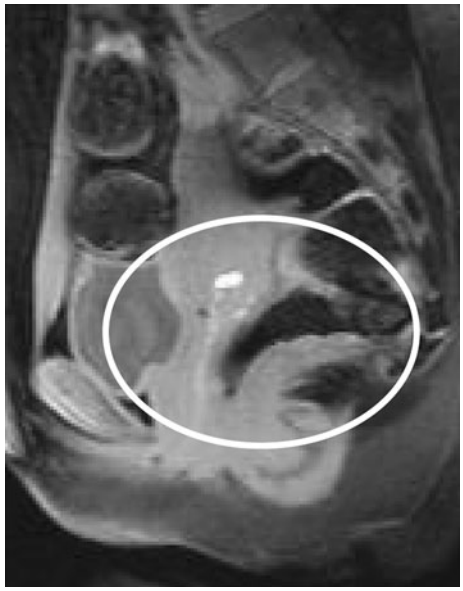

Fig. 7. 31-year-old patient. Sagittal T1-weighted flash 2D with fat suppression. Fibrotic tissue with irregular margins inside the rectovaginal septum with multiple hyperintense spots.

Among the 26 patients with deeply infiltrating endometriosis surgically and histopathologically proven, 6 had bladder endometriosis (anterior compartment) (Fig. 8). This site of involvement was diagnosed with a sensitivity of 83.3% and a specificity of 100% (Table 5).

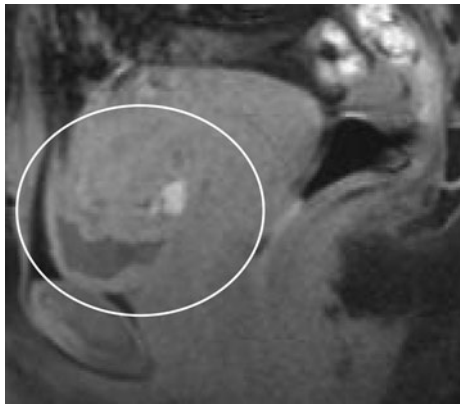

Fig. 8. 37-year-old patient. Sagittal T1-weighted flash 2D with fat suppression. Multiple hyperintense spots in the upper bladder without involvement of the detrusor muscle. Laparoscopy confirmed the presence of endometriosis.

Kappa and agreement

We measured the degree of agreement (and P value) between MR and laparoscopy, 3DTVUS and laparoscopy, and finally between MR and 3DTVUS.

The interpretation of κ value as a parameter of agreement or reproducibility was based on Landis and Koch score [9] (Table 6).

MR vs. laparoscopy

The strength of agreement between MR and laparoscopy in diagnosing deeply infiltrating endometriosis was statistically significant ($P < 0.001$).

The strength of agreement resulted 'moderate' for involvement of USL and posterior vaginal fornix, 'substantial' in the case of rectovaginal septum, ureters and sigmoid colon, 'almost perfect' for bladder involvement. The results were statistically significant (Table 7).

3DTVUS vs. laparoscopy

The strength of agreement between transvaginal ultrasound and laparoscopy in diagnosing deeply infiltrating endometriosis was 'fair'.

The strength of agreement was 'substantial' for the rectovaginal septum and posterior vaginal fornix endometriosis, 'moderate' for USL and sigmoid colon involvement, and 'fair' for bladder infiltration (Table 8).

Table 5. Results of MR

Location of deep infiltrating endometriosis	Sensitivity MR (%)	Specificity MR (%)	PPV MR (%)	NPV MR (%)	Accuracy MR (%)
USL	69.2	94.3	75	92.5	89.3
Posterior vaginal fornix	83.3	88.8	62.5	96	87.8
Rectovaginal septum	76.4	100	100	80	87.8
Sigmoid colon	75	100	100	96.6	96.9
Ureters	66.6	100	100	98.3	98.4
Bladder	83.3	100	100	96.4	96.9

Table 6. Score of Landis and Koch [9]

Kappa	Strength of agreement
<0.00	Poor
0.00–0.20	Slight
0.21–0.40	Fair
0.41–0.60	Moderate
0.61–0.80	Substantial
0.81–1.00	Almost perfect

Table 7. MR vs. laparoscopy

Location of pelvic endometriosis	κ Cohen MR–LPS	*P*
Deeply infiltrating endometriosis	0.79	<0.001
USL	0.64	<0.001
Posterior vaginal fornix	0.62	<0.001
Rectovaginal septum	0.74	<0.001
Sigmoid colon	0.8	<0.001
Ureters	0.75	<0.01
Bladder	0.86	<0.001

Table 8. 3DTVUS vs. laparoscopy

Location of endometriosis	κ Cohen 3DTVUS–LPS	*P*
Deeply infiltrating endometriosis	0.21	0.17
USL	0.5	<0.05
Posterior vaginal fornix	0.73	<0.001
Rectovaginal septum	0.74	<0.001
Sigmoid colon	0.44	0.11
Ureters	NA	NA
Bladder	0.35	0.15

MR vs. 3DTVUS

We found a 'fair' correlation in diagnosis of deeply infiltrating endometriosis between the two imaging modalities examined in the present study.

The strength of agreement was 'fair' in the case of USL infiltration, 'poor' for sigmoid colon, 'moderate' for bladder endometriosis, and 'substantial' for rectovaginal septum and posterior vaginal fornix (Table 9).

Table 9. MR vs. 3DTVUS

Location of endometriosis	κ Cohen MR–3DTVUS	*P*
Deeply infiltrating endometriosis	0.21	0.17
USL	0.23	0.2
Posterior vaginal fornix	0.64	<0.001
Rectovaginal septum	0.65	<0.001
Sigmoid colon	−0.08	>0.48
Ureters	NA	NA
Bladder	0.44	0.11

Discussion

To the best of our knowledge, no studies have compared MR imaging and 3DTVUS in identifying and evaluating the disease's extent in patients suffering from deeply infiltrating endometriosis and the accuracy of 3DTVUS and MR in deep infiltrating endometriosis with reference to laparoscopic results.

Despite physical examination in women with signs and symptoms of posterior pelvic endometriosis, the diagnosis in a number of cases varies from 60% to 83% [6, 7]. Different imaging methods are required to effectively assess the disease extent in deeply infiltrating endometriosis which is a multifocal disease [10]. They include transrectal sonography (TRS), MR, and TVUS.

Bazot et al. [6, 7] found that TRS was suitable for evaluating endometriotic involvement of the USL and rectosigmoid colon reporting a sensitivity of 73% and 83%, respectively. This author recommends TRS in preoperative work with women who have a high likelihood of rectosigmoid colon involvement. Limits of TRS are anterior compartment, endometrial cysts, and obliteration of the pouch of Douglas.

Transvaginal sonography is the first-line imaging method in patients with pelvic disorders and shows a high degree of accuracy in diagnosis of endometrial cysts. 3DTVUS can help the investigator in evaluation of ovarian lesions by a scrupulous morphologic analysis; it reduces the number of false positive diagnoses when analyzing complex lesions such as endometrial cysts, ovarian dermoids, fibromas, and corpus luteum cysts which may give a wrong impression of malignancy when using conventional TVUS.

In our study TVUS performed with both 2D and 3D scans shows 87.5% of sensitivity and 100% of specificity. Alcazar et al. [11] found that two-dimensional transvaginal sonography (2DTVUS) alone had 89% of sensitivity and 91% of specificity. Multiplanar and volume rendering display methods combined with the ability to

rotate volume data into standard orientations are essential components of 3DUS's current and future success. Obvious advantages of three-dimensional ultrasound are improved recognition of the ovarian lesion anatomy, accurate characterization of the surface features, clear depiction of the size and volume of the mass. The surface mode is used in the assessment of superficial structures and differentiation between benign and malignant disease. Application of transparent maximum/minimum mode enables visualization of the intratumoral calcification or the identification of the bone structures in dermoid tumors. In our series there was one case of dermoid cyst. MR accuracy in diagnosing endometrial cyst was 93.9%. In four cases the investigator suspected malignant change of an endometrial cyst so additional sequences were performed: no contrast-enhanced nodules were noted on T1-weighted images in such cases.

Bazot et al. [6, 7] consider TVUS the first-line imaging technique for suspected deep pelvic endometriosis.

In our study the accuracy of 2D- and 3DTVUS for the diagnosis of deeply infiltrating endometriosis was 77.7%, as opposed to the MR which had a high accuracy (93.9%). The strength of agreement between MR and laparoscopy in diagnosing deeply infiltrating endometriosis was 'substantial', being the best imaging technique in patients with suspicion of deeply infiltrating endometriosis. We found a 'fair' correlation in diagnosis of deeply infiltrating endometriosis between the two imaging methods examined in the present study; so we recommend in patients with chronic dysmenorrhea, dyspareunia, clinical suspicion of deep endometriosis a work-up with MR, especially when surgical procedures are needed. A satisfactory preoperative work-up is necessary to identify the exact location of all deep lesions and to provide guidance in deciding which is the most appropriate surgical option.

In our series the USL were one of the most affected locations.

For this kind of involvement the accuracy of MR and TVUS were 89.3% and 85.4%, respectively. These results are similar to those reported in previous study [6, 7]. MR shows a better correlation with laparoscopy than TVUS. The strength of agreement between these two imaging modalities was 'fair' in the case of USL infiltration. MR had three false positive results, while TVUS had two false positive diagnoses. Among the three patients with false positive diagnosis of USL involvement at MR, two had a prerectal infiltration with fibrosis that created a false impression of USL infiltration. It is likely that the other false positive result was a case of misdiagnosis. Among patients with false positive preoperative diagnosis of USL infiltration, none had at any abnormalities that were detected at surgery, so those USL were not biopsied. On MR images false negative results were caused by retroflexed uterus, large endometriomas, and bowel interposition. TVUS had five false negative results in diagnosis of USL infiltration.

Magnetic resonance yielded a diagnosis of posterior vaginal fornix endometriosis with a sensitivity of 83.3% and a specificity of 88.8%. False positive results were caused by obliteration of the pouch of Douglas with fibrotic tissue. MR was performed with additional oblique transverse and coronal sections in order to give a better visualization of this kind of involvement, as this lesion can be treated in selected cases with a transvaginal surgical approach. 2D- to 3D transvaginal ultrasound was accurate in diagnosing this kind of involvement.

Transvaginal sonography was as accurate as MR for the diagnosis of rectovaginal septum endometriosis. Sensitivity of 2D- and 3DTVUS for this location was higher than reported by Bazot et al. [6, 7]. We also classified the infiltration of rectal walls up to the rectosigmoid junction as "rectovaginal septum endometriosis". In our series most of the patients had an involvement of both the pouch of Douglas and the upper third of the rectovaginal septum. Probably rectovaginal septum endometriosis is secondary to the involvement of the peritoneum of Douglas that lies on the cranial portion of rectovaginal septum. The strength of agreement between MR and TVUS and between these techniques and laparoscopy for this location was 'substantial'.

Magnetic resonance had one false negative result in a patient with muscular infiltration of the rectum. In other three patients with false negative result at MR, small lesions of prerectal peritoneum were resected.

Transvaginal sonography yielded a diagnosis of pelvic endometriosis located on the sigmoid only in one case of the three patients that underwent this exam (sensitivity 33.3% and specificity 100%). Bazot et al. [6, 7] found that the limit of TVUS is the distance from the probe and the presence of fecal material. Conventional MR sequences may in some cases need a water enema to better view sigmoid involvement. MR yielded a diagnosis of endometriosis of the sigmoid in three of four patients with this site of involvement. In most cases it was characterized by an asymmetric thickening of the lower surface of the sigmoid wall or a fibrotic area with hyperintense spots on T1-weighted images. Contrast enhancement of the lesion on T1-weighted postcontrast images confirmed the diagnosis in some cases. There was one false negative result at MR: in this patient at preoperative work-up it was discovered to be only a fluid collection. MR shows a better correlation to laparoscopy for sigmoid involvement than TVUS. We found no correlation between the two imaging modalities considered in the present study.

Bladder was the only site of involvement in 11.5% of patients and in the same number of cases it was associated with at least one location of the disease in the posterior pelvic compartment. All patients with bladder endometriosis had a nodule located in the dome of the bladder at the uterovesical fold. One patient had infiltration of the whole wall. At MR, T1-weighted fat-suppressed images increased the visualization of bladder

implants. MR had one false negative result. In the present study TVUS shows a 'fair' correlation to laparoscopy for bladder infiltration. It is probable that this result is due to the small size of lesions found in our series on the anterior compartment. On the other hand, Fedele et al. [5] found a high degree of accuracy of TVUS for bladder endometriosis.

An important advantage of MR was to employ FLASH 3D T1-weighted sequences in the coronal plane with MIP reconstructions (1 mm) in order to record preoperatively ureteral stenosis. It was seen at MR in one patient with bilateral infiltration of the ureters. There was one false negative result. Another patient with ureteral stenosis was not included because at the time of preoperative work-up, she had a ureteral stent.

Some investigators have stated that the role of MR in diagnosing endometriosis depends on the sites of the implants, thus recognizing its useful role in detecting those located at the USL and in the rectovaginal septum. In the present study we have investigated the potential use of 2D- to 3D transvaginal ultrasound and of MR in diagnosing deeply infiltrating endometriosis. Our results suggest that MR shows a better correlation to laparoscopy than 2D- to 3D transvaginal ultrasound with regard to the anterior pelvic compartment. These imaging modalities are equivalent for rectovaginal septum and posterior vaginal fornix endometriosis. Other locations of posterior pelvic endometriosis (LUS, sigmoid colon, and ureters) are better seen at MR. We found that the main limitation of 2D- to 3D transvaginal ultrasound was the distance from the probe of some locations such as deep pelvic endometriosis located on the sigmoid.

Fedele et al. [5] and Balleyguier et al. [12] recommend transvaginal ultrasound as the first-line imaging technique for bladder endometriosis. The sensitivity of 2D- to 3D transvaginal ultrasound for the diagnosis of bladder endometriosis was low in the present study. We can speculate that this discrepancy is due to the small size of vesicouterine nodules reported in our series compared to those reported in previous studies. In our study we also observed that bladder endometriosis was in most cases associated to adenomyosis of the anterior uterine wall, thus supporting the etiologic hypothesis of extension of adenomyosis from anterior uterine wall to the bladder.

Several limitations of our study must be considered. First of all the fact that only 24 patients underwent 2D- to 3D ultrasound; second, the prevalence of endometriosis and of deep pelvic endometriosis was very high representing a possible source of bias; third, we did not stage endometriosis at the preoperative work-ups, so the present study did not correlate a staging system based on imaging modalities with the staging of the disease at surgery.

2D- to 3D transvaginal ultrasound can help the radiologist in a differential diagnosis of the multiple causes of pelvic pain in women of childbearing age. According to our results, diagnosis of endometriomas, vaginal, and rectovaginal endometriosis is reliable at ultrasound. However, in patients with a consistent clinical suspicion of deep pelvic endometriosis MR represents an optimal "all in one" exam to diagnose and define the exact extent of deeply infiltrating endometriosis; this represents a multifocal disease, thus requiring an imaging method able to cover the entire pelvis to diagnose all possible lesions. High contrast resolution, multiplanarity, and greater field of view are the main advantages of MR.

Magnetic resonance is also useful as it points out preoperatively some lesions that at surgery can be hidden by adhesions.

Because of the difficulty of surgical procedures, it is strongly recommended to refer patients with suspected or diagnosed deep endometriosis to specific multidisciplinary teams.

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