Chapter 10

Addendum

An update of MR imaging in endometriosis

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Abstract

Endometriosis is often a diagnostic challenge, because patients present with a broad spectrum of symptoms. Imaging techniques are therefore fundamental for diagnosis of (deep infiltrating) endometriosis and preoperative mapping of disease extent.

Recently, new MR imaging techniques have been proposed for female pelvic imaging, including 3T MR imaging, diffusion-weighted MR imaging (DWI) and 3DT2-weighted MR imaging. The aim of this paper is to review MR imaging findings in endometriosis and discuss recently proposed MR imaging techniques, in order to explore and summarize experiences in the field of MR imaging in endometriosis.
**Background**

Endometriosis is an oestrogen-dependent disease, characterized by ectopic growth of endometrial glands and stroma that may lead to pelvic pain and infertility. Patients may present with a broad spectrum of symptoms including dysmenorrhoea, dyspareunia, dyschezia, hematochezia, dysuria, hematuria and chronic pelvic pain. It is estimated to affect 5-10% of women [1]. Endometriosis may be divided into superficial peritoneal endometriosis, including ovarian endometrial cysts, and deep infiltrating endometriosis. The severity of pain is not consistently related to stage of disease [2], but may relate to the site of disease [3]. Most women with endometriosis experience lengthy delays to diagnosis. Whilst the achievement of diagnosis may not alleviate women’s incapacitation altogether, prolonged delays with painful symptoms may worsen the prognosis for fertility [4].

**Pathogenesis**

Different theories exist regarding the pathogenesis of endometriosis. The most accepted theory is that of Sampson, who postulated in 1927 the presence of endometrial cells outside the uterus was due to tubal regurgitation and dissemination of menstrual shedding [5]. Other theories include lympho- and hematogenic dissemination, the theory of coelomic metaplasia and the induction theory. Proponents of the latter theory assume that degenerating menstrual endometrium releases endogenous factors, which subsequently induce a metaplastic process in the serosal epithelium of ovaries and in the serosal cells of mesothelium, resulting in endometrial tissue. Finally, according to the theory of coelomic metaplasia, ectopic endometrium develops in situ from local tissues, including germinal epithelium of the ovary and remnants of the Müllerian and Wolffian ducts. Regurgitation of endometrial cells during menstruation is thought to occur in the majority of women, of whom only a minority develop endometriosis 6. It is thought that genetic predisposition may play a role in the development of endometriosis. Other additional factors proposed to determine susceptibility to endometriosis are differences between eutopic endometrium of patients
diagnosed with endometriosis and women without endometriosis [7;8], environmental factors and alterations in immune and endocrine functions.

Diagnosis

Endometriosis is formally diagnosed when visualized by a gynecologist during laparoscopy using the American Society for Reproductive Medicine (ASRM) classification [9]. The histologic diagnosis of endometriosis is based on the typical presence of both endometriotic glands and stroma, although the diagnosis can be made when only one of these components is present [10].

Imaging modalities used in the analysis of endometriosis include, transvaginal sonography (TVS), transrectal sonography (TRS), rectal endoscopic sonography (RES), magnetic resonance (MR) imaging and computed tomography (CT). In our opinion CT should not be used to diagnose endometriosis, because of its lack of contrast resolution and its radiation exposure.

Transvaginal ultrasonography (TVS) is usually the first imaging technique used to evaluate patients suspected of endometriosis. Hudelist et al demonstrated that TVS accurately predicts the presence of endometriosis affecting the ovaries, vagina, rectum, uterosacral ligaments, rectovaginal septum and pouch of Douglas [11]. Moreover, TVS has the advantage of widespread availability and cost-effectiveness.

MR imaging is predominantly used in patients suspected of DIE, to confirm or exclude diagnosis and to assess the extent of disease to provide a roadmap to surgery. A high diagnostic accuracy was demonstrated previously [12-19] (Table 1).

In the ESHRE (European Society of Human Reproduction and Embryology) guidelines for endometriosis, laparoscopy is recommended for diagnosis of peritoneal endometriosis.
Table 1. Accuracy of MR imaging in DIE.

<table>
<thead>
<tr>
<th>Authors / year of publication</th>
<th>Location of endometriosis</th>
<th>MR imaging accuracy (%)</th>
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<tbody>
<tr>
<td>Busard et al 2011</td>
<td>Infiltration of the muscular layer of the bowel wall</td>
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<tr>
<td>Grasso et al 2010</td>
<td>Posterior vaginal fornix</td>
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<td></td>
<td>Sigmoid</td>
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<td></td>
<td>Bladder</td>
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<tr>
<td></td>
<td>USL</td>
<td>89.3</td>
</tr>
<tr>
<td></td>
<td>Rectovaginal septum</td>
<td>87.8</td>
</tr>
<tr>
<td></td>
<td>Ureters</td>
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</tr>
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<td>Hottat et al 2010</td>
<td>DIE (Colon, bladder, vagina, USL)</td>
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<td>Chamie et al 2009</td>
<td>Retrocervical</td>
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<td></td>
<td>Rectosigmoid</td>
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</tr>
<tr>
<td></td>
<td>Bladder</td>
<td>89.1</td>
</tr>
<tr>
<td></td>
<td>Vagina</td>
<td>96.7</td>
</tr>
<tr>
<td></td>
<td>Ureters</td>
<td>95.7</td>
</tr>
<tr>
<td>Abrao et al 2007</td>
<td>Retrocervical involvement</td>
<td>71.0</td>
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<td></td>
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<td>Kataoka et al 2005</td>
<td>Posterior cul-de-sac obliteration by endometriosis</td>
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<td>Chapron et al 2004</td>
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Both MR imaging and US are recommended to assess extent of disease in patients suspected of Deep infiltrating endometriosis (DIE). In the literature, several studies aimed to compare MR imaging, TVS and rectal endoscopic sonography (RES) for diagnosis of (deep infiltrating) endometriosis [18;20-25], but no consensus has been reached on this topic. Both imaging techniques are highly dependent on the expertise of the operating gynaecologist or radiologist and this might be one explanation why results of studies that attempt to compare them may differ between hospital centres. An advantage of MR imaging evaluation is that it provides a complete overview of the anterior and posterior compartments of the pelvis at the same time. MR imaging does also provide the possibility to assess endometriosis infiltrating the sigmoid, an area in which TVS, as well as MR imaging performed with an endovaginal coil [26], is limited as the location above the level of the uterine fundus is too far from the probe or coil to visualize accurately [27]. Also, endometriosis infiltrating the ureter and hydroureteronephrosis may not be diagnosed by TVS. In most hospital centres therefore, TVS is the modality of choice for screening of women suspected of endometriosis and MR imaging is chosen for analysis of patients suspected of DIE. Previously, the utility of MR imaging in assessing the response to therapy with gonadotropin-releasing hormone (GnRH) analog was also evaluated. Although a significant decrease in the number of endometriomas was found 28, no significant changes in deep infiltrating endometriosis have been reported.

**MR imaging technique**

Our standard MR imaging protocol (Table 2) for analysis of (deep infiltrating) endometriosis, includes T2- and fat-suppressed T1-weighted images in different planes without use of intravenous gadolinium, rectal or vaginal gel opacification. T2-weighted images are used for detection and anatomical localization of disease (locations of endometriosis are shown in Figure 1), while fat suppressed T1-weighted images are useful to facilitate detection of hemorrhagic implants of endometriosis and endometrial cysts. The use of intravenous gadolinium for diagnosis of deep infiltrating endometriosis was assessed in a previous study, and authors concluded that it did not improve diagnostic accuracy in these patients [29].
Table 2. MR imaging protocol of the pelvis.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>High resolution turbospin echo T2-weighted sequence</th>
<th>Fat suppressed spin echo T1-weighted sequence</th>
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<td>TR (ms)</td>
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<td>740-790</td>
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<tr>
<td>TE (ms)</td>
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<td>Echo-train length</td>
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<tr>
<td>Number of acquisitions</td>
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<tr>
<td>Slice thickness (mm)</td>
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</tr>
<tr>
<td>Field of view (mm)</td>
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<td>200-300</td>
</tr>
<tr>
<td>Scanning plane</td>
<td>Axial, coronal and sagittal</td>
<td>Axial and sagittal</td>
</tr>
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Fig 1. Locations of pelvic endometriosis: 1. endometrial cyst; 2. retrocervical endometriosis (posterior fornix); 3. retrocervical endometriosis (torus uterinus); 4. endometriosis infiltrating the bowel wall; 5. endometriosis infiltrating the bladder wall; 6. abdominal wall endometriosis
MR imaging findings in endometriosis

Endometrial cysts

Endometrial cysts of the ovaries (also referred to as endometriomas) usually contain a dense, brown, chocolate-like fluid, but may also contain watery fluid occasionally. They are thought to originate from invagination of endometriosis within the ovarian cortex, forming pseudo cysts [30;31]. Adhesions are usually associated with endometrial cysts and attach them to nearby pelvic structures. On MR imaging endometrial cysts show hypointense signal intensity (shading) on T2-weighted imaging and hyperintense signal on T1-weighted imaging, indicating hemorrhage (Fig 2). The shading sign is predominantly caused by a high viscosity of the fluid, caused by recurrent menstrual bleeding and is also influenced by the paramagnetic susceptibility effect of methemoglobin [32;33].

However, this sign may also be seen in hemorrhagic functional ovarian cysts [34] and contents of endometrial cysts may occasionally contain yellowish-brown, watery fluid that lacks shading [35]. Although most endometrial cysts show a standard MR imaging appearance, they may appear highly variable. Features earlier described include, fluid-fluid levels on T2-weighted imaging, representing blood sedimentation, debris, a low signal intensity rim [36], blood clots (Fig 2) and thin septa. Occasionally, fluid-fluid levels are visible on T1-weighted imaging.

**Fig 2.** A 29 year old woman diagnosed with endometriosis. A: Sagittal T2-weighted image shows endometrial cyst of the left ovary, demonstrating heterogeneous hypointensity (shading). B: Sagittal T1-weighted image shows homogeneous hyperintensity of the cysts, indicating hemorrhage. C: Cyst wall with endometrial epithelium, stroma and hemorrhage (black arrow).
Hydro- and hematosalpinx

Pelvic inflammatory disease is one of the most common causes of tubal or peritubal damage. Other causes include endometriosis, peritubal adhesions from a previous operation, tubal cancer, and tubal pregnancy. Diagnosis is usually based on clinical or TVS findings [37]. Hydrosalpinx occurs when a distally blocked fallopian tube fills with fluid. MR imaging may be useful for determining the cause of a hydrosalpinx or its associated adnexal process by characterizing the nature of the contents of the dilated tube. On MR imaging hydrosalpinx depicts as fluid filled tubular structures folded on themselves to form a C or S shape [38]. A hydrosalpinx may be the only imaging finding indicating endometriosis. High signal intensity of the tubes on T1-weighted imaging with corresponding hypointensity (shading) on T2-weighted imaging, indicates hematosalpinx, that may result from endometriosis. In addition debris can be present within the dependent portion of the tube.

Deep infiltrating endometriosis

Deep infiltrating endometriosis is histologically defined as an endometriotic lesion penetrating into the retroperitoneal space or the wall of the pelvic organs [39]. Deep endometriosis is a nodular lesion which is histologically characterized by dense tissue composed of fibrous and smooth muscle cells with islands or strands of glands and stroma. The major component of the nodular lesion is not endometrial tissue but fibromuscular tissue with sparse finger-like extensions of glandular and stromal tissue [40]. The standard MR imaging appearance of DIE lesions is isointense signal intensity compared to muscle on T2-weighted imaging with or without foci of high signal intensity, suggesting cystic changes in endometrial glands. On T1-weighted MR imaging lesions show isointense signal intensity compared to muscle with or without foci or small cysts of high signal intensity, indicating hemorrhage.

Retrocervical DIE

Deep infiltrating endometriosis is most frequently found in the retrocervical area, including the posterior vaginal fornix and torus uterinus (Fig 3). Reduced pouch of Douglas depth and volume in women with deep endometriosis suggest
that such lesions develop not in the rectovaginal septum but intraperitoneally and that burial by anterior rectal wall adhesions creates a false bottom, giving an erroneous impression of extraperitoneal origin. The rectovaginal septum is located caudally to the posterior vaginal fornix and, on the basis of normal anatomy, may therefore not be a primary site for endometriosis to develop [41]. The torus uterinus is defined by a small transverse thickening that binds the original insertion of uterosacral ligaments behind the posterior cervix. From the location of the torus uterinus or uterosacral ligaments, endometriosis may extend to the bowel wall, causing bowel wall infiltration of endometriosis.

Fig 3. A 28 year old woman diagnosed with endometriosis. A and B: Sagittal and axial T2-weighted images show a hypointense endometriotic nodule in the fornix posterior. No contact with the bowel wall is shown.

Endometriosis involving the uterine ligaments
Normal uterosacral ligaments are depicted on MR imaging as fibrous bands that form a connection between the cervix and anterior body of the sacrum. In case of involvement of the uterosacral ligament(s) with endometriosis, fibrotic thickening is found with regular or irregular margins (Fig 4) [12]. Involvement may be unilateral or bilateral, with unilateral presence being more frequently located on the left side. Although less frequent compared to the uterosacral ligaments, endometriosis is also found involving the round ligament. It also
depicts on MR imaging as fibrotic thickening with regular or irregular margins. The most reported site of involvement is the extrapelvic portion of the round ligament, also called inguinal endometriosis or abdominal wall endometriosis.

![MR Images of Endometriosis](image)

**Fig 4.** A 33 year old woman diagnosed with endometriosis. A and B: Sagittal and axial T2-weighted images show thickening of the left uterosacral ligament demonstrating hypointense signal intensity. Extension of endometriosis to the bowel is seen with infiltration of the serosa and minimal thickening of the muscularis, indicating infiltration of the muscular layer by endometriosis. Moreover thickening of the left round ligament is shown.

**DIE infiltrating the bowel**

Patients with bowel involvement of endometriosis may present with dyschezia, hematochezia, pencil-like stool or bowel obstruction. The location of pelvic DIE lesions being more frequently observed in the posterior pelvic compartment and left side is in favor of the theory of regurgitation, the effect of gravity and the importance of peritoneal fluid flow patterns in the pathogenesis of DIE. Abdominal DIE lesions (appendix, ileocaecal junction) are far less frequent than pelvic DIE lesions, and unlike these, they are most often located in the right side of the abdominal cavity [42]. Meyers et al demonstrated presence of a clockwise peritoneal fluid flow with predominant sites of repeated or arrested flow, including the pouch of Douglas at the rectosigmoid level and the left lower quadrant along the superior border of the sigmoid mesocolon and colon [43].
MR imaging depicts bowel involvement in endometriosis and may be used to assess depth of infiltration and extent of lesions. In most lesions, concomitant DIE located retrocervical is found. Lesions located in the posterior fornix may show a “continuous” or “hourglass” configuration with the rectum, whereas lesions located at the torus uterinus may show a “continuous” or “hourglass” configuration with the rectosigmoid or sigmoid. Less frequently, endometriosis located on the serosa of the uterine fundus is found to extend towards the sigmoid or DIE infiltrating the bowel shows no connection to endometriosis located retrocervical. Thickening of the muscularis propria of the bowel wall is seen, when endometriosis has infiltrated into this layer of the bowel and can be recognized by a ‘fan shaped’ hypointense lesion on T2-weighed imaging (Fig 5) with or without foci of high signal intensity, representing dilated endometrial glands [19]. Submucosal swelling (edema) may be seen as intermediate to hyperintense signal at the luminal side of the bowel wall, and is not specific for infiltration of endometriosis into this layer of the bowel [19;44]. Furthermore, the length of the affected area and distance from the anus in bowel wall involvement may be assessed on MR imaging.
Fig 5. A 29 year old woman diagnosed previously with endometriosis by laparoscopy who presented with dyschezia and hematochezia. A and B: Sagittal T2-weighted images show a lesion at the torus uterinus, demonstrating isointensity compared to muscle. In contact with this lesion, thickening of the muscular layer of the bowel wall is shown (fan-shaped configurations), demonstrating hypointense signal intensity that indicates infiltration of endometriosis into the muscularis (arrows). Furthermore thickening of the (sub) mucosal layer of the bowel is shown, demonstrating hyperintense signal compared to muscle, indicating edema with or without infiltration of endometriosis into this layer of the bowel wall. C: Microscopic view of the operation specimen shows endometriosis infiltrating the muscularis propria (black curved arrow). Thickening and distortion of the muscular layer of the bowel is shown, as a consequence of infiltration by endometriosis.
**DIE infiltrating the bladder**

DIE infiltrating the bladder wall is predominantly found in patients with extensive DIE, but may also develop after uterine surgery, in most cases a caesarean section. Patients may present with dysuria, hematuria and pollakisuria. The majority of lesions are located in the posterior bladder wall in front of the vesico-uterine pouch. This can be explained by the theory of Sampson, as intraperitoneal regurgitated endometrial cells seed in the most dependent portions of the peritoneal cavity [5] (Fig 6). Characteristic features of bladder endometriotic lesions on MR imaging are small (submucosal) hemorrhagic cysts within the lesion, demonstrating high signal intensity on T1-weighted imaging and low signal intensity on T2-weighted imaging [45]. Different reports exist on involvement of the anterior uterine wall in bladder endometriotic lesions. Fedele et al [46], found that when excision of bladder endometriosis included both the bladder lesion and 0.5-1 cm deep portion of the adjacent myometrium, recurrence was less frequent. This may be explained by involvement of the anterior uterine wall in bladder endometriotic lesions. Previously, involvement of the anterior uterine wall, described on MR imaging, was found to be present in almost all patients [45]. Bladder endometriotic lesions showed a continuous or hourglass configuration with the anterior uterine wall.

**DIE involving the vaginal vault**

Endometriosis at the vaginal vault following hysterectomy has only been sparsely described previously [47]. Patients may present with a regular menstrual type of bleeding after hysterectomy, deep dyspareunia and chronic pelvic pain. The differential diagnosis includes atrophic vaginitis, vaginal vault granulation and infiltrating ovarian tumors. It may be difficult to differentiate between vaginal vault endometriosis and scar tissue on MR imaging. Foci of high signal intensity within the lesion on T2-weighted imaging, or foci of high signal intensity on T1-weighted imaging, may indicate presence of DIE within the vaginal vault. Vaginal vault endometriosis is thought to develop if an ovary or the bowel with functional endometriosis gets adherent to the vaginal vault, or if endometriosis located in the anterior or posterior cul-de-sac, not recognized during surgery, is left behind in the vaginal vault [48]. Moreover, we hypothesize lack of post-surgical therapeutic hormonal treatment in pre-menopausal patients (e.g. gonadotrophin-releasing
hormones) may cause progression and pain symptoms of endometriosis located at the vaginal vault. Laparoscopic vaginal apex excision is an effective management option, after carefully excluding other causes of deep dyspareunia and chronic pelvic pain [47;49].

**Fig 6.** A 37 year old patient known with endometriosis infiltrating the bladder (diagnosed by previous laparoscopy). A, B, C and D: Sagittal and coronal T2-weighted and fatsuppressed T1-weighted images show endometriosis infiltrating the bladder wall, demonstrating isointense signal compared to muscle, with foci of high signal intensity on T2-weighted, due to dilated endometrial glands and small cysts on T1-weighted imaging, due to hemorrhage (white arrows).

**Endometriosis involving the sciatic nerve**
Endometriosis involving the sciatic nerve is very rare. Only a small group of cases has been described in literature previously. Symptoms include cyclic sciatica and muscle weakness. The pain is intense with a pain free interval that gradually shortens.
and may become permanent after a few years. There is a clear predominance of sciatic pain on the right side. It has been suggested that the sigmoid impedes the implantation of endometriosis nodes on the left sciatic nerve [50]. MR imaging depicts infiltration of the sciatic nerve by endometriosis (Fig 7), and associated denervation of target muscles. Usually, concomitant extensive endometriosis of the sacro-uterine ligament is found that extends towards the sciatic nerve.

**Fig 7.** A 28 year old woman who presented with sciatic pain in the right leg. A and B: Sagittal and axial T2-weighted images show a lesion in the right fossa obturatorius that infiltrates the sciatic nerve (arrow), demonstrating isointense signal compared to muscle. Denervation of the right obturatorius and piriformis muscles is prominent. Moreover extension of the lesion to the bladder with infiltration of the posterior bladder wall and DIE located at the rectosigmoid are shown (curved arrow).

**Extrapelvic endometriosis**

**Abdominal wall endometriosis**

The abdominal wall is the most common location of extrapelvic endometriosis. Patients may present with cyclic or continuous pain symptoms of an abdominal wall mass of which the size may fluctuate during the menstrual cycle. There are different theories regarding the pathogenesis. Most lesions are found in a surgical scar, whereas a minority of lesions develop in patients without a history of surgery. Scar endometriosis is thought to develop from dissemination of endometrial tissue during surgery. Theories regarding the pathogenesis of abdominal wall
endometriosis in patients without a history of surgery, include, extension of endometriosis of the round ligament, facilitated transportation of endometrial tissue by a herniation of the abdominal wall and lymph- or hematogenic dissemination. Inguinal endometriosis is right-sided in most cases and is often found to be associated with inguinal hernias. Endometrial tissue may implant in the inguinal tissues, because a patent canal of nuck provides communication between the peritoneal cavity and the inguinal canal [51]. Endometriotic lesions of the abdominal wall may be diagnosed with US or MR imaging, although MR imaging is useful for the assessment of extension to surrounding tissues [52;53]. On MR imaging lesions show isointense to muscle on T2-weighted imaging with or without foci of high signal intensity, representing cavities filled with fluid and iso- to slightly hyperintense on fat-suppressed T1-weighted imaging (Fig 8).

**Fig 8.** A 30 year old woman who presented with a painful mass in the right inguinal region that increased in size during menses. A, B and C: show a lesion in the aponeurosis of the right oblique muscle that demonstrated isointense signal compared to muscle with foci of high signal intensity within, indicating fluid. D: Axial T1-weighted image shows slightly hyperintense signal compared to muscle.
Thoracic endometriosis, diaphragmatic endometriosis and catamenial pneumothorax

Thoracic endometriosis (TE) and diaphragmatic endometriosis are very rare. They are often a diagnostic challenge, but scapular or thoracic pain during menses was found to be highly specific for diagnosis of TE [54]. Patients also frequently present with catamenial pneumothorax and recurrent pneumothorax. There are different theories regarding the pathogenesis of catamenial pneumothorax, but the most accepted is that it is caused by diaphragmatic deposits of endometriosis nodules and perforations, that can be explained by Sampson’s theory of retrograde menstruation and an understanding of the peritoneal circulation [55]. Involvement of the right side of the diaphragm occurs significantly more frequently than does involvement of the left side [56]. As laparoscopy, thoracoscopy and CT are predominantly used to assess diaphragmatic and TE, MR imaging features are not well known. In one case report, a diaphragmatic endometriotic mass shows heterogeneous signal intensity on T2- and T1-weighted imaging with foci of high signal intensity on T1-weighted imaging and corresponding low signal intensity on T2-weighted images, indicating hemorrhage [57].

Hepatic endometriosis

Hepatic endometriosis is extremely rare. It may present as liver tumour and the diagnosis is not usually made till after surgery. Ultrasound (US), computed tomography (CT) and MR imaging are used for diagnosis. Only a couple of cases in which MR imaging features are described have been reported in literature. On MR imaging hepatic endometriosis appears heterogeneous on T2-, T1- and T1-weighted imaging after gadolinium injection, with predominant high signal intensity on T2-weighted imaging [58]. Although malignant tumours arising in endometriosis are very uncommon, adenosarcoma arising in hepatic endometriosis has been described previously [59].

Complications

Hydroureteronephrosis

Hydroureteronephrosis is a serious complication of extensive DIE. In most cases it is caused by progressive enclosure of the ureter by endometriosis, also called extrinsic
ureteral endometriosis (Fig 9) [60]. Ureteral endometriosis has been estimated to be present in 0.3-1.5% of endometriosis patients. The lesion is usually unilateral, left-sided, and found in the distal third of the ureter [61]. Patients with ureteral endometriosis often present with non-specific symptoms. European guidelines (ESHRE) recommend US (trans-rectal and/or trans-vaginal and/or renal), or MR imaging in patients suspected of DIE. In some hospital centres, MR imaging is not included in the standard work-up of these patients and US does not always include renal assessment. In our experience, diagnosis of hydroureteronephrosis is therefore often delayed [62]. Unfortunately, however, ureteral endometriosis may lead to hypertension and silent renal loss, making early diagnosis critical.

Fig 9. A 35 year old woman diagnosed previously with endometriosis by laparoscopy. She was analysed for chronic pelvic pain elsewhere and a left hydroureter was found incidentally. A renogram showed the function to be less than 10% compared to the right, normal ureter. Blood creatinine level was normal. A-C: Sagittal, coronal and axial T2-weighted images show an extensive DIE lesion with involvement of the left SU ligament (arrow) and infiltration of the bowel wall (curved arrow). A-D: hydroureteronephrosis with thinning of the renal cortex is shown as a consequence of obstruction by DIE.
Tubo-ovarian abscess

The presence of endometrioma is a risk factor for the development of a tubo-ovarian abscess (TOA) [63]. Introduction of pathogenic organisms into ovarian endometriomas usually follows surgical drainage or aspiration, but may also develop spontaneously [64]. US, CT and MR imaging are all used in the diagnostic work-up for pelvic inflammatory disease (PID) and ovarian abscess (Fig 10).

**Fig 10.** A 34 year old patient, known with endometriosis previously, whom presented with progressive pelvic pain, nausea, vomiting and irregular menstrual bleeding. A and B: T2-weighted and fat suppressed T1-weighted imaging show extensive pelvic abscesses, probably tubo-ovarian of origin, demonstrating intermediate signal intensity on both T2- and T1-weighted imaging. C: diffusion-weighted image (b-value 1200 s/mm$^2$) shows high signal intensity of the masses. D: corresponding ADC map; the calculated ADC value ranged from 0.50 to 0.90 x 10$^{-3}$ mm$^2$/s, indicating restricted diffusion, and therefore suspect for a tubo-ovarian abscess.
Only one previous study compared the accuracy of US and MR imaging for diagnosis of PID. MR imaging was compared to US and laparoscopy. The overall accuracies for diagnosis by MR imaging and US were 93% and 80%, respectively. Moreover, MR imaging provided more information about the differential diagnosis and showed a higher accuracy in diagnosis of pelvic abscess.

**Malignant transformation**

Tumors arising from endometriotic cysts include clear cell, endometrioid carcinomas and mullerian mucinous borderline tumors. The risk of developing ovarian cancer was demonstrated to be elevated in patients with endometrioma. Clear cell adenocarcinoma is the most common endometriosis-associated ovarian cancer, followed by endometrioid cancer [65;66]. Advancing age (>45 years) and the size of the endometriomas (>9 cm) were independent predictors of the development of ovarian cancer among women with ovarian endometrioma [67]. To differentiate blood clots (Fig 11) from malignant mural nodules within endometrial cysts, contrast-enhanced imaging may be used. Contrast enhanced mural nodules on T1-weighted images after the administration of a contrast medium are suggestive of malignancy [68], but enhanced mural nodules are not always complicated with malignancy. Endometriotic cysts complicated with malignancy often lack shading and show high signal intensity on T2-weighted imaging. The high signal intensity may be caused by dilution of thick hemorrhagic fluid by non hemorrhagic fluid produced by the malignant tumors, although this may be observed in benign endometrial cysts as well. Moreover, blood clots are characteristically located in the dependent portion of the cyst.

Mucinous cystic tumors typically demonstrate as a multilocular cystic mass. The signal intensity of each loculus varies based on the viscosity of contents, blood products, or debris [69]. Mullerian mucinous borderline tumors arising in endometrial cysts were described previously to show a different appearance on MR imaging compared to intestinal type mucinous tumors. Fluid contents within tumors exhibited high signal intensity on T2- and T1-weighted images and mural nodules showed prominent high signal intensity on T2-weighted imaging.
A 38 year old woman diagnosed with endometriosis. A: Sagittal T2-weighted image shows an endometrial cyst of the right ovary, demonstrating intermediate signal with a large hypointense nodule in the dependent portion of the cyst with coexisting septations. B: Sagittal T1-weighted image shows hyperintensity of the cyst, indicating hemorrhage and a varying signal intensity of the nodule within. Cystectomy of the right ovary was performed by laparotomy. C: Histopathologic evaluation shows cyst wall with endometrial stroma and hemorrhage (black curved arrow). D: The nodule within the endometrial cyst consists of a blood clot with fragments of endometrium and fibrin (black arrow).
Optional techniques

Vaginal or rectal gel opacification
In most cases, endometriotic lesions, which are fibromuscular structures, have an MR imaging signal intensity very close to that of the surrounding fibromuscular structures. In this regard, vaginal and rectal distension and opacification using ultrasound gel may help to delineate the cervix, vaginal fornices, and vaginal wall, as well as the rectum and wall of the rectosigmoid colon junction [70]. Several groups assessed the use of vaginal or rectal gel opacification for diagnosis of deep infiltrating endometriosis [28;71-74]. Although data suggest that there may be a benefit of the administration of vaginal and rectal gel contrast, there is no consensus following these study outcomes. We conclude administration of rectal and vaginal gel contrast may be used as an optional technique in the assessment of deep infiltrating endometriosis.

Diffusion-weighted imaging
Diffusion-weighted imaging (DWI) was previously evaluated in endometrial cysts and deep infiltrating endometriosis. Some preliminary studies showed, ADC values have about the same ability to differentiate endometrial from other pelvic cysts as do signal intensity on T1- and T2-weighted images [75;76]. ADC values were also found to correlate with T2 signal intensity ratios in endometrial cysts that show shading on T2-weighted imaging [77]. However, DWI may be added to the standard imaging protocol in specific cases evaluated for endometriosis. Takeuchi et al showed that DWI may be helpful in the differentiation between decidualized ovarian endometriosis and ovarian malignancy during pregnancy [78]. During pregnancy, the uterine endometrium transforms into a dense highly vascularised cellular matrix known as decidua. This process can also occur in endometriomas. On MR imaging, decidualized endometrioma appear as solid nodules within a cystic ovarian mass, a finding that is classically indicative of malignant transformation. In a previous study, the apparent diffusion coefficient (ADC) of decidualized mural nodules was significantly higher than that of malignant mural nodules of 7 ovarian cancers. Signal intensity similar to uterine decidua on MR imaging and a high ADC value are suggestive of decidualisation of ovarian endometriosis.
In deep infiltrating endometriosis, calculated ADC values of lesions were consistently low and lesions showed low signal intensity on high $b$-value diffusion-weighted images [77]. Therefore, in cases in which differentiation between colorectal carcinoma and endometriosis infiltrating the bowel wall is difficult, DWI in addition to conventional MR imaging may help to differentiate between them, as colorectal carcinoma demonstrates high signal intensity on high $b$-value diffusion-weighted images [79]. Finally, we hypothesize that DWI may be useful in case of suspected PID or tubo-ovarian abscess (TOA), although to the best of our knowledge no studies are performed regarding DWI in PID. DWI may have additional value to determine the extent of infection, as it shows high signal intensity on high $b$-value diffusion-weighted images and low signal on the apparent diffusion coefficient map in case of TOA.

**Potential future applications**

Recent technological advances in MR imaging, including the implementation of 3T systems and the development of new MR sequences, provide promising future applications for the diagnostic work-up of endometriosis. MR imaging performed with a 3T system provides higher spatial and contrast resolution compared to 1.5T. Possible disadvantages, caused by the higher field strength, include a higher SAR (specific absorption rate) and radiofrequency field inhomogeneity. Use of 3T MR imaging in two previous studies showed high accuracies for diagnosis of deep infiltrating endometriosis [15;80]. Furthermore, the shading sign in endometrial cysts on T2-weighted images and signal voids along the cyst wall (due to hemosiderin estoposition) on susceptibility-weighted images were demonstrated to be more prominent on 3T MR imaging [31;81]. To overcome field inhomogeneity, using 3T MR imaging in the female pelvis, a multipoint Dixon technique was recently proposed to replace conventional fat suppressed T1-weighted images. It has the potential to be made highly insensitive to magnetic field inhomogeneity [82]. In previous studies the dual echo Dixon sequence achieved stronger fat suppression in the female pelvis compared to a fat suppressed sequence with spectral inversion at lipids and chemical shift selective saturation [83;84].
Another recently proposed sequence that may add value to female pelvic MR imaging is a 3DT2-weighted sequence, as this sequence allows retrospective free alignments of images according to anatomic/pathologic structures [85]. Previously, 3DT2-weighted imaging was studied in the pelvis at 1.5 and 3.0T and compared with conventional 2DT2-weighted imaging [86-88]. The 3DT2-weighted SPACE MR imaging caused substantial time saving in comparison with conventional multiplanar 2D turbo spin-echo MR imaging, with similar image quality and diagnostic accuracy [89].

**Conclusion**

MR imaging, in addition to TVS may be used to provide a complete overview of the (anterior and posterior compartments) of the pelvis in patients evaluated for endometriosis and may also add in diagnosis of complications of endometriosis. New imaging techniques, including 3T MR imaging and 3D sequences, recently proposed for female pelvic imaging and endometriosis show promising results for future applications.
References


