Chapter 8

Discussion and general conclusions
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The purpose of this thesis was to gain new insights into MR imaging of (deep infiltrating) endometriosis and explore advanced imaging techniques, including diffusion-weighted MR imaging and 3DT2-weighted imaging with a high sampling efficiency technique (SPACE). We aimed to describe the MR imaging appearance of DIE lesions and endometriosis located in the abdominal wall and correlate imaging findings to histopathology, where possible. Diffusion-weighted MR imaging and 3DT2 (SPACE) MR imaging were evaluated for their role in diagnosis and the preoperative assessment of DIE lesions.

Deep infiltrating endometriosis

To help improve diagnosis of DIE, we described the appearance of endometriosis infiltrating the bowel and bladder wall. MR imaging findings were correlated to findings at histopathology, where possible. We found that lesions infiltrating the muscularis of the bowel showed a standard, fan shaped configuration, depicting hypointense signal intensity on T2-weighted MR imaging. At histopathology, this configuration correlated to thickening of the muscularis, as a consequence of infiltration of endometriosis into this layer of the bowel. Previously, endometriosis with bowel involvement was described as a “mushroom cap” configuration on MR imaging [1], although no lesions that infiltrated the bowel over a long distance were included in this study. We found that in more extensive lesions, the “mushroom cap” appearance may not be recognized anymore. In 28 patients who underwent segmental bowel resection, the sensitivity, specificity and accuracy for diagnosis of infiltration of the muscular layer of the bowel wall on MR imaging were 100%, 75% and 96%. Patients who undergo segmental bowel resection, are in general patients with more extensive disease. Therefore a bias exists, as most lesions infiltrated the muscular layer of the bowel wall in our patient group.

MR imaging showed accurate diagnosis of endometriosis with bowel wall involvement previously [2,3]. In one previous study a distinction was made between the different layers of the bowel wall [3]. In this study, bowel wall infiltration on MR imaging was shown to correlate highly with findings at histopathology. However, only a small group of patients was assessed and
readers gave colon wall invasion scores that were higher than scores at pathologic examination in a couple of patients.

We also showed that thickening of the submucosa may be recognized by high signal intensity on T2-weighted imaging at the luminal side of the bowel wall, confirming results of a previous study [1]. Thickening of the submucosa was present in all lesions diagnosed with endometriosis infiltrating the muscular layer of the bowel and probably caused by edema and lymphocytic infiltration [4]. This submucosal thickening is not specific for infiltration of endometriosis into this layer, but may be caused by underlying endometriosis.

Endometriosis infiltrating the bladder wall showed homogeneously or heterogeneously isointens signal intensity compared to muscle on T2- and fat-suppressed T1-weighted MR imaging in almost all cases. In the majority of cases foci of high signal intensity on T2-weighted MR imaging were present, suggesting dilated endometrial glands and foci or small cysts of high signal intensity were depicted on T1-weighted MR imaging, indicating hemorrhage. These small hemorrhagic cysts were present in 59% of cases and predominantly found in the submucosal layer of the bladder wall. Small intralesional hemorrhagic cysts have not been described in other bladder lesions and may therefore be valuable for diagnosis.

On MR imaging we demonstrated that involvement of the anterior uterine wall in bladder endometriosis is present in the majority of cases and showed a “continuous” or “hourglass” configuration with the bladder lesion. In only a small group of patients adenomyosis of the anterior uterine wall was found, supporting previous studies [5,6]. These findings do not confirm the uterus-vesical adenomyosis extension theory, which states that adenomyosis of the anterior uterine wall extends to the bladder. A previous study demonstrated that if resection of bladder endometriosis included both the bladder lesion and 0.5-1 cm of the anterior uterine wall, recurrence was less frequent [7]. An explanation proposed by the authors stated that recurrences may arise from adenomyosis of the anterior uterine wall. Results of our study confirm recurrences may arise from endometriosis of the anterior uterine wall that is not excised with the lesion. Involvement of the anterior uterine wall however is in general not in contact with the junctional zone, and should therefore not be referred to as adenomyosis.
Frequent involvement of the anterior uterine wall in bladder endometriosis may be explained by the seeding theory, which states endometriosis develops secondary to intraperitoneal seeding of endometrial cells [8].

**Abdominal wall endometriosis**

We described the appearance of abdominal wall endometriosis (AWE) on MR imaging in a group of 10 patients. Abdominal wall endometriosis develops in a surgical scar in the majority of patients, but may also be found in patients without previous surgery. In most patients the lesion was located in the rectus abdominis or ventrally or dorsally to the aponeurosis of the rectus oblique muscle. Lesions showed a standard MR imaging appearance, depicting hypointense signal intensity compared to muscle on T2-weighted imaging and slightly hyperintense signal on T1-weighted imaging with or without foci of high signal intensity on T2- or T1-weighted imaging. Depending on the site and size of AWE, treatment options include hormonal therapy and surgery. Hormonal treatment may help to reduce symptoms, but recurrence is common after discontinuation of treatment [9]. To avoid recurrence, wide excision is recommended. Size of the lesion and extent of the mass, especially when it involves the rectus abdominis muscle or peritoneum, have shown to be risk factors for recurrence [10]. MR imaging may be valuable to determine the location and depth of infiltration in surrounding tissues preoperative to surgery.

**Advanced imaging techniques**

New imaging sequences, recently proposed for pelvic imaging, include diffusion-weighted MR imaging and 3DT2-weighted MR imaging. We evaluated the use of diffusion-weighted MR imaging in the standard MR imaging protocol for (deep infiltrating) endometriosis. Results showed ADC values in DIE are consistently low with no significant difference between pelvic locations (Mean ADC value in endometriosis located retrocervical: \(0.70 \times 10^{-3}/\text{mm}^2/\text{s}\); rectosigmoid: \(0.77 \times 10^{-3}/\text{mm}^2/\text{s}\); bladder: \(0.79 \times 10^{-3}/\text{mm}^2/\text{s}\)). This confirms a previous study, in which DIE lesions showed similar smooth muscle components, independent of their location [11]. The diffusion restriction may be explained by fibrosis and smooth muscle components present at histopathology.
Diffusion-weighted MR imaging was also performed in patients diagnosed with colorectal carcinoma to assess if DWI has additional value to differentiate between colorectal carcinoma and endometriosis infiltrating the bowel. We showed ADC values in endometriosis infiltrating the bowel were significantly lower compared to ADC values in colorectal carcinoma, but due to a considerable overlap, quantitative DWI is not able to help differentiate between them. DIE lesions depicted low signal intensity on high $b$-value diffusion-weighted images, which may be referred to as the T2-black-out effect [12]. The low signal intensity on high $b$-value images may be valuable to help differentiate endometriosis infiltrating the bowel and colorectal carcinoma, as colorectal carcinoma shows high signal intensity on high $b$-value images, as a consequence of a high cellularity of these lesions. In most patients, differentiation between DIE infiltrating the bowel and colorectal carcinoma is facilitated by clinical and imaging features. Occasionally, clinical features are not specific and imaging techniques performed may not show characteristic signs. In these cases, qualitative assessment of high $b$-value diffusion-weighted MR imaging, in addition to conventional MR imaging, may help to differentiate between them.

In endometrial cysts that demonstrated shading on T2-weighted imaging, the calculated mean ADC value was $1.10 \times 10^{-3} \text{mm}^2/\text{s}$. These results are comparable to previous reports [13,14], although mean ADC was slightly higher in our study. This may be explained by a slightly higher percentage of T1 hyperintense lesions with a slightly hyperintense aspect (low grade of shading) on T2-weighted imaging in our study. ADC values showed considerable variation and were almost linearly related to the degree of shading found on T2-weighted imaging. We hypothesized that diffusion-weighted MR imaging may have no additional value for the differentiation between endometrial cysts and other ovarian cysts.
The mean ADC value in AWE was also decreased (0.93 x 10^{-3}/mm^{2}/s), but higher compared to the mean ADC values in DIE. In a previous study, ADC values in desmoid tumors (range: 1.2 to 1.9 x 10^{-3}/mm^{2}/s) and nodular fasciitis (1.1 and 2.3 x 10^{-3}/mm^{2}/s) were higher compared to ADC values in AWE [15]. ADC values may therefore be valuable to help differentiate AWE from other lesions, but more patients should be studied to confirm findings. The higher ADC values in AWE compared to DIE may be explained by a difference in tissue composition, as histology of DIE lesions shows stroma and glands surrounded predominantly by smooth muscle and some fibrosis, and AWE lesions show stroma and glands surrounded by fat, fibrosis and in case they are located in the rectus abdominal muscle by striated muscle.

Recently, a 3DT2-weighted MR imaging (SPACE) sequence has been proposed for female pelvic MR imaging. This sequence was previously studied in the pelvis at 1.5 and 3.0T [16-19] and was compared with conventional 2DT2-weighted MR imaging. 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 [16,17]. However, in our centre there is no time saving comparing the 2DT2- and 3DT2-weighted MR imaging. An advantage of the 3D SPACE sequence is that it allows retrospective free alignments of images according to anatomic/pathologic structures. The versatility of the 3D SPACE sequence also aids in standardizing pelvic MR imaging protocols for all indications. In our study, excellent inter-rater agreement for diagnosis of DIE was obtained using 3DT2 and 2DT2 MR imaging. The 3DT2-weighted sequence provided higher diagnostic confidence scores compared to 2DT2 and significant higher diagnostic confidence scores were obtained using a combination of 3DT2 and 2DT2 MR imaging compared to 2DT2 alone in retrocervical endometriosis and endometriosis with bowel involvement. However, 3DT2 showed significantly more artefacts and a lower overall image quality, compared to 2DT2. This was also described in a previous study on 3DT2-weighted MR imaging in rectal carcinoma, using 3T [19]. Therefore, the 3DT2-weighted MR imaging sequence may not completely replace 2DT2, but may be used in addition to 2DT2-weighted MR imaging in a single plane, to limit examination time.
Future perspectives
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 [3,20]. Furthermore, the shading sign in endometrial cysts on T2-weighted images and signal voids along the cyst wall (due to hemosiderin deposition) on susceptibility-weighted images were demonstrated to be more prominent on 3T MR imaging [21,22].
References


