Magnetic resonance imaging of deep infiltrating endometriosis: comparison of a 2DT2-weighted TSE sequence and 3DT2-weighted TSE sequence with high sampling efficiency (SPACE)
Abstract

Objective: The purpose of this study is to compare image quality and diagnostic confidence of 3DT2 (SPACE) and 2DT2 MR imaging for the evaluation of deep infiltrating endometriosis (DIE).

Materials and Methods: A total of 121 patients, referred for MR imaging because of suspected DIE with bowel involvement underwent both 2DT2 and 3DT2 MR imaging.

Two independent readers assessed both datasets for presence of DIE, artefacts and overall image quality. Inter-rater agreement scores were calculated using Cohen’s kappa and image quality and diagnostic confidence scores were compared using the Wilcoxon ranked-sum test.

Results: Inter-rater agreement scores for diagnosis of DIE using both 3DT2 SPACE and 2DT2, or solely 3DT2 and 2DT2 were excellent. Diagnostic confidence scores were similar for 3DT2 and 2DT2. Analysis of both the 3DT2 and 2DT2 dataset showed significant higher diagnostic confidence compared to solely 2DT2 for one location, which differed per reader. 2DT2 showed significantly lower artefacts and a higher overall image quality (p=0.006; p=0.000, respectively).

Conclusion: Although 3DT2 SPACE could replace routine 2DT2-weighted imaging, authors prefer 2DT2 over 3D, because of significantly less artefacts and a higher overall image quality with almost similar diagnostic confidence scores. 3DT2 might be added to the standard protocol in indistinctive cases.
Introduction

MR imaging is valuable for diagnosis of deep infiltrating pelvic endometriosis (DIE) and has shown a high accuracy previously (1,2). Furthermore, preoperative assessment of disease extension in DIE is essential to decide whether surgical intervention is indicated and to choose an adequate surgical technique (3,4). The standard MR imaging protocol for endometriosis includes 2DT2-weighted sequences in multiple planes (1,5). T2-weighted images are valuable for detection and anatomical localization of disease. Recently, a new imaging sequence, the 3DT2-weighted SPACE sequence (Sampling perfection with application optimized contrasts using different flip angle evolutions) was developed, that combines highly resolved 3D datasets with high soft tissue contrast (6). Previously, in body MR imaging, 3DT2 was studied in the liver (7), spine (8), knee (9) and pelvis (10-12). In the pelvis, 3DT2 was performed at 1.5 and 3.0T and compared with conventional 2DT2-weighted imaging (11-14). The 3DT2-weighted sequence caused substantial time saving in comparison with conventional multiplanar 2D turbo spin-echo (TSE) MR imaging, with similar image quality and diagnostic accuracy (11). However, in the preoperative assessment of the rectal cancer, 3DT2 caused more motion artefacts, compared to conventional 2DT2 (14).

If it is possible to achieve similar image quality and diagnostic performance in endometriosis, using 3DT2 SPACE compared to 2DT2 sequences, the latter may be replaced, giving the possibility of retrospective free alignment of images according to anatomic/pathologic structures. This may be especially valuable in the preoperative assessment of extension of endometriotic lesions. The purpose of this study is to compare image quality and diagnostic confidence between 3DT2 SPACE and conventional 2DT2 MR imaging in the evaluation of DIE.

Materials and methods

Study Population

This prospective study was performed in a tertiary referral center for endometriosis between January 2009 and January 2011. The institutional review board (IRB) granted permission; the requirement for informed consent was waived.
A total of 121 patients were included (average age: 35; range 20 to 51). During the study period, 3DT2 SPACE was added to the routine imaging sequences for patients with suspected bowel involvement. Diagnosis of endometriosis was based on a combination of clinical information, clinical examination, imaging techniques (transvaginal ultrasonography and MR imaging) and pathology.

**MR imaging**

MR imaging of the pelvis was performed at 1.5 Tesla (Avanto, Siemens, Erlangen, Germany) using a pelvic phased-array coil, and included high resolution turbospin echo (TSE) T2-weighted imaging in the axial, coronal, and sagittal plane; fat-suppressed spin echo T1 weighted imaging in the axial and sagittal planes; and coronal T2-weighted 3D TSE with SPACE, using a multislice technique. No intravenous contrast enhancement was used (15). Prior to the 3D TSE sequence, all patients underwent intravenous administration of 20mg butylscopolamine (Buscopan; Boehringer Ingelheim, Alkmaar, The Netherlands) to prevent peristalsis artefacts.

The sequences were performed in the following order: 2DT2 / 2DT1 (with fat suppression) / 3DT2 SPACE. Detailed imaging parameters of the 2D and 3DT2-weighted sequences are shown in Table 1. The SPACE datasets were reconstructed, 3mm slice thickness images in the sagittal, axial and coronal plane with the possibility to perform arbitrary chosen additional reconstructions. All reconstructions were created in a standard multiplanar reconstruction (MPR) tool available within the local PACS system and then saved in the patients’ image database. Reader 1 performed additional reconstruction in 4 cases and reader 2 in one case.

**MR analysis**

Examinations were analysed on a picture archiving and communication system (Sectra RIS/PACS) viewing station (Sectra Imtec AB, Linköping, Sweden) using standardized data scoring sheets.

Two abdominal radiologists scored the data. First the standard sequences were analysed in combination with 2DT2. Next, after a time interval of at least 4 weeks, to avoid recall bias, the 3DT2 dataset was analysed, first without 2DT2 (but with the other standard series, including fat suppressed T1), and then in combination with 2DT2. Finally, both radiologists marked the sequence of preference for their final diagnosis.
Table 1. Imaging parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sagittal 3D TSE T2-weighted sequence with a high sampling efficiency technique (SPACE)</th>
<th>Three plane 2D TSE T2-weighted sequence</th>
<th>Two plane 2D TSE T1-weighted sequence (fat sat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR (ms)</td>
<td>1500</td>
<td>6000-10000</td>
<td>740-790</td>
</tr>
<tr>
<td>TE (ms)</td>
<td>131</td>
<td>136</td>
<td>19</td>
</tr>
<tr>
<td>Echo-train length (ms)</td>
<td>85</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>Flip Angle (degrees)</td>
<td>a</td>
<td>180</td>
<td>90</td>
</tr>
<tr>
<td>Matrix size (x)</td>
<td>384 x 386</td>
<td>512 x 326 to 435</td>
<td>256x144 (sag) 320x180 (ax)</td>
</tr>
<tr>
<td>Interslice gap (mm)</td>
<td>0</td>
<td>0.8-1.2</td>
<td>0.8-1.2</td>
</tr>
<tr>
<td>Slice thickness (mm)</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Field of view (mm)</td>
<td>400</td>
<td>350 to 400</td>
<td>350-400</td>
</tr>
<tr>
<td>Scanning plane</td>
<td>Sagittal</td>
<td>Axial, sagittal, and coronal</td>
<td>Axial and sagittal</td>
</tr>
<tr>
<td>Acquisition time (min)</td>
<td>8</td>
<td>3 planes ~ 8/9</td>
<td>2 planes ~5</td>
</tr>
</tbody>
</table>

* Flip angles of the refocusing pulses in SPACE are variable.

The radiologists independently evaluated the image quality on the basis of severity of artefacts and overall image quality. Artefacts were graded on a 4-point scale (1 = severe artefacts; 2 = diagnostic relevant artefacts; 3 = diagnostic irrelevant artefacts; 4 = no artefacts (Fig 1)) and overall image quality was graded on a 5-point scale (1 = improper quality; 2 = not optimal quality; 3 = proper quality; 4 = good quality; 5 = excellent quality). Presence of DIE located retrocervical/vaginal cuff, infiltrating the bowel wall or infiltrating the bladder was graded on a 5-point scale (1 = definitely absent; 2 = probably absent; 3 = possibly present; 4 = probably present; 5 = definitely present). In seven patients that underwent hysterectomy prior to MR imaging evaluation, the vaginal cuff was assessed for presence of endometriosis.

Mean times for analysis of the different datasets were recorded and calculated. The following criteria were used for diagnosis of DIE: the joint presence of signal
Fig 1. A 31 year old patient diagnosed with endometriose ASRM (American Society for Reproductive Medicine) stage 4 endometriosis elsewhere, who presented with dyschezia. Both readers scored positive for endometriosis infiltrating the sigmoid, assessing the 2DT2 dataset, 3DT2 dataset and 3DT2 dataset in addition to the 2DT2 dataset. A: Sagittal 2DT2-weighted image shows endometriosis infiltrating the rectosigmoid, demonstrating isointense signal intensity compared to muscle (white arrow). B: Sagittal 3DT2-weighted image image (after administration of buscopan) shows almost the same imaging plane, endometriosis infiltrating the rectosigmoid is recognized (white arrow). Reader 1 scored diagnostic relevant artefacts assessing 3DT2, and “no artefacts” assessing the 2DT2 dataset. Reader 2 scored “no artefacts” assessing both the 2DT2 and 3DT2 dataset.

intensity abnormalities (hyperintense foci that corresponded to hemorrhagic foci on T1-weighted fat-suppressed MR images, small hyperintense cavities observed on T2-weighted MR images that corresponded to dilated endometrial glands and tissue areas that corresponded to fibrosis, with signal intensity close to that of pelvic muscle on T1- and T2-weighted MR images) and morphologic abnormalities, as previously described (1). Additional criteria regarding endometriosis infiltrating the muscular layer of the bowel wall included: thickening of the muscularis, showing a “fan shaped” configuration with isointense signal compared to muscle on T2-weighed MR images (Fig 2) with or without thickening of the (sub)mucosa that demonstrated slightly high to high signal intensity at the luminal side of the bowel wall (5).
**Statistical analysis**

Statistical parameters (e.g. mean and standard deviation) were calculated using the Statistical Package for Social Sciences, version 15.0 (SPSS, Inc., Chicago, IL). The Wilcoxon ranked-sum test was used to compare image quality and diagnostic confidence scores of 3DT2 SPACE and 2DT2-weighted sequences. Diagnostic confidence was assessed using a 3-point scale. Images graded as 5 “definitely present” or 1 “definitely absent” were assigned 3 points, images graded as 4 “probably present” or 2 “probably absent” were assigned 2 points and images graded as 3 “possibly present” were assigned 1 point. A p-value of less than 0.05 was considered statistically significant.

The inter-rater agreement scores were calculated using Cohen’s kappa coefficient. Presence of deep infiltrating endometriosis was defined by taking together scores 3 to 5. The degree of agreement was defined according to Landis and Koch (<0: no agreement; 0.00-0.20: slight agreement; 0.21-0.40: fair agreement; 0.41-0.60: moderate agreement; 0.61-0.80: substantial agreement; 0.81-1.00: excellent agreement).

**Results**

**MR imaging**

MR imaging diagnosed endometriosis in 103 out of 121 patients. In 60 patients presence of endometriomas was found. Endometriosis was located retrocervical in 88 patients and in the vaginal cuff in 5 out of 121 patients. Bladder and bowel involvement of endometriosis were diagnosed in 13 and 65 patients (out of 121 patients), respectively. The 2DT2 sequence showed significantly less artefacts and a higher overall image quality compared to 3DT2 SPACE (Table 2 / Fig 3).

**Table 2.** Image quality comparison between 2D and 3DT2-weighted datasets, as scored by two independent readers

<table>
<thead>
<tr>
<th>Image quality</th>
<th>Mean score 2D</th>
<th>Mean score 3D</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artefacts</td>
<td>3.3</td>
<td>3.1</td>
<td>0.006</td>
</tr>
<tr>
<td>Overall image</td>
<td>4.1</td>
<td>3.6</td>
<td>0.000</td>
</tr>
</tbody>
</table>

* Means of the scores of 121 patients scored by two independent readers.
* Scoring on a 4 point scale.
* Scoring on a 5 point scale.
Both readers preferred to analyze the 2DT2 dataset over the 3DT2 SPACE dataset. Reader 1 chose the 2DT2 TSE sequence as the preferred dataset in 66 out of 121 cases and reader 2 in 75 out of 121 cases. The preference between reader 1 and 2 differed in 43 cases. The mean times for analysis of the 2DT2, 3DT2 and combination of 2DT2 and 3DT2 datasets for reader 1 were 1.22, 1.25 and 2.14 minutes, respectively, and for reader 2, were 1.27, 1.15 and 2.00 minutes, respectively.

**Fig 2.** A 30 year old patient who was diagnosed with endometriosis previously by diagnostic laparoscopy. She presented with hematochezia and subfertility. Both readers scored positive for endometriosis infiltrating the sigmoid, assessing the 2DT2 dataset, 3DT2 dataset and 3DT2 dataset in addition to the 2DT2 dataset. A and B: Sagittal 2DT2- and 3DT2-weighted MR imaging show endometriosis infiltrating the muscular layer of the sigmoid, demonstrating isointense signal intensity compared to muscle (white arrows).
Fig 3. A 41 year old patient with persistent pain symptoms after hormonal therapy for endometriosis. Endometriosis was diagnosed previously by laparoscopy.
Both readers scored positive for endometriosis located retrocervical, assessing the 2DT2 dataset, 3DT2 dataset and 3DT2 dataset in addition to the 2DT2 dataset.
A: Sagittal 2DT2-weighted image shows a lesion located retrocervical demonstrating isointense signal intensity compared to muscle, corresponding to fibrosis, consistent with a deep infiltrating endometriotic lesion (white arrow).
B: Sagittal 3DT2-weighted image (after administration of buscopan) shows the same imaging plane. Deep infiltrating endometriosis located retrocervical is recognized (white arrow). Reader 1 scored “no artefacts” assessing 2DT2 and “diagnostic relevant artefacts” assessing 3DT2. Reader 2 scored “no artefacts” assessing the 2DT2 dataset and “diagnostic irrelevant artefacts” assessing the 3DT2 dataset.

Inter-rater agreement scores for retrocervical endometriosis, bladder and bowel involvement of endometriosis showed excellent agreement (Table 3). Diagnostic confidence scores are shown in Table 4. Diagnostic confidence scores were similar for 3DT2 and 2DT2.

Table 3. Inter-rater agreement scores for MR imaging diagnosis of endometriosis (retrocervical/ vaginal cuff, bladder, bowel) by two independent readers

<table>
<thead>
<tr>
<th>Location of endometriosis</th>
<th>2DT2-weighted MR imaging</th>
<th>3DT2-weighted MR imaging</th>
<th>2DT2- and 3DT2-weighted MR imaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrocervical / vaginal cuff</td>
<td>0.90</td>
<td>0.88</td>
<td>0.83</td>
</tr>
<tr>
<td>Bladder</td>
<td>0.89</td>
<td>0.89</td>
<td>0.96</td>
</tr>
<tr>
<td>Bowel</td>
<td>0.83</td>
<td>0.83</td>
<td>0.92</td>
</tr>
</tbody>
</table>
Table 4. Mean diagnostic confidence scores for diagnosis of endometriosis etrocervical/vaginal cuff, bladder and bowel involvement

<table>
<thead>
<tr>
<th>Location of endometriosis</th>
<th>2DT2-weighted MR imaging</th>
<th>3DT2-weighted MR imaging</th>
<th>2DT2- and 3DT2-weighted MR imaging</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reader 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retrocervical / vaginal cuff</td>
<td>2.65</td>
<td>2.79</td>
<td>2.86*</td>
</tr>
<tr>
<td>Bladder</td>
<td>2.96</td>
<td>2.98</td>
<td>2.99</td>
</tr>
<tr>
<td>Bowel</td>
<td>2.72</td>
<td>2.74</td>
<td>2.80</td>
</tr>
<tr>
<td></td>
<td>Reader 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retrocervical / vaginal cuff</td>
<td>2.67</td>
<td>2.70</td>
<td>2.75</td>
</tr>
<tr>
<td>Bladder</td>
<td>2.92</td>
<td>2.97</td>
<td>2.98</td>
</tr>
<tr>
<td>Bowel</td>
<td>2.52</td>
<td>2.66</td>
<td>2.74*</td>
</tr>
</tbody>
</table>

*aSignificantly higher compared to diagnostic confidence scores using 2DT2-weighted MR imaging.

Diagnostic confidence scores of reader 1 for diagnosis of retrocervical endometriosis were significantly higher comparing the combination of 3DT2 SPACE and 2DT2 to solely 2DT2-weighted MR imaging (p=0.000). For reader 2, diagnostic confidence scores for bowel endometriosis were significantly higher comparing the combination of 3DT2 SPACE and 2DT2 to solely 2DT2-weighted MR imaging (p=0.000).

Discussion

In this study we demonstrated that 3DT2-weighted SPACE showed slightly higher diagnostic confidence scores (not significant) compared to routine 2DT2-weighted imaging for the diagnosis of DIE. Furthermore, the combination of 3D- and 2DT2-weighted imaging showed even better confidence levels of which 2 parameters were significantly higher compared to 2DT2 (retrocervical endometriosis for reader 1 and in bowel endometriosis for reader 2). In contrary, 2DT2 showed significantly less artefacts and a higher overall image quality compared to 3DT2 SPACE. Moreover when readers were asked to choose a single T2-weighted
dataset, both readers preferred the 2D dataset over 3D in the majority of cases. Giving the excellent inter-rater agreement scores for diagnosis of deep infiltrating endometriosis for both 2D and 3DT2-weighted MR imaging, one would prefer 3DT2, especially the combination with 2DT2, above 2DT2 alone.

This is supported by the described advantages of 3DT2-weighted imaging in previous literature including the possibility of retrospective free alignment of images according to anatomic/pathologic structures, which may make multiple 2D acquisitions unnecessary, limiting imaging time and a high spatial resolution (11;16). Diagnostic confidence scores comparing 3DT2 SPACE to the routine 2DT2-weighted sequence did not significantly differ, but because 2DT2 showed significantly less artefacts, similar acquisition time and a higher overall image quality, the authors would prefer 2D compared to 3DT2 SPACE. Furthermore, the administration of butylscopolamine is not mandatory in 2DT2-weighted imaging on 1.5 Tesla.

In practice however, in indistinctive severe cases 3DT2-weighted imaging will be added to the standard 2D imaging set, raising the imaging time by 8 minutes (administration time of butylscopolamine not included).

In our study 3DT2 SPACE showed significantly more artefacts and a lower overall image quality. Artefacts were mainly caused by bowel peristalsis, despite the use of butylscopolamine prior to the 3D sequence. One explanation for these artefacts may be the longer imaging time, which is approximately triple that of a single 2DT2-weighted sequence. Presence of significantly more motion artefacts using 3DT2 SPACE compared to conventional 2D sequences, was also described in a previous study that assessed 3DT2 SPACE at 3.0T in rectal cancer (14). In this study, butylscopolamine was administered before the localizing series. Because of the short half-life time, this might have caused it to be ineffective at the time 3D was acquired at the end of the protocol.

In contrary, Hori et al (12) found significantly more motion artefacts comparing 2DT2-weighted imaging to 3DT2 VISTA, a sequence comparable to 3DT2 SPACE, administrating butylscopolamine before the 2DT2 sequence. Slightly more respiratory motion artefacts were described on 2DT2 images. Similarly, in a study of Proscia et al (11), in the evaluation of the female pelvis, 3DT2 SPACE showed significantly less motion artefacts, (including bowel motion) compared to 2DT2, without use of butylscopolamine. Comparing these outcomes to our results, we did not find an explanation for the contradiction findings.
Both readers favoured the 2DT2-weighted images above the 3DT2-weighted images, which may be explained by artefacts, but also by the difference in T2 signal. Previously, increased blurring was described in 3D TSE Cube compared to 2DT2 at 3.0 Tesla, probably due to the greater T2 decay during the long echo train (16).

There are some limitations that need to be acknowledged regarding the present study. Because T2 contrast in 3DT2 SPACE is theoretically altered in comparison with the standard 2DT2 sequence (6), it was impossible to blind readers to which pulse sequence was assessed. Instead of blinding readers, images were reviewed independently with a time interval between analysis of 2D and 3D MR imaging. Furthermore, histopathology as reference standard was only available in a minority of cases, as most patients diagnosed with deep infiltrating endometriosis are treated with hormonal therapy. For this reason we were not able to compare diagnostic accuracy between sequences.

In conclusion, although 3DT2 SPACE could replace routine 2DT2-weighted imaging, the authors prefer 2DT2 over 3D, because of significantly less artefacts and a higher overall image quality, with almost similar diagnostic confidence scores. In indistinctive severe cases 3DT2-weighted imaging might be added to the standard 2D imaging set at the expense of increasing imaging time and the administration of butylscopolamine.
References


