Magnetic Resonance Imaging of the Peritoneal Cavity among Peritoneal Dialysis Patients, Using the Dialysate as “Contrast Medium”

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Abstract. The objectives of this study were to evaluate whether adequate observation of abdominal pathologic features related to peritoneal dialysis (PD) was possible with magnetic resonance imaging (MRI) under routine conditions, i.e., against the background of the dialysate and without contrast medium. For 16 male and seven female patients (mean age, 51.8 ± 15.0 yr; mean duration of PD, 324 ± 542 d), 25 peritoneal MRI studies were performed with the intraperitoneal dialysate as usual. Indications were symptoms or combinations of symptoms, such as leakage or abdominal wall edema (n = 3), bloody dialysate (n = 4), suspected herniation (n = 1), suspected ultrafiltration failure (n = 2), and abdominal pain (n = 5), or routine assessment after initiation of PD (n = 12). The MRI protocol, which was performed with a 1.0-T scanner, consisted of breath-hold, coronal and transverse, T2-weighted, half-Fourier single-shot turbo spin-echo sequences, using a standard body-array coil. MRI studies were well tolerated and successfully completed for all except two patients. Results indicated a leak along the catheter (n = 1), a leak in an umbilical hernia (n = 1), suspected leakage (n = 1), hernias (n = 5, in three patients), intraperitoneal adhesions (n = 5, in four patients), a ruptured ovarian cyst (n = 1), and pleural effusions (n = 4). Pathologic findings unrelated to PD or located extra-abdominally were observed in 19 of the 25 studies. The catheter tip position was easily identified for all patients. In conclusion, this first report on peritoneal MRI using only dialysate as the “contrast medium” indicates that MRI permits detailed observation of all relevant, PD-related, abdominal pathologic features against the dialysate background, thus avoiding system contamination (and thus the risk of peritonitis).

Peritoneal dialysis (PD) is effective in replacing renal function but is associated with the risk of certain procedure-specific complications. The most common problems are of an infectious nature (1). Other technique-related complications are herniation, leaks (with fluid accumulation adjacent to the site of the leak), intraperitoneal adhesions after peritonitis, and gradual deterioration of dialytic efficiency (2). The corresponding clinical presentations may include symptoms such as bloody dialysate, pain or abdominal discomfort, visible or palpable hernias, dyspnea, soft-tissue swelling, and diminished ultrafiltration.

In the diagnostic evaluation of these PD patients, peritoneal imaging may be necessary to confirm a clinically suspected diagnosis, to localize leaks, or to provide detailed information before surgical repair of the defect (3). The standard for imaging of peritoneal abnormalities among PD patients is computed tomography (CT) with intraperitoneal administration of contrast medium (4). According to a Medline search, there has been only one report on magnetic resonance imaging (MRI) of peritoneal abnormalities among PD patients with gadodiamide as the contrast agent (5). Intraperitoneal administration of contrast medium for both CT and MRI is a time-consuming procedure that must be performed by trained personnel under aseptic conditions. In addition, the procedure is associated with the potential risk of germ inoculation, followed by peritonitis, and contrast media are expensive.

In T2-weighted MRI scans, water appears hyperintense, i.e., bright (white). Therefore, PD fluid, which consists of water, electrolytes, and glucose, may be excellently observed by MRI in a manner comparable to that for CT contrast media. The dialysate should provide sufficient contrast between the peritoneal surface and abdominal organs and thus delineate any PD-related pathologic conditions. To prove this hypothesis, a study was undertaken with 23 patients who were undergoing chronic ambulatory PD (CAPD), to examine whether adequate observation of the peritoneal cavity and any PD-associated abdominal pathologic features was possible with peritoneal MRI, using the dialysate as the only contrast medium.
Materials and Methods

Patients

This open observational prospective study was conducted in accordance with the Helsinki Declaration of Human Rights, and informed consent was obtained from all patients. Overall, 16 male and seven female patients (mean age, 52.0 ± 15.3 yr; range, 27 to 83 yr) were examined according to the protocol described below. At the time of the MRI study, the patients had undergone CAPD for a mean of 323.6 ± 542.1 d (median, 12 d; range, 3 to 2039 d). End-stage renal failure resulted from diabetes mellitus type 2 in five patients, chronic glomerulonephritis and chronic interstitial nephritis in four patients each, vascular nephropathy and unknown causes in three patients each, polycystic kidney disease in two patients, and diabetes mellitus type 1 and multiple myeloma in one patient each.

Overall, 25 peritoneal MRI studies were performed for the 23 patients. Peritoneal MRI was considered to be indicated for all patients with symptoms or combinations of symptoms such as bloody dialysate, abdominal discomfort and/or pain, suspected herniation, fluid overflow at the exit site, abdominal wall edema, weight gain, or diminished ultrafiltration (Table 1). Twelve consecutive patients who just had begun CAPD and were without specific complaints were also asked to participate in the peritoneal MRI study, to allow us to obtain more experience with the technique. For four patients with complications of PD, conventional CT with intraperitoneal contrast medium administration were performed in parallel, for comparison of the techniques.

All examinations were performed independently by two experienced radiologists, who were blinded with respect to the clinical symptoms of the patients. The results were then compared and discussed (in cases of differences). Finally, a diagnostic report, including information on the completeness and quality of the study, the position of the PD catheter, the presence or absence of PD-related pathologic conditions, and non-PD-related abnormal findings, was recorded for each patient.

Peritoneal MRI

No changes in the PD regimen were made for peritoneal MRI studies. Examinations were performed under daily-life conditions, without specific preparations or extra dialysate exchanges and with the patient’s usual intraperitoneal fill volume of 2000 ml of dialysate.

MRI studies were performed by using a superconducting imaging system (Magnetom Impact Expert; Siemens Medical Systems, Erlangen, Germany) with a field strength of 1.0 T. The images were obtained with a standard body-array coil. The study protocol consisted of two breath-hold, interleaved, and two interleaved, transverse, T2-weighted, half-Fourier single-shot turbo spin-echo sequences (repetition time, 8.2 ms; echo time, 66 ms). The flip angle was 180 degrees. The slice thickness was 5 mm and the matrix size was 256 × 256, with fields of view of 400 mm (axial) and 450 mm (coronal). When indicated, a T2-weighted, turbo spin-echo sequence (repetition time, 5.52 ms; echo time, 128 ms) was added. The flip angle was 180 degrees. The slice thickness was 3 mm and the matrix size was 128 × 512, with a field of view of 400 mm. Assessment of the abdominal (and surrounding tissue) anatomic and pathologic features was made solely against the contrast medium of the dialysate.

Table 1. Findings for CAPD patients with PD-related clinical complaints and/or suspected intra-abdominal pathologic conditions

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age (yr)</th>
<th>MRI Indication</th>
<th>Findings</th>
<th>Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>46</td>
<td>Leakage 5 d after acute initiation of PD</td>
<td>Leak along catheter</td>
<td>Interruption of PD, switch to hemodialysis</td>
</tr>
<tr>
<td>2</td>
<td>83</td>
<td>Abdominal wall edema</td>
<td>Leak in an umbilical hernia, femoral herniation without leak</td>
<td>Surgical repair</td>
</tr>
<tr>
<td>3</td>
<td>69</td>
<td>Abdominal wall edema, bloody dialysate</td>
<td>Subcutaneous fluid accumulation below umbilicus, no leak</td>
<td>Spontaneous leak occlusion?, watchful waiting</td>
</tr>
<tr>
<td>4</td>
<td>46</td>
<td>Bloody dialysate</td>
<td>Ruptured ovarian cyst</td>
<td>None, spontaneous cure</td>
</tr>
<tr>
<td>5</td>
<td>53</td>
<td>Bloody dialysate</td>
<td>No pathologic findings</td>
<td>Watchful waiting</td>
</tr>
<tr>
<td>6</td>
<td>65</td>
<td>Bloody dialysate</td>
<td>No pathologic findings</td>
<td>Watchful waiting</td>
</tr>
<tr>
<td>7</td>
<td>61</td>
<td>Suspicion of unilateral femoral hernia</td>
<td>Bilateral scrotal hernias, abdominal wall scar herniation</td>
<td>Surgical repair</td>
</tr>
<tr>
<td>8</td>
<td>27</td>
<td>Generalized edema, suspected ultrafiltration failure</td>
<td>No diaphragm leak, marked right-sided pleural effusion</td>
<td>Fluid intake restriction and high-glucose dialysate</td>
</tr>
<tr>
<td>9</td>
<td>65</td>
<td>Generalized edema, upper abdominal pain</td>
<td>No diaphragm leak, no abdominal wall hernia, left-sided pleural effusion</td>
<td>Fluid intake restriction, gastric acid suppressive therapy, relief of pain</td>
</tr>
<tr>
<td>10</td>
<td>45</td>
<td>Abdominal pain</td>
<td>Adhesions in lower pelvis</td>
<td>None, spontaneous relief</td>
</tr>
<tr>
<td>11</td>
<td>50</td>
<td>Abdominal pain</td>
<td>Adhesions around spleen</td>
<td>Watchful waiting</td>
</tr>
<tr>
<td>12</td>
<td>56</td>
<td>Abdominal pain</td>
<td>None, but myomatous uterus</td>
<td>Watchful waiting</td>
</tr>
<tr>
<td>13</td>
<td>82</td>
<td>Abdominal pain</td>
<td>Pancreatic cyst</td>
<td>None, spontaneous relief</td>
</tr>
</tbody>
</table>

*PD, peritoneal dialysis; CAPD, chronic ambulatory PD; MRI, magnetic resonance imaging.*
CT Peritoneography

For four patients with pathologic findings, CT peritoneography was performed in parallel with the peritoneal MRI study, for comparison. The study protocol for CT peritoneography was described previously (6). In brief, the dialysate was drained completely, and non-contrast-enhanced spiral CT scans of the empty abdomen were obtained with 10-mm sections from the diaphragm to the pubic symphysis. Next, the catheter extension was disconnected, followed by intraperitoneal instillation of 50 ml of iopentol (Imagopaque, 300 mg iodine/ml; Nycomed Imaging, Oslo, Norway) by a specially trained PD nurse or a physician, under sterile conditions. A new dialysate bag was then connected, and 1000 ml of dialysate were instilled. The patient was encouraged to move and walk about for 30 min, to achieve good distribution of the dialysate/contrast medium mixture. Again, spiral CT scans of 10-mm thickness were obtained from the diaphragm to the pubic symphysis. Another dialysate exchange was performed immediately after the contrast CT examination, to drain the dialysate/contrast medium mixture.

CT Peritoneography

Figure 1. Coronal, T2-weighted, half-Fourier single-shot turbo spin-echo scan for a 27-yr-old, female, chronic ambulatory peritoneal dialysis (CAPD) patient with dyspnea and overhydration. On the right side, marked pleural effusion can be observed. The arrowheads point to the intact right diaphragm; no leakage was observed during the study. On the left side, dialysate surrounds the spleen and no pleural effusion can be observed.

Figure 2. (A) Axial, T2-weighted, half-Fourier single-shot turbo spin-echo scan for an 83-yr-old male patient with abdominal wall edema. At the level of the umbilicus, a small bowel loop can be observed, filled with air in an umbilical hernia (open star). The hernia is surrounded by hyperintense liquid emerging from the abdominal cavity to the subcutaneous tissue (arrow). A peritoneal leak within the umbilical hernia was diagnosed. It should be noted that the soft-tissue edema even reached the paravertebral region (closed stars). (B) Corresponding axial computed tomographic (CT) peritoneographic scan, obtained with the use of intraperitoneally administered iopentol, for the same patient. Contrast medium application revealed no additional findings, compared with magnetic resonance imaging (MRI). The arrowhead points to the leak, and the bubble-like structure within the subcutis corresponds to air within the small bowel loop herniation.

The CT studies were also independently evaluated by the two radiologists. The results of the CT scans and MRI studies were compared only after evaluation and documentation of the latter results had been completed.

Results

In 23 of the 25 MRI studies, the examination was successfully completed and was well tolerated by the patient. The reasons for interruption of the examination were intolerable dyspnea in a young female patient with marked pleural effusion (Figure 1), with an inability to remain in the supine position, and intolerable thoracic pain resulting from a splinter from World War II trauma in a male patient.
Comparison of contrast CT scans with the respective peritoneal MRI studies with the dialysate as the contrast medium yielded identical results. In none of the cases could additional information that was not provided by peritoneal MRI be obtained from the CT scans. Examples are presented below.

The detailed indications for peritoneal MRI and the results of the studies are outlined in Table 1. Pathologic findings to explain the clinical symptoms were observed in eight of the 13 studies. Leaks were localized exactly for two patients, i.e., along the catheter and in an umbilical herniation. As demonstrated in Figure 2, peritoneal MRI and contrast CT peritoneography revealed similar patterns of fluid distribution for the latter patient and were able to localize the leak. For a 69-yr-old female patient with abdominal wall edema and bloody dialysate in two consecutive bags, subcutaneous fluid accumulation was demonstrated, but no leak could be detected with either peritoneal MRI or a contrast CT study. Because there were no other explanations, it was suspected that a small perforation of the peritoneum had occurred but had spontaneously occluded during the overnight period of bed rest between the occurrence of edema and the imaging studies.

Bloody dialysate was observed for another three patients. For a 46-yr-old female patient who had undergone two peritoneal MRI studies within 10 mo, the bloody appearance of the dialysate could be attributed to rupture of a simple, right-sided, ovarian cyst. Figure 3 demonstrates the enlarged right ovary surrounded by hyperintense dialysate and no cyst (as observed 10 mo earlier). No pathologic conditions explaining the bloody dialysate were identified for a 53-yr-old female patient and a 65-yr-old male patient. The bleeding resolved spontaneously and did not recur thereafter.

For a 61-yr-old male patient with a clinically evident, left-sided, femoral hernia, peritoneal MRI revealed a large, left-sided, scrotal herniation containing sigmoid colon and dialysate and a small, right-sided, scrotal herniation. Again, MRI (Figure 4A) and CT peritoneography (Figure 4B) yielded similar results. Furthermore, an abdominal wall scar herniation (after tumor nephrectomy) between the 11th and 12th ribs was observed on the left side (not shown). Because of the risk of hernial rupture attributable to the elevated intra-abdominal pressure produced by the dialysate in the upright position, both scrotal hernias were surgically treated. The scar herniation was not treated, and it has not changed to date, under close clinical observation.

Leaks could be definitely excluded for two patients with pleural effusions and generalized edema (an example is presented in Figure 1). For both patients, restriction of oral
Fluid intake and the use of a high-glucose dialysate resulted in improved ultrafiltration, with disappearance of the effusions.

Abdominal pain of unknown origin was the reason for peritoneal MRI for four patients. In a 50-yr-old male with recurrent peritonitis, adhesions were found around the spleen. For patient 10, adhesive structures, possibly resulting from prior adnexitis, were observed in the lower pelvis (Figure 5). For a 56-yr-old female patient with pain, leiomyoma of the uterus was the only pathologic finding. For the fourth patient, a pancreatic cyst was observed. For all four patients, analgesic therapy was administered as needed, and the symptoms resolved with time.

For the 12 patients without suspected PD-related problems who were studied shortly after CAPD initiation, no relevant pathologic results were noted. Only a small, asymptomatic, left-sided, femoral herniation, which has not been surgically treated, was noted for a 70-yr-old female patient. For a 41-yr-old male patient who was markedly overhydrated at the initiation of PD, bilateral pleural effusions were observed.

The overall results for all 25 peritoneal MRI studies, with respect to catheter localization, extraperitoneal fluid accumulation, intraperitoneal adhesions, hernias, leaks, and non-PD-related findings, are presented in Table 2. The catheter tip could be localized in all studies except the two that were not completed. The tip was located in the lower abdomen in all patients but was regularly within the rectouterine/recto-bladder space (Douglas’ space) in 16 only patients. Only six patients exhibited no additional pathologic condition (unrelated to PD or located extra-abdominally). The findings were cholecystolithiasis (n = 6), liver cysts (n = 3), a liver hemangioma (n = 1), pancreatic cysts (n = 3) (observed twice for patient 2), a hiatal hernia (n = 1), splenomegaly (n = 2), renal cysts (n = 2), nephrolithiasis (n = 1), adrenal neoplasia (n = 2), a right-sided ovarian cyst (n = 1), a uterine leiomyoma (n = 1), diverticulosis of the sigmoid colon (n = 1), a small pericardial effusion (n = 1), and a cyst in the sacroiliac joint and an enlarged right bulbourethral gland (n = 1).

**Discussion**

For PD patients, the occurrence of bloody dialysate, pain, soft-tissue swelling, or ultrafiltration failure may necessitate

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**Table 2. Overview of the results of 25 peritoneal MRI studies for 23 patients**

<table>
<thead>
<tr>
<th>Abnormal/Pathologic Findings</th>
<th>No. of Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI study complete</td>
<td>23/25 2/25</td>
</tr>
<tr>
<td>Catheter located in regular position b</td>
<td>16/23 7/23</td>
</tr>
<tr>
<td>Leaks c</td>
<td>3/25 22/25</td>
</tr>
<tr>
<td>Inguinal herniation</td>
<td>3/20 20/23</td>
</tr>
<tr>
<td>Hernias, other locations</td>
<td>2/23 21/23</td>
</tr>
<tr>
<td>Diaphragm herniation</td>
<td>0/25 25/25</td>
</tr>
<tr>
<td>Adhesions</td>
<td>5/23 18/23</td>
</tr>
<tr>
<td>Pleural effusion</td>
<td>4/25 21/25</td>
</tr>
<tr>
<td>Pathologic findings not related to CAPD or located extraabdominally</td>
<td>19/25 6/25</td>
</tr>
</tbody>
</table>

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*It should be noted that multiple abnormal findings are possible for individual patients.*

*b Regular, within rectouterine/recto-bladder space (Douglas’ space).*

*c Including one suspected leak, which occluded spontaneously during overnight bed rest.*
observation of the peritoneal cavity and surrounding structures during the diagnostic evaluation (4). Several methods, including sonography, scintigraphy (7), and CT, are used to evaluate intra-abdominal, PD-related problems. CT with intraperitoneal administration of contrast medium, however, has been demonstrated to be the standard method (8). Compared with conventional roentgenography and scintigraphy, contrast CT provides the highest resolution in the delineation of anatomic details and the demonstration of extraperitoneal fluid (9). Recently, contrast CT peritoneography was also used to evaluate the functional surface area of the peritoneum with stereologic methods, which might yield more information on the solute-exchange capacity of the peritoneum in the future (10).

Unfortunately, CT peritoneography is rather time-consuming when widely accepted standard protocols are followed (6,8), with plain CT scans being obtained first, followed by instillation of contrast medium under aseptic conditions and acquisition of another series of CT scans. Specially trained personnel are needed to perform intraperitoneal contrast medium instillation, to prepare the patients for the examination (4). Recently, MRI using contrast medium has been reported to offer multiplanar imaging capabilities for the evaluation of PD-related complications (5). However, the same limitations seem to apply to MRI as well as CT peritoneography when intraperitoneal contrast media are used (5).

There has been little experience with CT peritoneography without intraperitoneal administration of contrast media, and the results seem to be poor (3). When MRI is used, water is observed as hyperintense with T2-weighted, turbo spin-echo techniques. Therefore, the high signal intensity of water or electrolyte solutions should highlight normal and pathologic anatomic features of the peritoneal cavity. The successful use of physiologic saline solution as an intraperitoneal “contrast medium” for the evaluation of patients with peritoneal carcinomatosis has been reported (11).

It seemed reasonable to use T2-weighted, turbo spin-echo imaging without intraperitoneal contrast medium administration for the evaluation of PD-related complications among PD patients, because the abdomens of these patients are filled with an electrolyte solution to treat renal failure. This first report on peritoneal MRI with the dialysis fluid as the only contrast medium clearly demonstrates the effectiveness of this technique in elucidating PD-related complications. As shown in 25 studies performed under daily-life conditions, normal features, as well as all types of known PD-related, intra- and extraperitoneal, pathologic conditions (Table 2), were excellently demonstrated. No different or additional information was obtained by CT peritoneography with intraperitoneal contrast medium administration when both techniques were performed for comparison (Figures 2 and 4).

In our still-limited experience, the major benefit of peritoneal MRI is that no alterations in PD techniques are required for the MRI examination. Therefore, there is no need for PD-trained nurses to spend time preparing the patients for contrast studies. When intraperitoneal dialysate serves the purpose of a contrast medium, system contamination (and thus the risk of peritonitis) is avoided (12). Contrast medium costs are eliminated, and the relatively high x-ray load to which the patients are exposed during CT is avoided. Although the costs of peritoneal MRI may be considered a major drawback, this technique may be a valuable alternative to conventional contrast CT peritoneography for patients with histories of allergic reactions to contrast media.

We conclude that peritoneal MRI using the dialysate as the only contrast medium may be a valuable alternative to CT peritoneography for effective observation of all noninfectious, PD-related, intra-abdominal complications among PD patients. Important resources may be conserved, because this newly described technique of peritoneal imaging is performed under daily-life conditions, on an outpatient basis.

Acknowledgments
We acknowledge the skillful help of the technical assistants in the Radiology Department with the MRI and CT studies and the dedicated work of our PD nursing team. This work was presented in part at the 33rd Annual Meeting of the American Society of Nephrology, Toronto, Canada, October 13–16, 2000.

References
