MRI Detection of Peritoneal Adhesion with Dialysate Enhancement

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Introduction

Peritoneum is the largest and most complexly arranged serous membrane in body. It is composed of layer of mesothelium supported by a thin layer of connective tissue, forming the lining of abdominal cavity that covers most of the intra-abdominal organs, including liver, spleen, stomach and cecum. While providing superb soft tissue contrast in abdominal imaging, MRI thus far could not provide any detection and characterization of post-surgical peritoneal adhesion, which remains an extremely common complication in abdominal and pelvic operations, and a source of considerable morbidity [1]. Peritoneal dialysis fluid (dialysate) is a clinically accepted medium in treatment of patients in later stage of chronic kidney failure. Typical dialysate consists of water, electrolytes and glucose, likely yielding distinct MR relaxation properties. In this study, peritoneal dialysis fluid was characterized, and demonstrated as a peritoneal contrast agent to detect peritoneal adhesion in rodents.

Methods

MR Characterization of Dialysate as a Contrast Agent: Clinically approved 4.25% dextrose peritoneal dialysis fluid (Fresenius Medical Care, Bad Homburg, Germany, ~0.1 mL/g) was chosen in this study to enhance the peritoneal cavity for visualizing the abdominal structures. For measurement of MR relaxation properties, five phantoms were made with this standard dialysate diluted to volume concentrations of 0%, 10%, 20%, 50% and 100%, respectively using PBS in cylindrical tubes. Their transverse and longitudinal relaxation rates were measured using a multi-echo SE sequence (TR = 3 s with TEs of 20, 40, 60, 80, 100, 120, 140, 160, 180, 200 ms) and single-echo SE sequence (TE = 10 ms with TRs of 2, 4, 6, 8, 10 s), respectively.

Animal Procedures: To evaluate MRI detection of peritoneal adhesion with dialysate, adhesion was induced in male Sprague-Dawley (SD) rats (150-250 g, N = 6) using a surgical procedure of abdominal wall and cecal abrasion similar to that previously described [2]. Briefly, a 3 cm vertical midline incision was made through the abdominal wall and peritoneum. Both dorsal and ventral surfaces of the cecum was exposed and abraded with a size-15 scalpel blade until blood appeared on the cecal surface in all cases. The parietal peritoneum lateral to the midline incision was also scraped 30 times until petechial hemorrhage was observed. The abdominal incision was closed subsequently in two layers with 4-0 silk sutures. Animals were scanned with MRI at day 21 after the surgical procedure. They were then sacrificed one day after MRI. The abdomen was opened through a U-shaped incision for confirmation of the adhesion site. Surface area of peritoneal adhesion was estimated by measuring the representative lengths according to the shape of the adhesion (such as ellipse, rectangle and trapezoid) by two independent observers.

MRI: All MRI experiments were performed on a 7 Tesla MRI scanner (70/16 PharmaScan, Bruker, Germany) with a 60 mm quadrature RF coil. Animals were anesthetized with isoflurane/air using 1.5% for maintenance. Each animal was given IP injection of pre-warmed 100% dialysate (~0.1 mL/g) after overnight fasting to reduce intestinal motion during MRI scan. T_2*-weighed GE images were acquired by a multi-slice 2D flow-compensated sequence with respiratory gating and TR ≈ 1 s, TE = 7.5 ms, FA = 90º, FOV = 6.0×6.0 cm, slice thickness = 1.2 mm, acquisition matrix = 192×192, voxel size = 0.31×0.31×1.2 mm^3, NEX = 2, and total scan time of ~7 min. The boundary of the peritoneal adhesion near cecum was manually segmented and smoothed for each animal in the multi-slice image data set obtained after the dialysate administration. The corresponding adhesion area was computed from the estimated length of adhesion boundary on each slice and the center-to-center slice spacing by a blinded observer. Two normal rats (N = 2) without any surgical procedure for adhesion were also scanned with identical protocols after IP injection of pre-warmed 100% dialysate as controls, and scanned 1 to 3 days after the dialysate administration to examine the dialysate clearance from peritoneal cavity.

Results

Table 1 lists the dialysate relaxation properties measured. The dialysate was clearly shown to be a medium of long longitudinal and transverse relaxation times. T_1 and T_2 values of undiluted dialysate were found to be 3017.5 ± 35.3 ms and 108.4 ± 2.0 ms at 7 Tesla, respectively, distinctly differing from those of most soft tissues in abdominal region. As the dialysate volume concentration decreased with PBS dilution, R_2 was found to decrease linearly while R_1 remained largely the same. Fig. 1 shows the typical sagittal images of rats with and without peritoneal adhesion obtained after the dialysate administration. For the rats surgically induced for peritoneal adhesion, intraperitoneal dialysate enhancement has clearly depicted the peritoneal adhesion sites at cecum in five out of six animals studied. The postmortem inspection confirmed the successful adhesion inductions in five out of the six animals (Fig. 2), and no adhesion induction in one animal. Fig. 3 plots the adhesion surface areas determined by in vivo dialysate-enhanced MRI and postmortem measurement. Good correlation (R = 0.99) was observed. For the two normal rats, the intraperitoneal enhancement was found to be visible for up to 2 days.

Discussion

Our experimental results demonstrated intraperitoneal dialysis fluid as a useful MRI contrast medium of long T_1 and T_2 values. While previous MRI studies employed dialysate mainly to monitor the complications of continuous ambulatory peritoneal dialysis such as peritoneal leak in patients [3-5], the current work illustrated that intraperitoneal administration of dialysate provided an excellent intraperitoneal enhancement that could be used to delineate peritoneal adhesion. Peritoneal dialysate enhancement may be potentially applicable in clinical MRI detection and evaluation of post-surgical peritoneal adhesion and to monitor therapeutic interventions (i.e., against peritoneal adhesion) in future preclinical research. It may also be valuable in examining the complex abdominal structures (both intra- and retroperitoneal organs) and abnormalities.

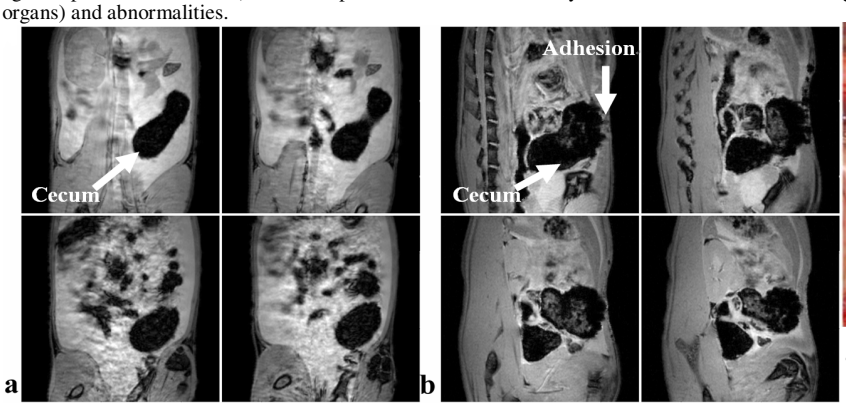

Fig. 1 Typical MR images from a male SD control rat without peritoneal adhesion (**a**) and one with surgically induced peritoneal adhesion (**b**) obtained after IP administration of dialysate. Peritoneal enhancement enabled the detection of the peritoneal adhesion site at cecum in rats.

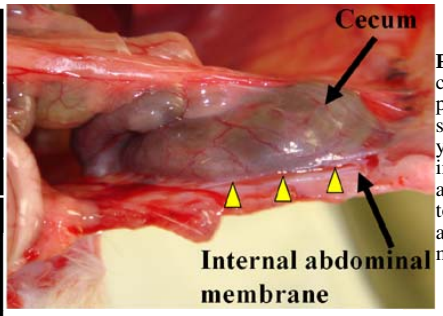

Fig. 2 Postmortem confirmation of the peritoneal adhesion site at cecum. The yellow arrows indicate the adhesion of cecum to the internal abdominal membrane.

Table 1 MR relaxation properties of dialysate diluted in PBS (mean ± SD).

Dialysate Concentration (% vol. in PBS)	0%	10%	20%	50%	100%
R_1 (ms^{-1})	292.3±5.0	304.4±4.1	334.9±1.4	338.9±1.2	331.4±3.9
R_2 (ms^{-1})	1077.6±39.7	2158.9±60.1	3162.6±60.0	5002.5±65.1	9225.1±90.5

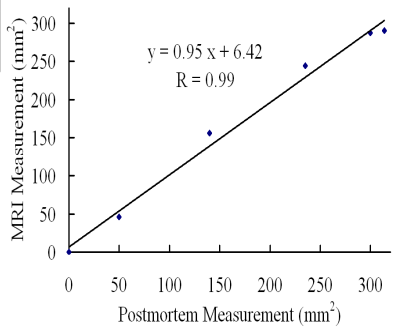

Fig. 3 Surface areas of the peritoneal adhesions estimated by in vivo MRI and postmortem measurements in the six animals studied. One animal yielded no adhesion as confirmed by postmortem inspection.

References [**1**] T Liakakos et al, Dig Surg 2001;18:260-273. [**2**] Y Lzumi et al, Surgery 2007;141:678-681. [**3**] FC Prischl et al, J Am Soc Nephrol 2002;13:197-203. [**4**] K Yavuz et al, Abdom Imaging 2005;30:361-368. [**5**] KM Arbeiter et al, Pediatr Radiol 2001;31:745-747.