Received:
11 June 2015

Revised:
5 November 2015

Accepted:
21 December 2015

doi: 10.1259/bjr.20150471

Cite this article as:

Takaji R, Mori H, Yamada Y, Kiyonaga M, Matsumoto S. Medial pathway patterns of the right retromesenteric plane: anatomical investigation using MDCT in patients with acute pancreatitis and pyelonephritis. *Br J Radiol* 2016; **89**: 20150471.

FULL PAPER

Medial pathway patterns of the right retromesenteric plane: anatomical investigation using MDCT in patients with acute pancreatitis and pyelonephritis

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Objective: To investigate the medial pathways of the right retromesenteric plane by reviewing multidetector CT (MDCT) findings in patients with acute pancreatitis and pyelonephritis.

Methods: 112 patients with acute pancreatitis and 114 patients with pyelonephritis underwent MDCT scans. 64 of the 112 patients with acute pancreatitis and 34 of the 114 patients with pyelonephritis had right retromesenteric plane thickening because of inflammatory extensions. The medial pathways of the right retromesenteric plane were evaluated by two radiologists in consensus.

Results: In 18 (28%) of the 64 patients with acute pancreatitis and 10 (29%) of the 34 patients with pyelonephritis, the right retromesenteric plane continued to the central retroperitoneum behind the descending duodenum and pancreatic head (Type 1 pathway). The right retromesenteric plane extended to the right wall of the

descending duodenum (Type 2 pathway) in 46 patients (72%) with acute pancreatitis and 24 patients (71%) with pyelonephritis. There was no significant difference in the pathway patterns of the right retromesenteric plane between the acute pancreatitis group and the pyelonephritis group (Type 1 pathway, $p = 0.89$; Type 2 pathway, $p = 0.76$).

Conclusion: Two patterns were confirmed regarding the medial pathways of the right retromesenteric plane; this anatomical knowledge is important for evaluating the extension of retroperitoneal diseases.

Advances in knowledge: Medial aspect of the right retromesenteric plane is thought to have two pathways. The right retromesenteric plane continuing to the right duodenal wall is a common type. Knowledge of these variations is important when evaluating the retroperitoneal diseases.

INTRODUCTION

The retroperitoneal planes play an important role as extension routes for various retroperitoneal diseases such as pancreatitis and pyelonephritis.^{1–8} Therefore, knowledge of the normal pathways of the retroperitoneal planes is a pre-requisite when predicting the extension of retroperitoneal diseases. Traditionally, retroperitoneal planes were believed to be composed of single layer of the fascia: anterior renal fascia, posterior renal fascia and lateroconal fascia.⁹ It has been shown that each fascia is formed by multiple discrete mesenteric leaves during foetal life in other literature, and now, the concept of the interfascial plane is accepted as the potential space that can be the pathway of fluid, inflammation and tumours. Anterior renal fascia, posterior renal fascia and lateroconal fascia are represented by the retromesenteric plane, retrorenal plane and lateroconal plane, respectively.^{1,6–8,10}

In many previous literature, configurations of the retroperitoneal planes have been analyzed by using cadaveric models and investigating the distribution of the thickened fascial planes and fluid collections in patients with retroperitoneal pathologies.^{1,3,5–21} However, there have been only two previous literature regarding the medial pathways of the right retromesenteric plane.^{3,9} The right retromesenteric plane separating the anterior pararenal space from the perirenal space is thought to be composed of the left leaf of the primary mesocolon, primary parietal peritoneum and anterior renal fascia in front of the right kidney, and the right leaf of the primary mesoduodenum, primary parietal peritoneum and anterior renal fascia behind the pancreatic head and descending duodenum (Figure 1). The retromesenteric plane is laterally attached to the fascial trifurcation and continues to the central retroperitoneum behind the descending duodenum and pancreatic head; however, there is controversy as to whether

Figure 1. Diagram of the right retromesenteric plane created based on previous reports (Dodds et al,⁶ Gerota,¹⁰ Takeguchi and Ibukuro¹⁹ and Mindell et al²⁰). The right anterior pararenal space and perirenal space are separated by the right retromesenteric plane. This fascial plane is thought to be composed of three laminated fascial planes: the left leaf of the primary mesocolon (dotted line), the primary parietal peritoneum (solid-dotted line), the right anterior renal fascia in front of the right kidney (red circle) and behind the pancreatic head and descending duodenum, the right leaf of the primary mesoduodenum (dashed line), primary parietal peritoneum (solid-dotted line) and anterior renal fascia (blue circle). This fascial plane continues to the midline and laterally fuses with the right retrorenal plane and continues the lateroconal plane, which forms the fascial trifurcation. Ao, abdominal aorta; IVC, inferior vena cava; SMA, superior mesenteric artery; SMV, superior mesenteric vein.

or not the right perirenal space communicates with the left perirenal spaces across the midline.^{9,16,20} According to the compartment model proposed by Meyers et al,⁹ the right anterior renal fascia (retromesenteric plane) continues to the central retroperitoneum behind the descending duodenum and pancreatic head. Recently, Yagan et al,³ on the basis of a review of the air distribution on CT in eight patients with duodenal perforation, proposed an alternative medial course for the right anterior renal fascia (retromesenteric plane) extending to the right wall of the descending duodenum. However, to our knowledge, there have been no previous reports regarding the medial pathways of the right retromesenteric plane involving a large study sample size. The right retromesenteric plane plays an important role either as a barrier of processes such as inflammation and tumours or as a pathway facilitating their spread along this plane. The knowledge of the variability of the medial pathways of this plane is essential when evaluating the tumour extension on CT images on the basis of the TNM classification in patients with right renal cell carcinomas.^{22,23} The purpose of this study was to retrospectively investigate the medial pathways of the right retromesenteric plane by reviewing multidetector CT (MDCT) images in patients with acute pancreatitis and pyelonephritis.

METHODS AND MATERIALS

Patient selection

This retrospective study was approved by the ethics committee of Oita University Faculty of Medicine, and the requirement for informed consent was waived. Radiologists (MK and SM), who served as the study co-ordinators, reviewed the medical records and classified the final diagnosis regarding patient selection. Between February 2005 and July 2012, a computerized search of radiology report databases at our institution for abdominopelvic MDCT reports that contained the words “acute pancreatitis” or “pyelonephritis” generated a list of 140 consecutive patients with acute pancreatitis and a list of 146 consecutive patients with pyelonephritis. Of the 140 patients suspected of having acute pancreatitis on MDCT, 134 were diagnosed as such based on diagnostic criteria.²⁴ Of these 134 patients, those with ascites surrounding the right retromesenteric plane ($n = 6$), renal cell carcinoma ($n = 1$), retroperitoneal neoplasms ($n = 2$), hypoalbuminaemia (serum albumin level $< 3.0 \text{ g dl}^{-1}$; $n = 6$) and a history of abdominal surgery ($n = 7$) were excluded. The number of patients with acute pancreatitis in the final study group was 112 (73 males and 39 females; mean age, 61 years; age range, 21–89 years). The aetiologies of acute pancreatitis were as follows: gallstone pancreatitis ($n = 27$), alcoholic pancreatitis ($n = 34$), spontaneous pancreatitis ($n = 7$), pancreatitis due to endoscopic retrograde cholangiopancreatography ($n = 16$), acute exacerbation of chronic pancreatitis ($n = 12$), ischaemic pancreatitis ($n = 2$); pancreatitis due to pancreatic divisum ($n = 6$), traumatic pancreatitis ($n = 3$) and autoimmune pancreatitis ($n = 5$).

Of the 146 patients suspected of having pyelonephritis on MDCT, 129 were diagnosed as such based on clinical and laboratory diagnostic criteria [e.g. flank pain, suprapubic pain, urinary frequency, bacteriuria, dysuria or haematuria and the elevation of serum C-reactive protein levels (reference value $< 5 \text{ mg l}^{-1}$) and blood white cell count (reference value, $3.5\text{--}8.8 \times 10^9 \text{ l}^{-1}$)]. Of these 129 patients, those with the following characteristics were excluded: ascites surrounding the right retromesenteric plane ($n = 1$), renal cell carcinomas ($n = 4$), retroperitoneal neoplasms ($n = 2$), hypoalbuminaemia (serum albumin level $< 3.0 \text{ g dl}^{-1}$) ($n = 3$) and a history of abdominal surgery ($n = 5$). The number of patients with pyelonephritis in the final study group was 114 (62 males and 52 females; mean age, 58 years; age range, 19–87 years). The aetiologies of pyelonephritis were bacterial infections ascending from the urinary bladder ($n = 53$) and ureter stones ($n = 61$).

CT Technique

CT of the abdomen was performed using a 32-section MDCT scanner (Aquilion 32 TSX-101A/DA; Toshiba Medical Systems, Tochigi, Japan) or a 320-section MDCT scanner (Aquilion ONE TSX-301A/2A; Toshiba Medical Systems) in our institution (Table 1). The scanning parameters used for MDCT were as follows: 120 kVp, 200–400 mAs, a rotation time of 0.5 s, a pitch of 0.98 (32 detectors) and 0.6 (320 detectors), and a section thickness of 1 mm with a 1-mm reconstruction interval. CT images were retrieved through the picture archiving and communication system (SYNAPSE 3.0 MR-001; Fujifilm, Tokyo, Japan).

Table 1. CT protocols

CT techniques (scan delay times)	Acute pancreatitis (<i>n</i> = 112)	Pyelonephritis (<i>n</i> = 114)
Triple-phase CE-CT (40, 70, and 150 s) ^a	54	–
Dual-phase CE-CT (30 and 130 s) ^a	–	35
Single-phase CE-CT (100 s) ^a	37	37
Unenhanced CT	21	42

CE-CT, contrast-enhanced CT.

^aA total of 100 ml of contrast medium (Lopamiron™ 370; Bayer Schering Pharma, Berlin, Germany or Omnipaque® 300; Daiichi Sankyo, Tokyo, Japan) was infused at a rate of 3 ml s⁻¹ by means of a power injector in all patients.

In 54 of the 112 patients with acute pancreatitis, unenhanced CT was followed by triple-phase contrast-enhanced CT in consideration of the existence of pancreatic carcinoma. In our institution, triple-phase contrast-enhanced CT is usually performed in cases of suspected pancreatic carcinoma because this protocol is thought to be a useful method for differentiating carcinoma from other pancreatic disease.²⁵ After the start of contrast material infusion, contrast-enhanced CT scanning of the pancreas was performed for 40 s in the pancreatic parenchymal phase, for 70 s in the portal venous phase and for 150 s in the delayed phase. In 37 patients, unenhanced CT was followed by single-phase contrast-enhanced CT obtained at 100 s after the start of contrast material infusion. A total of 100 ml of contrast medium (Lopamiron™ 370; Bayer Schering Pharma, Berlin, Germany) was infused at a rate of 3 ml s⁻¹ by means of a power injector in all of these patients. In the remaining 21 patients, only unenhanced CT was performed.

In 35 of the 114 patients with pyelonephritis, unenhanced CT was followed by dual-phase contrast-enhanced CT. After the start of contrast material infusion, contrast-enhanced CT

scanning of the pancreas was performed for 30 s in the corticomedullary phase and for 180 s in the excretory phase. In 37 patients, unenhanced CT was followed by single-phase contrast-enhanced CT obtained at 100 s after starting the contrast material infusion. A total of 100 ml of contrast medium (Omnipaque® 300; Daiichi Sankyo, Tokyo, Japan) was infused at a rate of 3 ml s⁻¹ with a power injector in all of those patients. In the remaining 42 patients, only unenhanced CT was performed. The data sets obtained were sent to a computer workstation (Aquarius NetStation v. 1.2; Terarecon, San Mateo, CA).

Imaging analysis

MDCT examinations were retrospectively evaluated by two radiologists (RT and YY, with 12 and 24 years' of experience, respectively) in consensus, who were aware of the diagnosis of acute pancreatitis or pyelonephritis. The reviewers assessed the existence of right retromesenteric plane thickening caused by inflammatory fascial thickening and reactive fluid collection intruding into the interfacial planes. The medial pathways of the right retromesenteric plane were then classified into three types. Two types (Type 1 and Type 2) were classified on the basis of the previous

Figure 2. Diagram illustrating the classification of the medial pathways of the right retromesenteric plane. (a) Type 1 pathway: right retromesenteric plane extending behind the descending duodenum and pancreatic head (yellow line). (b) Type 2 pathway: right retromesenteric plane continuing to the right wall of the descending duodenum (yellow line). Ao, abdominal aorta; IVC, inferior vena cava; SMA, superior mesenteric artery; SMV, superior mesenteric vein.

Table 2. Classification of the medial pathways in patients with right retromesenteric plane thickening

Medial pathway patterns	Acute pancreatitis group (<i>n</i> = 64)	Pyelonephritis group (<i>n</i> = 34)	<i>p</i> -value ^a
Type 1	18	10	0.89
Type 2	46	24	0.76

^a χ^2 test.A *p*-value of <0.05 indicated a significant difference.

literature: Type 1 was a pathway behind the descending duodenum and pancreatic head (Figure 2a);⁹ Type 2 was a pathway to the right wall of the descending duodenum (Figure 2b).³ Type 3 was the other type that had never been reported in the literature.

Image analysis used 1-mm reconstructed axial images; multiplanar reconstruction images and coronal multiplanar volume reformation maximal intensity projection (MIP) images were available for the assessment of the pathways of the right retromesenteric plane. The slab thickness used for MIP images was approximately 3–5 mm. These images were reviewed by using a window level of 10 HU and a window width of 300 HU on unenhanced images, and by using a window level of 40 HU and a window width of 350 HU on enhanced images.

Statistical analysis

A χ^2 test was used to compare the frequency of the medial pathways of the right retromesenteric plane between the acute pancreatitis group and the pyelonephritis group to arrive at a more precise frequency. Statistical analysis was performed using the GraphPad prism v. 5.00 for Windows® (GraphPad Software, San Diego, CA). A *p*-value of <0.05 indicated a significant difference.

RESULTS

Acute pancreatitis group

Right retromesenteric plane thickening caused by inflammatory extension was noted in 64 of the 112 patients with acute pancreatitis (44 males and 20 females; mean age, 64 years; age range, 26–89 years) (Table 2). The Type 1 pathway was seen in 18 (28%) of 64 patients (Figure 3a), and the Type 2 pathway was seen in the remaining 46 (72%) patients (Figures 4a–d and 5). There were no other pathways (Type 3) observed in this study group. In 26 of 46 patients with Type 2 pathway, the thickened fasciae continuing from the left wall of the descending duodenum to the central retroperitoneum behind the pancreatic head were confirmed, and the thickened fasciae attaching right and left walls of the descending duodenum continued at the transitional portion between the duodenal bulb and the descending duodenum (superior duodenal flexure) (Figure 5).

Pyelonephritis group

The right retromesenteric plane thickening caused by the inflammatory extension was noted in 34 of the 114 patients with pyelonephritis (22 males and 12 females; mean age, 60 years; age range, 21–85 years) (Table 2). 10 (29%) of these patients were classified as having the Type 1 pathway (Figure 3b) and the remaining 24 (71%) patients were classified as having the Type 2 pathway (Figure 4e). Other pathways (Type 3) were not encountered. Among patients with the Type 2 pathway (*n* = 24),

inflammatory extension to the medial aspect of the descending duodenum was not confirmed.

There was no significant difference in the pathway patterns of the right retromesenteric plane between the acute pancreatitis group and the pyelonephritis group (Type 1 pathway, *p* = 0.89; Type 2 pathway, *p* = 0.76).

DISCUSSION

The pathway patterns to the lateral, cranial and caudal aspects of the right retromesenteric plane have been described by many investigators.^{1,5–14,16–18,21} Meyers et al⁹ reported that the anterior renal fascia (retromesenteric plane) and the posterior renal fasciae (retrorenal plane) fused with each other on the lateral side; they were firmly fixed to each other above the adrenal gland and were connected to the diaphragmatic fascia. However, some investigators^{15,21} reported that the renal fascia (retromesenteric plane) fuses with the parietal peritoneum at the level of attachment of the transverse mesocolon. In the caudal aspect of the renal fascia (retromesenteric plane), two pathways have been postulated. One pattern is the closure of the caudal cone of the right renal fasciae (retromesenteric planes)^{14,18} and the other pattern is the opening of the caudal apex of the perirenal space towards the iliac fossa.¹¹

There have been only two previous literature describing the pathway patterns of the medial aspect of the right retromesenteric plane.^{3,9} Meyers et al⁹ reported that the right anterior renal fascia (retromesenteric plane) continues to the central retroperitoneum behind the descending duodenum and pancreatic head. Recently, Yagan et al³ reported that air extended posteriorly into the right perirenal space in seven (88%) of eight patients following perforation of the descending duodenum; they hypothesized that the right anterior renal fascia (retromesenteric plane) can extend medially to the descending duodenum rather than the central retroperitoneum.

In our study, we investigated the medial pathways of the thickened right retromesenteric plane in patients with acute pancreatitis and pyelonephritis. In 18 (28%) of the 64 patients with acute pancreatitis and 10 (29%) of the 34 patients with pyelonephritis, the right retromesenteric plane continued to the central retroperitoneum behind the descending duodenum and pancreatic head (Type 1 pathway), which is consistent with the compartment model proposed by Meyers et al.⁹ Conversely, the right retromesenteric plane extended to the right wall of the descending duodenum (Type 2 pathway) in the remaining 47 (72%) patients with acute pancreatitis and the 24 (71%) patients with pyelonephritis, which is consistent with the hypothesis proposed by Yagan et al.³

Figure 3. Acute pancreatitis group. (a) A 73-year-old male (Type 1 pathway). Post-contrast-enhanced CT image at the level of the pancreatic head (P) and descending duodenum (D) shows lateral extension of the pancreatitis. The thickened right retromesenteric plane extends behind the descending duodenum and pancreatic head (arrowheads). (b-e) A 75-year-old female (Type 2 pathway). (b-d) Post contrast axial CT images and (e) coronal multiplanar volume reformation maximal intensity projection (5-mm slab thickness) show the thickened right retromesenteric plane (arrowheads) continuing to the right wall of the descending duodenum (arrows). AC, ascending colon.

There was no significant difference in the pathway patterns of the right retromesenteric plane between the acute pancreatitis group and the pyelonephritis group in our study. Although the frequency of the pathway patterns in our study could not strictly be compared with that in the study by Yagan et al³ because of the different dynamics between the inflammatory extensions by acute pancreatitis and pyelonephritis and the more acute air extension by duodenal perforation, the different size of the study samples is thought to be main reason for the difference in the

frequency between them. However, the Type 2 pathway is more common than the Type 1 pathway in both studies.

We also assessed the pathway patterns to the medial aspect of the descending duodenum in patients with a Type 2 pathway. MDCT with 1-mm section thickness allowed for detailed evaluation of the pathway of the right retromesenteric plane through the use of multiplanar reconstruction and MIP. In all patients with acute pancreatitis having inflammatory extension to the medial aspect

Figure 4. Acute pancreatitis group. (a-d) A 79-year-old male (Type 2 pathway). Post-contrast axial CT images show the cranial and medial extension of the pancreatitis. At the superior duodenal flexure (circles in a,b), the right retromesenteric plane (arrowheads) that attaches to the right wall of the descending duodenum continues to the left wall of the descending duodenum at the superior duodenal flexure and extends to the central retroperitoneum behind the pancreatic head (white arrows). AC, ascending colon; D, duodenum; P, pancreas.

Figure 5. Pyelonephritis group. (a) A 60-year-old male (Type 1 pathway). The non-contrast-enhanced CT image shows the thickened right retromesenteric plane (arrowheads) behind the descending duodenum (D) and pancreatic head (P). (b) A 78-year-old male (Type 2 pathway). The non-contrast CT image shows the dilatation of the renal pelvis (asterisk), perirenal bridging septae (arrows), and the thickened right retromesenteric plane (arrowheads) extending to the right wall of the descending duodenum. AC, ascending colon.

of the descending duodenum, the right retromesenteric plane that was attached to the right wall of the descending duodenum continued to the left wall of the descending duodenum at the superior duodenal flexure and extends to the central retroperitoneum behind the pancreatic head. From these findings, the inflammation of the right retromesenteric plane is thought to extend to the medial aspect of the descending duodenum through the superior duodenal flexure. There were no patients with pyelonephritis showing inflammatory extension to the medial aspects of the descending duodenum. The reason why acute pancreatitis extended more widely to the right retromesenteric plane than pyelonephritis is thought to be because acute pancreatitis causes inflammatory extensions to the extrapancreatic tissues as a result of autodigestion of enzyme-rich fluids.^{26,27} Knowledge of the pathway patterns of the right mesenteric plane is clinically important for CT evaluation of the extension of the retroperitoneal diseases. It has been reported that pseudoaneurysms at the celiac and superior mesenteric arteries were caused by inflammatory extension of the acute pancreatitis.^{28,29} In patients with a Type 1 pathway, inflammation is thought to more easily extend these arteries through the right retromesenteric plane compared with patients with a Type 2 pathway because the descending duodenum plays a role as a barrier of inflammatory extension in a Type 2 pathway. Tumour invasion to the right mesenteric plane is one of the important criteria in TNM classification in patients with right renal cell carcinoma; the thickening of the right mesenteric plane on CT images is suggestive of tumour invasion and the patient is diagnosed as stage T4.^{22,23}

Dodds *et al*⁶ considered the right retromesenteric plane to be formed by the fusion of some of the lobes of the mesentery during foetal life, wherein the fusion fascia behind the pancreatic head and descending duodenum is formed by the fusion of the right lobe of the primary mesoduodenum, primary parietal peritoneum and anterior renal fascia (Figure 1), and continues to the central retroperitoneum at 10 weeks embryo. This pathway of the right retromesenteric plane is consistent with Meyers' compartment model.^{9,17}

Conversely, Yagan *et al*³ proposed that the right retromesenteric plane continues to the right wall of the descending duodenum, meaning that there is no fascia behind the descending duodenum separating the anterior pararenal space from the

Figure 6. Proposed diagram for the manner of fusion of the right retromesenteric plane in cases where the right retromesenteric plane extends to the right wall of the descending duodenum based on an embryological viewpoint⁶ and our observations. The right retromesenteric fascia behind the descending duodenum adheres to or fuses with the duodenal posterior wall when the fusion fascia is formed at 10 weeks foetus. As a result, the right retromesenteric plane continues to the right (arrow) and left (arrowhead) walls of the descending duodenum. Ao, abdominal aorta; IVC, inferior vena cava; SMA, superior mesenteric artery; SMV, superior mesenteric vein.

perirenal space. In our study, the right retromesenteric plane continued to the right wall of the descending duodenum in approximately 70% of patients; in the left side of the descending duodenum, the retromesenteric plane continued from the left wall of the descending duodenum to the central retroperitoneum. From an embryological viewpoint⁶ and our findings, we propose that the right retromesenteric fascia behind the descending duodenum adheres to or fuses with the posterior wall of the descending duodenum when the fusion fascia is formed at 10 weeks foetus (Figure 6).

A limitation of the present study was that the right retromesenteric plane was only evaluated in patients with inflammatory extension to the right retromesenteric plane, whereby we evaluated inflammatory extensions to the fascial plane not only from the ventral side in patients with acute pancreatitis but also from the dorsal side in patients with pyelonephritis. However,

cadaveric studies would be needed to confirm our hypothesis described above.

In conclusion, the medial aspect of the right retromesenteric plane is thought to have two pathways, with the right retromesenteric plane continuing to the right wall of the descending duodenum being the more common type. This anatomical knowledge is important in the evaluation of the extension of retroperitoneal diseases.

ACKNOWLEDGMENTS

The authors thank Morton A Meyers, MD (Department of Radiology, School of Medicine, Health Sciences Center, State University of New York, Stony Brook, NY, USA), and Maarten van Leeuwen, MD (Department of Radiology, University Medical Center Utrecht, Netherlands), for helping us to understand the essential anatomy of the right retromesenteric plane.

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