Pancreatobiliary Lymphatics: Evaluation with 3.0T MR imaging

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Purpose

1. The presence of lymphatic involvement has been reported to be important prognostic factors (1,2). Despite the recent advances in radiological methods, it seems that it is difficult to evaluate the lymphatic involvement by pancreatobiliary malignant tumors (3,4). To the best of our knowledge, there is no report analyzing the radiological anatomy of the pancreatobiliary lymphatics.

2. Heavily T2-weighted sequence using MRCP visualizes all stationary fluids in the body as bright structures against a dark background and is useful for depicting the pancreatic ducts, bile ducts (5) and lymphatic main trunks including the thoracic duct, cisterna chyli (6,7) and intestinal lymph trunks (8). Anatomical orientations between the lymphatics, and pancreas and liver could not be recognized because solid tissues show a loss of signal with this technique (Fig. 1 on page 3). Therefore, it is thought to be difficult to reveal the detailed anatomy of the lymphatics around the pancreas and hepatoduodenal ligament by using heavily T2-weighted sequence.

3. The purpose of this study is to analyze the normal MR imaging anatomy of pancreatobiliary lymphatics using fat-suppressed T2-weighted images with three-dimensional spectral pre-saturation with inversion recovery volume isotropic turbo spin echo acquisition (SPIR VISTA), which visualizes the stationary fluid such as lymphatics as high signal intensity and the solid tissues such as the liver and pancreas as recognizable low signal intensity (Fig. 1 on page 3).
Fig. 1: Image Comparison of Heavily T2-weighted image and Fat suppressed Tree-dimensional SPIR VISTA image at the pancreatic head region (a) MR cholangiopancreatography (b) Heavily T2-weighted image, Main pancreatic duct and biliary duct can be recognized, but pancreatic head can be not recognized (c) Fat suppressed tree-dimensional SPIR VISTA image, Pancreatic head as well as main pancreatic duct and biliary duct can be recognized.

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Methods and Materials

Materials

In this study, a consecutive series of 175 cases had undergone MR imaging evaluation of suspected hepatic, pancreatobiliary, adrenal or duodenal diseases between July 2009 and August 2011. Inclusion criteria were as follows: no malignant or inflammatory diseases and no history of thoracoabdominal surgery. A total of 27 cases, consisting of adults free of abdominal diseases (n = 11), and patients with liver cysts (mean size, 16.2; size range, 8-25 mm) (n = 7), hepatic cavernous hemangioma (mean size, 15 mm; size range, 10-26 mm) (n = 6), hepatic focal nodular hyperplasia (size, 22 mm) (n = 1), gallbladder polyp (size, 4 mm) (n = 1) and duodenal diverticulum (size, 12 mm) (n = 1) were enrolled in the present study. They consisted of a mean age of 59.1 years (age range, 36-82 years): 15 men (mean age, 57.5 years; age range, 36-75 years) and 12 women (mean age, 61.1 years; age range, 42-86 years) (P = 0.32).

Radiological methods

All cases underwent MR imaging, which was performed by using a 3T MR imaging and a 32-channel sensitivity-encoding torso and cardiac coil (Table 1 on page 8). Fat-suppressed T2-weighted images with a three-dimensional spectral pre-saturation with inversion recovery volume isotropic turbo spin echo acquisition (SPIR VISTA) were acquired. In cases with suspected pathologies of the pancreas (n = 11), gallbladder (n = 4), duodenum (n = 1) and adrenal gland (n = 1), dynamic fat-suppressed spoiled gradient-recalled-echo T1-weighted images with a three-dimensional acquisition sequence (Table 1 on page 8) were obtained during suspended respiration before (precontrast) and at 30-35 seconds (arterial phase), 65-70 seconds (portal venous phase), and 100-120 seconds (delayed phase) after administration of gadoxetic acid. In 10 cases with suspected hepatic pathologies, dynamic fat-suppressed spoiled gradient-recalled-echo T1-weighted images with a three-dimensional acquisition sequence (Table 1) were performed during suspended respiration at 30-35 seconds (arterial phase), 65-70 seconds (portal phase), 100-120 seconds (hepatic venous phase), and 5 minutes (equilibrium phase) after the injection of the intravenous contrast agent. Additional hepatobiliary phase images were obtained at 20 minutes after the administration of gadoxetic acid. Both contrast materials (0.025 mmol per kilogram of body weight) were administered intravenously as a bolus at a rate of 1 mL/sec via an intravenous cubital line (20-22 gauge), which were flushed with 20 mL of saline by using a power injector. The images were acquired in the transverse plane. Although T1-weighted, T2 weighted, and diffusion-weighted images and/or MR cholangiopancreatographic images were also obtained, these images were not used in this study.

The Anatomy of the Pancreatobiliary Lymphatics
Schematic images of the anatomy of the pancreatobiliary lymphatics described on the basis of previous studies (9,10) were shown in Fig. 2 on page 8.

**Anterior Surface of the Pancreatic Head**

In the upper portion of the anterior surface of the pancreatic head, lymphatic vessels run upward, together with the lymphatics coming from the upper part of the posterior wall of the first part of the duodenum and reach the lymphatics along the anterior aspect of the common hepatic artery. Lymphatic vessels from the middle portion of the anterior surface of the pancreatic head travel to the left along the gastrocolic trunk and anterior surface of the superior mesenteric vein. In the lower portion of the anterior surface of the pancreatic head and inferior to the attachment of the mesocolon, the lymphatic vessels first run obliquely downwards and pass behind the superior mesenteric artery and vein.

**Posterior Surface of the Pancreatic Head and Hepatoduodenal Ligament**

In the upper portion of posterior surface of the pancreatic head, lymphatic vessels converge into large nodes consisting of the node lying on the posterior aspect of the trunk of the common hepatic artery, the lowest retroportal node and the lowest retrocholedochal node. The middle and lower portion of the posterior surface of the pancreatic head consist of the lymphatics along the posterior pancreaticoduodenal arcade and lymphatic vessels travelling across the posterior surface of the head. In the hepatoduodenal ligament, there is a network of lymphatic vessels and nodes along the main portal vein (10).

**Right abdomino-aortic portion and Inter-aorticovenous portion**

The lymphatics of the anterior and posterior surface of the pancreatic head and hepatoduodenal ligament converge at right abdomino-aortic nodes situated on the right side between the celiac trunk and the superior mesenteric artery and terminate at the inter-aorticovenous nodes lying in the upper and lower angles formed by the inferior vena cava and the left renal vein.

**Image Interpretation**

MR images were reviewed independently by two gastrointestinal radiologists (M.K. and Y.Y.) who had approximately 7 and 20 years experience in abdominal MR imaging, respectively. The radiologists defined a structure as lymphatics if it showed high signal intensity similar to the cisterna chyli which is described in a previous study as a saccular or tubular dilatation of the lymphatic channels in the retrocrural space, which originates at the L1-Th11 level of the vertebral body (11).

Both readers assessed the visibility of eight lymphatic segments as follows.
1. Anterior surface of the pancreatic head

The upper lymphatics along the anterior aspect of common hepatic artery, the middle lymphatics along the gastrocolic trunk and lower lymphatics along anterior inferior surface of the pancreatic head were assessed.

2. Posterior surface of the pancreatic head and hepatoduodenal ligament

The upper lymphatics at the lowest retroportal and retrocholedochal areas and middle to lower lymphatics at the posterior surface of the head were assessed. In the hepatoduodenal ligament, the lymphatics along the main portal vein were assessed.

3. Right abdomino-aortic portion and Inter-aorticovenous portion

The right abdomino-aortic lymphatics and the inter-aorticovenous lymphatics were assessed.

The visibility of each of the lymphatics was graded and recorded by using the following five point scale: 1=definitely detected, 2=probably detected, 3=undetermined, 4=probably not detected, 5=definitely not detected. The portal venous phase images on dynamic contrast-enhanced MR imaging were referred in order to confirm the route of the lymphatics because the fat-suppressed T2-weighted images with a three-dimensional T2 SPIR VISTA sequence completely eliminate the signal intensity from the vessels.

In addition, the diameters of eight lymphatic segments were measured by a single observer (Y.Y.). The maximum diameter of the short axis of each lymphatic was measured in each segment of the lymphatics. The measurements of the diameter were obtained on magnified images on the computer monitor. As for the lymphatics at the hepatoduodenal ligament, the middle portion of the lymphatics along main portal vein between the confluence with the splenic vein and the bifurcation of the left and right portal veins were measured.

Statistical Analysis

Interobserver agreement among the two readers for the visibility of eight lymphatic segments was calculated with kappa statistics. The level of agreement was defined as follows: kappa values of less than 0 were considered to indicate no agreement; values of 0.00-0.40, poor agreement; values of 0.41-0.75, good agreement; and values of 0.76-1.00, excellent agreement. The CT grade for the visualization of each of the lymphatics assigned by each reader was tabulated. The visibility of each of the lymphatics was calculated by defining confidence level ratings of 1 and 2 as positive, and 3-5 as negative for each reader. Any discrepancies between reviewers were resolved by consensus review.
**Table 1:** MR imaging Parameters

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Fig. 2: Schematic images of the anatomy of the pancreatobiliary lymphatics
(a)Lymphatics at the Anterior Surface of the Pancreatic Head #Upper lymphatics along the anterior aspect of the common hepatic artery #Middle lymphatics along the gastrocolic trunk #Lower lymphatics #Right abdomino-aortic lymphatics and Inter-aorticovenous lymphatics (b)Lymphatics at the Posterior Surface of the Pancreatic Head and in the Hepatoduodenal Ligament #Lymphatics in the hepatoduodenal ligament #Upper lymphatics at the lowest retroportal and retro-choledochal areas ###Middle to lower lymphatics at the posterior surface of the head #Right abdomino-aortic lymphatics and Inter-aorticovenous lymphatics

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Results

Lymphatics Visualization

The CT grades for the visualization of each of the lymphatics assigned by the readers are shown in Table 1-3. Interobserver agreements in scoring visibility of the evaluated lymphatics were good or excellent agreement.

1. Anterior surface of the pancreatic head *(Table 2 on page 11 ) (Fig. 3 on page 11)*

The upper lymphatics along the anterior aspect of the common hepatic artery were visualized in all (100%) 27 cases. The visibility of the middle lymphatics along the gastrocolic trunk and lower lymphatics along anterior inferior surface of the pancreatic head was 24 (89%) and 23 (85%) of 27 cases. Three cases in the middle lymphatics and 4 cases in the lower lymphatics were not visualized. Furthermore, the upper lymphatics have the largest short axis average (6.0 mm in diameter).

2. Posterior surface of the pancreatic head and hepatoduodenal ligament *(Table 3 on page 12 ) (Fig. 4 on page 13)*

The upper lymphatics at the lowest retroportal and retro-choledochal areas, middle to lower lymphatics at the posterior surface of the head, and the lymphatics in the hepatoduodenal ligament were visualized in all cases. Furthermore, upper lymphatics and the lymphatics in the hepatoduodenal ligament have a larger short axis average (both 5.6 mm in diameter) than the middle to lower lymphatics (4.0 mm in diameter).

3. Right abdomino-aortic portion and Inter-aorticovenous portion *(Table 4 on page 14 ) (Fig. 5 on page 15)*

The visibilities of the lymphatics at both the right abdomino-aortic portion and inter-aorticovenous portion were 96 % (26 of 27 cases). Furthermore, the lymphatics at the right abdomino-aortic portion have a larger short axis average (5.7 mm in diameter) than that of the inter-aorticovenous portion (4.5 mm in diameter).
### Table 2: The CT Grades for the Visualization of the Lymphatics at the Anterior Surface of the Pancreatic Head

<table>
<thead>
<tr>
<th>Score of Visualization</th>
<th>Visibility (%)</th>
<th>Aaverage of largest short axis (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
<td>100</td>
<td>6.0 ± 1.8</td>
</tr>
<tr>
<td>Uper</td>
<td>24 3 0 0 0</td>
<td>4.3 ± 1.1</td>
</tr>
<tr>
<td>Middle</td>
<td>17 7 2 1 0</td>
<td>4.0 ± 1.1</td>
</tr>
<tr>
<td>Lower</td>
<td>13 10 2 2 0</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 3: Lymphatics at the Anterior Surface of the Pancreatic Head (a, c and e) Post contrast MR images, (b, d and f) Fat suppressed Tree-dimensional SPIR VISTA images. Upper lymphatics along the anterior aspect of the common hepatic artery (b), middle lymphatics along the gastrocolic trunk (d), and lower lymphatics along anterior inferior surface of the pancreatic head (f) can be visualized as high signal intensity structures.

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Table 3: The CT Grades for the Visualization of the Lymphatics at the Posterior surface of the pancreatic head and in the hepatoduodenal ligament

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**Fig. 4:** Lymphatics at the Posterior surface of the pancreatic head and in the hepatoduodenal ligament (a, c and e) Post contrast MR images, (b, d and f) Fat suppressed Tree-dimensional SPIR VISTA images. Lymphatics in the hepatoduodenal ligament (b), upper lymphatics at the lowest retroportal and retro-choledochal areas (d), and middle to lower lymphatics at the posterior surface of the head (f) can be visualized as high signal intensity structures.

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Table 4: The CT Grades for the Visualization of the Right Abdomino-aortic Lymphatics and Inter-aorticoovenous Lymphatics

<table>
<thead>
<tr>
<th>Segment</th>
<th>Score of Visualization</th>
<th>Visibility (%)</th>
<th>Average of largest short axis (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right abdomino-aortic portion</td>
<td>20 6 1 0 0</td>
<td>96</td>
<td>5.7±1.3</td>
</tr>
<tr>
<td>Inter-aorticoovenous portion</td>
<td>24 2 1 0 0</td>
<td>96</td>
<td>4.5±1.0</td>
</tr>
</tbody>
</table>

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Fig. 5: (a and c) Post contrast MR images, (b and d) Fat suppressed Tree-dimensional SPIR VISTA images. Right abdomino-aortic lymphatics (b) and Inter-aorticovenous lymphatics (d) can be visualized as high signal intensity structures.

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In previous reports, there are two methods for MR lymphangiography. One method is heavily T2-weighted sequence using MRCP, which visualizes all stationary fluids such as lymphatic fluid as bright structures against a dark background. Okuda et al (6) reported that the detectability of the thoracic duct and cisterna chyli were more than 90% using heavily T2-weighted sequence on 1.5 T MR system. In the pictorial essay, Arrive et al (8) showed normal lymphatics in the small mesentery and retroperitoneal space on heavily T2-weighted sequence. Another method is contrast-enhanced MR lymphangiography at 3.0 T with parallel imaging techniques. Using these techniques, Notohamiprodjo et al (12) evaluated peripheral lymph vessels of the lower extremity and concluded that MR lymphangiography at 3.0 T provides very high spatial resolution and anatomical detail of normal and abnormal peripheral lymph vessels.

Heavily T2-weighted sequence enables us to visualize the thoracic duct and cisterna chyli because the routes of these lymphatics could be recognized even if solid tissues are not depicted. However, the depiction of the pancreas and liver is necessary to recognize the routes of the pancreatobiliary lymphatics because these lymphatics are complicated and closely associated with these solid tissues.

In our study, fat-suppressed T2-weighted sequences with a three-dimensional SPIR VISTA using a low refocusing flip angle was chosen according to the literatures (13, 14) so that the sequence has image qualities with not only the suppression of flow signal within artery and vein and high signal visualization of stationary fluids within the lymphatics but also the recognition of the solid tissues such as pancreas and liver. Using these sequence parameters, the pancreatobiliary lymphatics that were classified into 8 segments have 85-100% visibility. Visibility (80%) of the lower lymphatics at the anterior surface of the pancreatic head was the lowest; the reason for this was thought to be due to it being the smallest among the lymphatics as well as motion artifact by the peristalsis of the stomach or duodenum.

Summary

1. The pancreatobiliary lymphatics in normal conditions could be sufficiently visualized on fat-suppressed T2-weighted images with three-dimensional SPIR VISTA.

2. We experienced hepatic (Fig. 6 on page 18) and pancreatobiliary pathologies (Fig. 7 on page 18) influencing the pancreatobiliary lymphatics. In the future, we will confirm the diagnostic utilities of this MR sequence by comparing the lymphatics in the hepatic and
Fig. 6: In patient with liver cirrhosis. All of the hepatobiliary lymphatics show marked dilatation due to the congestion of lymphatic flow.

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Fig. 7: In patient with ductal adenocarcinoma of the pancreatic head. Dilatation and decreased signal intensity of the lymphatics at the right abdomino-aortic portion and posterior surface of the pancreatic head due to invasion of the pancreatic head cancer. The upstream lymphatics along the anterior aspect of the common hepatic artery and in the hepatoduodenal ligament dilate due to obstruction of downstream lymphatics.

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References


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