CLINICAL IMAGE

MR Imaging Features of Solid-pseudopapillary Tumor of the Pancreas

Koya Nakatani*, Yuji Watanabe, Akira Okumura, Tadashi Nakanishi, Masako Nagayama, Yoshiki A Moh, Takayoshi Ishimori, and Yoshihiro Dodo

Department of Radiology, Kurashiki Central Hospital
1-1-1 Miwa, Kurashiki 710-8602, Japan
(Received March 5, 2007; Accepted May 16, 2007)

Solid-pseudopapillary tumor (SPT) of the pancreas is characterized as cystic, necrotic, and hemorrhagic degeneration. In this study, magnetic resonance (MR) findings of 4 cases were reviewed. Patchy or spotty areas of high intensity that suggested hemorrhagic degeneration were constantly detected on fat-suppressed T1-weighted images. Dynamic contrast-enhanced MR imaging revealed mild and gradual increase of contrast enhancement in solid portions. Multi-contrast MR imaging that included fat-suppressed T1-weighted imaging and dynamic contrast-enhanced imaging allowed accurate diagnosis of SPT and its differentiation from other tumors.

Keywords: MRI, pancreas, solid-pseudopapillary tumor

Introduction

Solid-pseudopapillary tumor (SPT) of the pancreas is a rare neoplasm that occurs predominantly in young female patients. Since Franz first described this tumor in 1959, it has been designated by various names, including solid and cystic tumor, papillary cystic neoplasm, and others. SPT usually appears as an encapsulated mass composed of a mixture of cystic, solid, and hemorrhagic components. Histologically, cystic portions are considered to result from the degeneration of solid portions.

A variety of imaging modalities, such as ultrasonography (US), color Doppler US, and x-ray computed tomography (CT) have been used to differentiate SPT from other pancreatic tumors. Magnetic resonance (MR) imaging provides excellent tissue contrast via multi-contrast sequences and can demonstrate the wide spectrum of histological features of SPT. Especially, hemorrhagic components can be displayed as areas of high signal intensity on fat-suppressed T1-weighted imaging.

It is important to correlate MR with histopathological findings. The purpose of this study is to investigate multi-contrast MR imaging features and correlate them with histopathological findings.

Materials and Methods

This study included 3 women (aged 25 to 31 years) and a 65-year-old man with histopathologically proven SPT of the pancreas between 1999 and 2006. Three of the patients underwent dynamic contrast-enhanced MR imaging. In all four, surgical specimens were examined microscopically.

MR imaging was performed on a 1.5T superconductive magnet system with a synergy abdomen coil (Intera, Intera Achieva; Philips Medical Systems, Best, the Netherlands). After initial T1-weighted localizing images were obtained in the sagittal, coronal, and transaxial directions, T1-weighted gradient-echo (GRE) imaging (repetition time/echo time \([{\text{TR/TE}}] = 157–188/4.6; 70° \) flip angle; fat-suppressed (FS)-T1-weighted spin-echo (SE) imaging \([{\text{TR/TE}}] = 564–628/90\), and heavily T2-weighted turbo SE images \([{\text{TR/TE}}] = 7200–11450/300–400\) were acquired in the order of scan.

Contrast-enhanced dynamic MR imaging was performed with 3-dimensional FS fast field-echo sequence \((11.5–33/4.7–5.1; 35–60° \) flip angle). Images were obtained before and after a rapid intravenous bolus injection of 0.1 mmol/kg of gadopentetate dimeglumine (Magnevist®: Nihon Schering, Osaka, Japan). Five consecutive imaging sets were obtained immediately after injection as arterial,
**Table 1.** Clinical and histological findings in 4 cases of solid-pseudopapillary tumor (SPT) of the pancreas

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (years)</th>
<th>Gender</th>
<th>Size (cm)*</th>
<th>Site</th>
<th>Composition</th>
<th>Calcification</th>
<th>Margin</th>
<th>Malignant Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26</td>
<td>Female</td>
<td>9.0</td>
<td>Tail</td>
<td>Solid and cystic</td>
<td>–</td>
<td>Regular</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>Female</td>
<td>4.0</td>
<td>Head</td>
<td>Solid (with minimally cystic)</td>
<td>+</td>
<td>Regular</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>31</td>
<td>Female</td>
<td>5.0</td>
<td>Head</td>
<td>Solid and cystic</td>
<td>–</td>
<td>Regular</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>65</td>
<td>Male</td>
<td>3.0</td>
<td>Tail</td>
<td>Solid</td>
<td>+</td>
<td>Irregular</td>
<td>Venous Invasion</td>
</tr>
</tbody>
</table>

*Maximum diameter of tumor in postoperative gross pathologic specimen.

---

**Fig. 1.** A 26-year-old woman with solid-pseudopapillary tumor (SPT). A gross specimen of the tumor consisted of markedly cystic components with hemorrhagic fluid and solid components. At this level of magnetic resonance (MR) imaging, a cystic part is seen. Both $T_1$- and fat-suppressed (FS) $T_1$-weighted images show high intensity in the mass. Both FS $T_2$- and heavily $T_2$-weighted images show areas of mixed high and low intensity with fluid-fluid levels (arrow).

---

Portal venous, and late venous phases. Additional contrast-enhanced images were obtained with FS-$T_1$-weighted SE sequence (564–628/13).

Spectral presaturation with inversion recovery (SPIR) was used for fat suppression in the $T_2$-weighted imaging, and water selective excitation (WATS) with 1-3-3-1 pulse train was used in the $T_1$-weighted sequences.

All images were reviewed to evaluate the MR features of SPT. Morphologic features, signal intensity characteristics, and enhancement patterns of tumors were assessed.

**Results**

All 4 tumors were completely resected and histologically proven to be SPT. Table 1 summarizes the clinical and histological findings. All the tumors appeared as round, oval, or lobulated masses. Two were located in the pancreatic head, and two in the pancreatic tail. Diameters ranged from 3.0 to 9.0 cm (mean, 5.3 cm). Tumor margins were smooth and regular in 3 patients (Figs. 1–3) and irregular in the fourth (Fig. 4). Two appeared mixed solid and cystic; one appeared to have a large solid portion and a minimal cystic portion; and the fourth appeared completely solid. Amorphous or spotty calcification was seen in two of the tumors.
Fig. 2. A 25-year-old woman with solid-pseudopapillary tumor (SPT). A gross specimen consisted mainly of solid components with minimal cystic components and contained hyalinized fibrous tissues with calcification. The mass appears hypointense on a T۱-weighted image, but an area of patchy and spotty high intensity (arrow) can be seen on a fat-suppressed (FS) T۱-weighted image. It appears heterogeneously hyperintense on an FS T۲-weighted image. On dynamic images, it is hypovascular but shows progressive filling of contrast agent.

Fig. 3. A 31-year-old woman with solid-pseudopapillary tumor (SPT). A gross specimen of the tumor showed solid and cystic areas. The mass is hypointense on a T۱-weighted image, but an area of patchy high intensity (thin white arrow) is seen on a fat-suppressed (FS) T۱-weighted image. Fluid-fluid levels (thick white arrow) are seen on an FS T۲- and a heavily T۲-weighted image. On dynamic images, the tumor shows minimal contrast enhancement in an arterial phase, but progressive filling of contrast agent is seen and a border of the cystic part is identified in a late phase (black arrow).
Fig. 4. A 65-year-old man with an atypical manifestation of solid-pseudopapillary tumor (SPT). The mass has a jagged and irregular margin. This tumor is considered to be malignant because of the histological presence of venous invasion. It is completely solid and shows homogeneously low intensity on a T1-weighted image. However, a fat-suppressed (FS) T1 image reveals an area of spotty high intensity (arrow).

Table 2. Magnetic resonance findings in 4 cases of solid-pseudopapillary tumor (SPT) of the pancreas

<table>
<thead>
<tr>
<th>Case</th>
<th>Components</th>
<th>T1WI</th>
<th>FS-T1WI</th>
<th>FS-T2WI</th>
<th>Heavily T2WI</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Solid</td>
<td>Low</td>
<td>Low with patchy</td>
<td>Mixed</td>
<td>Mixed intermediate&lt;sup&gt;†&lt;/sup&gt;-low</td>
<td>(No CE study)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>slight high</td>
<td>and spotty high</td>
<td>high-low</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cystic</td>
<td>Mixed high-low</td>
<td>Mixed high-low</td>
<td>Mixed high-low*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Solid</td>
<td>Low</td>
<td>Low with patchy</td>
<td>Mixed high-low</td>
<td>Mixed intermediate&lt;sup&gt;†&lt;/sup&gt;-low</td>
<td>A little and gradual increase</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>and spotty high</td>
<td>high-low*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Solid</td>
<td>Low</td>
<td>Low with patchy high</td>
<td>Mixed high-low</td>
<td>Mixed intermediate&lt;sup&gt;†&lt;/sup&gt;-low</td>
<td>Same as above</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cystic</td>
<td>Low</td>
<td>Low with patchy high</td>
<td>Mixed high-low*</td>
<td>Mixed intermediate&lt;sup&gt;†&lt;/sup&gt;-low</td>
<td>Same as above</td>
</tr>
<tr>
<td>4</td>
<td>Solid</td>
<td>Low</td>
<td>Low with patchy high</td>
<td>Mixed high-low*</td>
<td>Mixed high-low*</td>
<td>Same as above</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>*Mixed high and low intensity area with a fluid-fluid level.</sup>

<sup>†“intermediate” means slight high intensity but lower than the intensity seen on fat-suppressed (FS) T2-weighted images.</sup>
Table 2 summarizes the MR findings. On T1-weighted images, solid portions showed as areas of low intensity (Figs. 2–4) and, in only one case, as heterogeneous areas of low intensity with patchy high intensity (Fig. 1). In all four, fat-suppressed T1-weighted images revealed areas of patchy or spotty high intensity in the solid portions (Figs. 1–4). Fat-suppressed T2-weighted images demonstrated the solid portions as areas of heterogeneous high and low intensity. Heavily T2-weighted images showed the solid portions as areas of intermediate or low intensity in all cases. Histologically, these solid portions showed a pseudopapillary pattern and cystic, hemorrhagic, and hyalinized degeneration.

Cystic portions observed in 2 cases on MR imaging were ill-defined areas of heterogeneous high intensity on FS T2-weighted images. FS T1-weighted images showed mixed high and low signal intensity. Fluid-fluid level was seen as a gravity-dependent layer with low signal intensity on heavily T2-weighted images, suggestive of bloody fluid or necrotic tissue debris (Figs. 1, 3).

On dynamic contrast-enhanced MR imaging, all SPT showed minimal contrast enhancement in the early arterial phase that gradually increased in the late phases (Figs. 2–4). Contrast-enhanced MR imaging with 2D turbo SE sequence demonstrated the solid portions as mildly hyperintense, which allowed differentiation between solid and cystic portions (Fig. 3).

Discussion

SPT of the pancreas usually appears as an encapsulated mass demarcated from the remaining pancreas. The histological sections show alternation of solid and yellowish areas with cystic, necrotic, and hemorrhagic areas. Histologically, SPT is characterized by solid areas alternating with a pseudopapillary pattern and cystic spaces resulting from degenerative changes of the solid portion. In 1996, the World Health Organization (WHO) proposed the term “solid-pseudopapillary tumor” for these tumors whose 2 most conspicuous histological features were solid areas and a pseudopapillary pattern. Solid areas are formed by cords of polygonal, monomorphous cells that are separated by small vessels that exhibit variable degrees of perivascular collagen deposition. Near the cystic spaces, degenerative changes with aggregates of foamy histiocytes, cholesterol clefts, foreign body giant cells, and hemorrhage are observed.

MR findings of SPT correlated with histopathological features. The identification of intratumoral hemorrhage would be a clue to the accurate diagnosis of SPT. MR imaging findings of intratumoral hemorrhage seemed to vary depending on the age of the hemorrhage. Ohtomo’s group referred to areas of high intensity on T1-weighted images as indicative of intratumoral hemorrhage. Buetow and associates referred to fluid-debris levels indicating blood products. Cantisani and colleagues reported that SPT showed heterogeneous high or low signal intensity on T1-weighted images and heterogeneous high intensity on T2-weighted images and that the absence of high T1 signal should not exclude the diagnosis. Though our study consisted of a small number of cases, areas of high intensity that suggested hemorrhagic portions were constantly detected on fat-suppressed T1-weighted images, even in the tumors without discrete cystic portions. Therefore, FS T1-weighted imaging could be essential to detect intratumoral hemorrhage characteristic of SPT. Heavily T2-weighted imaging is also useful to identify hemorrhage, which appears like debris as a gravity-dependent layer with low signal intensity.

A variety of MR findings of SPT were also demonstrated, even in this study of only 4 patients. The 2 small tumors showed minimal or no cystic degeneration, as reported by Coleman. This result suggests that lack of a cystic portion should not exclude the diagnosis of SPT.

SPT sometimes manifests atypically, as metastases, ductal obstruction, or parenchymal and extracapsular invasion, or in a male patient. SPT is known to have malignant potential. Mao’s group reviewed 292 cases of SPT of the pancreas and reported that the incidence of malignancy was 14.7%. Venous invasion, high nuclear grade, and prominent necrobiotic nests can be the histological parameters of malignant potential. In this study, SPT in a man was considered malignant because of a histological finding of venous invasion, though no distant metastasis was found.

SPT is considered to have a favorable prognosis. If resected adequately, SPT with malignant potential has as good a prognosis as benign SPT. Long survival can be expected even in patients with hepatic metastases.

Because SPT is rarely aggressive, it should be differentiated from other malignant tumors, such as ductal adenocarcinoma, anaplastic ductal carcinoma, malignant islet cell tumor (ICT), acinar cell carcinoma (ACC), pancreaticoblastoma, and metastatic tumor (especially from renal cell carcinoma). Pancreatoblastoma is a rare tumor of young children often seen with liver metastases at diagnosis. Ductal adenocarcinoma and anaplastic ductal car-
cinoma are invasive and often cause arterial encasement. However, it is frequently quite difficult to differentiate ICT or ACC from SPT because MR findings are similar. Contrast-enhanced dynamic MR imaging could allow differentiation among them based on differences in enhancement. Contrast enhancement in SPT is typically subtle and gradually increases. ICT often appears as hyperintensity at an early phase of contrast-enhanced dynamic MR imaging. ACC has been reported to be hypovascular in comparison to normal pancreatic parenchyma on dynamic contrast-enhanced CT study. Histological findings using immunohistochemical staining are also useful to differentiate SPT from ICT and ACC. SPT is typically positive for vimentin, alpha-1-antitrypsin, alpha-1-antichymotrypsin, neuron-specific enolase (NSE), progesterone receptors, CD10, and CD56 and negative for chromogranin, epithelial membrane antigen (EMA), cytokeratin, and endocrine and pancreatic enzyme markers.

Serous cystadenoma and mucinous cystic neoplasm are usually multilocular cystic tumors and demonstrate characteristic MR findings different from those of SPT. However, the MR findings may resemble those of SPT when they have hemorrhagic components.

Further investigation of a large series of patients is necessary to establish the characteristic findings of multi-contrast MR imaging in evaluating SPT.

Conclusion

Multi-contrast MR imaging using fat-suppressed T1-weighted imaging and dynamic contrast-enhanced imaging enables accurate diagnosis of solid-pseudopapillary tumor of the pancreas.

References