To demonstrate the features of intraductal papillary mucinous tumor (IPMT) of the pancreas on magnetic resonance imaging (MRI) and magnetic resonance cholangiopancreatography (MRCP) and to propose a guide for its optimal management based on the characteristic imaging findings.

Sixteen patients with pathologically-proven IPMT are included in the study. All patients underwent MRI and MRCP. The imaging features were retrospectively reviewed and correlated with operative and pathological findings. Follow-up imaging was evaluated as well.

MRCP depicted dilatation of the pancreatic duct of varying degree in all patients. Three types of IPMT were identified. Main duct IPMT (N=2) was characterized by marked dilatation of main pancreatic duct with diffuse intraductal papillary soft tissue tumors. Branch duct IPMT (N=8) was characterized by a cystic lesion with septa and soft tissue component and usually found in the uncinate process of pancreatic head. Combined type IPMT (N=6) has characteristics of both main duct type and branch duct type tumor. Among the 16 cases, two were benign adenomas, ten were malignant and four were dysplastic. Vessel invasion was found in one patient whereas regional lymph node metastasis was found in two patients.

MRI is a good imaging modality to detect, diagnose and evaluate the extent of the advanced-stage IPMT. Most IPMTs are malignant and the pathological type is one of the most important prognostic factor. Once an IPMT is diagnosed, especially combined type tumor and those with large cystic lesions and marked dilated pancreatic duct, surgical intervention should be prompted. Small branch duct type IPMTs should be closely followed up if no intervention is performed.

Key words: Intraductal Papillary Mucinous Tumor; Magnetic Resonance Imaging; Magnetic Resonance Cholangiopancreatography; Pancreas

Intraductal papillary mucinous tumor (IPMT) of the pancreas was identified and classified only recently. It originates from the epithelium of the main pancreatic duct and its side branches. In 1982, Oohashi et al reported the endoscopic findings of this intraductal mucinous tumor [1]. More and more cases were reported worldwide probably due to raised awareness of the tumor, better knowledge about the imaging features of the tumor and advancement in the imaging modalities. Although its incidence still remains unclear, it is now considered as the most common cystic tumor of pancreas [2]. In the past, ERCP was considered the gold standard for diagnosis of IPMT [3]. However, there is increased risk of inducing pancreatitis during the procedure. Moreover, complete opacification of the pancreatic duct and the cystic tumor may sometimes be difficult because the filling of the contrast medium may be blocked by mucin glob, causing reflux of the contrast medium through the patulous papilla vater [4, 5]. In contrast, MRCP, due to its non-invasiveness, multi-
MRI and MRCP of IPMT

planar capability and good tissue contrast, is thought to be one of the best imaging modality for evaluating pancreatic lesions [5].

In this article, different types of IPMT are presented [6, 7]. The characteristic imaging features of this specific lesion on MRI and MRCP are illustrated and correlated with surgical and pathological findings. Familiarity with the imaging findings of IPMT is important not only for correctly diagnosis this tumor but also for identifying the extent of the lesion and suggesting the most appropriate therapeutic strategy.

MATERIALS AND METHODS

In a retrospective search at our institution for pathologically-proven IMPT, sixteen patients of this disease (11 males and 5 females; age range: 35-77; mean age: 63) received MRI and MRCP examination were collected between January 1997 and May 2006. All patients underwent surgical intervention after MRI examination and 3 patients underwent repeated surgical intervention due to tumor recurrence. Eight patients had serial imaging follow-up for more than half a year with MRI or CT scan.

MR Imaging Study

All MR images were performed on a 1.5 T Siemens Magnetom Vision MR scanner (Siemens, Erlangen, Germany) with a standard circularly polarized phased-array body coil. Breath-hold MR cholangiopancreatography was performed in all patients using two different data acquisition techniques: ① single-shot voxel projection with a thickness of 7 cm single slice (projection technique). ② two-dimensional multislice acquisition postprocessed by maximum intensity projection (MIP) (multislice technique). In the projection technique, MRCP was performed with a heavily T2-weighted echo-train spin-echo (SE) sequence (TR 2800 msec, TE 1100 msec, 240 × 256 matrix, echo-train length 240) with fat-saturation technique on a thick projectional slab from coronal, coronal-oblique to sagittal plane. The FOV ranged from 25 to 30 cm depending on the area of interest or patient’s constitution. A single image was acquired during a 7-second breath-hold-period on an individual scan. In the multislice technique, fifteen contiguous slices were obtained using the half-Fourier acquisition single-shot turbo-spin echo (HASTE) sequence with the imaging planes parallel to the long axis of main pancreatic duct. Fifteen images were acquired during a 20-second breath-hold period. Parameters used for this technique were as follow: repetition time (TR) msec/ effective echo time (TE) msec =∞/ 95; flip angle 150° echo-train length 128; FOV 270 × 270 mm; number of signal acquired, 1; matrix of 220 × 256 and a 4 mm slice thickness without gap. Images were postprocessed using maximum intensity projection (MIP) algorithm to yield a 3D MIP-reconstructed MRCP.

After MRCP examination, MR imaging of liver was performed in all patients. Fifteen axial T2-weighted images were acquired with turbo SE sequences (TR 4300 msec, TE 138 msec, 180° flip angle, 260 Hz per pixel, echo-train length 29) during a 22-second breath-hold period. Prior to the dynamic triphasic examination, one set of unenhanced axial T1-weighted images was acquired with a gradient-echo, in-phase fast low-angle shot (FLASH) sequence. The imaging parameters were as follows: TR/TE: 150/4.1 msec, 90° flip angle, 7-10 mm slice thickness with a distant factor of 0.25, 30-37 cm field of view, 140 × 256 matrix, 260 Hz per pixel. This allowed 15 contiguous sections to be obtained in a 20-second breath-hold period. Dynamic triphasic study was performed using fat saturation technique with the same imaging parameter. One set of unenhanced imaging was obtained before administration of contrast medium. Another 3 sets of enhanced images were acquired 25, 90 and 300 seconds after initiation of rapid intravenous bolus injection of gadopentetate dimeglumine (Gd-DTPA, Magnevist; Berlex Laboratories, Wayne, NJ) at a dose of 0.1 mmol per kilogram of body weight. Finally, another fifteen T1-weighted FLASH images were acquired in coronal plane focusing on the hepatic hilum. All the patients underwent ERCP and surgical interventions within two weeks after MRI and MRCP examinations.

Imaging Analysis

According to the extent of the tumor and their different imaging presentations, these tumors were subdivided into three types: ① Main duct type ② Branch duct type ③ Combined type, according to the classification by Lim JH et al [4]. If the intraductal tumor is confined in the main pancreatic duct (MPD), a main duct IPMT is considered. If lobulated multicystic dilatation of one or more branch ducts without discernable intraductal lesion in the MPD, a branch duct IPMT is considered. If both cystic dilatation of branch ducts and intraductal soft tissue in the MPD are presented, it is considered a combined type IPMT. The extent of tumor involvement is judged from imaging findings despite the final pathological results. Several imaging characteris-
tics were evaluated: the morphology, location and size; the largest diameter of the MPD; communication between the cystic lesion and the pancreatic ducts; the involvement of vessel and lymph node. If the tumor presented as a cystic lesion, the largest dimension was measured as its size. MRCP was used to evaluate the diameter of the MPD and to demonstrate the communication between the cystic lesion and the MPD. If the MPD is larger than 2 mm in diameter, it was defined as a dilated duct. Enhancement pattern of the soft tissues components, mural nodules or septa within the cystic lesions was also evaluated. A peripancreatic lymph node with its smallest dimension larger than 1 cm is considered a metastatic node. The pathological diagnosis was made according to the revised WHO classification of exocrine pancreatic neoplasm [8].

Serial imaging follow-up for more than half an year, for evaluation of the interval change was available in 8 patients.

RESULTS

Sixteen patients were enrolled in this study, including 11 males and 5 females. Benign adenoma was found in 2 patients, both are branch duct type; dysplasia was found in 4 patients, one main duct type, two branch duct type and one combined type; carcinoma was found in 10 patient, one main duct type, four branch duct type and 5 combined type. On the other hand, the main duct type tumor was found in 2 patients, one dysplasia, the other one adenocarcinoma; the branch duct type tumor was found in 8 patients, two adenomas, two dysplastic and the rest four adenocarcinomas; the combined type tumor was found in 6 patients, one dysplastic and five adenocarcinomas. Dilatation of the MPD was found in 15 patients, ranging from (3 to 65) mm in diameter, normal MPD was found in 1 patient. The average diameter of MPD was about 2.75 mm in patients with adenomas, 9.5 mm with dysplastic IPMTs and 16mm with adenocarcinomas. The average size of the cystic lesions was about 3.58 cm in patients with adenomas, 4.13 cm with dysplastic IPMTs and 4.16 cm with adenocarcinomas.

IPMT, main duct type

The main duct IPMT was found in two patients. Both cases exhibit obvious dilatation of the MPD. MR imaging of the first patient (case 1) failed to show normal pancreatic parenchyma. Only markedly dilated main pancreatic duct filled with diffuse intraluminal papillary tumors was seen (Fig. 1a). The papillary tumors are mildly hypointense on T2 weighted images with intense gadolinium enhancement (Fig. 1b). Adenocarcinoma was found by pathological examination. The other patient had obvious dilatation of MPD over pancreatic tail with multiseptated cystic appearance. No obvious dilated side branch was noted, but histological examination found tumor cells in small branches. The pathological result was dysplasia. None of the two cases had vessel invasion by tumor or lymph node metastasis.

Figure 1. Main duct type IPMT. Axial fast spin-echo T2-weighted image a. shows multiple papillary soft tissue nodules (black arrows) of intermediate signal intensity in the lumen of the markedly dilated sausage-like main pancreatic duct (arrowheads). b. The papillary tumors demonstrate moderate gadolinium enhancement (white arrows).
IPMT, branch duct type

Among the 8 patients of the branch duct IPMT, solitary cystic lesions was found in 6 patients, two cystic lesions in one patient and three cystic lesions in the remaining one. Two cystic lesions located at pancreatic tail, two at pancreatic body and seven at the uncinate process or pancreatic head. The cystic tumor ranged from 2.5 to 6 cm. Intracystic soft tissue or septations demonstrating moderate gadolinium enhancement was seen in all patients (Fig. 2). MRCP clearly demonstrates communication between the cystic mass and the MPD in 5 cases but equivocal in the other three cases. Common bile duct (CBD) invasion was noted in one patient with adenocarcinoma. No other adjacent organ invasion was found by MR imaging. No vessel invasion or lymph node metastasis was found by imaging study or during surgery.

IPMT, combined type

Combined type IPMT was found in six patients. MRCP clearly demonstrates the dilated MPD and ectatic branch ducts as well as the intraductal filling defects (Fig. 3). Communication between the cystic lesion with the MPD was discernable in 5 cases and equivocal in one case. Moderate enhancement of the intraductal, intracystic soft tissue and the thin septa were found in all patients. CBD invasion was noted in one patient with adenocarcinoma. Solitary

Figure 2. Branch duct type IPMT. a. Axial T2-weighted image shows a cystic lesion with septations and intracystic soft tissue at the pancreatic head. b. The septations and intracystic soft tissue (short arrows in a and b) obvious gadolinium enhancement on the fat suppressed T1-weighted FLASH image. c. MRCP depicts the cystically dilated branch ducts containing septations (short arrows). d. Photograph of the resected specimen shows obvious intracystic septations or soft tissue (arrows).
lymph node metastasis in group 14 was disclosed in one patient with adenocarcinomas during surgery and proved pathologically. Another patient was suspected to have regional lymph node metastases by MR but not mentioned in the operation note. Vessel invasion was found in one patient with adenocarcinoma.

**Surgical intervention**

The surgical methods mainly depend on the location and extent of the tumors. Whipple’s operation was performed in patients with tumors at pancreatic head or uncinate process; subtotal or distal pancreatectomy was performed with pancreatic body or tail tumors; total pancreatectomy was performed with diffuse tumor spreading along almost entire pancreatic duct.

**Follow up**

In our study, serial imaging follow-up for more than half an year was available in 8 patients. First tumor recurrence was noted in 6 patients, at a 5 to 27 month interval. In these 6 patients, five had adenocarcinomas and one had dysplastic IPMT; three were branch duct type and the other three were combined type. Of the two patients free of tumor recurrence, one had branch duct type dysplastic IPMT and the other had combined type adenocarcinoma. Progression from a small branch duct IPMT initially

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**Figure 3.** Mixed type IPMTs. **a.** Axial T2-weighted image shows a cystic mass at the pancreatic neck and papillary soft tissue (black arrows) within the cystic mass and the dilated main pancreatic duct. **b.** The soft tissue exhibits obvious enhancement in the Gadolinium-enhanced imaging (white arrows). **c.** MRCP reveals communication between the cystic mass and the pancreatic duct. **d.** Photograph of the resected specimen shows the intraductal nodules (arrows).
to diffuse involvement of the entire pancreas 2-3 years later were found in 2 patients with adenocarcinoma. Total pancreatectomy was performed and diffusely-seeded adenocarcinoma along the pancreatic ducts is found on pathology. One patient with vessel invasion before surgery developed carcinomatosis 5 months later. Another patient with adenocarcinoma and lymph node metastasis before surgery developed peritoneal carcinomatosis and lung metastases one year after surgery.

**DISCUSSION**

IPMT is primarily an intraductal papillary tumor associated with excessive mucin secretion and results in progressive ductal dilatation or cyst formation. In the main duct IPMT, the involvement may be diffuse with numerous papillary tumors spreading along the entire markedly dilated MPD. The involvement may also be segmental with small sessile papillary nodules residing in an area along the MPD [8]. In our opinion, it is virtually pathognomonic if enhanced soft tissue nodules are found in the dilated MPD or in the multicystic lobulated tumor in branch ducts with dilatation of the MPD. However, tiny sessile excrescence is difficult to detect on both ERCP, MRCP and contrast enhanced T1 weighted images [12]. In these patients with minute papillary tumor, demonstrating the presence of mucin and communication between the cystic lesion and the MPD is important to correctly diagnose IPMT [10]. In our experience, MRCP can depict most communications (10 out of 14 patients), but it is unable to demonstrate the presence of mucin as both mucin and pancreatic juice appear bright on the T2-weighted images [4].

IPMT is generally considered a low-grade malignancy. Histologically, the lesions consist of a spectrum of abnormalities from hyperplasia, adenoma, dysplasia to papillary carcinoma. However, different histological patterns frequently coexist in the same tumor [9,11]. The clinical behaviors and prognosis of different types of IPMT are not fully known and the method of surgery depends on the extent of the tumor [13, 14, 15]. In our study, most IPMTs (10 of out of 16), especially the combined type tumors (4 out of 5), are pathologically adenocarcinomas. Only two cases were main duct type. Two cases had synchronous tumor masses. Both adenomas were branch duct type. So we hypothesize that most tumors originate from the branch ducts and spread into the MPD, namely from side branch tumors becoming combined type tumors (as two of our cases with relentless progression) while few tumors originate from the MPD or synchronously develop in the MPD or side branches. Since the combined type tumor might develop in later stage of the diseases, it has more possibility to be malignant. The larger the cystic lesion (in our study, the cutoff could be about 4cm) or the more dilated the MPD, the higher possibility of the tumor being malignant. Most recurrent tumors were adenocarcinomas (5 out of 6). The pathological type (adenoma, dysplasia or adenocarcinoma) should be one of the most important factor in predicting tumor recurrence. Lymph node metastasis and vessel invasion could be other important factors. A main duct type tumor or a branch duct type tumor noted by imaging could turn out to be a combined type tumor pathologically (as one of our main duct type cases). Considering the above points, surgical intervention should be considered once a mixed type IPMT is diagnosed, especially those with large cystic size or markedly dilated MPD. Close imaging follow up is strongly suggested even with a small branch duct type because it could be malignant and could actually be a combined type pathologically. Finally, IPMTs seem to have lower rates of vessel invasion, lymph node metastasis and distant metastasis than that of general pancreatic cancer.

**CONCLUSION**

In conclusion, MR is a good imaging modality to detect, diagnosis and evaluate IPMTs. MRCP combined with MRI provide characteristic grape-like multicystic dilatation of the branch ducts in the uncinate process or pancreatic body (branch duct IPMT) or diffuse dilatation of the MPD filled with papillary soft tissue tumors with enhancement (main duct IPMT) or both imaging features (combined type IPMT).

Most IPMTs are malignant and the pathological type is one of the most important prognostic factor. Once an IPMT is diagnosed, especially mixed type tumor and those with large cystic lesions and marked dilated pancreatic duct, surgical intervention should be prompted. Small branch duct type IPMTs should be closely followed up if no intervention is performed.

**REFERENCES**

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胰臟管內乳突狀黏液性腫瘤在磁振造影及磁振膽胰管攝影之影像表現

我們整理出胰臟管內乳突狀黏液性腫瘤（IPMT）在磁振造影及磁振膽胰管攝影之影像表現並由影像上的特點提出一些觀點供臨床處理作參考。

此研究包括了16個經病理切片證實為IPMT的病人。所有的病人都接受了磁振造影及磁振膽胰管攝影檢查，而有5位並接受了內視鏡膽胰管攝影檢查。我們整理出影像的特點並和手術及病理的結果做了對照。

所有的病人的胰管都呈現了不同程度的擴張。IPMT約可分成三型。主胰管型IPMT的表現為主胰管明顯擴張伴隨著彌漫性的管內乳突狀軟組織腫瘤。分枝型IPMT的表現則是呈現一囊狀腫塊伴隨了分隔及軟組織成份，並且常位於胰臟頭部的迴側部。混合型則包含了前兩型的特性。

1) 磁振造影是個很好的影像工具，可以偵測、診斷及評估IPMT及範圍。2) 磁振膽胰管攝影可偵測IPMT並可在大多數的情況下呈現出囊狀腫塊和主胰管的交通。儘管如此，內視鏡膽胰管攝影仍是診斷細微早期分枝型IPMT的標準檢查。3) 密集的影像追跡是很重要的，而如果腫瘤有長大及主胰管有擴張的情況，則就需要考慮手術。

關鍵詞：管內乳突狀黏液性腫瘤；磁振造影；磁振膽胰管攝影；胰臟