Mucin-producing Pancreatic Tumors: Comparison of MR Cholangiopancreatography with Endoscopic Retrograde Cholangiopancreatography

PURPOSE: To compare magnetic resonance cholangiopancreatography (MRCP) with endoscopic retrograde cholangiopancreatography (ERCP) in the detection of mucin-producing pancreatic tumors.

MATERIALS AND METHODS: The authors retrospectively reviewed MRCP and ERCP images obtained in 28 patients with mucin-producing pancreatic tumors. Detectability of the pancreatic duct and its branches, intraductal cystic lesions, and intracystic nodules or septa was assessed.

RESULTS: MRCP depicted cystic dilated ductal branches significantly better than did ERCP (P < .001). The difference in the number of nodules or septa detected with MRCP compared with ERCP was not significant. MRCP, however, simultaneously showed not only the main pancreatic duct but also the cystic lesions; this was not always possible with ERCP.

CONCLUSION: MRCP appears to be more effective and less invasive than ERCP to evaluate changes in the size and extent of tumors and to determine if new lesions appear, as well as to follow up mucin-producing pancreatic tumors.

Mucin-producing pancreatic tumors have been described relatively recently (1,2). They are likely to originate from the main pancreatic duct or its collateral ducts (intraductal mucin-producing tumors) or from the peripheral ducts (mucinous cystadenocarcinoma and cystadenoma) of the pancreas. Mucinous cystadenocarcinoma and cystadenoma are malignant or premalignant tumors (3), so they should be surgically resected. Conversely, intraductal mucin-producing tumors have papillary hyperplastic, atypical, or overtly malignant epithelium (4). Some intraductal mucin-producing tumors (eg, papillary hyperplastic lesions) are not malignant and should be followed up instead of surgically resected (4).

Endoscopic retrograde cholangiopancreatography (ERCP) and endoscopic ultrasonography (US) are useful in the diagnosis of mucin-producing tumors, especially intraductal tumors (5,6). ERCP can show localized cystic dilatation of the ductal branches and filling defects, and endoscopic US can precisely display the internal architecture of the cysts (7). ERCP and endoscopic US, however, have some drawbacks: Acute pancreatitis occurs in 5% of all cases after ERCP (8-10), technical failure is a possibility (8,11), and some patients cannot tolerate an endoscopic examination.

Recently, magnetic resonance (MR) imaging technology has made it possible to visualize the pancreatic and bile ducts without the use of contrast material or endoscopy (12,13). Several studies have compared the usefulness of MR cholangiopancreatography (MRCP) and ERCP in the evaluation of biliary and pancreatic disorders (13-15). For example, the sensitivity of MRCP is 93%-100% for detection of biliary and pancreatic dilatation and strictures and 81%-89% for irregularities or defects of the main pancreatic duct (13,15). These authors suggest that MRCP will replace ERCP in the diagnosis of calculi of the biliary tract, cancers of the pancreatic and bile ducts and gallbladder, and chronic pancreatitis. To our
knowledge, however, no studies have compared MRCP and ERCP in the diagnosis of mucin-producing tumors of the pancreas. The aim of this study was to compare the efficiencies of MRCP and ERCP in the diagnosis of mucin-producing tumors of the pancreas.

MATERIALS AND METHODS

In our retrospective study, the ERCP images were reviewed by three radiologists (K.K., T.I., N.Y.), who agreed on image quality and lesion detectability. The MRCP images were analyzed retrospectively by the same radiologists without knowledge of any clinical data or ERCP findings. None of the radiologists had performed the MRCP examinations. When the interpretations differed, the interpreters reevaluated images and agreed on the diagnosis.

Patient Population

From April 1995 through June 1997, disease in 35 patients seen at our institutions was diagnosed as cystic lesions of the pancreas by means of US or computed tomography. Of those 35 patients, 28 (11 women, 17 men; mean age, 64 years; age range, 34–81 years) had mucin-producing pancreatic tumors. On the basis of the criteria of Nakazawa et al (1), 21 patients had branch-type (intraductal) tumors, seven had peripheral-type tumors (mucinous cystadenocarcinoma and cystadenoma), and none had “mucinous carcinomas” derived from adenocarcinomas. All patients successfully underwent ERCP; MRCP, and endoscopic US (7.5- and 12-MHz mechanical radial scanner [GF-UM3; Olympus, Tokyo, Japan]). The final diagnosis and the macroscopic appearance were determined on the basis of pathologic examination of the resected specimens in 18 patients (11 with branch-type tumors and seven with peripheral-type tumors) and endoscopic US findings in 10 (all with branch-type tumors). The criteria for endoscopic US diagnosis of mucin-producing tumors have been detailed previously (7) and include the following: (a) solid tumor of the cyst wall that protrudes into the cystic area from the cyst wall, (b) multiple thick septa (>3 mm) in the cyst, and (c) macrocystic multilocular tumors with thick cystic walls. They have a thick wall, and multiple cysts are occasionally present in the tumor. In addition to the pathologic and endoscopic US examinations, we performed cystologic examination of the pancreatic fluid obtained during ERCP from the 21 intraductal tumors; no pancreatic fluid was obtained from peripheral tumors. In 15 of the 21 patients (71%) with intraductal tumors, a patulous orifice of the major papilla and mucinous fluid were observed. In these 21 patients with cystologic findings of adenocarcinoma or adenoma, surgical resection was performed in 11 and follow-up without surgery in 10. The pathologic characteristics of the 28 tumors are described in Table 1.

<table>
<thead>
<tr>
<th>Tumor Type</th>
<th>Pathologic Finding</th>
<th>Location</th>
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</thead>
<tbody>
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<td></td>
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<tr>
<td>Solitary</td>
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<tr>
<td>Papillary adenoma</td>
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<tr>
<td>Not proved*</td>
<td>5 0 1 ... 6</td>
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</tr>
<tr>
<td>Multiple</td>
<td>Papillary adenoma</td>
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<tr>
<td>Not proved*</td>
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</tr>
<tr>
<td>Peripheral</td>
<td>Mucinous cystadenocarcinoma</td>
<td>6 0 0 ... 6</td>
</tr>
<tr>
<td>Mucinous cystadenoma</td>
<td>0 0 1 ... 1</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 1
Characteristics of the 28 Mucin-producing Pancreatic Tumors

* Diagnosis was made with endoscopic US.

MRCP Examination

ERCP was performed in the morning or afternoon after the patients had fasted for at least 5 hours. In 11 patients, a 5-F balloon-tip cannula was used to allow more opacification of the branches of the pancreatic duct. In the remaining 17 patients, ERCP was performed by using a 5-F standard cannula. ERCP was successful in all patients. The contrast medium was 76% amidotrizoate sodium meglumine (76% Urografin; Schering, Osaka, Japan) in a volume of 8–25 mL (mean, 14 mL) with a model JF 1T-10 fibroscope (Olympus, Tokyo, Japan).

MRCP Examination

MRCP was performed with a 1.5-T unit (Visart Hyper; Toshiba, Tokyo, Japan), a surface body coil (spine quadrature coil), and commercially available software. MRCP images were obtained in the morning or afternoon, after the patients had fasted for 12 hours. MRCP was performed with breath-hold two-dimensional (2D) and three-dimensional (3D) half-Fourier fast spin-echo techniques with the patient supine. To restrain bowel motion, we routinely administered intramuscularly 10 mg of butylscopolamine bromide or 1 mg of glucagon for 2D and 3D imaging. In addition, 1,200 mg of ferric ammonium citrate (Otsuka Pharmaceutical, Tokyo, Japan) with 50 mL of water was administered orally to decrease the signal from the bowels.

All 28 patients underwent coronal or paracoronal (10°–30° left anterior oblique) 2D and 3D MRCP and axial 2D MRCP without supplemental oxygen. In 2D imaging, images were obtained during only one 90° pulse and then during 180° pulses for 160 times (repetition time msec/echo time msec = 5/250), with echo train length of 180, field of view of 350 × 350 mm, matrix of 320 × 320, section thickness of 60 mm, 3-second breath hold, bandwidth of 83.3 kHz, echo spacing of 12.5 msec, acquisition time of 3 seconds, and fat suppression (inversion time, 170 msec). In 3D imaging (10,000/250), the pulse sequence included echo train length of 164, field of view of 350 × 350 mm, matrix of 288 × 384, section thickness of 2 mm and slab thickness of 60 mm (2-mm thickness × 30 sections) and no overlap, intermittent breath holds during each repetition time, bandwidth of 83.3 kHz, echo spacing of 12.5 msec, acquisition time of 5 minutes 30 seconds, and fat suppression (inversion time, 170 msec). Postprocessing of 3D coronal images was performed with a maximum intensity projection algorithm by a radiologic
technician in 3–4 minutes per patient. The 3D images were reconstructed at $10^{9}$ intervals.

Image Analysis

The three blinded radiologist readers evaluated the randomized MRCP images to assess the following: (a) detectability of the main pancreatic duct and its branches, (b) detectability of the intraductal cystic lesions in the branches, and (c) presence of intraductal nodules or septa. Detectability was graded as excellent (the whole anatomic part was seen), moderate (most of the anatomic part was seen), poor (the anatomic part was poorly seen), or not shown. Then, they evaluated the ERCP images on the basis of the same grading scale. In addition, they also compared findings on the 2D and 3D MRCP images. The 3D MRCP source images were used only to confirm the presence of intraductal cystic lesions and to rule out different sources of fluid signals such as hepatic and renal cysts and fluid in the gastrointestinal tract. When the interpretations differed, the readers reevaluated images and agreed on the diagnosis.

### Statistical Analysis

The $\chi^2$ test was used to compare detectability of the normal main pancreatic duct and its branches on MRCP and ERCP images and of the pancreatic ducts and lesions on 2D and 3D MRCP images. A paired Student $t$ test was used to compare the number of cystic dilated branches detected in the pancreatic duct and the number of nodules or septa detected in the main pancreatic duct or its dilated branches with each of the two techniques. Differences with a $P$ value of less than .05 were considered statistically significant.

### TABLE 2

<table>
<thead>
<tr>
<th>Detectability</th>
<th>Location</th>
<th>ERCP</th>
<th>MRCP</th>
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<tr>
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<td>Tail</td>
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<td>Body</td>
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<tr>
<td></td>
<td>Tail</td>
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</tr>
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</table>

Note.—Data are number of patients ($n = 28$) with finding. Numbers in parentheses are percentages.

### TABLE 3

<table>
<thead>
<tr>
<th>Detectability</th>
<th>Location</th>
<th>ERCP</th>
<th>MRCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>Head</td>
<td>3</td>
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<tr>
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<td>Body</td>
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<td>Moderate</td>
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<tr>
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</tr>
<tr>
<td></td>
<td>Tail</td>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>

Note.—Data are number of patients ($n = 28$) with finding. Numbers in parentheses are percentages.

* Difference between modalities was statistically significant ($P < .01$).

### Figure 1

Mucinous cystadenoma in the tail of the pancreas. Both the (a) coronal 3D MRCP image and (b) ERCP image clearly depict the main pancreatic duct (arrowheads). The branches of the pancreatic duct are clearly demonstrated in b but not in a. The cystic tumor (arrow) in the pancreatic tail is depicted entirely in a but only partially in b.
RESULTS

Tables 2 and 3 show the number of main pancreatic ducts and branches that were detected in the 28 patients on MRCP and ERCP images. In most cases, detectability of the main pancreatic duct was graded as excellent on both MRCP and ERCP images (Fig 1); there were no statistically significant differences between the two techniques. The main pancreatic duct in the pancreatic tail was only moderately detectable on ERCP images due to the presence of mucinous fluids in the duct (Fig 2). The number of normal branches with excellent detectability was significantly higher with ERCP than with MRCP (P < .01) (Figs 1, 3).

Table 4 shows the number of cystic dilated branches detected with MRCP and ERCP. Detection was significantly better with MRCP than with ERCP (P < .001) (Figs 3, 4).

Table 5 shows the number of nodules or septa detected in the dilated branches of the duct with MRCP and ERCP. Differences between modalities were not statistically significant. MRCP simultaneously depicted the main pancreatic duct and the cystic lesions in seven branch-type (Figs 3, 5) and all peripheral-type (Fig 1) mucin-producing tumors, but ERCP did not. ERCP depicted the normal main pancreatic duct and its branches better than did MRCP, but the latter depicted the diseased ducts more clearly than did the former.

Table 6 compares the detectability of the pancreatic duct and its branches and lesions on 2D and 3D MRCP images. Differences between the two techniques in the detection of the normal main pancreatic duct and its branches were not statistically significant, but 3D images depicted significantly more cystic dilated branches (P < .01) and nodules or septa in the dilated branches (P < .05) than did 2D imaging.

Finally, cytologic examination of the pancreatic fluid obtained from the intraductal lesions during ERCP showed that 11 of the 21 lesions (52%) were suspicious for adenocarcinoma or adenoma and 10 (48%) were suspicious for hyperplastic lesions. After the ERCP procedure, the serum amylase level was elevated (132–820 U/L; mean, 261 U/L) in eight of the 28 patients (29%), but no cases of clinically apparent pancreatitis were encountered.

DISCUSSION

Mucin-producing pancreatic tumors are a comparatively recently described entity (1,2). Of these tumors, intraductal mucin-producing pancreatic tumors have been reported by many Japanese researchers (1,2,5,6,16–21), as well as European and American researchers (22–25). In 1982, Ohhashi et al (16) defined mucin-hypersecreting pancreatic cancer at endoscopy.
as a tumor associated with hyperexcretion of the mucinous fluid through the patulous orifice of the papilla of Vater. They found dilatation of the main pancreatic duct and/or its branches with filling defect(s) at pancreatography. Obara et al (17) also reported nine cases of mucin-hypersecreting pancreatic tumors, including cancer and adenoma. They found diffuse dilatation of the main pancreatic duct or its branches with nodules of mucin or tumors, as well as a better prognosis (range of postoperative follow-up, 3–41 months; mean follow-up, 21.8 months).

Kuroda (18), Nakazawa et al (11), and Yamada et al (2) proposed a new conceptual category, suggesting that mucin-hypersecreting pancreatic tumors and mucinous cystic tumors of the pancreas (mucinous cystadenocarcinoma and cystadenoma) belong to the same entity. Both tumors originate from the epithelium of the pancreatic duct, and they produce and excrete copious amounts of mucus. Tumors in the pancreatic duct or in cysts show papillary growth. Columnar, mucin-producing epithelium grows with papillary configuration. Malignant tumors typically contain extensive nonmalignant epithelium with a smaller amount of malignant epithelium. Thus, mucin-producing pancreatic tumors are composed of two morphologic features: One is the intraductal papillary tumors derived from the main pancreatic duct (main duct type) or its branches (branch type), and the other is the mucinous cystadenocarcinoma and cystadenoma that originate from the peripheral ducts (peripheral type).

As described previously, hyperplastic lesions that do not need to be surgically resected contain intraductal mucin-producing tumors (4). Therefore, a less invasive but precise technique to follow up those benign lesions instead of ERCP or endoscopic US is necessary. MRCP is a new technique for visualizing the biliary and pancreatic ducts and detecting various abnormalities such as cystic changes, stones, stenosis, dilatation, and nodules of the biliary or pancreatic ducts (12–15). MRCP does not require the use of contrast material or endoscopy, and the examination can be easily repeated.

In our study, the detection rate of the main pancreatic duct was equivalent for MRCP and ERCP, although the sensitivity of detecting the normal ductal branches with MRCP was less than that with ERCP. The most important finding in our study was that detectability of cystic dilatation of the branches and of nodules or septa in the cystic lesions was significantly better with MRCP than with ERCP (Figs 4, 5). We believe the reason MRCP was better at depicting the cystic lesions is that mucin or tumors, as well as a better prognosis (range of postoperative follow-up, 3–41 months; mean follow-up, 21.8 months).

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uous fluid produced by the tumors or the tumors themselves inhibited adequate inflow of the contrast material into the cystic dilated branches. Thus, direct visualization of the fluid in the cystic lesions with MRCP was superior to that provided by opacifying the lesions with contrast material at ERCP. Most mucinous cystadenocarcinomas and cystadenomas are not connected to the main pancreatic duct or its branches; therefore, ERCP usually fails to depict their cystic appearance. In contrast, because MRCP can depict the fluid signal intensity, it is easily able to show both the cystic lesions and the ductal systems in the same plane (Fig 1). Conversely, MRCP does not offer any pathologic information for deciding whether the lesions are malignant. From this point of view, ERCP is superior to MRCP because pancreatic fluid sampling for cytologic examination and main pancreatic duct biopsy through the papilla are possible during ERCP. We believe, however, that MRCP is more useful and less invasive than ERCP for follow-up to evaluate changes in the size and extent of tumors and to determine if new lesions appear.

In our study, 3D images enabled significantly better detection of cystic dilatation of the branches and of nodules or septa in the dilated branches than did 2D images (Table 6). This difference may be a result of differences in section thickness (2D imaging, 60 mm; 3D imaging, 2 mm). This means that 3D imaging is necessary to evaluate the extent of mucin-producing pancreatic tumors and to observe the relationships between the bile duct and the pancreatic duct and the pancreatic cystic lesions in the main pancreatic duct and its branches. Two-dimensional imaging can be used to provide an overview of the main pancreatic duct just before 3D imaging.

One of the drawbacks of MRCP is the poor detectability of normal pancreatic branches. Use of software developed to improve the detection of signal in the fine ducts and stimulation of the pancreatic fluid by means of secretin injection may help solve this problem. Nevertheless, we believe that MRCP is much more effective than ERCP in the follow-up of mucin-producing tumors of the pancreas because the pathophysiologic characteristics of the disorder is to induce mucin production, which leads to dilatation of the main pancreatic duct or its branches and causes dilated ducts as well as cystic tumors. These changes are easily detected with MRCP.

In conclusion, MRCP is more effective and less invasive than ERCP in the evaluation of the changes in size and extent of mucin-producing tumors of the pancreas, and the former may replace the latter in the evaluation of these tumors, for which follow-up is necessary.

Acknowledgment: The authors thank Tsutomu Tomita, who operated the MR imaging equipment and acquired the MRCP images.

References