Diffusion-Weighted MR Imaging of Pancreatic Cancer and Chronic Pancreatidis

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Aims and objectives

Chronic pancreatitis is a progressive inflammatory disorder in which pancreatic secretory parenchyma is destroyed and replaced by fibrous tissue, eventually leading to stricture and dilatation of the pancreatic duct system [1, 2]. The presence of benign duct dilatation in chronic pancreatitis combining mass-forming focal pancreatitis may mimic a pancreatic cancer, which is a severe disease with poor prognosis and often presents with pancreatic duct dilatation [3, 4-6]. Besides, non-visual demarcated pancreatic cancer with pancreatic duct dilatation may be difficult to differentiate from benign duct dilatation in chronic pancreatitis in traditional dynamic MR imaging. Even true-cut biopsy may not be able to distinguish pancreatic cancer from focal pancreatitis because the inflammation within the tumor may be the only content of the specimen [7]. Thus, it is important to make a correct diagnosis to avoid unnecessary operative and invasive procedures. Recently, diffusion-weighted MR imaging and apparent diffusion coefficient (ADC) measurements have been applied to the abdomen, such as hepatic, pancreatic and renal lesions [3]. High b-value diffusion-weighted MR Imaging also have been reported might be a useful tool for detecting pancreatic adenocarcinoma with high sensitivity and specificity [8]. The purpose of this study is to evaluate whether diffusion-weighted imaging (DWI) and ADC measurement can help to distinguish pancreatic cancer from chronic pancreatitis with benign duct dilatation.
Methods and materials

Patients

Forty-five patients with suspicious of pancreatic cancer were retrospectively reviewed in this study. The pancreatic cancer group was composed of 11 patients (3 women and 8 men; age range 43-79 years, mean age 67.3 years) with pathological proof of adenocarcinoma by core-needle biopsy, operative resection sample of pancreatic tumor or liver metastasis. The benign group was composed of 34 patients of chronic pancreatitis combining benign duct dilatation with (n=2) or without (n=32) visible of pancreatic mass (17 women and 17 men, age range 30-91 years, mean age 67.9 years). The chronic pancreatitis was diagnosed without histopathologic proof, based on repeated imaging (MRI or dynamic computed tomography), low tumor marker and clinical follow-up (mean 9.4 months) after the initial presentation.

MR Protocol

All patients underwent MRI of the upper abdomen performed on a 1.5T MR scanner (Signa HDxt; GE Healthcare, Milwaukee, WI, USA) with 8-channel phased-array coil. Initial imaging consisted of axial T2-weighted fast spin-echo imaging (T2WI) with fat suppression (repetition time [TR], 11250 ms; echo time [TE], 92.1 ms; echo train length, 64 times; field-of-view [FOV], 300-380 mm; slice thickness, 6.0 mm; space, 0.6 mm; asset factor, 2; number of excitations [NEX], 1; matrix, 288 x 224) followed by Magnetic resonance cholangiopancreatography (3D fast recovery fast spin echo respiratory gating; TR, 2600-8570 ms; TE, 425 ms; FOV, 240 mm; slice thickness, 1.6 mm; asset factor, 2; NEX, 1; matrix, 320 x 192). DWI was acquired through the pancreas at 22 slice locations utilizing a finger pulse- triggered diffusion-weighted single-shot spin-echo echo-planar imaging (EPI) technique (TR, 18750 ms; TE, 66.3 ms; b = 0 and 1000 seconds/mm², FOV, 300-380 mm; slice thickness, 5 mm; spacing, 1 mm; asset factor, 2; NEX, 2; matrix, 96 x 128). A magnitude ADC image was calculated from the images with a diffusion gradient applied along the x, y, and z orthogonal axes. Non-contrast T1-weighted imaging (T1WI) with fat suppression (fast spoiled gradient echo recalled acquisition in the steady state; TR, 3.72 ms; TE, 1.76 ms; FOV, 300-380 mm; slice thickness, 5 mm; #ip angle, 12°; bandwidth, 31.25 kHz; asset factor, 2; NEX, 1; matrix: 288 x 160) and serial gadolinium-enhanced images were acquired at late arterial, portal venous phase and delayed venous phase with injection dose of 0.1 mmol/kg of body weight.

Image Analysis

All images were loaded to a workstation and magnitude ADC values were calculated using the software provided by the MR scanner manufacturer (AW server 2.0, GE Healthcare). The pancreatic cancer and mass-forming focal pancreatitis were initially
localized on T1-weighted fat-saturated non-contrast and serial contrast-enhanced images and visually correlated with DWI of \( b = 0 \) and 1000 seconds/mm\(^2\). During localization, pancreatic cancer was recognized by its poor arterial enhancement and demarcation from the rest of the gland. Chronic pancreatitis with presence of mass lesion, such as mass-forming focal pancreatitis, was localized as enlarged area on the pancreatic parenchyma with indistinguishable enhancement pattern from the remaining gland. The ADC measurement was performed by an experienced radiologist. Magnitude ADC values of the pancreas were measured in all patients using an operator-defined region-of-interest (ROI). Areas of cysts and side branch ectasia were excluded during measurement of the pancreatic gland. The ADC values of mass lesions were measured with an ROI as large as possible (43-120 mm\(^2\)) in patients with pancreatic cancer and mass-forming focal pancreatitis. In chronic pancreatitis without visible mass, ROI was placed in pancreatic head parenchyma proximal to duct dilatation. The ADC value of remaining pancreas was calculated from the mean measurement of head, body, and tail of pancreas with a standard-sized ROI = 100 mm\(^2\).

**Statistical Analysis**

The Student’s t-test was used to determine whether there was a significant difference between the ADC values in the cancer lesion, the remaining pancreas, pancreatic head parenchyma in the benign group, the remaining pancreas in the benign group, the ADC ratio of pancreatic lesion to the remaining parenchyma in cancer and benign groups. All values were expressed as mean ± SD, and a P value of < 0.05 was considered statistically significant. The statistical analysis was performed using the SPSS software program.
Results

The maximum tumor diameter of pancreatic cancer ranged from 2.7 to 6.7 cm (mean 4.1 cm), the corresponding values for the mass-forming focal pancreatitis were 2.6 to 4.5 cm (mean 3.6 cm). There was no significant difference of ADC values between the pancreatic head parenchyma (1.59 ± 0.31 × 10^{-3} \text{mm}^2/\text{second}) and the remaining pancreas in the benign group (1.57 ± 0.22 × 10^{-3} \text{mm}^2/\text{second}; P = 0.782, Table 1 on page 6). The mean ADC value of pancreatic cancer (1.32 ± 0.13 × 10^{-3} \text{mm}^2/\text{second}) was significantly lower than the remaining pancreas (1.67 ± 0.40 × 10^{-3} \text{mm}^2/\text{second}; P = 0.008, Table 2 on page 6) and pancreatic head parenchyma in the benign group (P = 0.001, Table 3 on page 6). Receiver operating characteristic (ROC) curve analysis between pancreatic cancer and pancreatic head parenchyma in the benign group yielded 0.817 of area under curve (AUC) with optimal cutoff value of 1.405 × 10^{-3} \text{mm}^2/\text{second} for differentiating pancreatic cancer from non-cancerous pancreatic parenchyma (sensitivity of 81.8 % and specificity of 73.5 %). The ratio of pancreatic cancer to the remaining pancreas (0.82 ± 0.17) compared to the ratio of pancreatic head parenchyma to the remaining pancreas in the benign group (1.01 ± 0.12) also revealed significant difference (P = 0.001). The corresponding ROC curve analysis yielded 0.829 of AUC with optimal cutoff value of ratio of 0.877 for the detection of pancreatic cancer (sensitivity of 72.7 % and specificity of 94.1 %) (Fig. 1 on page 7, Table 4 on page 7).
Table 1. Mean ADC values in chronic pancreatitis with benign duct dilatation

<table>
<thead>
<tr>
<th>Benign group (n=34)</th>
<th>ADC ± S.D*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pancreatic head parenchyma</td>
<td>1.59 ± 0.31</td>
</tr>
<tr>
<td>Remaining pancreas</td>
<td>1.57 ± 0.22</td>
</tr>
</tbody>
</table>

P value 0.782

*Data are mean values in units of $10^{-3}$ mm$^2$/second

ADC = apparent diffusion coefficient

Table 2

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Table 2. Mean ADC values in pancreatic cancer group

<table>
<thead>
<tr>
<th>Cancer group (n=11)</th>
<th>ADC ± S.D*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cancer</td>
<td>1.32 ± 0.13</td>
</tr>
<tr>
<td>Remaining pancreas</td>
<td>1.67 ± 0.40</td>
</tr>
</tbody>
</table>

P value 0.008

*Data are mean values in units of $10^{-3}$ mm$^2$/second

ADC = apparent diffusion coefficient

Table 3

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Table 3. Mean ADC values of pancreatic cancer and the benign group

<table>
<thead>
<tr>
<th>Pancreatic disease</th>
<th>ADC ± S.D*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cancer (n=11)</td>
<td>1.32 ± 0.13</td>
</tr>
<tr>
<td>Pancreatic head parenchyma (n=34)</td>
<td>1.59 ± 0.31</td>
</tr>
</tbody>
</table>

P value 0.001

*Data are mean values in units of $10^{-3}$ mm$^2$/second

ADC = apparent diffusion coefficient
**Fig. 1:** ROC curves for differentiating pancreatic cancer from non-cancerous pancreatic parenchyma of the 2 parameters

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Table 4. Result from the ROC curves analysis of the 2 parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AUC*</th>
<th>Optimal Cutoff Values</th>
<th>Sensitivities (%)</th>
<th>Specificities (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC-v</td>
<td>0.817</td>
<td>1.405*</td>
<td>81.8</td>
<td>73.5</td>
</tr>
<tr>
<td>ADC-r</td>
<td>0.829</td>
<td>0.877</td>
<td>72.7</td>
<td>94.1</td>
</tr>
</tbody>
</table>

*Data is in units of $x 10^{-3}$ mm$^2$/second

AUC = area under curve

ADC-v indicates ADC values of pancreatic cancer versus pancreatic head parenchyma in benign group.

ADC-r indicates the ratio of pancreatic cancer to remaining pancreas versus the ratio of pancreatic head parenchyma to remaining pancreas.
Conclusion

Differentiating pancreatic cancer from chronic pancreatitis with benign duct dilatation is difficult because both of above may present duct dilatation with pancreatic mass. Since DWI has been widely used for detection tumor recently, we try to evaluate whether DWI and ADC measurement can also help to distinguish pancreatic cancer from non-cancerous pancreatic parenchyma. In our study, most pancreatic cancer was visual demarcated from the remaining pancreas with its hyperintense signal relative to the background remaining pancreas. The ADC value was significantly lower for the tumor than for non-cancerous tissue and the ADC map images revealed the matching color of it (Fig. 2 on page 10). One of our cases of malignancy presents pancreatic duct dilatation without significant demarcated mass in pancreas while DWI shows high signal intensity in pancreatic head compared to the remaining pancreas (Fig. 3 on page 10). Conversely, the signal intensity of mass-forming focal pancreatitis in chronic pancreatitis, which combing pancreatic duct dilatation and mimic pancreatic cancer in traditional dynamic MR imaging, in DWI and ADC color map are visually indistinguishable from the remaining pancreas (Fig. 4 on page 10). The ADC values of pancreatic cancer tend to be lower than normal pancreas in most of the previous studies because the presence of dense fibrosis and increased cellular elements. However, when the tumor reveals loose fibrosis that are more prevalent than the cellular component or mucin, the ADC values can be higher than the normal pancreas [8, 9]. Sometimes, cystic change may be present in the pancreatic tumor. It should be excluded while selecting the ROI area since that might be associated with increased motion of the water protons in the tissue, and hence influence the ADC value. In our study, the ADC values of pancreatic cancer is significant different from non-cancerous pancreatic parenchyma. The result of ROC curves show superior specificity in detecting pancreatic cancer by using ADC ratio of pancreatic cancer to the remaining pancreas than using ADC value, although the P value revealed no statistically difference between these two methods (P=0.910). The limitation of this study was limited cases with pancreatic cancer to compare the ADC values. Further study with larger number of cases and long-term follow-up should be considered. In conclusion, measurement of ADC values can help in differentiating pancreatic cancer from chronic pancreatitis with benign duct dilatation.
Fig. 2: A 70-year-old patient with adenocarcinoma in the tail of pancreas with multiple liver metastases. (A) Axial contrast-enhanced fat-suppressed T1WI shows an irregular heterogenous tumor in the tail of pancreas (arrow) with relative hypoenhancement and multiple liver metastases (arrowheads). (B) Diffusion-weighted image shows the tumor (arrow) and liver masses with high signal intensity compared to the surrounding pancreatic parenchyma. The signal intensity of the liver masses (arrowheads) is similar to that of the pancreatic tumor and suggests liver metastases. (C) Colored ADC map with an ADC color scale demonstrates the similar ADC values of pancreatic tumor (arrow; 1.12 × 10^-3 mm^2/second) and liver metastases (arrowheads, 1.15 × 10^-3 mm^2/second). Both of above ADC values are significant lower than the value of remaining pancreas (1.39 × 10^-3 mm^2/second).

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Fig. 3: A 74-year-old patient with adenocarcinoma in head of pancreas. (A) Axial contrast-enhanced fat-suppressed T1WI shows pancreatic duct dilatation without significant visual mass in pancreatic head (arrow). (B) Diffusion-weighted image shows high signal intensity in pancreatic head (arrow) compared to the remaining pancreas. (C) Colored ADC map shows predominant blue color (arrow; ADC value of 1.24 × 10^-3 mm^2/second) suggesting restricted water diffusion, which is different from the remaining pancreas (ADC value of 1.67 × 10^-3 mm^2/second).

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Fig. 4: A 46-year-old patient with mass-forming focal pancreatitis in head of pancreas. (A, B) Axial contrast-enhanced fat-suppressed T1WI shows pancreatic duct dilatation (arrowhead) with a suspicious mass in pancreatic head (arrow). (C, E) Diffusion-weighted image with colored ADC map of mass in pancreatic head (arrow; ADC value of $1.24 \times 10^{-3}$ mm$^2$/second) shows signal intensity visually indistinguishable from the remaining pancreas (D, F) (arrowhead; ADC value of $1.29 \times 10^{-3}$ mm$^2$/second).

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References


