Hilar Cholangiocarcinoma: Diagnosis and Evaluation of Resectability with the Three-Dimensional Thin-section Contrast-enhanced Dynamic MR Imaging Sequence

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Abstract. Hilar cholangiocarcinoma is a malignant tumour with high mortality, thus early diagnosis of tumour and accurate staging are crucial for planning of treatment and survival improvement. The purpose of this study was to evaluate the diagnostic value of the three-dimensional (3D) T1-weighted thin-section dynamic enhanced MR imaging sequence in the preoperative evaluation of hilar cholangiocarcinoma. Thirty-one patients with hilar cholangiocarcinomas confirmed by surgery and pathology were performed preoperative MR imaging examination, sequences including two-dimensional (2D) T1- and T2-weighted plain scanning, 2D MR cholangiopancreatography (MRCP), 3D T1-weighted thin-section dynamic enhanced tri-phasic scanning in the early arterial, late arterial and portal venous phases, and 2D T1-weighted enhanced scanning in the equilibrium phase. Imaging data of 3D T1-weighted enhanced sequence, 2D T1-weighted enhanced sequence, and 2D MRCP were interpreted by two abdominal radiologists through consensus reading in blind manner, focusing on the assessment of the morphological type, the longitudinal extent of tumour infiltration in the bile ducts and the involvement of neighboring blood vessels. The accuracy between 3D T1-weighted and 2D T1-weighted enhanced sequences in assessing the tumour resectability was compared. 3D T1-weighted enhanced images directly displayed hilar tumour in 31 patients and accurately classified their morphological types, whereas 2D T1-weighted enhanced images missed 8 patients of periductal-infiltrating tumours (8/31, 25.8%). Using the Bismuth-Corlette classification, 3D T1-weighted enhanced sequence was closed to MRCP (28/31, 90.3%) in delineating the intraductal extent of tumour infiltration, but 2D T1-weighted enhanced sequence (10/31, 32.3%) obviously underestimated the extent. Difference between the two MR sequences had statistical significance (P<0.05). Involvement of the hepatic artery, the portal venous trunk and their branches was shown more frequently on 3D T1-weighted enhanced images than on 2D T1-weighted enhanced images. The positive predictive value and accuracy of 3D T1-weighted sequence (84.2%, 90.3%) for assessing tumour resectability were higher than those of 2D T1-weighted enhanced sequence images than on 2D T1-weighted enhanced images. The positive predictive value and accuracy of 3D T1-weighted sequence (84.2%, 90.3%) for assessing tumour resectability were higher than those of 2D T1-weighted enhanced sequence (64.0%, 71.0%). Therefore, 3D T1-weighted thin-section dynamic enhanced sequence is better than 2D T1-weighted enhanced sequence in the preoperative assessment of the morphological type, the intraductal infiltrating extent and the tumour resectability of hilar cholangiocarcinomas.

Keywords: cholangiocarcinoma, hilar, dynamic imaging, magnetic resonance imaging.

1. Introduction

Hilar cholangiocarcinomas are malignant tumours arising from the epithelium of hepatic ducts at the liver hilum. They account for 25% of cholangiocarcinomas and are frequently adenocarcinomas [1-3]. The 5-year survival rate of these tumours is only 1% without surgical resection and is improved to 20% after curative resection [3, 4]. Thus, preoperative imaging evaluation including classification and staging of tumour is crucial for treatment planning and assessment of prognosis. Diagnostic value of helical computed tomography (CT) with multi-phasic contrast-enhanced scanning has been reported for hilar cholangiocarcinomas [5-8]. Magnetic resonance cholangiopancreatography (MRCP) and conventional two-dimensional (2D) T1- and T2-weighted MR sequences have also been used [9-14]. The recently

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introduced three-dimensional (3D) T1-weighted thin-section dynamic enhanced MR imaging sequence allows fast dynamic volumetric acquisitions of thin sections that satisfactory diagnostic results have already been reported in liver and breast imaging [15-18]. Yet there are few literature reports addressing the diagnostic value of 3D T1-weighted MR sequence for hilar cholangiocarcinomas. Therefore, the purpose of this study was to determine the efficacy of 3D T1-weighed thin-section dynamic enhanced MR imaging sequence for diagnosis and resectable evaluation of hilar cholangiocarcinomas.

2. Methods

2.1. Patients

Between Jul. 2004 and Sep. 2006, a total of 78 consecutive patients, suspected of having biliary obstruction at the level of hepatic hilum on clinic or other imaging examination basis, were performed an entire set of MRI examination including 3D T1-weighted thin-section dynamic enhanced MR imaging sequence for the upper abdomen in Huaxi hospital, where the research is conducted. Written informed consent was obtained from each patient for administration of MR contrast material. The inclusion criteria of this study included (a) adequate MR imaging quality for analysis, (b) surgery performed within 2 weeks or less after the MR examination in the hospital, and (c) histologically confirmed hilar cholangiocarcinoma. As a result, thirty-one patients (22 men, 9 women, age range 21-74 years, average 53 years) met above inclusion criteria and thus were enrolled into the study. All 31 patients presented with jaundice and had ultrasound examinations prior to MR scanning. CT scan was also performed on 17 of the 31 patients. Curative resection was performed on 16 patients and explorative laparotomy was performed on 15 patients.

2.2. MR Imaging Protocol

All patients underwent MR imaging using a 1.5 T MR system (Siemens Sonata, Erlangen, Germany) and a torso phased-array coil. A 22-gauge intravenous catheter was placed in an arm vein and connected to a MR-compatible power injector. For each patient, unenhanced acquisitions were performed prior to enhanced sequences. The unenhanced MR sequences included axial fast spin-echo (FSE) T2-weighted (TR1000ms/TE83ms, 8-mm slice thickness), 2D GE (gradient echo, GE) T1-weighted (TR100ms/TE4.8ms, 8-mm slice thickness), and 2D oblique coronal single-shot FSE (SSFSE) MRCP(TR4500ms/TE760ms, 60-mm slab thickness, 6-8° angle change between adjacent slabs, acquiring 9-12 times). 3D T1-weighted thin-section dynamic enhanced MR imaging scanning with 3D-VIBE sequence (three-dimensional volumetric interpolated breath-hold examination, 3D-VIBE) was started at 15s, 40s and 65s after initialization of contrast material injection in order to obtain tri-phasic enhanced images corresponding to the early arterial, late arterial and portal venous phases respectively. The imaging parameters of 3D sequence were TR4.2ms/TE1.8ms, flip angle of 12°, FOV of 300-360mm, matrix of 256×256, and in-plane spatial resolution of 2.0mm or less. The entire slab thickness ranged from 80-mm to 100-mm, and the partition thickness was 2-mm (in Kz spatial resolution of 2.0mm). Acquisition of 3D thin-section images for each phase was finished during a single breath-hold at the end of expiration (time range, 14-16s, mean time 15.1s). The total table time for the completion of dynamic tri-phasic acquisition averaged around 80s. Hepatic hilum was defined as the center of scanning coverage in every patient. All patients received 10ml of Gadolinium-contrast material (dose range 0.12–0.18mmol/kg) at a flow rate of 2–3ml/s followed by flash of 20ml normal saline. After 3D dynamic scanning, axial enhanced scanning with 2D GE T1-weighted (TR 124ms/TE 2.5ms, 8-mm slice thickness) was immediately performed to acquire images of the equilibrium phase.

2.3. Image Analysis

Image postprocessing and analysis were done at the workstation of the MR system (Leonardo, Siemens, Germany). Images of three sequences including (a) the original and reconstructed tri-phasic 3D thin-section dynamic enhanced images, (b) the enhanced 2D T1-weighted images in the equilibrium phase, and (c) the MRCP images were consecutively interpreted with the consensus reading of two abdominal radiologists who knew only the diagnosis of hilar cholangiocarcinomas, but were blind to the operative findings and the image.
orders of every sequence. Observation was especially focused on the tumour location, morphological type, enhancement pattern, infiltrating extent of bile duct, involvement of adjacent vessels, and metastases. Diagnostic value of three MR sequences was evaluated from the following three aspects: (1) The ability to correctly classify the morphological types of hilar cholangiocarcinomas (mass-forming type, periductal-infiltrating type, and intraductal-growing type), based on the new classification system for cholangiocarcinoma proposed by The Liver Cancer Study Group of Japan [1]. (2) Because MRCP has been demonstrated to have accuracy similar to direct cholangiography for identifying the level and extent of biliary obstruction [9-13], the longitudinal extent of tumour infiltration in the bile ducts depicted on the 3D and 2D T1-weighted enhanced images were compared to the findings on MRCP using the Bismuth-Corlette classification [7]. The Chi-square test was used to compare accuracies of 3D and 2D T1-weighted enhanced sequences for depicting the extent of tumour infiltration in the bile ducts (SPSS12), significance was defined as $P<0.05$. (3) The ability of 3D and 2D T1-weighted enhanced sequences to correctly assess the tumour resectability with comparision of surgical findings is based on the current criteria of curative resectability for hilar cholangiocarcinoma [3, 19].

3. Results

3.1. Morphological Classification of Hilar Cholangiocarcinoma

According to the Japanese Classification Scheme [1], the morphologic types of 31 hilar cholangiocarcinomas delineated by three MR sequences were summarized as following (Table 1).

3D thin-section dynamic enhanced images directly visualized all of 31 tumours and accurately classified their morphologic types including 11 mass-forming types, 18 periductal-infiltrating types and 2 intraductal-growing types. (a) Eleven mass-forming tumours were shown as well-defined masses with average diameter of 3.2 cm (range 2.1-4.6 cm) and irregular borders in the liver hilum. In the arterial phase, there was mild peripheral (n=8) or no (n=3) contrast enhancement of the tumours. Gradual centripetal enhancement yet less than the normal hepatic parenchyma was seen in the portal venous phase (Fig.1A, 1B). Central necrosis with rim-like enhancement was noticed in 2 mass-forming tumours. (b) All 18 periductal-infiltrating tumours displayed focal asymmetrical or symmetrical wall thickening of the involved bile ducts with the narrowed or obliterated lumen in the liver hilum. The involved bile duct segments were seen as point- or rim-like findings on axial images and railway-like appearances on coronally or sagittally reconstructed images using multi-planar reconstruction (MPR) technique (Fig.2A~2D). There was contrast enhancement of the tumours in both the arterial and portal venous phases (especially the portal venous phase) in 14 cases; only in the portal venous phase in 3 cases or only in the arterial phase in 1 case. (c) The two intraductal-growing tumours were depicted as intraductal masses with mild contrast enhancement. The involved bile ducts showed obvious wall thickening but with smooth outer walls in the liver hilum (Fig.3A~3C).

The 2D T1-weighted enhanced images directly exhibited all 11 mass-forming tumours. However, of 18 periductal-infiltrating tumours, only 10 tumours were seen as focal wall thickening with enhancement. The remaining 8 tumours were not directly visualized on 2D T1-weighted enhanced images. A 2D T1-weighted sequence also revealed intraductal masses but with suboptimal morphological details in 2 patients with intraductal-growing tumours (Fig.3D).

MRCP images clearly showed luminal narrowing or obliteration of the involved bile ducts in the liver hilum as well as the dilatation of bile duct proximal to the obstructing tumours in 31 patients. Separation and non-union of the left and right hepatic ducts were observed in 28 patients (Fig.1E~3E). Except for 3 patients who were correctly identified as the periductal-infiltrating type due to the typical stringlike narrowing of the hepatic common duct (Fig.2E), the tumour morphologic types in the remaining 28 patients could not be determined on MRCP images.
Table 1. Morphological classification of 31 patients with hilar cholangiocarcinoma judged by three MRI sequences.

<table>
<thead>
<tr>
<th>Morphological classification of hilar cholangiocarcinoma (cases)</th>
<th>Mass-forming (11)</th>
<th>Periductal-infiltrating (18)</th>
<th>Intraductal-growing (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D T1-weighted</td>
<td>11</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>2D T1-weighted</td>
<td>11</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>MRCP</td>
<td>/</td>
<td>3</td>
<td>/</td>
</tr>
</tbody>
</table>

3.2. Extent of Tumour Infiltration in Bile Ducts

The extent of bile duct obstruction was categorized using the Bismuth-Corlette classification [7]. In this classification, type I is a non-obstructed primary confluence of the right and the left hepatic ducts; type II is obstruction limited to the primary confluence; type III involves the primary confluence with extension to the right (type IIIa) or the left (type IIIb) secondary confluence; and type IV involves the secondary confluence of both the right and left hepatic ducts. With MRCP being used as the standard of reference, Table 2 listed the comparison between 3D and 2D T1-weighted enhanced images for the assessment of the longitudinal extent of tumour infiltration along the bile ducts in 31 patients.

Table 2. The longitudinal extent of tumour in bile ducts revealed by 3D and 2D T1-weighted enhanced sequences in 31 patients with hilar cholangiocarcinoma compared with MRCP.

<table>
<thead>
<tr>
<th>Bismuth-Corlette classification based on MRCP (number of cases)</th>
<th>I (n=3)</th>
<th>II(n=10)</th>
<th>IIIa(n=6)</th>
<th>IIIb(n=10)</th>
<th>IV(n=2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D T1-weighted</td>
<td>3</td>
<td>10</td>
<td>5</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>2D T1-weighted</td>
<td>8</td>
<td>18</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Accuracies of 3D and 2D T1-weighted sequences were compared, $\chi^2=22.026$, $P=0.000<0.05$.

Compared to MRCP, one type IIIa and two type IIIb were mis-classified as type IV on 3D thin-section images, reaching a consistency between 3D sequence and MRCP of 90.3%. 2D T1-weighted enhanced sequence was correct in ten patients including three type I, five type II, one type IIIa and one type IIIb, yielding a consistency of 32.3% with MRCP. Statistical analysis also revealed that the difference between 3D and 2D T1-weighted enhanced sequences in judging the tumour infiltration extent in bile ducts was significant ($\chi^2=22.026$, $P<0.05$). Therefore, 3D sequence was closer to MRCP than 2D T1-weighted enhanced sequence for defining the extent of tumour infiltration in bile ducts (Fig.1~3).

3.3. Involvement of Blood Vessels and Metastases

Imaging findings of vascular involvement included blurring of the perivascular structure, tumour encircling, narrowing and discontinuity of blood vessels. In this group of patients, 3D sequence delineated the involvement of the main trunk of portal vein and hepatic arteries in 8 cases, the left branch of portal vein in 7, the right branch of portal vein in 3, and both branches of portal vein in 3. Whereas 2D T1-weighted enhanced images displayed involvement of the main trunk of portal veins in 7 cases, the left branch of portal vein in 4, the right branch of portal vein in 3 and the both branches of portal vein in 1. Surgical findings revealed that the main trunk of portal vein and hepatic artery were encircled by tumours in 10 patients, giving rise to the freezing appearance of the involved hilar structures. Of 14 patients with metastases of lymph nodes confirmed in surgical exploration, 3D thin-section images revealed abnormal lymph nodes in the hepatic hilum in 7 patients, while 2D T1-weighted images showed lymphadenopathy in 5 patients. Both sequences depicted the liver metastasis lesion in one patient.

3.4. Comparison of Tumour Resectability

Correct morphologic classification and accurate staging of hilar cholangiocarcinoma are necessary to
determine whether the tumour is resectable. Although there are disagreements among surgeons about the criteria for tumour resectability, non-resectability of hilar cholangiocarcinoma is suggested by: (a) cholangiographic evidence of severe bilateral involvement of the secondary confluence, (b) involvement of the main trunk of portal vein, (c) involvement of both bilateral branches of portal vein or bilateral involvement of the hepatic artery and portal vein, or (d) vascular involvement on one side and extensive bile duct involvement on the other side [3, 19]. Based on above criteria, tumour resectability of 31 patients judged by using positive imaging findings on 3D and 2D T1-weighted enhanced images respectively, were compared with the surgical findings (table 3).

Table 3. Assessment of tumour resectability revealed by 3D and 2D T1-weighted sequences in 31 patients with hilar cholangiocarcinoma with comparison of surgical findings.

<table>
<thead>
<tr>
<th></th>
<th>curative resection</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>3D T1-weighted</td>
<td>yes</td>
<td>16</td>
</tr>
<tr>
<td>sequence</td>
<td>no</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>2D T1-weighted</td>
<td>yes</td>
<td>16</td>
</tr>
<tr>
<td>sequence</td>
<td>no</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 3 showed that tumours were judged to be resectable in 19 patients and non-resectable in 12 based on 3D sequence, thus yielding a positive predicting value of 84.2% and an accuracy of 90.3% for assessing tumour resectability. Whereas 25 tumours were judged to be resectable according to 2D T1-weighted sequence, producing a positive predicting value of 64.0% and an accuracy of 71.0%. 2D T1-weighted sequence obviously overestimated tumour resectability.

Fig.1: A 36-year-old man with mass-forming type of moderately differentiated adenocarcinoma of bile duct. (1A) Axial contrast-enhanced 3D thin-section image in the early arterial phase shows the tumour in the liver hilum without obvious enhancement (arrow) and involvement of secondary bifurcation of the left hepatic ducts. (1B) There is less intensive enhancement of the tumour (arrow) than the normal hepatic parenchyma on 3D thin-section image of the portal venous phase. (1C) Involvement of secondary bifurcation of right hepatic duct (arrows) is seen at a lower level than (1B). The tumour is correctly classified as Bismuth-Corlette type IV on 3D images. (1D) 2D T1-weighted enhanced image with slice level similar to image (1C) shows inordinate hilar structure and the dilatated bile ducts, but can not suggest the involvement of the secondary bifurcation of right hepatic duct (arrow). (1E) Coronal 2D MRCP shows Bismuth-Corlette type IV tumour extension to the secondary bifurcations of both the left and right hepatic ducts (arrows).
Fig. 2: A 72-year-old man with periductal-infiltrating type of moderately differentiated adenocarcinoma of bile ducts. (2A, 2B) Axial enhanced 3D thin-section images in the early (2A) and late (2B) arterial phases show irregular thickening of the wall of the common hepatic duct (arrows) with progressive ring-like enhancement. (2C) Axial enhanced 3D thin-section image in the portal venous phase demonstrates wall thickening with ring-like enhancement in the secondary bifurcation of the left hepatic duct (arrow). The interface between the hepatic duct and the left branch of portal vein is clearly seen. (2D) Coronal reconstructed 3D MPR image in the portal venous phase shows railway-like wall thickening of the involved bile duct (arrows). The tumour is correctly classified as Bismuth-Corlette type IIIb on 3D images. (2E) Coronal 2D MRCP shows Bismuth-Corlette type IIIb tumour with string-like eccentric narrowing of the common hepatic and left hepatic ducts (short arrows), occlusion of the origin of the right hepatic duct (long arrow) and involvement of the secondary bifurcation of the left hepatic duct (arrowhead).

Fig. 3: A 43-year-old woman with intraductal-growing type of papillary adenocarcinoma of the bile duct. (3A, 3B) Axial 3D thin-section images in the early arterial (3A) and portal venous (3B) phases show intraductal tumour (arrows) that is slightly enhanced and has clear interface with hepatic artery and portal vein. The tumour is classified as Bismuth-Corlette type IIIa on 3D images. (3C) Coronal reconstructed 3D MPR image in the late arterial phase visualizes intraluminal tumour in the common hepatic and common bile ducts (arrows). (3D) Axial enhanced 2D T1-weighted image in the equilibrium phase demonstrates progressive enhancement of the tumour. The internal architecture and edge of the tumour are less clearly depicted than on the 3D thin-section image (arrow). (3E) Coronal 2D MRCP shows Bismuth-Corlette type IIIa tumour with the involvement and separation of the bifurcations of the left and right hepatic ducts, and the secondary bifurcation of the right hepatic duct (arrows).
4. Discussion

Hilar cholangiocarcinoma accounts for more than 50% of all malignancies originating from major bile ducts [3]. The periductal-infiltrating type is more common than the mass-forming type, whereas the intraductal-growing type is relatively uncommon [1-3, 7]. Because the tumour can spread along bile ducts to the intrahepatic and extrahepatic structures and may invade large blood vessels in the hepatic hilum, curative resection of tumours is often difficult and the prognosis is generally poor. It is apparent that in patients with hilar cholangiocarcinoma early detection of tumour and accurate evaluation of tumour extent are necessary for the selection of appropriate treatment planning [3, 7, 19].

Among all imaging modalities at present, MRI is becoming an important method for preoperative evaluation of hilar cholangiocarcinoma because of its high soft tissue contrast and non-invasive depiction of the intrahepatic and extrahepatic biliary ducts. Previous studies concerning the diagnostic value of MRI for hilar cholangiocarcinoma have been mainly focused on MRCP and conventional 2D sequences [9-14]. MRCP is excellent to provide information about the biliary ductal system, especially the luminal morphological abnormality, but it cannot provide any data about the extraductal tumour extension. Therefore, MRCP alone is not sufficient for accurate evaluation of hilar cholangiocarcinoma and requires the addition of other MRI sequences. 2D gradient-echo T1-weighted contrast-enhanced sequence can provide intra- and extra-ductal information simultaneously, but it is difficult to visualize small lesions and their morphological details because of inherent limits of 2D acquisition including relatively thick slice section and the inter-slice partition gap. Thus small tumours in some patients with hilar cholangiocarcinoma can not be directly visualized and may be missed on 2D T1-weighted enhanced images. In our cases, 2D T1-weighted enhanced images could not show the tumours in 8 patients of the periductal-infiltrating type, the diagnosis could only be speculated based on changes of the proximal and distal bile ducts.

3D MR sequence can produce isotropic T1-weighted images with high spatial resolution (pixel size ≤ 2.0mm in three directions), and can still ensure a full coverage of volume scanning. Breath-hold and thin slice section without gap reduce partial volume averaging and respiratory motion artefacts. Furthermore, coronal and sagittal images with high spatial resolution can also be generated by reconstructing of the isotropic 3D raw data (Fig.2D, 3C). Thus 3D sequence helps to improve the detection of small lesions and the delineation of their morphological details [15, 16].

Dynamic multi-phasic enhanced scanning with 3D sequence can accurately depict the characteristics of tumour blood supply, which contributes to the correct diagnosis of hilar cholangiocarcinoma and the differentiation from other tumours in the hilar area of the liver [20]. Due to the rich fibrous stroma, the mass-forming hilar cholangiocarcinomas frequently exhibit mild enhancement at the periphery of the mass in the arterial phase, and gradual centripetal enhancement in the portal venous and delayed phases [1-3, 21]. This enhancement pattern obviously differs from those of hepatocellular carcinoma and metastases in the hilar area of the liver. In our study, all 11 mass-forming tumours showed this type of enhancement pattern (Fig.1). The periductal-infiltrating tumour features the infiltrative tumour growth along the wall of bile ducts, as a result, demonstrating irregular (or regular in few cases) wall thickening of the involved bile duct, with enhancement in both the hepatic arterial and portal venous phases in most cases. On axial images the tumour is seen as ring- or dot-like findings and railway-like appearances on coronal or sagittal MPR images (Fig.2). In our study, 14 periductal-infiltrating tumours were enhanced in both arterial and portal venous phases, 3 tumours only in the portal venous phase, and 1 tumour only in the arterial phase. The intraductal-growing tumours frequently appear as slightly enhanced intraductal masses and thickening wall of the involved bile ducts with smooth outerwall (Fig.3).

The excellent spatial resolution of 3D sequence is helpful for early detection and accurately morphologic classification of hilar cholangiocarcinoma. In this study, small periductal-infiltrating tumours in 8 patients were not directly visualized on 2D T1-weighted enhanced images, but were clearly shown on 3D thin-section images. Accurate morphologic classification of hilar cholangiocarcinoma is important for planning the
appropriate treatment and predicting the prognosis. Most of the mass-forming and periductal-infiltrating tumours are highly malignant adenocarcinomas with poor prognosis, whereas the prognosis for intraductal-growing hilar cholangiocarcinoma, which is often papillary adenocarcinoma of low malignancy, is much better after surgical resection [1-3]. Furthermore, the surgical planning should be tailored according to the gross morphology of hilar cholangiocarcinoma. To achieve a permanent cure, partial resection of some liver parenchyma with a tumour-free margin should be performed in patients with the mass-forming type; but for periductal-infiltrating tumour, more aggressive surgery including extensive liver resection, lymph node dissection, and adjuvant anticancer therapy should be performed. For intraductal-growing hilar cholangiocarcinoma, only tumour resection with a tumour-free margin is sufficient, and long-term patient survival can be expected [1].

The infiltration extent of tumour along the bile duct is one of the important factors that determine tumour resectability. MRCP has been demonstrated in the literature to have accuracy similar to direct cholangiography for delineating the extent of intraductal tumour [9-13]. By careful tracing the intrahepatic bile ducts on the original and reconstructed 3D images, the secondary confluences of the right and left hepatic ducts whether to be involved, can be identified in most patients. Our results showed that the accuracy of 3D sequence was similar to MRCP, whereas 2D T1-weighted enhanced sequence significantly underestimated intraductal tumour extension. With MRCP being used as the standard of reference, difference of two sequences showed statistical significance ($P<0.05$). Thus 3D enhanced sequence was more accurate than 2D T1-weighted enhanced sequence for delineation of intraductal tumour extent. However, sometimes it also may be difficult to differentiate that mucosal enhancement of bile ducts is due to tumour spreading or reactive inflammation on 3D images.

The involvement of large blood vessels in the hilar area of the liver is also an important factor to influence tumour resectability. Another advantage of 3D sequence is its ability to accurately show vascular involvement in the liver hilum. In our study, 3D images showed involvement of the main trunk of portal vein in 8 patients and both branches of portal vein in 3, whereas 2D T1-weighted sequence only revealed involvement of the main trunk of portal vein in 7 and both branches of portal vein in 1. Surgical exploration confirmed that tumour encaesed the main trunk of portal vein and hepatic artery in 10 patients. Thus the original and reconstructed MPR images of 3D sequence delineated more vascular involvement than 2D T1-weighted sequence. However, accuracies of 3D sequence to evaluate involvement of the branches of hepatic artery and portal vein were not compared with surgical gross specimen in 15 patients, who were not performed curative resection but only explorative laparotomy. Similarly, 3D sequence exceeded 2D T1-weighted sequence for detecting metastases of lymph nodes in the hilar area of the liver.

Based on the positive findings revealed on 3D and 2D T1-weighted enhanced images respectively, assessment of tumour resectability by the two sequences were compared to surgical findings in 31 patients with hilar cholangiocarcinoma. 3D sequence was more accurate (90.3%) than 2D T1-weighted sequence (71.0%) for assessment of tumour resectability. However, 15.8% and 36.0% of tumours that were estimated to be resectable on 3D and 2D T1-weighted images respectively were found to be non-resectable at surgery. This may be related to (a) failure of the two sequences to accurately identify whether the secondary confluences of left or right hepatic ducts were involved, due to anatomic variations or influence of partial volume average; (b) underestimation of the extent of tumour infiltration along bile duct on 3D or 2D T1-weighted images; (c) failure of the two sequences to identify early involvement of the main trunk or branches of portal vein and hepatic artery; (d) failure to show small metastases of lymph nodes in the hilar area of the liver even on 3D thin-section images.

There were some limitations in our study. First, the comparison with surgical specimens was not possible in 15 patients who underwent only explorative laparotomy without curative resection. More patients with curative surgical resection should be enrolled for further verification of our results. Second, because image interpretation depended on experience of the readers, subjective bias could not be avoided. Third, due to the heavy patient-throughputs in our daily clinical practice and limited MR examination time, later delayed scanning was not performed to obtain the optimal tumour enhancement in every patient. Furthermore, the
scanning design for 3D and 2D T1-weighted enhanced sequences was asymmetric in terms of the scanning phases and slice thickness due to the difficulties in real routine clinical practice. These would also affect the reliability of the results to some extent.

In conclusion, 3D sequence can more accurately visualize the tumours and help to determine their morphological types in patients with hilar cholangiocarcinoma, especially for those small tumours. 3D sequence also reveals the longitudinal extent of tumour infiltration along bile ducts almost identical to MRCP findings. It depicts more vascular involvement and metastatic lymphadenopathy in the hilar area of the liver, and assesses tumour resectability more accurately than 2D T1-weighted enhanced sequence. Therefore, 3D T1-weighted thin-section dynamic enhanced MR sequence should be an important part of the comprehensive MR imaging diagnosis and preoperative evaluation for patients with hilar cholangiocarcinoma.

5. References


