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• *BRIEF REPORTS* •

Preoperative evaluation of pancreaticobiliary tumor using MR multi-imaging techniques

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Abstract

AIM: To evaluate the clinical value of MR multi-imaging techniques in diagnosing and preoperative assessment of pancreaticobiliary tumor.

METHODS: MR multi-imaging techniques, including MR cross-sectional imaging, MR cholangiopancreatography (MRCP) and 3D dynamic contrast-enhanced MR angiography (3D DCE MRA), were performed to make prospective diagnosis and preoperative evaluation in 28 patients with suspected pancreaticobiliary tumors. There were 17 cases of pancreatic adenocarcinoma, 8 cases of biliary system carcinoma and 3 cases of non-neoplastic lesions.

RESULTS: Using MR multi-imaging techniques, the accuracy in diagnosing the patients with pancreaticobiliary tumors was 89.3% (25/28). The accuracy in detecting the range of tumor invasion was 80.3% (57/71). The sensitivity, specificity, accuracy, positive and negative predictive value of MR multi-imaging techniques in preoperative assessment of the resectability of pancreaticobiliary tumor were 83.3%, 89.5%, 88.0%, 71.4%, and 94.4%, respectively. There was well diagnostic consistency between MR multi-imaging techniques and CT (κ = 0.64, $P<0.01$). The fusion image could be made from MRCP and 3D DCE MRA images.

CONCLUSION: MR multi-imaging techniques can integrate the advantages of various MR images. The non-invasive "all-in-one" MR imaging protocol is the efficient method in diagnosing, staging and preoperative assessment of pancreaticobiliary tumor.

Key words: Pancreaticobiliary tumor; Cholangiopancreatography

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INTRODUCTION

Pancreaticobiliary tumor is a common clinical disease. Currently, the only potential cure for pancreaticobiliary tumor is surgery. Early diagnosis and accurately preoperative assessment of tumor resectability are fundamental to achieve a successful treatment. For a long time, ultrasonography (US), computed tomography (CT), direct cholangiopancreatography, including endoscopic retrograde cholangiopancreatography (ERCP) or percutaneous transhepatic cholangiography (PTC), and conventional angiography are main imaging modalities for diagnosing and staging of pancreaticobiliary tumor. With recent technical advances in the field of MR imaging, such as rapid cross-sectional sequences, MR cholangiopancreatography (MRCP) and 3D dynamic contrast-enhanced MR angiography (3D DCE MRA), MR multi-imaging techniques have provided a non-invasive, safe and simple method in the preoperative diagnosis and evaluation of pancreaticobiliary tumor. The purpose of this study was to establish the MR multi-imaging techniques and to evaluate the clinical value of the synthetical MR imaging protocol.

MATERIALS AND METHODS

Patients

The study subjects included 28 patients (13 men and 15 women, mean age 64.9 years, range 28-83 years). The most common symptoms were abdominal discomfort, loss of weight and obstructive jaundice. All patients underwent US, enhanced or unenhanced CT scan and MR multi-imaging examination. In addition, ERCP was also performed in three patients, but the ERCP imaging did not display the entire pancreaticobiliary duct tree. Sixteen patients had explorative laparotomy from 1 to 30 d (mean 10 d) after MR examination. Twelve patients had intervention or palliative drainage (one endoscopic stent, one percutaneous transhepatic drainage and 10 actinotherapy or chemotherapy) because of the unresectability diagnosed preoperatively by various imaging modalities. Among the 28 patients, the final diagnoses were 17 cases as pancreatic adenocarcinomas, 8 as biliary system carcinomas and 3 as non-neoplastic lesions (Table 1).

MR multi-imaging protocol

MR imaging was performed with a 1.0T superconductive unit (Philips Gyroscan T10-NT, software version 4.6.2) containing a body coil. MR examination was performed after the patients had fasted for 8-10 h. The patients were examined in the supine position and abdominal band compression. MR multi-imaging protocol included cross-

Table 1 Pancreaticobiliary diseases (n = 28)

Pancreaticobiliary diseases	Number of cases
Pancreatic head carcinoma	14
Pancreatic body carcinoma	3
Gall bladder carcinoma	2
Hilar cholangiocarcinoma	3
Common bile duct carcinoma	3
Chronic pancreatitis	2
Common bile duct stone	1

sectional imaging, MRCP and 3D DCE MRA. The parameters of MR multi-imaging techniques are shown in Table 2. The total imaging time was approximately 40 min. Cross-sectional scan included T1- and T2-weighted images with spin-echo (SE) or turbo spin-echo (TSE) sequence. Non-breath-hold respiratory trigger (RT) and/or fat suppression (spectral saturation inversion recovery, SPIR) techniques were also used. Upper abdominal axial images were obtained through the liver and pancreas. The axial images served as guides to locate the MRCP examination. MRCP was performed with a coronal, multi-slice, heavily T2-weighted TSE sequence with RT and fat suppression techniques. The source images were 3D reconstructed by using a maximum-intensity-projection (MIP) algorithm to create a rotating radial display. The 3D DCE MRA used a single 22 s breath-hold, coronal, fast field-echo (FFE) sequence. A dose of 30-45 mL contrast agents, gadopentetate dimeglumine (Gd-DTPA), was injected through antecubital vein by hand in a bolus at a rate of 2-3 mL/s, followed by flushing with 20 mL physiologic saline solution. Three imaging sets were consecutively acquired. The images from each scan were viewed both as individual slices and after post-processing with MIP algorithm.

Imaging analysis

By careful review of the cross-sectional MR images and of the source and MIP reconstructed images obtained from MRCP and 3D DCE MRA examination, the study contents included the diagnosis of pancreaticobiliary tumor, the definition of the range of tumor infiltration and the prospective assessment of the surgical resectability with MR multi-imaging techniques. According to the tumor staging TNM classification, the signs of unresectability of pancreaticobiliary tumor were as follows: (1) Major abdominal vascular involvement (portal, splenic and superior mesenteric veins, celiac axis, *etc*.), including encasement, occlusion and tumor thrombosis; (2) Tumor adjacent organs or tissues infiltration, but excluding the simply extension into duodenum; (3) The presence of distant metastases or peritoneal carcinomatosis, particularly liver metastasis and ascites; (4) Regional and distant lymph node involvement (larger than 1 cm in diameter) or lymphadenopathy. If none of these criteria were found, the tumor was regarded as resectable.

Statistical analysis

When compared the results of resectability assessing of pancreaticobiliary tumor using MR multi-imaging protocol with the outcomes of surgical and US or CT findings, we evaluated the clinical value of MR multi-imaging techniques in diagnosing the pancreaticobiliary tumor and in judging the range of tumor involvement, statistically calculated the sensitivity, specificity, overall accuracy, positive and negative predictive value in assessing the surgical resectability, and analyzed the causes of false-positive and false-negative interpretation. The diagnostic consistency between MR multi-imaging techniques and CT was also calculated by using Kappa test. Using the image fusion software (Analyza 3.0), the MIP reconstructed images of MRCP and 3D DCE MRA were combined in 10 patients.

RESULTS

Tumor diagnosis and analysis

Of the 28 patients with pancreaticobiliary diseases, MR multi-imaging techniques allowed correct diagnosis of 25 pancreaticobiliary tumors, including 17 cases of pancreatic adenocarcinoma, 6 of cholangiocarcinoma and 2 of gall bladder carcinoma. The overall diagnostic accuracy was 89.3% (25/28). The remaining three cases were misdiagnosed as pancreatic head carcinoma, but the histological diagnoses from explorative laparotomy and surgical biopsy confirmed focal chronic pancreatitis in two cases and one choledoch-olithiasis with muddy stones.

In all 25 patients with pancreaticobiliary tumors, MRCP demonstrated the dilatation of pancreatic duct and bile duct

Table 2 MR multi-imaging technique parameters

Protocol angulation	T1WI/SPIR transversal	T2WI/SPIR transversal	T2WI coronal	MRCP coronal	DCE MRA coronal
Sequence	TSE/SE	TSE	TSE	TSE	FFE
TR (ms)	575/500	1 800	1 800	2 000	11
TE (ms)	12/15	99/80	100	700	2.5
FOV (mm)	345/375	345	435	395	450
Matrix	176×256	203×256	202×256	190×256	164×512
No. of slices	16	16	18	50	50
Thickness (mm)	10	10	6	2	2
Gap (mm)	1	1	0.6	0	0
Fast factor	4/-	18/14	23	101	-
NSA	5/2	4	4	2	1
Respiratory	Trigger	Trigger	Trigger	Trigger	Breath-hold

TR: time of repeat; TE: time of echo; FOV: field of view; NSA: number of signal average.

tree. Mass lesions were identified with MR cross-sectional technique at the location of pancreaticobiliary obstruction. The lesions were hypointense on T1WI and isointense to mildly hyperintense on T2WI. The T2-weighted fat-suppressed imaging was particularly useful for the evaluation of tumor extension, liver metastases and lymph node involvement. In 17 patients with pancreatic adenocarcinoma, the hypointense mass lesions were more conspicuous against a background of hyperintense normal pancreatic tissue on T1-weighted fat-suppressed images. On the source images of 3D DCE MRA, the pancreatic adenocarcinoma appeared as slowly continuous enhancement and the signal contrast between the mass lesion and surrounding normal tissue was more conspicuous on early-phase of the post-contrast images.

Detection of range of tumor invasion

MR multi-imaging techniques correctly identified the tumor extension into adjacent organs of liver, stomach and duodenum in 15 patients, 4 liver metastases, 3 peritoneal carcinomatosis and ascites, and 10 lymph node and 8 arterial involvements (Table 3). The portal vein system involvement was clearly visualized on the reconstructed images of 3D DCE MRA in 17 of 20 patients, including 6 cases of venous encasement, 8 of occlusion, 1 of tumor thrombosis and 2 of the formation of lateral circulation (Table 3). Therefore, the accuracy of MR multi-imaging techniques in detecting the range of pancreaticobiliary tumor invasion was 80.3% (57/71) (Table 3).

Table 3 Detection of range of pancreaticobiliary tumor invasion

	MR finding (*n*)	Final diagnosis (*n*)	Percentage (%)
Adjacent organ infiltration	15	17	88.2
Liver metastases	4	5	80.0
Lymph node involvement	10	13	76.9
Arterial involvement	8	13	61.5
Portal venous involvement	17	20	85.0
Peritoneal carcinomatosis	3	3	100.0
Total	57	71	80.3

Tumor resectability assessment

Of 25 patients with pancreaticobiliary tumor verified by surgical or synthetical imaging findings, MR multi-imaging techniques correctly diagnosed 5 of 6 resectable tumors with 1 case of false-negative interpretation and 17 of 19 unresectable tumors with 2 of false-positive interpretation. Therefore, the sensitivity, specificity, accuracy, positive and negative predictive value of MR multi-imaging techniques in assessing the resectability of pancreaticobiliary tumors were 83.3%, 89.5%, 88.0%, 71.4%, and 94.4%, respectively (Table 4).

The false-negative case was pancreatic head carcinoma. The encasement of superior mesenteric vein was detected by 3D DCE MRA, whereas the tumor underwent successful resection because it was only adherence to vessel without invasion. In two false-positive cases (one pancreatic head carcinoma and one cholangiocarcinoma), MR examination underestimated the portal venous and mesenteric vessels involvement by tumors, which were confirmed at surgery. In addition, of 17 cases with unresectability, some lymph node and arterial involvement or small liver metastases were not detected, but the tumors were also considered unresectable by MR assessment because of the presence of other signs of unresectability.

Table 4 Assessment of resectability of pancreaticobiliary tumor (*n*)

MR multi-imaging techniques	Final diagnosis	
	Resectability	Unresectability
Resectability	5[1]	2[2]
Unresectability	1[3]	17[4]

[1]True-positive, [2]Negative-positive, [3]False-negative, [4]True-negative.

Comparison of MR with CT in tumor resectability assessment

The comparison of MR multi-image techniques with CT examination in assessment of tumor resectability of 25 cases is shown in Table 5. The uniform results of evaluation were found in 21 cases, including 6 of resectability and 15 of unresectability. There was well diagnostic consistency between MR multi-imaging protocol and CT examination ($\kappa = 0.64$, $U = 7.95$, $P<0.01$).

Table 5 Comparison between MR and CT in tumor resectability assessment (*n*)

MR multi-imaging techniques	CT diagnosis	
	Resectability	Unresectability
Resectability	6	1
Unresectability	3	15

Image fusion of MRCP and MRA

The fusion images were successfully obtained by combining the MIP reconstructed images of MRCP and 3D DCE MRA in 10 patients with pancreaticobiliary tumor. The fusion image intuitionistically exhibited the spatial anatomical relationship between mass lesions and the pertinent surrounding structures and clearly visualized the range of tumor involvement of pancreaticobiliary duct tree and portal venous system, which provided more useful information for the planning of surgical operation.

DISCUSSION

US and CT are the first modalities in the field of pancreaticobiliary imaging[1-3]. With recent technical advances, the synthetical MR multi-imaging protocol, including cross-sectional MR imaging with or without fat-suppressed technique, MRCP and 3D DCE MRA has provided a non-invasive, safe and simple method in the accurate diagnosis and preoperative evaluation of pancreaticobiliary tumor[4-8].

Our study showed that of the 28 patients with pancreaticobiliary tumor, MR multi-image techniques could correctly diagnose 25 cases and the overall accuracy was

89.3%. The mass lesions were hypointense on T1WI and isointense to mildly hyperintense on T2WI. Pancreaticobiliary tumors appeared as slowly continuous enhancement and were best detected on early phase of post-contrast dynamic images, reflecting the fact that the tumor was desmoplastic lesion with sparse vascularity and tends to enhance less than the capillary-rich surrounding parenchyma[9-11]. The T2-weighted fat-suppressed imaging was particularly useful for the evaluation of tumor extension, liver metastases and lymph node involvement. Due to the presence of aqueous protein in the acini of the pancreas, rich endoplasmic reticulum and high manganese content of the pancreatic cells, pancreatic adenocarcinomas were best detected on T1-weighted fat-suppressed images[12-16]. However, the results from our study also suggested that the identification of small pancreatic tumor with focal chronic pancreatitis sometimes might be very difficult even with dynamic MR studies[10,17].

MRCP is the fundamentally new innovation in MR imaging of the pancreaticobiliary diseases. Advocated by German researcher Wallner BK and his group in 1991[18], the imaging quality and the diagnostic ability of MRCP have been improved increasingly with continued technologic advancements. MRCP is a non-invasive, safe, simple method without the ionizing radiation and injection of contrast agents. In most clinical situations, MRCP may replace direct cholangiopancreatography (ERCP or PTC) as a diagnostic tool[6,8,19,20]. In our study of 28 cases, MRCP satisfactorily demonstrated the pancreaticobiliary duct obstruction and dilatation with different degree, including three patients in whom ERCP was shown incompletely. Therefore, MRCP may provide an optimal imaging alternative when direct cholangiopancreatography is unsuccessful or inadequate[21-23]. The literature indicates that the overall sensitivity and specificity of MRCP in diagnosing the obstruction of pancreaticobiliary ducts was 95% and 97%[24,25]. The accuracy in diagnosing the location of obstruction was 96%, and the sensitivity and specificity in differentiating malignant from benign pancreaticobiliary obstruction were 88% and 95%, respectively[24,25]. For pancreaticobiliary tumor, MRCP can define the location and morphological characteristics of pancreaticobiliary obstruction as well as evaluate the range of tumor involvement and the surgical resectability. MRCP also helps to provide valuable information to determine the best approach for palliative drainage or endoscopically placed stent in the patients with unresectable tumors.

The MR angiography (MRA) technique has recently become available for non-invasive vascular imaging[26-28]. Non-enhanced MRA, including time-of-flight (TOF) and phase-contrast (PC) technique, is the first means of demonstrating vessels but is limited by its long data acquisition time, motion and flow artifact, and in-plane saturation. Since first reported by Prince *et al*[29], contrast enhanced MRA technique has demonstrated that it is more suitable for evaluation of the vascular structures due to the advantages of without flow artifact and saturation effects.

It has been reported that 3D DCE MRA can clearly demonstrate both intra- and extra-hepatic portal venous system and its lateral circulation, and also display portal vein, hepatic vein and inferior vena cava on one same image, which reflects the whole route of tumor metastases through blood circulation[30,31]. Repeated sequences after administration of contrast agents allow separate demonstration of the abdominal arteries and portal veins. In addition, the source images simultaneously demonstrate parenchymal lesion of the liver, pancreas, biliary tract and reflect the dynamic enhancement characteristics of tumor. The evaluation of both MIP reconstructed and source MRA images, as well as the morphological cross-sectional MR images (both T1WI and T2WI, with or without fat-suppressed technique), provided detail information on vessel anatomy and the relationship of the tumor with vascular wall. Our study showed, the accuracy of 3D DCE MRA in assessing the involvement of portal venous system was 85.0%, but the accuracy in detecting the arterial involvement was only 61.5%. The reason of the low accuracy for 3D DCE MRA in assessing the arterial involvement might be the long signal acquisition time due to the limit of the MR unit we used, and the demonstration of portal vein interfered the differentiation of arteries system.

Pancreaticobiliary tumors are considered unresectable, if invasion or encasement of any of the vascular structures is present or if there is liver metastasis, peritoneal carcinomatosis, lymphadenopathy or extension into the adjacent organs (excluding the duodenum). By far, the main index of resectability, in the absence of distant metastases, is the patency and absence of infiltration of the major abdominal vessels[32-36]. MR multi-imaging techniques can not only improve the diagnostic ability of pancreaticobiliary tumor, but also assess the surgical resectability[37-41]. In our study, the sensitivity, specificity, accuracy and negative predictive value of the "all-in-one" protocol in assessing the surgical resectability were 83.3%, 89.5%, 88.0%, and 94.4%, respectively. There was also well diagnostic consistency between MR multi-imaging techniques and CT examination ($\kappa = 0.64$, $P<0.01$). But our study also showed the positive predictive value of tumor resectability was only 71.4%. The main explanation might be the misestimation of the abdominal vessel involvement by 3D DCE MRA. In addition, the accuracy of MR multi-imaging techniques tend to underestimate the degree in diagnosing the lymph node and arterial involvement, which were 76.9% and 61.5%, respectively. However, it can be believed that with the fast development of MR equipment and software, the clinical value of MR multi-imaging techniques may be improved increasingly.

The image fusion technique could clearly exhibit the source, location and range of tumor lesions, and the spatial relationship between the mass and pertinent surrounding structures. Using special software approaches, the fusion image might even combine the morphological anatomy images, such as CT or MRI, and the metabolic function images, such as positron emission tomography or single photon emission computed tomography, which would provide more valuable information for helping in diagnosing and tumor staging and planning the proposal of surgical operation[42-44].

In summary, MR multi-imaging protocol integrates the advantages of various special imaging techniques. MR cross-sectional images can demonstrate the nature of tumor lesion and the range of tumor involvement. MRCP can visualize the whole pancreaticobiliary tree and the location and degree of duct obstruction. 3D DCE MRA can exhibit the spatial relationship between the mass lesion and pertinent structures and the range of vessel invasion. Therefore, the non-invasive "all-in-one" MR multi-imaging techniques may provide comprehensive information needed for the preoperative diagnosis and evaluation of pancreaticobiliary tumor, which otherwise can be obtained only by performing three different examinations, including ERCP or PTC, CT and angiography (Figure 1).

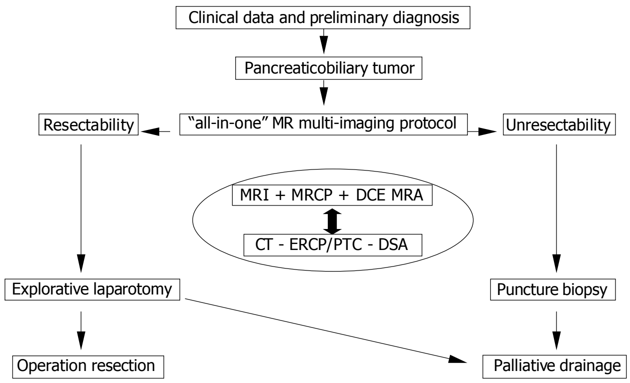

Figure 1 MR evaluation and treatment strategy for pancreaticobiliary tumor.

REFERENCES

1 **Kalra MK,** Maher MM, Sahani DV, Digmurthy S, Saini S. Current status of imaging in pancreatic diseases. *J Comput Assist Tomogr* 2002; **26**: 661-675

2 **Zeman RK,** Silverman PM, Ascher SM, Patt RH, Cooper C, al-Kawas F. Helical (spiral) CT of the pancreas and biliary tract. *Radiol Clin North Am* 1995; **33**: 887-902

3 **Szklaruk J,** Tamm E, Charnsangavej C. Preoperative imaging of biliary tract cancers. *Surg Oncol Clin N Am* 2002; **11**: 865-876

4 **Vahldiek G,** Broemel T, Klapdor R. MR-cholangiopancreaticography (MRCP) and MR-angiography: morphologic changes with magnetic resonance imaging. *Anticancer Res* 1999; **19**: 2451-2458

5 **Ferrucci JT.** Advances in abdominal MR imaging. *Radiographics* 1998; **18**: 1569-1586

6 **Vitellas KM,** Keogan MT, Spritzer CE, Nelson RC. MR cholangiopancreatography of bile and pancreatic duct abnormalities with emphasis on the single-shot fast spin-echo technique. *Radiographics* 2000; **20**: 939-957; quiz 1107-1108, 1112

7 **Kim MJ,** Mitchell DG, Ito K, Outwater EK. Biliary dilatation: differentiation of benign from malignant causes-value of adding conventional MR imaging to MR cholangiopancreatography. *Radiology* 2000; **214**: 173-181

8 **Motohara T,** Semelka RC, Bader TR. MR cholangiopancreatography. *Radiol Clin North Am* 2003; **41**: 89-96

9 **Irie H,** Honda H, Shinozaki K, Yoshimitsu K, Aibe H, Nishie A, Nakayama T, Masuda K. MR imaging of ampullary carcinomas. *J Comput Assist Tomogr* 2002; **26**: 711-717

10 **Gabata T,** Matsui O, Kadoya M, Yoshikawa J, Miyayama S, Takashima T, Nagakawa T, Kayahara M, Nonomura A. Small pancreatic adenocarcinomas: efficacy of MR imaging with fat suppression and gadolinium enhancement. *Radiology* 1994; **193**: 683-688

11 **Kalra MK,** Maher MM, Mueller PR, Saini S. State-of-the-art imaging of pancreatic neoplasms. *Br J Radiol* 2003; **76**: 857-865

12 **Boraschi P,** Braccini G, Gigoni R, Geloni M, Perri G. MR cholangiopancreatography: value of axial and coronal fast Spin-Echo fat-suppressed T2-weighted sequences. *Eur J Radiol* 1999; **32**: 171-181

13 **Kelekis NL,** Semelka RC. MRI of pancreatic tumors. *Eur Radiol* 1997; **7**: 875-886

14 **Semelka RC,** Ascher SM. MR imaging of the pancreas. *Radiology* 1993; **188**: 593-602

15 **Leyendecker JR,** Elsayes KM, Gratz BI, Brown JJ. MR cholangiopancreatography: spectrum of pancreatic duct abnormalities. *AJR Am J Roentgenol* 2002; **179**: 1465-1471

16 **Fayad LM,** Kowalski T, Mitchell DG. MR cholangiopancreatography: evaluation of common pancreatic diseases. *Radiol Clin North Am* 2003; **41**: 97-114

17 **Kim JH,** Kim MJ, Chung JJ, Lee WJ, Yoo HS, Lee JT. Differential diagnosis of periampullary carcinomas at MR imaging. *Radiographics* 2002; **22**: 1335-1352

18 **Wallner BK,** Schumacher KA, Weidenmaier W, Friedrich JM. Dilated biliary tract: evaluation with MR cholangiography with a T2-weighted contrast-enhanced fast sequence. *Radiology* 1991; **181**: 805-808

19 **Reinhold C,** Bret PM. Current status of MR cholangiopancreatography. *AJR Am J Roentgenol* 1996; **166**: 1285-1295

20 **Fulcher AS,** Turner MA. MR cholangiopancreatography. *Radiol Clin North Am* 2002; **40**: 1363-1376

21 **Soto JA,** Yucel EK, Barish MA, Chuttani R, Ferrucci JT. MR cholangiopancreatography after unsuccessful or incomplete ERCP. *Radiology* 1996; **199**: 91-98

22 **Lomanto D,** Pavone P, Laghi A, Panebianco V, Mazzocchi P, Fiocca F, Lezoche E, Passariello R, Speranza V. Magnetic resonance-cholangiopancreatography in the diagnosis of biliopancreatic diseases. *Am J Surg* 1997; **174**: 33-38

23 **Owens GR,** Shutz SM. Value of magnetic-resonance cholangiopancreatography (MRCP) after unsuccessful endoscopic-retrograde cholangiopancreatography (ERCP). *Gastrointest Endosc* 1999; **49**: 265-266

24 **Guibaud L,** Bret PM, Reinhold C, Atri M, Barkun AN. Bile duct obstruction and choledocholithiasis: diagnosis with MR cholangiography. *Radiology* 1995; **197**: 109-115

25 **Romagnuolo J,** Bardou M, Rahme E, Joseph L, Reinhold C, Barkun AN. Magnetic resonance cholangiopancreatography: a meta-analysis of test performance in suspected biliary disease. *Ann Intern Med* 2003; **139**: 547-557

26 **Edelman RR.** MR angiography: present and future. *AJR Am J Roentgenol* 1993; **161**: 1-11

27 **Vosshenrich R,** Fischer U. Contrast-enhanced MR angiography of abdominal vessels: is there still a role for angiography? *Eur Radiol* 2002; **12**: 218-230

28 **Sadick M,** Diehl SJ, Lehmann KJ, Gaa J, Mockel R, Georgi M. Evaluation of breath-hold contrast-enhanced 3D magnetic resonance angiography technique for imaging visceral abdominal arteries and veins. *Invest Radiol* 2000; **35**: 111-117

29 **Prince MR,** Yucel EK, Kaufman JA, Harrison DC, Geller SC. Dynamic gadolinium-enhanced three-dimensional abdominal MR arteriography. *J Magn Reson Imaging* 1993; **3**: 877-881

30 **Okumura A,** Watanabe Y, Dohke M, Ishimori T, Amoh Y, Oda K, Dodo Y. Contrast-enhanced three-dimensional MR portography. *Radiographics* 1999; **19**: 973-987

31 **Shirkhoda A,** Konez O, Shetty AN, Bis KG, Ellwood RA, Kirsch MJ. Mesenteric circulation: three-dimensional MR angiography with a gadolinium-enhanced multiecho gradient-echo technique. *Radiology* 1997; **202**: 257-261

32 **Nghiem HV,** Freeny PC. Radiologic staging of pancreatic adenocarcinoma. *Radiol Clin North Am* 1994; **32**: 71-79

33 **Pavone P,** Laghi A, Catalano C, Panebianco V, Fabiano S, Passariello R. MRI of the biliary and pancreatic ducts. *Eur Radiol* 1999; **9**: 1513-1522

34 **Hawes RH,** Xiong Q, Waxman I, Chang KJ, Evans DB, Abbruzzese JL. A multispecialty approach to the diagnosis

and management of pancreatic cancer. *Am J Gastroenterol* 2000; **95**: 17-31

35 **Pavone P,** Laghi A, Passariello R. MR cholangiopancreatography in malignant biliary obstruction. *Semin Ultrasound CT MR* 1999; **20**: 317-323

36 **Hochwald SN,** Rofsky NM, Dobryansky M, Shamamian P, Marcus SG. Magnetic resonance imaging with magnetic resonance cholangiopancreatography accurately predicts resectability of pancreatic carcinoma. *J Gastrointest Surg* 1999; **3**: 506-511

37 **Trede M,** Rumstadt B, Wendl K, Gaa J, Tesdal K, Lehmann KJ, Meier-Willersen HJ, Pescatore P, Schmoll J. Ultrafast magnetic resonance imaging improves the staging of pancreatic tumors. *Ann Surg* 1997; **226**: 393-405; discussion 405-407

38 **Catalano C,** Pavone P, Laghi A, Panebianco V, Scipioni A, Fanelli F, Brillo R, Passariello R. Pancreatic adenocarcinoma: combination of MR imaging, MR angiography and MR cholangiopancreatography for the diagnosis and assessment of resectability. *Eur Radiol* 1998; **8**: 428-434

39 **Lopez Hanninen E,** Amthauer H, Hosten N, Ricke J, Bohmig M, Langrehr J, Hintze R, Neuhaus P, Wiedenmann B, Rosewicz S, Felix R. Prospective evaluation of pancreatic tumors: accuracy of MR imaging with MR cholangiopancreatography and MR angiography. *Radiology* 2002; **224**: 34-41

40 **Fischer U,** Vosshenrich R, Horstmann O, Becker H, Salamat B, Baum F, Grabbe E. Preoperative local MRI-staging of patients with a suspected pancreatic mass. *Eur Radiol* 2002; **12**: 296-303

41 **Choi BS,** Kim TK, Kim AY, Kim KW, Park SW, Kim PN, Ha HK, Lee MG, Kim SC. Differential diagnosis of benign and malignant intraductal papillary mucinous tumors of the pancreas: MR cholangiopancreatography and MR angiography. *Korean J Radiol* 2003; **4**: 157-162

42 **Lamade W,** Vetter M, Hassenpflug P, Thorn M, Meinzer HP, Herfarth C. Navigation and image-guided HBP surgery: a review and preview. *J Hepatobiliary Pancreat Surg* 2002; **9**: 592-599

43 **Townsend DW,** Cherry SR. Combining anatomy and function: the path to true image fusion. *Eur Radiol* 2001; **11**: 1968-1974

44 **Israel O,** Keidar Z, Iosilevsky G, Bettman L, Sachs J, Frenkel A. The fusion of anatomic and physiologic imaging in the management of patients with cancer. *Semin Nucl Med* 2001; **31**: 191-205

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