Accuracy of Multidetector Computed Tomography Cholangiography in Evaluation of Cause of Biliary Tract Obstruction

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Objective: *To evaluate accuracy of multidetector computed tomography (MDCT) cholangiography in evaluation of cause of biliary tract obstruction.*

Material and Method: *MDCT cholangiographs of 50 patients with clinically suspected biliary tract obstruction were retrospectively reconstructed and reviewed. The causes of obstruction identified by MDCT were divided into three groups including calculus, benign stricture, and malignancy. Final diagnosis was based on pathological diagnosis or endoscopic retrograde cholangiopancreatography or follow-up. The MDCT diagnosis and final diagnosis were compared.*

Results: *The sensitivity, specificity, positive predictive value, and negative redictive value of MDCT cholangiography for detection of calculus, benign stricture, and malignancy were 91.7-100%, except for sensitivity and positive predictive value for detection of benign stricture, which were 66.7% and 66.7% respectively.*

Conclusion: *MDCT cholangiography is a fast, noninvasive technique that offers high diagnostic accuracy in evaluation of cause of biliary tract obstruction.*

Keywords: *Biliary tract obstruction, Multidetector computed tomography cholangiography, Jaundice*

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In patients with suspected biliary obstruction, the diagnosis is important for treatment planning. Ultrasonography has been used as the first imaging modality in evaluation of cause of biliary obstruction, due to its wide availability, and low cost[1,2]. However, considerable drawbacks inherent to ultrasonography are operator dependence and its limited diagnostic efficacy.

Endoscopic retrograde cholangiopancreaticography (ERCP) or percutaneous transhepatic cholangiography (PTC) have been considered the gold standard of biliary imaging and have therapeutic potentials[3]. Even so, they are invasive. Moreover, the surrounding organs cannot be demonstrated with these techniques.

Although, magnetic resonance cholangiopancreaticography (MRCP) has recently become a well-established, noninvasive diagnostic tool for assessing the biliary tree and also allows evaluation of surrounding structures, it is not widely available and is expensive[4,5].

In the past, axial conventional CT could not provide adequate information of biliary abnormalities since the orientation of these ducts was not suitable for evaluation in axial planes[6].

Recently, multidetector computed tomography (MDCT) has been introduced. MDCT's ability to obtain volume dataset with submillimeter spatial resolution allows the optimal display of bile duct by using multiplanar reconstruction (MPR) and minimal intensity projection (MinIP) without compromising image quality. By using MinIP, the fluid density, as contained in the biliary duct, is picked up from the contrast-enhanced vessel together with that of the enhanced hepatic and pancreatic parenchyma. The combined use of MPR and MinIP techniques significantly improves the images of the biliary ducts and their site of confluence compared with those obtained by axial CT[6-8].

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The purpose of the present study was to evaluate the accuracy of MDCT cholangiography using MPR and MinIP reconstruction in diagnosis of cause of biliary obstruction.

Material and Method

The present retrospective study was conducted with approval from our institutional review board.

Patients

The authors included all patients who underwent ERCP at Siriraj Hospital between November 2005 and April 2007, who also had both pre-contrast and post-contrast phase 64-channel MDCT of abdomen within four months before ERCP. All patients had symptoms and signs of biliary obstruction including jaundice, total bilirubin level > 1.2 mg/dl, direct bilirubin level > 0.5 mg/dl, alkaline phosphatase level > 100 IU/L. Patients were excluded from the present study if they had undergone an intervention of biliary duct before MDCT, had no reference examination, had no available medical record. With these criteria, there were 50 patients (33 men and 17 women; age range, 30-82 years; mean age, 58.7) included in the present study.

Examination technique

All MDCT examinations were performed with a 64-channel MDCT scanner (Lightspeed VCT; GE Medical Systems, Wisconsin, USA) using the following parameters: detector row configuration, 64 x 1 mm; collimation, 1 mm; slice thickness, 1.25 mm; pitch, 1.375; reconstruction interval, 1 mm; 300 mAs; 120 kVp. Each patient received 800-1000 ml of radiopaque water-soluble contrast media orally 10-15 minutes before examination. No biliary contrast agent was given. First, precontrast abdominal CT scans were performed to screen for calculi. Then, portovenous phase CT scans were obtained 80 seconds after initiation of intravenous injection of 100 ml of nonionic contrast agent at a flow rate of 2.0 to 4.0 ml/sec.

Image evaluation

All image dataset were transferred to a 3D workstation (Vitrea®, version 3.8) to create MDCT cholangiographic images by using MPR and MinIP reconstruction techniques. MPRs and MinIP reconstruction were performed by using variable slab thickness according to the degree of bile duct dilatation in coronal oblique planes oriented throughout the biliary tract. All reconstructed images were reviewed by two experienced radiologists who were blinded to the final diagnosis. Image interpretations were performed in consensus and the radiologists were asked to evaluate for degree of duct dilatation, the presence of calculi or biliary stricture, and to indicate whether the stricture was likely secondary to malignant or benign etiology.

By comparing with diameter of adjacent portal veins, the degree of biliary dilatations were divided into four levels: 1) no dilatation, common bile duct diameter is less than 6 mm with imperceptible intrahepatic duct; 2) mild, common bile duct is greater than 6 mm and the dilated bile duct diameter is smaller than adjacent portal veins; 3) moderate, bile duct diameter is equal to adjacent portal veins; and 4) severe, bile duct diameter is larger than adjacent portal veins.

The causes of obstruction were classified into three groups including 1) calculus, 2) benign stricture, and 3) malignant obstruction.

Biliary stones were existed on the presence of a high-density material within the biliary duct surrounded by a lower density bile (Fig. 1). Benign stricture was suggested when there is a short segment of biliary stricture (< 1 cm) with symmetric narrowing and a smooth margin[9] (Fig. 2). Whereas the cause of biliary obstruction was assumed malignant if any of the following were seen; 1) abrupt obstruction of bile duct with a long segment of biliary stricture (> 1.5 cm); 2) asymmetric narrowing and irregular margin of the obstructed biliary duct[9,10]; 3) hyperenhancement of

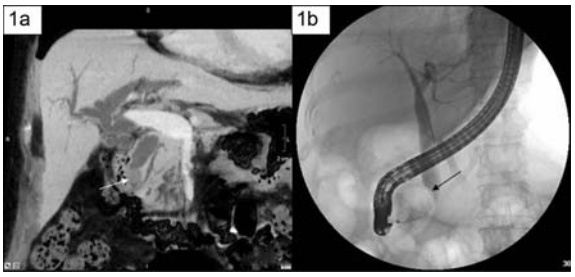

Fig. 1 Images of 76-year-old woman with jaundice
a) Coronal minimum intensity projection (7-mm-thick slab) shows a calculus within distal common bile duct (white arrow), resulting in a marked dilatation of the upstream common bile duct and intrahepatic ducts. b) ERCP demonstrates a smooth filling defect in the distal common bile duct (black arrow), representing choledocholithiasis. A large distal common bile duct stone was removed during ERCP

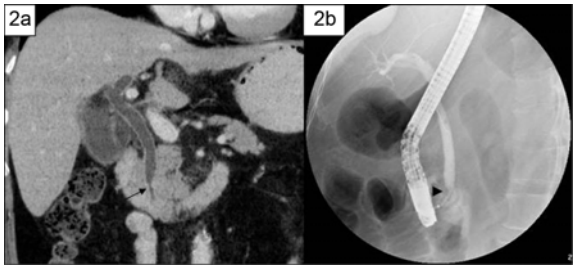

Fig. 2 Images in 57-year-old man with jaundice and weight loss
a) Coronal minimum intensity projection image demonstrates a focal narrowing (arrow) involving the distal common bile duct. Note the smooth margins of the stricture without evidence of abnormal soft-tissue mass or wall thickening. b) ERCP confirms the presence of a focal narrowing at distal common bile duct (arrow head). This was a benign stricture

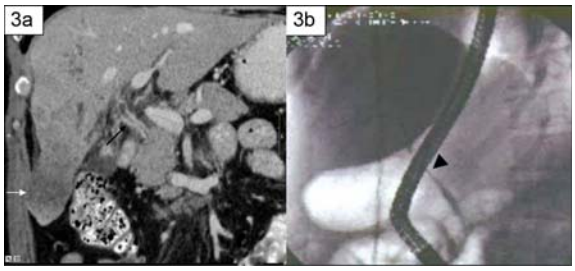

Fig. 3 Images in 59-year-old man with obstructive jaundice
a) Multiplanar reformatted image (coronal oblique 2-mm-thick slice) shows a long segment of common bile duct wall thickening with hyperenhancement (black arrow), suggesting infiltrative malignancy. An ill-defined mass in right hepatic lobe (white arrow), suggesting intrahepatic metastasis, was also demonstrated. b) ERCP confirms the presence of segmental narrowing involving mid part of common bile duct (arrow head). The pathological diagnosis was infiltrative cholangiocarcinoma

the bile duct stricture wall in portovenous phase (a difference of more than 10 HU in mean CT numbers between the involved bile duct wall and the upstream common bile duct wall); 4) maximum thickness of the involved ductal wall more than 1.5 mm[11]; 5) visualization of tumor; or 6) distant metastasis (Fig. 3, 4).

Reference examinations

ERCP was performed in all patients 0 to 113 days after MDCT. The mean delay time between the two studies was 15 days.

Of these 50 patients, eleven had pathological confirmation. Three patients had cytological proven cholangiocarcinoma from bile duct brushing during ERCP. Eight patients had undergone surgery, four of those had benign stricture, whereas the remaining four had malignancy. One patient who was found to have negative for malignancy from bile duct brushing also underwent surgery and appeared to be benign stricture secondary to chronic pancreatitis. Twenty-four patients in whom bile duct calculi were found at ERCP had undergone calculi extraction and had been well during the 1-year follow-up, which made the possibility of malignancy very unlikely.

Fifteen patients had been followed clinically with CA 19-9, interval CT scans, or ERCP for up to 1 year. Of these 15 patients, 13 patients were determined to have malignancy due to combination of marked elevation of CA 19-9, and disease progression seen on follow-up CT studies. Two out of 15 patients were considered to be benign stricture based on improvement of jaundice after treatment of cholangitis.

Fig. 4 Coronal minimum intensity projection image (11-mm-thick slab) demonstrates a periampullary soft tissue mass (arrow) with focal narrowing of the distal common bile duct. The diagnosis of periampullary adenocarcinoma was confirmed by tissue biopsy during ERCP

Statistical analysis

By comparing MDCT diagnosis with the final diagnosis obtained from reference standards, the diagnostic accuracy of MDCT cholangiography in evaluation of cause of biliary obstruction was evaluated in terms of sensitivity, specificity, accuracy, positive predictive value and negative predictive value.

Result

In the present study, MDCT cholangiography demonstrated biliary tree dilatation in 48 of 50 patients (96%) with cholestatic jaundice, mild in 16 of 50 (32%), moderate in 15 of 50 (30%), and severe in 17 of 50 (34%). The degree of biliary dilatation seen on MDCT cholangiography and the final diagnosis are summarized in Table 1.

The final diagnosis of calculi was made in 24 of 50 patients (48%), all were confirmed by ERCP and clinical follow-up. The final diagnosis of benign stricture was made in six of 50 patients (12%) that included four patients confirmed with surgery, and two patients confirmed with ERCP and clinical follow-up. The final diagnosis of malignancy was made in 20 of 50 patients (40%) where four patients were confirmed with surgery, three patients were confirmed with cytological brushing during ERCP, and thirteen patients were confirmed with clinical follow-up.

The causes of biliary obstruction based on ERCP and MDCT cholangiography findings are summarized in Table 2.

Biliary duct calculi group

The biliary duct stones were seen on MDCT cholangiography in 22 of 24 patients. Of the two false negative results, one patient had black-colored calculus removed during ERCP six days after MDCT but neither biliary duct dilatation nor common bile duct stone was depicted on MDCT. Another patient had a moderate dilatation with a smooth narrowing of distal common bile duct on MDCT and was thought to have benign stricture. On ERCP performed 43 days later, a small distal common bile duct stone was extracted. The sensitivity, specificity, accuracy, PPV, and NPV of MDCT cholangiography in diagnosis of biliary stones were 91.7%, 100%, 96%, 100%, and 92.9%, respectively.

Benign stricture group

On MDCT cholangiography, a correct diagnosis of benign stricture was obtained in four of six patients. Two patients were misdiagnosed as malignant stricture. One of these two patients had underlying chronic pancreatitis. The MDCT showed a marked biliary duct dilatation with abrupt irregular narrowing of distal common bile duct as well as mass-like lesion at the pancreatic head, therefore, the patient was thought to have associated pancreatic carcinoma. ERCP on the next day demonstrated severe irregular narrowing of distal common bile duct, measuring 1 cm in length. Pathological result showed chronic inflammation with fibrosis. Another patient who had mild left intrahepatic duct dilatation with abrupt irregular bile duct narrowing, and hyperenhancement of left intrahepatic duct wall on MDCT cholangiography, was thought to have infiltrative cholangiocarcinoma. However, the next-day, ERCP showed mild dilatation of left intrahepatic duct without obstructive lesion or filling defect. After antibiotic treatment for acute cholangitis, the patient had clinically improved and became symptom-free during 1-year follow-up. The sensitivity, specificity, accuracy, PPV, and NPV of

Table 1. Degree of biliary dilatation seen on MDCT cholangiography in patients with biliary obstruction (n = 50)

Degree of biliary duct dilatation	Stone	Benign stricture	Malignancy	Total
No	2	0	0	2 (4%)
Mild	12	3	1	16 (32%)
Moderate	6	2	7	15 (30%)
Severe	4	1	12	17 (34%)

Table 2. The causes of biliary obstruction based on reference examinations and findings on MDCT cholangiography

Findings on MDCT cholangiography	Causes of biliary obstruction based on reference examinations		
	Stone	Benign stricture	Malignancy
Stone	22	0	0
Benign stricture	1	4	1
Malignancy	0	2	19

MDCT cholangiography in diagnosis of benign biliary stricture were 66.7%, 95.5%, 92%, 66.7%, and 95.5%, respectively.

Malignancy group

Malignant obstruction was correctly diagnosed on MDCT cholangiography in 19 of 20 patients. One patient was incorrectly diagnosed as benign stricture since smooth tapering of distal common bile duct without mass was seen on MDCT cholangiography. One week later, ERCP showed marked common bile duct dilatation with bulging of distal common bile duct into the duodenum. The patient underwent Whipple's operation and pathological result confirmed the diagnosis of infiltrative cholangiocarcinoma (measuring 1.5 x 1 x 1 cm). The sensitivity, specificity, accuracy, PPV, and NPV of MDCT cholangiography in diagnosis of malignant biliary stricture were 95%, 93.3%, 94%, 90.5%, and 96.6%, respectively.

The overall diagnostic accuracy of MDCT cholangiography in evaluation of cause of biliary obstruction is 92-96%. Regardless of calculi, the overall accuracy of MDCT in diagnosis and classification of benign versus malignancy biliary stricture was 88.5% (23 out of 26 patients).

Discussion

Although many imaging techniques including ultrasonography, CT scan, MRCP, and ERCP can be used to evaluate the cause of biliary obstruction, each technique still has some limitations.

According to the previous literatures[1,5,12,13], the sensitivity of ultrasound for detection of choledocholithiasis ranged from 20-80%.

MRCP offers a high diagnostic accuracy in evaluation of biliary duct pathology[14,15], however, the limited availability, high cost, and long examination time still limit its use.

ERCP has some advantages over other noninvasive techniques since it provides both diagnosis and therapeutic intervention in the same setting. Biopsy can also be performed to establish tissue diagnosis. However, ERCP does not provide extraluminal information. Moreover, it has a failure rate of 3-10% and 0.5-5% rate of complications, including adverse reaction from sedatives, pancreatitis, perforation of the gastrointestinal tract, bleeding, cholangitis, sepsis, and death[16].

The recent implementation of MDCT scan and post-processing image reconstruction techniques has facilitated a better visualization of the biliary system. With MPR technique, the biliary duct anatomy can be displayed in various planes. Moreover, MinIP technique enables us to depict a small biliary duct and pancreatic duct more clearly, since it displays only the pixel of lowest attenuation within the range of a slab thickness. This technique offers the one-step evaluation of the biliary tree and the surrounding structures. Thus, it allows a complete and definitive preoperative staging of the malignant diseases.

Several investigators[8,17] have reported the usefulness of MDCT cholangiography using MPR and MinIP technique without cholangiographic contrast agents. With this technique, the detection of biliary duct abnormalities and stones greatly depends on the image quality provided with multidetector CT scan.

Despite the fact that up to 20% of common bile duct stones have isoattenuation with bile and cannot be detected by CT according to the prior studies[18], the authors achieved the sensitivity of 91.7%, specificity of 100%, and accuracy of 96% in the diagnosis of choledocholithiasis using 64-detector CT with 1.25 mm slice section, MPR, and MinIP reconstruction. These results achieved considerable improvement compared with the prior studies using single-slice CT technique, by which reported sensitivity and specificity of 65-88% and 84-97%, respectively[19,20]. However, these improved results are not totally unexpected due to the ability of 64-MDCT to visualize bile duct using thinner slice section within a shorter scan period, which led to a reduction of image degradation from motion artifacts and volume averaging. Moreover, it allows the acquisition of data sets with nearly isotropic voxels for MPR and MinIP reconstruction, which has similar spatial resolution compared with axial planes.

However, the sensitivity of detection of biliary stone achieved in the present study remains similar to results reported by the more recent studies using 4-slice MDCT technology which ranges from 87 to 93.3%[21,22].

Besides CT technique applied, the ability to detect biliary stones by CT depends on size, position, and density of stone as well as degree of bile duct dilatation. Retrospectively, the calculi missed in the present study were small, pigmented stones, and located in the lower common bile duct. One stone missed was within the nondilated bile duct, which made the stones difficult to be detected.

Recently, *in vitro* study by Chan et al[23] showed that the conspicuity of biliary stone tends to increase with the use of high x-ray tube potential

(140 kVp) rather than with lower x-ray tube potential (120 kVp and lower). Thus, one might postulate that the sensitivity and diagnostic accuracy of CT in detection of biliary stone may improve with the use of 140 kVp rather than 120 kVp that is used in the present study. However, further investigations are needed to confirm this statement.

Regarding the detection and classification of bile duct narrowing, the present study showed that CT has a very high sensitivity (95%) and specificity (93.3%) in diagnosing malignant strictures. These results show a significant improvement compared to a previous report using a single slice technology (sensitivity 77%, specificity 63%). In the present study, one malignant stricture was missed and thought to be related to the small size of tumor (< 1.5 cm), and obscuration of small enhancing periampullary mass by an isoattenuated oral contrast material in partially collapsed duodenum. The authors believe that a specific protocol of MDCT in biliary tract imaging that uses a negative contrast material (*e.g.* water) should have further improved the present results[24,25],

The presented data on diagnostic accuracy, sensitivity, and specificity of MDCT cholangiography in detection of choledocholithiasis are comparable to those of MRCP reported in the previous literatures[26-28], where sensitivity, specificity, and diagnostic accuracy range between 81-100%, 84-100%, and 90-96% respectively.

In diagnosis of benign stricture, the authors misinterpreted benign stricture as malignant stricture in 2 out of 6 cases, which led to a fair sensitivity of 66.7% and a specificity of 95.5%. In one of two patients, a confident diagnosis of benign stricture could not be made even on ERCP, which necessitate a biopsy to make a definite diagnosis.

Leave aside the biliary stones; the authors could correctly classify benign and malignant biliary stricture in 23 out of 26 patients, resulting in the overall accuracy of 88.5%. This result is similar to the prior study by Choi et al[11], which reported an accuracy of 90% in classification of biliary strictures based on the visualization of hyperenhanced bile duct wall in portovenous phase 4-slice MDCT with 3.2 mm slice thickness.

In the present study, the authors found that degree of biliary duct dilatation caused by malignancies tend to be more severe than those caused by benign strictures whereas biliary calculi can cause a variable degree of biliary duct dilatation, ranging from none to severe dilatation, depending on its size. Even though the differentiation between benign strictures and malignancies could not be based solely on the degree of biliary dilatation, however the presence of severe biliary dilatation without detectable stones should raise a concern of malignancy.

The present study has some limitations. Firstly, this is a retrospective study. Although the radiologists had no knowledge of the final diagnosis, they were aware of the patients' clinical presentation of biliary obstruction, and were instructed to carefully evaluate bile ducts for evidence of focal narrowing or calculi. This could influence the improvement of accuracy as the radiologists were focused on a limited portion of the examination, which may not be realistic in a prospective evaluation of CT examinations. In addition, since the present study included patients undergoing MDCT within a 4-month period before ERCP, the lapse of time between the two studies may allow changes of lesion appearances, and calculi to pass from the gallbladder to common bile duct or from the common bile duct to gastrointestinal tract, resulting in a reduction of diagnostic performance. Secondly, a pathological diagnosis was not available in all cases, as all patients with biliary calculi were followed clinically after stone removal and the diagnosis of some benign and malignant strictures were based on a clinical follow-up. Thirdly, there may be selection bias as the authors only evaluated the patients who underwent ERCP after MDCT. Thus, patients who were managed successfully without ERCP, or those who underwent operative intervention without endoscopic therapy were not evaluated. Lastly, the small number of cases, particularly in benign stricture group, is another limitation in the present study.

Conclusion

The MDCT cannot be expected to rival the excellent results obtained by ERCP, since it does not provide tissue diagnosis or therapeutic potential. However, 64-channel MDCT cholangiography using MinIP and MPR reconstruction is a fast alternative noninvasive imaging test that offers high diagnostic accuracy in detection of biliary calculi and differentiation of benign from malignant biliary strictures. It would be particularly useful in preoperative planning when tissue confirmation or therapeutic intervention is not needed, or when ERCP failed. Given its comparable diagnostic accuracy, superior resolution, and availability, MDCT cholangiography may be used as an alternative to MRCP for noninvasive one-stop-shop imaging of the biliary tree.

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ความแม่นยำในการตรวจสาเหตุของทางเดินน้ำดีอุดกั้นโดยใช้เครื่องเอกซเรย์คอมพิวเตอร์ความเร็วสูงชนิดหลายหัววัด

ตรงธรรม ทองดี, อรศิริ อมรวิทยาชาญ, รณิษฐา ทองดี

วัตถุประสงค์: *เพื่อศึกษาความแม่นยำในการตรวจสาเหตุของทางเดินน้ำดีอุดกั้นโดยใช้เครื่องเอกซเรย์คอมพิวเตอร์ความเร็วสูงชนิดหลายหัววัด*

วัสดุและวิธีการ: *ทำการศึกษาภาพการตรวจเครื่องเอกซเรย์คอมพิวเตอร์ความเร็วสูงชนิดหลายหัววัดในผู้ป่วย 50 คน ที่มีอาการของทางเดินน้ำดีอุดกั้น โดยแบ่งกลุ่มสาเหตุของการอุดกั้นจาก นิ่ว, ทางเดินน้ำดีอุดกั้นจากโรคที่ไม่ร้ายแรง, โรคมะเร็ง เปรียบเทียบกับผลการตรวจทางพยาธิวิทยา หรือการตรวจด้วยการส่องกล้อง*

ผลการศึกษา: *ภาพการตรวจด้วยเครื่องเอกซเรย์คอมพิวเตอร์ความเร็วสูงชนิดหลายหัววัดมีความแม่นยำ, ความจำเพาะ ในการตรวจพบนิ่วในทางเดินน้ำดี, โรคมะเร็งทางเดินน้ำดีและทางเดินน้ำดีอุดตันจากโรคที่ไม่ร้ายแรง 91.7-100% ยกเว้นค่าความไว และคุณค่าเชิงทำนายของผลบวกในทางเดินน้ำดีอุดตันจากโรคที่ไม่ร้ายแรงมีค่า 66.7% และ 66.7% ตามลำดับ*

สรุป: *การตรวจทางเดินน้ำดีด้วยเครื่องเอกซเรย์คอมพิวเตอร์ความเร็วสูงชนิดหลายหัววัด มีความรวดเร็ว, ปลอดภัย และแม่นยำในการตรวจผู้ป่วยที่มีภาวะทางเดินน้ำดีอุดกั้น*