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The value of drip infusion cholangiography using multidetector-row helical CT in patients with choledocholithiasis

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Abstract The purposes of this study were to investigate the feasibility of drip infusion cholangiography computed tomography (CTCh) for choledocholithiasis and to compare the detection of the stone on CTCh with that of MR cholangiopancreatography (MRCP). CTCh examinations were performed after infusion of intravenous biliary contrast material (iotroxic acid meglumine, 100 ml) for patients with suspected biliary diseases and were reconstructed to maximum intensity projection (MIP) and multiplanar reformation (MPR). Of 432 patients who underwent CTCh, we identified 15 who underwent surgery or cholangioscopic removal for choledocholithiasis and 32 patients who underwent cholecystectomy due to cholecystolithiasis. Their MRCP images were compared with the CTCh images. The sensitivity and specificity of CTCh for detecting choledochal stones were 87% and 96% whereas those of MRCP were 80% and 88%. The sensitivity and specificity of CTCh for detecting gallstones were 78% and 100% whereas those of MRCP were 94% and 88%. CTCh allowed high sensitivity and specificity for detecting choledochal stones but diminished the detection for cholecystolithiasis compared with MRCP.

Keywords CT cholangiography · MR cholangiopancreatography (MRCP) · Maximum intensity projection (MIP) · Multiplanar reformation (MPR) · Choledocholithiasis

Introduction

MR cholangiopancreatography (MRCP) is widely used for hepatobiliary and pancreatic diseases; the noninvasive method without irradiation is one of the remarkable points. According to previous reports [1, 2], MRCP allows noninvasive, accurate detection of biliary stones, strictures, and dilatation similar to that with endoscopic retrograde cholangiopancreatography (ERCP) and avoids the complications of ERCP.

ERCP and percutaneous cholangiography (PTC) have been considered the standard of reference for the evaluation of the biliary tree and remains important because of its potential to direct image-guided therapy, but it has an invasive profile. Drip infusion cholangiography computed tomography (CTCh) is a classical, noninvasive method for the evaluation of the biliary system. This contrast material has a biliary excretory profile and while not used in the United States, European countries approve it. More recently, the spatial resolution on CTCh with multidetector-row helical CT (MDCT) is superior to that of MRCP. In addition, CTCh is useful for assessing the orientation of cystic duct and intrahepatic bile duct on surgical planning and has various possibilities [3]. CTCh using MDCT allows for a substantial range of tissue to be imaged within a single breath hold. But CTCh has some limitations, such as serum bilirubin level and adverse reaction [4]. Some older biliary contrast agents on CTCh were said to have a poor safety profile [5]; therefore, both ERCP and MRCP were in the ascendancy for biliary imaging [6].

To our knowledge, there is no report of comparison between CTCh and MRCP for choledocholithiasis. The purposes of this study were to investigate the feasibility of CTCh for the diagnosis of choledochal stones and to compare the detection rate of CTCh with that of MRCP.

Materials and methods

Patients

All patients gave informed consent; 432 underwent CTCh examinations for suspected biliary diseases in our hospital from March 2003 and February 2005. As an alternative to MRCP, CTCh was routinely used in our hospital. The findings at surgery or cholangioscopic stone removal were accepted as the standard references for the evaluation of CTCh and MRCP. We excluded patients who underwent neither of the two treatment procedures. Intraoperative cholangiography (direct cholangiography) was performed in all cases; therefore, we regarded operation records as the gold standard. After review of records of the radiology reporting system and surgical operation list by one of authors (JF), we identified 35 patients who were proved to have choledocholithiasis by surgery and cholangioscopic removal, and 20 of 35 patients underwent CTCh examinations. Fifteen of 20 patients with choledocholithiasis also underwent MRCP examinations; thus, this group comprised one of our study population.

Two of 15 patients had undergone cholecystectomy before. CTCh was performed within 2 weeks of MRCP examination. Open cholecystectomy was performed for 136 patients 1 day to 2 weeks after the clinical diagnosis and imaging tests whereas 129 patients underwent laparoscopic cholecystectomy. Surgical treatments were performed immediately after clinical diagnosis for patients who had symptoms, such as severe abdominal pain. Of these patients, we recruited 32 who were examined by both CTCh and MRCP for cholecystolithiasis; 7 of the 32 had both gallstones and choledochal stones. Therefore, 40 patients (15+32−7; 16 men, 24 women; mean age 57 years; range 35–93 years) comprised our study population for comparison of the detection of stones between CTCh and MRCP.

CT cholangiography (CTCh)

Biliary excretory contrast material (iotroxic acid meglumine, Biliscopin DIC, 100 ml, Schering AG, Berlin, Germany) was infused by slow injection over 30 min for all patients. All 432 patients were examined at 30–45 min after the end of the drip infusion of contrast material and rotated by 360° on the CT table just before the scanning, when possible. CT scanning using an eight-detectors-row helical CT (LightSpeed Ultra: GE Medical Systems, Milwaukee, WI, USA) was performed with 7–10 s breath hold. Scan parameter was as follows: collimation, 8×1.25 mm; table speed, 13.5 mm/rot; pitch, 10.6 (1.35:1); reconstruction slice thickness, 1.25 mm; reconstruction interval, 1.25 mm. For all patients, maximum intensity projection (MIP) images were made from a workstation (Virtual Place: AZE Ltd., Tokyo, Japan), and multiplanar reformation (MPR) images were also reconstructed on MDCT console or the workstation as postprocessing techniques. Volume rendering (VR) reconstructions were also made for the presentation to surgeons and patients, if needed (five of 20 patients). VR was not an useful for the detection of choledocholithiasis, but for viewing the entire biliary tree.

MR cholangiopancreatography (MRCP)

MRCP using Signa Horizon 1.5-T system (GE Medical Systems) with torso phased-array coil was performed as follows: single-shot fast-spin-echo MR sequence (SSFSE), coronal and oblique coronal 50-mm thick slices on a 256× 192 matrix, total acquisition time 2–3 sec, TR minimum, TE 900 ms, field of view 25 cm. These images were processed by a standard MIP in order to obtain views of the entire biliary tree.

Imaging analysis

The CTCh and MRCP images were reviewed independently by two diagnostic radiologists (MO and RI) who were unaware of the final results. The review was performed using a DICOM viewer on the workstation; therefore, we could adjust the window level/width of CTCh and MRCP images. Any disagreements were solved with a consensus *readout*. Biliary calculi were diagnosed on CTCh and MRCP as round and oval shapes seen in the lumen. Surgical and cholangioscopic findings identified during stone removal were used as the standard of reference for the evaluation of CTCh and MRCP. Sensitivity and specificity of CTCh and MRCP for detecting calculi in the biliary system were calculated. In addition, we compared the depiction of intrahepatic bile duct and cystic duct using MIP and MPR. And we investigated the visualization of intrahepatic bile ducts, extrahepatic bile ducts, cystic duct, and opacification of gallbladder on CTCh and MRCP. From the imaging analysis, the following three parameters were extracted and compared between CTCh and MRCP: (1) Opacification of the gallbladder, (2) opacification of the intrahepatic and extrahepatic bile duct, and (3) opacification of the cystic duct. And grades were noted, such as "excellent" (score 3; entire anatomy or opacity visible), "moderate" (score 2; less than 50% of anatomy or opacity visible), "poor" (score 1; anatomy or opacity difficult to detect), and "not seen" (score 0). Wilcoxon's signed rank test was used to compare the difference between CTCh and MRCP. A p value of less than 0.05 was considered significant.

Results

In all CTCh examinations in our hospital, four of 432 patients (0.9%) had mild adverse reactions although neither required treatment. Four patients complained of nausea, but these patients recovered soon without treatment. Both MIP and MPR images for all CTCh examinations were reconstructed within approximately 7 min for each patient whereas MRCP reconstructions were almost real-time. One patient with bile leakage after cholecystectomy and two with pneumobilia were clearly presented on CTCh whereas MRCP could not allow detection of these findings. Bile leakage showed subhepatic fluid collection as a high density of contrast material. Two patients after open cholecystectomy showed pseudostricture (inflammatory stricture) and were noninvasively evaluated for unchanged stricture at the follow-up examinations using CTCh.

Sensitivity and specificity for detecting choledocholithiasis

Thirteen of 15 patients (87%) were proven to have a choledochal stone on CTCh; two patients did not show choledocholithiasis on CTCh because of less contrast between opacity of contrast material and that of calculi in the common bile duct whereas choledocholithiasis was detected by MRCP in 12 of 15 patients (80%) (Table 1). Both CTCh and MRCP showed high sensitivity and specificity for detecting calculi in the common bile duct (Figs. 1, 2). For detecting small choledochal stones by CTCh, MPR images were superior to MIP images because of high confidence in the diagnosis (Fig. 3) although these reconstruction methods were not directly compared in this study. The reason for better performance of MPR is that in MIP, the superimposition of structures in the projection algorithm obscures the visualization of stones.

Table 1 Detection of calculi in the common bile duct and the gallbladder

Findings Location/modality	TP	TN	FP	FN	Sens.	Spec.
Choledochal stone						
CTCh	13	24	1	2	87%	96%
MRCP	12	22	3	3	80%	88%
Gallstone						
CTCh	25	8	0	7	78%	100%
MRCP	30	7	1	2	94%	88%

TP true positive, *TN* true negative, *FP* false positive, *FN* false negative, *Sens.* sensitivity, *Spec.* specificity, *CTCh* computed tomography cholangiography, *MRCP* MR cholangiopancreatography

Sensitivity and specificity for detecting cholecystolithiasis

MRCP (sensitivity 94%, specificity 88%) showed a better diagnostic performance than CTCh (sensitivity 78%, specificity 100%) for detecting calculi in the gallbladder (Table 1) because of no enhancement of the gallbladder in the case of becoming stuck in the gallbladder neck (infundibular stone) on CTCh.

Comparison between CTCh and MRCP

1. Opacification of the gallbladder in 13 of 15 patients was compared between CTCh and MRCP because two patients had undergone cholecystectomy. The average score was 2.1 for CTCh and 2.6 for MRCP (not significant).
2. Opacification of the intrahepatic and extrahepatic bile duct. For the depiction of peripheral intrahepatic bile duct in 15 patients, CTCh images were superior to MRCP images. The average score was 2.8 for CTCh and 1.9 for MRCP ($p< 0.004$, significant).
3. Opacification of the cystic duct.

Thirteen patients without cholecystectomy were compared between CTCh and MRCP. The average score was 2.7 for CTCh and 2.0 for MRCP (not significant).

Comparison between MPR and MIP for detecting cystic duct and small lithiasis

MPR images appeared to be superior to MIP images for confidence in diagnosing choledochal stones. Diagnosis based only on MIP images was not clinically reliable. A combined use either of multisection images, or at least source images, was essential. The MPR image enabled an investigation of the details of the choledochal pathologies.

Serum bilirubin and adverse reactions

Serum bilirubin concentration was below 3 mg/dl in 401 of 432 patients (93%), exceeding 3 mg/dl in 31 patients (7%). In 18 of the 31 patients (58%) exceeding 3 mg/dl, insufficient visualization of the biliary tract could be obtained.

Discussion

We found that CTCh had some advantages for detecting intrahepatic bile duct stones and cystic duct, whereas CTCh had an approximate equivalent detection rate for choledochal stone as MRCP. CTCh directly opacified the

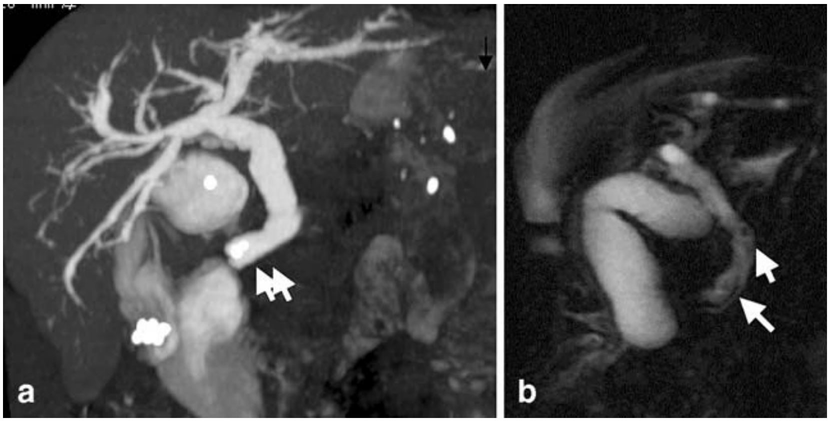

Fig. 1 A 93-year-old woman with cholecystolithiasis and choledocholithiasis. **a** Computed tomography cholangiography (CTCh) maximum intensity projection (MIP) showed several calcified gallstones and two calcified choledochal stones (*arrows*). **b** MR cholangiopancreatography (MRCP) image could not clearly depict gallstones because of insufficient contrast between bile and calculi; additionally, unsuccessful breath hold. However, MRCP showed two stones (*arrows*) in the common bile duct

biliary tree, and MDCT allowed a short imaging time, thus providing more useful images than MRCP, especially intrahepatic bile duct and cystic duct. For laparoscopic cholecystectomy, it was useful to detect the orientation of the cystic duct by CTCh.

ERCP and PTC should be the standard of reference for evaluation of the biliary tree but have an invasive profile, such as relatively high complications (3.5%) [7]. Therefore, the invasive modalities should be used primarily for therapeutic intervention.

Lam et al [8] stated that CTCh had additional advantages over MRCP in the assessment of anastomotic patency and pneumobilia postoperation. For patients after operation, CTCh could depict the flow through the anastomosis and was suitable for this evaluation as a low-invasive examination. In our experience, one patient with bile leakage after cholecystectomy and two with pneumobilia were clearly presented on CTCh. MRCP remains important in the investigation of greater biliary obstructed patients prior to intervention and especially enhances diagnostic ability for extrahepatic bile duct cancer. In addition, MRCP may be useful for the purpose of screening for pancreaticobiliary disease because of its noninvasive profile. MPR of CTCh, which can allow us to identify small structures, plays a central role for detecting choledochal stones as basic images used for diagnosis. For small biliary calculi, MPR images are superior to MIP images. In other words, the MIP images may mislead without the guidance of the MPR images. Images of coronal and sagittal planes can be easily obtained by using a workstation, but conventional axial planes may be the best way to triage for detecting calculi. Meanwhile, MIP images are useful for demonstrating the insertion of the cystic duct and entire biliary system, thus allowing surgical planning.

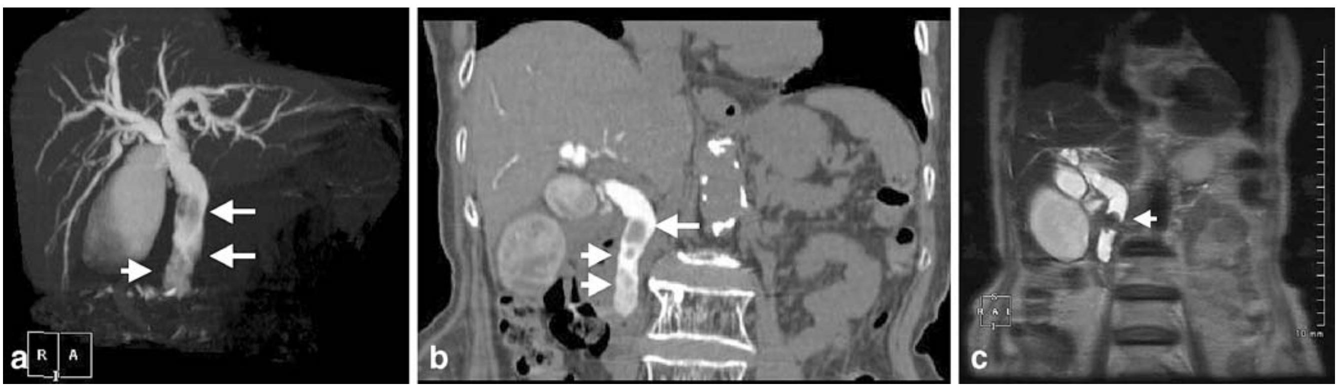

Fig. 2 A 93-year-old woman with choledocholithiasis. **a** Maximum intensity projection (MIP) on computed tomography cholangiography (CTCh) showed choledochal stone and sludge (*arrows*) as filling defects. **b** Multiplanar reformation (MPR) on CTCh clearly depicted choledochal stone and sludge (*arrows*) as filling defects. MPR images appeared to be superior to MIP images for confidence in diagnosing choledochal stones and enabled an investigation of the details of the choledochal pathologies. **c** MR cholangiopancreatography (MRCP) [Single-shot fast-spin-echo MR sequence (SSFSE) coronal plane with 6-mm slice thickness] could depict one low-signal stone (*arrow*) in the common bile duct shown as high signal. Other sludge could not be detected on MRCP

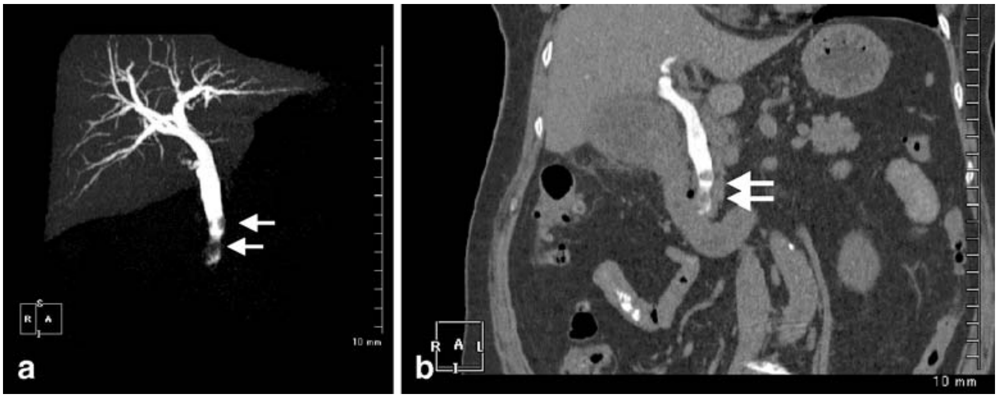

Fig. 3 A 77-year-old woman with cholecystolithiasis and choledocholithiasis. Computed tomography cholangiography (CTCh) image [maximum intensity projection (MIP)] depicted two gallstones as filling defects in the common bile duct (*arrows*). The cystic duct was clearly seen at the normal position, but the gallbladder could not be visualized due to a tiny gallstone (not shown) in the neck of the gallbladder. CTCh image [multiplanar reformation (MPR)] also clearly depicted two gallstones as filling defects in the lower common bile duct (*arrows*). The unenhanced gallbladder with enlargement (acute cholecystitis) was clearly seen

Oral, contrast-enhanced, three-dimensional helical CTCh with iopanoic acid was reported by Stabile Ianora et al [3]; they stated that it was useful as a preliminary to ERCP and for patients who could not be subjected to cholangiopancreatography in cases of doubtful diagnosis after ultrasound (US) and MRCP. However, CTCh was performed 12–14 h after oral administration of iopanoic acid. They demonstrated a limited opacification of the gallbladder because of early CT scanning, acute or chronic cholecystitis, and infundibular stones or insufficient absorption. In our experience, infundibular stones caused a limited opacification of the gallbladder with a higher incidence. On CTCh, the sensitivity for detecting gallstones (Table 1) was 78% because opacification of the gallbladder was not great enough. The right hepatic artery rarely passes posterior to the proximal portion of the common hepatic duct and can create an extrinsic impression on the duct. This impression may create the appearance of an intraluminal filling defect, which confuses the reader as a pseudolesion on CTCh and MRCP [9]. This pitfall can be avoided by examining multiple imaging planes. In addition, we know the surgically important biliary anomalies for diagnosis [10]. These anomalies of the cystic duct could be detectable using CTCh [11]. Minimal side effects rarely occur after the injection of biliary excretory contrast agent, and it is less effective to obtain optimal visualization in patients with hyperbilirubinemia (>3 mg/dl). From our experience, hyperbilirubinemia did not allow diagnosable visualization; however, slow injection (>30 min) may allow a lower rate of adverse reaction.

CTCh and MRCP are not likely to replace operative cholangiography in patients for whom ERCP has not been performed. But pseudostricture (inflammatory stricture) after operation should be noninvasively evaluated using CTCh or MRCP; thus, these noninvasive examinations may be useful for patient care. CTCh, which serves as a communication tool between diagnostic radiologists and surgeons, plays a important role in therapy planning. Both CTCh and MRCP showed high sensitivity for detecting calculi in the common bile duct, and CTCh was superior to MRCP for the opacification of the intrahepatic and extrahepatic bile duct in our experience. However, our study is a preliminary comparison between CTCh and MRCP because of a limited number of patients and a limitation of the subjective scoring system for the appreciation of intrahepatic ducts. Further studies are needed to determine when CTCh examination is preferable.

References

1. Holzknecht N, Gauger J, Sackmann M, Thoeni RF, Schurig J, Holl J, Weinzierl M, Helmberger T, Paumgartner G, Reiser M (1998) Breath-hold MR cholangiography with snapshot techniques: prospective comparison with endoscopic retrograde cholangiography. Radiology 206:657–664
2. Lomas DJ, Bearcroft PW, Gimson AE (1999) MR cholangiopancreatography: prospective comparison of a breath-hold 2D projection technique with diagnostic ERCP. Eur Radiol 9:1411–1417
3. Stabile Ianora AA, Memeo M, Scardapane A, Rotondo A, Angelelli G (2003) Oral contrast-enhanced three-dimensional helical-CT cholangiography: clinical applications. Eur Radiol 13:867–873

4. Takahashi M, Saida Y, Itai Y, Gunji N, Orii K, Watanabe Y (2000) Reevaluation of spiral CT cholangiography: basic considerations and reliability for detecting choledocholithiasis in 80 patients. J Comput Assist Tomogr 24:859–865
5. Chen MY, Ansell G, Ott DJ (1996) Complications of diagnostic studies of the gastro-intestinal tract. In: Ansell G, Bettmann MA, Kaufman JA, Wilkings RA, (eds) Complications in diagnostic imaging and interventional radiology. Blackwell, Science; 483–502
6. Breen DJ, Nicholson AA (2000) The clinical utility of spinal CT cholangiography. Clinical Radiology 55: 733–739
7. Harbin WP, Mueller PR, Ferrucci JT Jr (1980) Transhepatic cholangiography: complications and use patterns of the fine-needle technique: a multi-institutional survey. Radiology 135:15–22
8. Lam WW, Lam TP, Saing H, Chan FL, Chan KL (1999) MR cholangiography and CT cholangiography of pediatric patients with choledochal cysts. Am J Roentgenol 173:401–405
9. David V, Reinhold C, Hochman M, Chuttani R, McKee J, Waxman I, Wang L, Li W, Kaplan R, Edelman RR (1998) Pitfalls in the interpretetion of MR cholangiopancreatography. Am J Roentgenol 170:1055–1059
10. Benson EA, Page RE (1976) A practical reappraisal of the anatomy of the extrahepatic bile ducts and arteries. Br J Surg 63:853–860
11. Hirao K, Miyazaki A, Fujimoto T, Isomoto I, Hayashi K (2000) Evaluation of aberrant bile ducts before laparoscopic cholecystectomy: helical CT cholangiography versus MR cholangiography. Am J Roentgenol 175:713–720