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FULL PAPER

Multidetector CT in detection of troublesome posterior sectoral hepatic duct communicating with cystic duct

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Objective: To investigate whether multiple detector CT (MDCT) could detect troublesome aberrant posterior sectoral hepatic duct (PHD) communicating with cystic duct (CD).
Methods: The most troublesome bile duct anomaly during cholecystectomy is an aberrant PHD communicating with CD. It has been suggested that an unenhanced small duct between Rouviere's sulcus and CD on MDCT could be coincident to an aberrant PHD communicating with CD. A total of 224 patients who underwent laparotomy with complete lymph node dissection in the hepatoduodenal ligament for hepatobiliary or pancreatic tumour were enrolled. Retrospective review of preoperative MDCT images and surgical records was performed.
Results: Preoperative MDCT detected 8 (3.6%) unenhanced ducts between Rouviere's sulcus and CD. Surgical records identified 7 (3.1%) cases of aberrant PHD communicating with CD, and all 7 cases showed an unenhanced duct between Rouviere's sulcus and CD on preoperative MDCT imaging. Among the 7 patients, 5 (71%) were without bile duct dilatation.
Conclusion: MDCT could detect troublesome aberrant PHD communicating with CD, regardless of the presence or absence of bile duct dilatation.
Advances in knowledge: MDCT could detect most troublesome PHD communicating with CD, regardless of the presence or absence of bile duct dilatation.

INTRODUCTION

Bile duct injury is one of the most serious complications of cholecystectomy, and it includes injury of anatomically normal and aberrant bile ducts.[1] Previous reports revealed that the frequency of bile duct injury in cases with aberrant bile ducts was 3.2 to 8.4 times higher than that in cases without it.[2–5] Further, the time period required for the diagnosis and treatment of a leaking aberrant bile duct was significantly longer than that required for a bile leak in an anatomically normal bile duct because of non-filling of the bile duct during standard cholangiographic techniques.[6] Aberrant bile duct anatomy is common (found in 14–28% of human autopsy specimens),[7–10] and the most commonly injured aberrant bile duct during cholecystectomy is the right posterior sectoral hepatic duct (PHD).[11–15]

PHD is divided into 2 types according to its route. A PHD running cranially to the right portal vein is the supraportal type, and the one running caudate to the right portal vein is the infraportal type (Figure 1a,b).[11,16,17] It is noteworthy that all aberrant PHDs are reported to be infraportal type,[11,17] and they can be classified according to their positional relationship with the cystic duct (CD) (Figure 1c).[11,18] In these confluence patterns of aberrant PHD, a PHD communicating with CD is at the greatest risk of injury during cholecystectomy (Figure 2a).[11,18,19] Meticulous dissection close to the CD might be unable to prevent an aberrant PHD injury in this type, although bile duct injury could be prevented by using this method in other types of aberrant PHDs.[20,21] Therefore, it is very important to confirm the presence of a PHD communicating with CD before surgery.

In this department, a weekly preoperative conference is held to discuss hepato-biliary-pancreatic tumours, and four senior surgeons and three radiologists attend it. Multiple detector CT (MDCT) is performed on all patients preoperatively, and precise anatomical evaluation of the portal vein, artery, and bile duct in the hepatoduodenal ligament is performed in each case. At the conference, it was noticed that MDCT occasionally shows an unenhanced small duct between Rouviere's sulcus and CD (Figure 2b). During

Figure 1. Normal anatomy of the posterior sectoral hepatic duct (PHD) and confluence type of aberrant PHD (a) A PHD running cranially to the right portal vein is supraportal type. (b) A PHD running caudate to the right portal vein is infraportal type. (c) Confluence type of aberrant PHD. All aberrant PHDs are infraportal type. (a) PHD draining into the common hepatic duct or upstream hepatic duct. b: PHD and cystic duct opening at the same position of common hepatic duct. c: PHD communicating with the cystic duct. d: PHD draining into the common bile duct. AHD, anterior sectoral hepatic duct; CD, cystic duct; CBD, common biliary duct; Pant, right anterior portal vein; Ppost, right posterior portal vein; RHA, right hepatic artery; *, right posterior hepatic artery. The right posterior hepatic artery is located betweenthe PHD and Ppost.

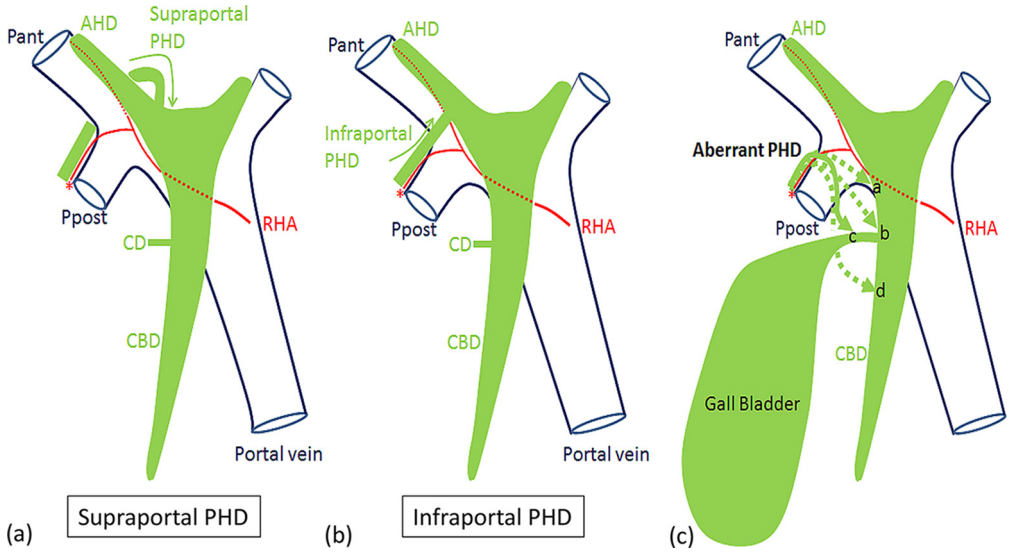
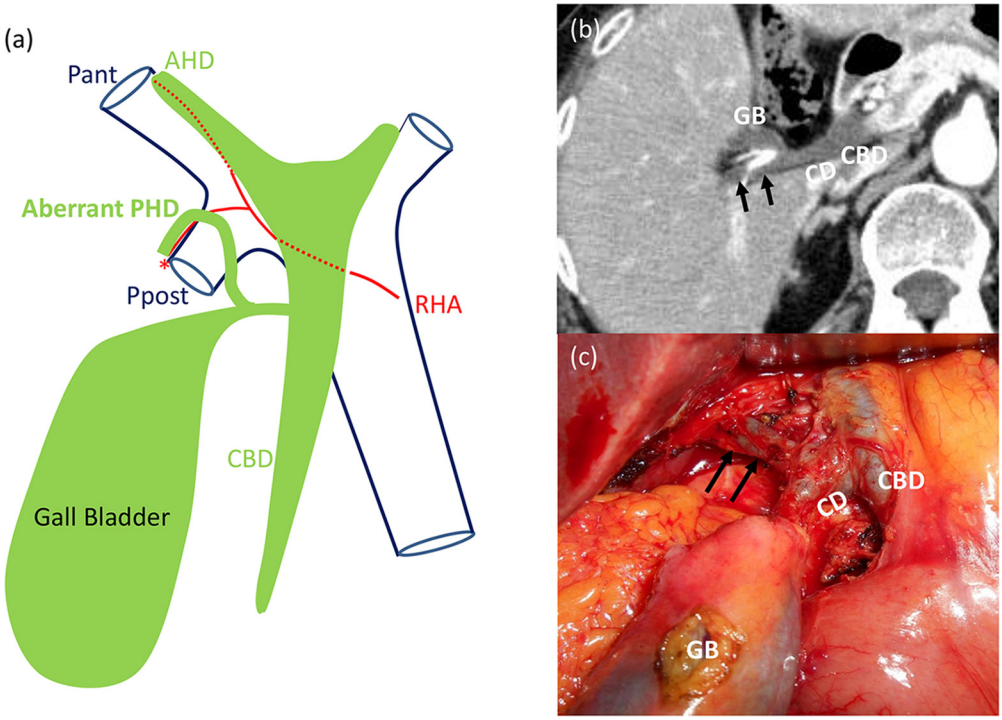


Figure 2. Most troublesome aberrant posterior sectoral hepatic duct (PHD). (a) Schema of PHD communicating with cystic duct (CD). AHD, anterior sectoral hepatic duct; CBD, common biliary duct; Pant, right anterior portal vein; Ppost, right posterior portal vein; RHA, right hepatic artery; *, right posterior hepatic artery. (b) CT image showing an unenhanced small duct (arrows) between Rouviere's sulcus and the CD. GB, gallbladder. (c) Intraoperative photograph. Arrows show the infraportal PHD draining into the CD.



laparotomy, the small duct detected on MDCT was confirmed to be an aberrant PHD communicating with CD (Figure 2c), and we became aware of the possibility of preoperative diagnosis of this troublesome PHD using MDCT. In this study, a retrospective review of MDCT images and surgical records was performed to investigate whether the unenhanced duct between Rouviere's sulcus and CD on MDCT could be coincident to a PHD communicating with CD.

METHODS AND MATERIALS

Patients

Patients whose extrahepatic bile duct anatomy could be disclosed by lymph node dissection in the hepatoduodenal ligament at laparotomy were enrolled in this study. Patients who underwent simple cholecystectomy without lymph node dissection were not included, because aberrant PHD might be undetected at laparotomy in these cases. A thorough search of the computerized database of the hepatobiliary pancreatic surgery division was performed to identify the eligible patients.

Between January 2012 and November 2015, 259 patients underwent laparotomy with complete lymph node dissection in the hepatoduodenal ligament for hepatobiliary or pancreatic tumours. Of these, 35 patients were excluded (30 patients due to an unidentifiable CD on CT [including 20 post-cholecystectomy patients], and 5 due to insufficient surgical records), and the remaining 224 patients were included. The study was approved by institutional review board, with waiver of informed consent. Characteristics of the eligible 224 patients are described in Table 1. The most common disease and surgical procedure were pancreatic cancer and pancreaticoduodenectomy, respectively.

Table 1. Characteristics of the 224 patients

Age (years), median (range)	72 (18–91)
Men, *n* (%)	128 (57.3)
Disease, *n* (%)	
Pancreatic cancer	97 (43.5%)
Intraductal papillary mucinous neoplasm	29 (13.0%)
Other pancreatic tumour	12 (5.4%)
Extrahepatic cholangiocarcinoma	41 (18.4%)
Intrahepatic cholangiocarcinoma	6 (2.7%)
Intraductal papillary neoplasm of bile duct	2 (0.9%)
Gall bladder cancer	16 (7.2%)
Duodenum tumour	21 (9.4%)
Surgical procedure,[a] *n* (%)	
Pancreaticoduodenectomy	190 (84.8%)
Cholecystectomy and extrahepatic bile duct resection	16 (7.1%)
Left lobectomy	7 (3.1%)
Hepatectomy (segment 4 and 5)	4 (1.8%)
Total pancreatectomy	3 (1.4%)
Cholecystectomy	2 (0.9%)
Left trisegmentectomy	1 (0.05%)
Hepatectomy (segment 5 and 8)	1 (0.05%)

[a]All procedure included lymph node dissection in the hepatoduodenal ligament.

MDCT examination

All MDCT studies were performed using a scanner with 16 rows of detectors (Aquilion 16; Toshiba Medical Systems, Tokyo, Japan). CT images, both unenhanced and contrast-enhanced, were routinely obtained with the patient in the supine position during full inspiration. For contrast-enhanced imaging, 100 ml of non-ionic contrast material with iodine was administered at a rate of 3.2 ml s^{-1} using a mechanical power injector through a 20-gauge angiographic catheter inserted into a forearm vein. An unenhanced image and 4 contrast-enhanced images (early arterial, delayed arterial, portal venous and delayed phase) were routinely obtained. The scanning parameters for each phase were 1 mm collimation, 3 mm slice thickness, 3 mm reconstruction interval, 120 kV and auto mA.

Imaging analysis

MDCT images were available from the picture archiving and communication system, and all images were reviewed on the picture archiving and communication system monitor. All CT images were evaluated retrospectively by three experienced radiologists and one hepatobiliary and pancreatic surgeon with a consensus of evaluators, and they were blind to the operative findings.

Type of PHD

The maximum diameter of the common bile duct larger than 8 mm was regarded as bile duct dilation.[22,23] Each PHD was investigated, whether its route was the supraportal or infraportal type on MDCT (Figure 1). A PHD draining into the anterior sectoral hepatic duct from the cranial or caudal side of the right portal vein could be diagnosed as a supraportal or infraportal type on preoperative MDCT (Figure 3).

Unenhanced duct between Rouviere's sulcus and CD

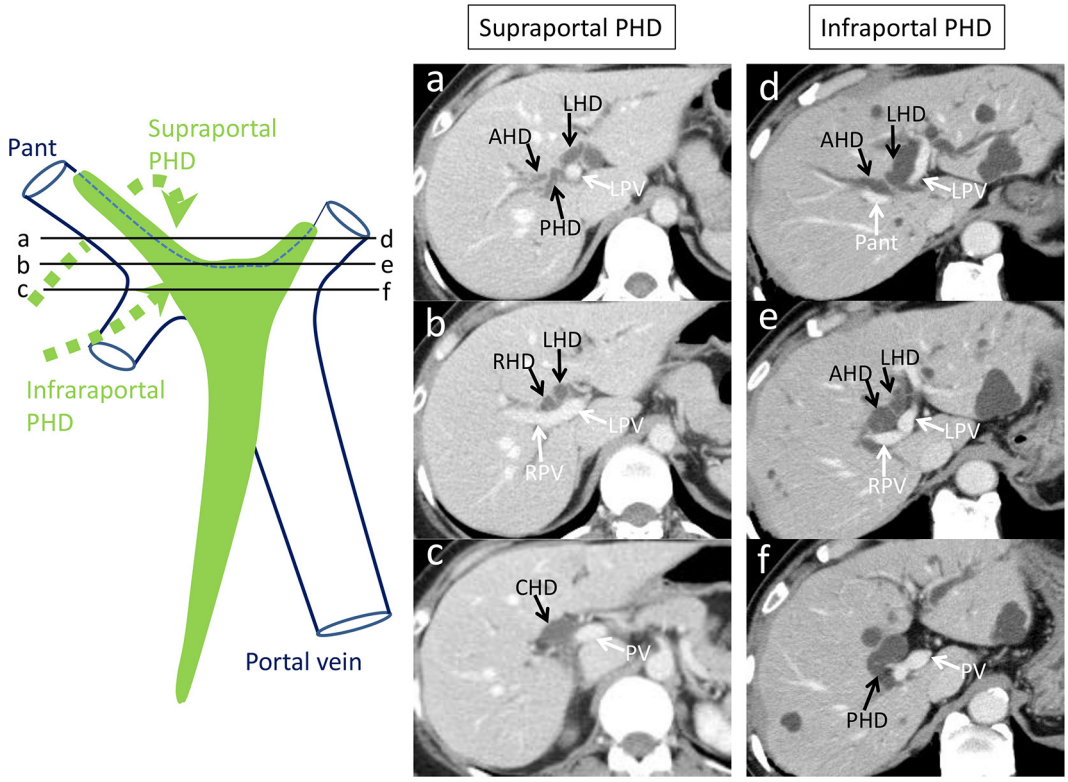
It was thought that the unenhanced duct between Rouviere's sulcus and CD on MDCT might be coincident to an aberrant PHD communicating with CD (Figure 2). If an unenhanced small duct between Rouviere's sulcus and CD was seen on the preoperative MDCT, the diameter of the duct was measured. The unenhanced duct was confirmed not to be a branch of the artery or portal vein on arterial or portal venous phase, but to be a PHD, by checking the positional relationship between the posterior segmental branch of the portal vein and artery (Figure 2a,b).

Review of surgical records

Type of PHD

Type of PHD (supraportal type or infraportal type) was checked in each case.

Figure 3. Diagnosis of the type of posterior sectoral hepatic duct (PHD) using CT. (a), (d) bilateral portal vein level, (b), (e) portal vein bifurcation level, (c), (f) main portal vein level. A PHD draining into the AHD from the cranial side of the right portal vein is identified as supraportal PHD (a, b, c), and when draining into the AHD from the caudal side of the right portal vein, it is identified as infraportal PHD (d, e, f). Pant, right anterior portal vein; AHD, anterior sectoral hepatic duct; LHD, left hepatic duct; LPV, left portal vein; RPV, right portal vein.



Confluence pattern of infraportal PHD

In the infraportal type, the confluence pattern of PHD was investigated.

Aberrant PHD communicating with CD

Cases of an aberrant PHD communicating with CD were identified by reviewing the surgical records.

RESULTS

Type of PHD

Preoperative MDCT showed 122 (54.5%) patients with bile duct dilatation and 102 (45.5%) patients without it. In patients with bile duct dilatation, preoperative CT showed 111 supraportal type (91.0%), 10 infraportal type (8.2%) and 1 unidentifiable type PHD (0.8%) (Table 2). Surgical findings identified 112 supraportal type (91.8%) and 10 infraportal type PHDs (8.2%). In patients without bile duct dilatation, preoperative CT showed 9 supraportal type (8.8%), 3 infraportal type (2.9%) and 90 unidentifiable type PHDs (88.2%). Surgical findings identified 97 supraportal type (95.1%) and 5 infraportal type PHDs (4.9%). In total, 15 (6.7%) cases of infraportal type existed (Table 3).

Confluence pattern of infraportal PHD

Among 15 cases of infraportal type, 6 cases (2.6%) were PHD draining into common hepatic duct or anterior sectoral hepatic

Table 2. Types of posterior sector hepatic duct

Patients with bile duct dilation (n = 122, 54.5%)			
	Supraportal type	**Infraportal type**	**Unidentifiable**
Preoperative CT findings	111 (91.0%)	10 (8.2%)	1 (0.8%)
Surgical findings	112 (91.8%)	10 (8.2%)	0 (0%)
Patients without bile duct dilatation (n = 102, 45.5%)			
	Supraportal type	**Infraportal type**	**Unidentifiable**
Preoperative CT findings	9 (8.8%)	3 (2.9%)	**90 (88.2%)**
Surgical findings	97 (95.1%)	5 (4.9%)	0 (0%)

Table 3. Detectability of aberrant posterior hepatic duct draining into the CD using MDCT

	Presence	Absence
Preoperative CT finding: Unenhanced duct between Rouviere's sulcus and the CD	8	216
Surgical finding: Aberrant posterior hepatic duct draining into the CD	7	217

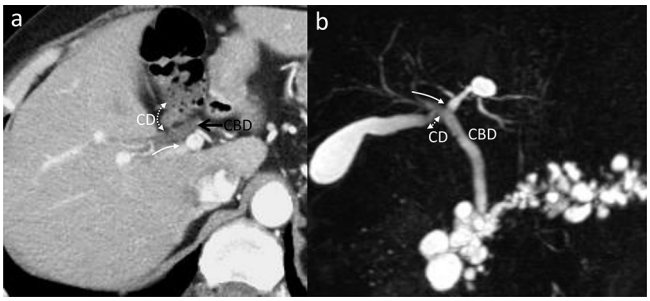
CD, cystic duct; MDCT, multiple detector CT.

duct type, and 2 cases (0.9%) were PHD draining into common bile duct type. Seven cases (3.1%) were aberrant PHD communicating with CD (CD draining into PHD: 6 cases, PHD draining into CD: 1 case).

Diagnosis of aberrant PHD communicating with CD using MDCT

Preoperative MDCT detected 8 (3.6%) unenhanced ducts between Rouviere's sulcus and CD (Figures 2b, 4 and 5). The diameter of the unenhanced ducts ranged from 3.75 to 10 mm, with a median value of 3.75 mm. Surgical records identified 7 (3.1%) cases of aberrant PHD communicating with CD, and all 7 cases showed unenhanced duct between Rouviere's sulcus and CD on preoperative MDCT imaging. Among the 7 patients, 5 (71%) were without bile duct dilatation.

Figure 5. False-positive case. (a) CT shows an unenhanced small duct (white arrow) draining into the CD (dot arrow). (b) Magnetic resonance cholangiopancreatography shows that the small duct on CT is not aberrant posterior sectoral hepatic duct draining into the CD, but is instead the right hepatic duct. CD, cystic duct.

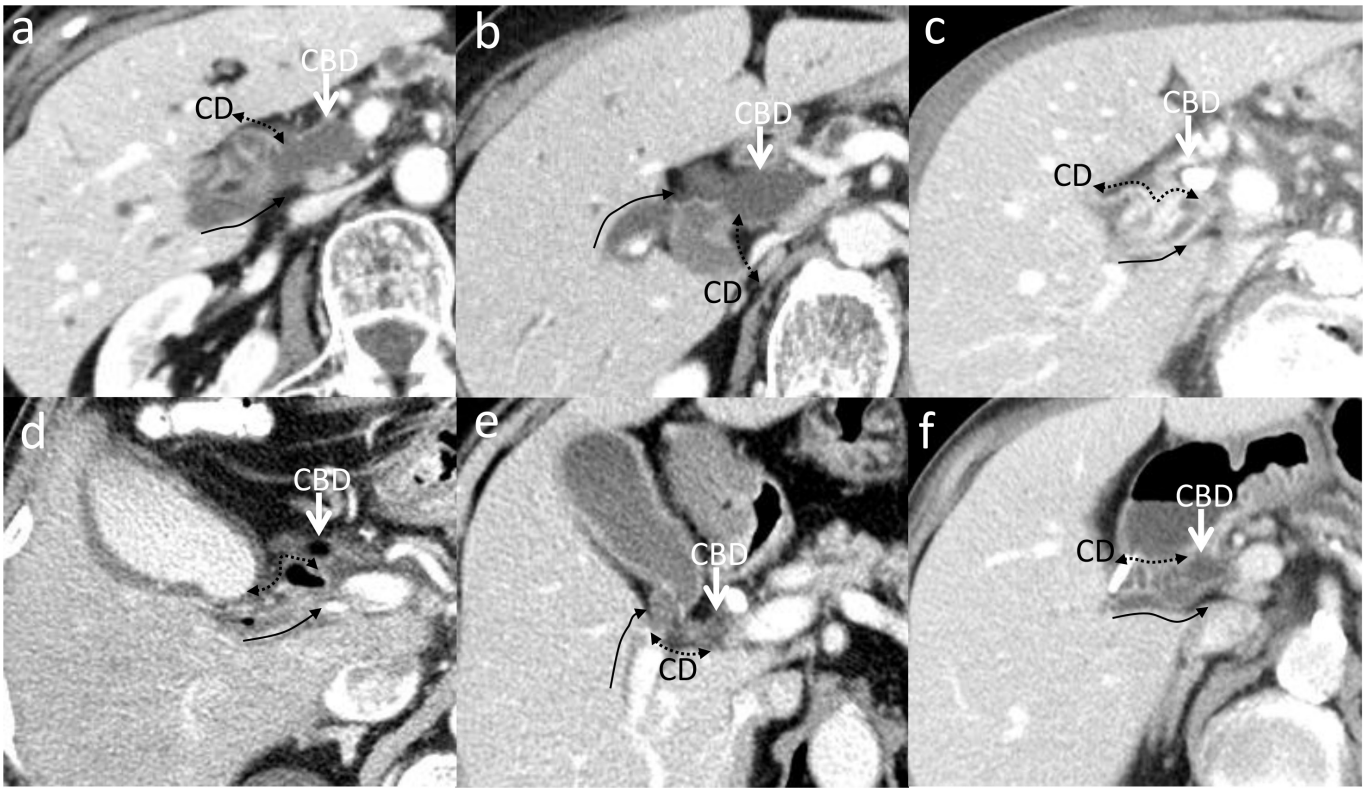


One false-positive case on MDCT imaging existed (Figure 5). In that case, the CD drained in the confluence of the bilateral hepatic duct and the unenhanced duct between the CD and Rouviere's sulcus was actually the right hepatic duct.

DISCUSSION

Over 75,0000 cholecystectomies are performed each year in the United States.[24,25] Bile duct injury during cholecystectomy is an infrequent but serious complication that can lead to high morbidity rate and even death.[1] Previous reports suggest the

Figure 4. CT imaging of 6 cases (a–f) of aberrant PHD draining into the cystic duct (CD). Black arrow shows a PHD draining into the CD, and dot arrow shows the CD. CT imaging of remaining case is shown in Figure 3. CBD, common bile duct; PHD, posterior sectoral hepatic duct.



incidence of bile duct injury during open cholecystectomy is between 0.1 and 0.3 percent and it is significantly higher (0.3–0.7%) during laparoscopic cholecystectomy.[26–28] Further, bile duct injury during laparoscopic cholecystectomy tends to be more severe than that due to open cholecystectomy. To prevent bile duct injury during cholecystectomy, various strategies, such as intraoperative cholangiography, alterations of surgical technique, and preoperative diagnosis of bile duct anatomy, have been considered. Some studies have shown a reduction in risk if surgeons perform routine intraoperative cholangiography.[28–30] However, others have argued that bile duct injury is not prevented by cholangiography, and that only correct interpretation of anatomy and meticulous dissection will avoid this complication.[3,31]

Anatomical anomaly of the bile duct is one of the commonest causes of bile duct injury.[11] Most aberrant bile ducts injured during cholecystectomy are aberrant PHDs, and all aberrant PHDs were reported to be the infraportal type.[11,32] The risk of injuring aberrant PHD (Figure 1c), except for the PHD communicating with the CD, can be minimized by using dissection close to the gall bladder-CD junction.[11,20,21] However, this meticulous dissection might be unable to avoid injury of PHD communicating with CD.[11] Intraoperative cholangiography might also be ineffective in this type of aberration. If a catheter for a cholangiography is intubated on the downstream side of the confluence of the aberrant PHD and the CD, cholangiography can't detect the aberrant PHD.[11] These results suggest that an aberrant PHD communicating with CD is a most critical anatomy for cholecystectomy,[11,15,19] and preoperative detection of this type of anomaly is crucial. Only one previous study focused on this issue. Kurata et al reported that 51 (6.8%) patients had aberrant infraportal PHD among 753 patients who underwent laparoscopic cholecystectomy.[11] An aberrant PHD communicating with CD was detected in 16 (2.1%) patients in their report, and the result was similar to our report (3.1%).

This study evaluated whether MDCT could detect this most troublesome aberrant PHD. Results of this study indicated that MDCT was not useful for detecting infraportal PHD in cases without bile duct dilation. However, it is noteworthy that all cases of aberrant PHD communicating with CD showed unenhanced duct between Rouviere's sulcus and CD on preoperative MDCT imaging. MDCT might be useful to prevent injury to PHD communicating with CD.

Other imaging modalities such as magnetic resonance cholangiography (MRC), CT cholangiography and drip infusion cholangiography with CT have been reported to be useful to detect the bile duct anomaly.[11,33–35] Kurata et al reported that MRC or endoscopic retrograde cholangiography was routinely applied before the laparoscopic cholecystectomy, and it was completed without any complication in all 753 patients.[11] Although usefulness of MRC and CT cholangiography has been widely proven,[11,33–35] some previous reports demonstrated that CT cholangiography showed higher visualization than MRC.[34] In the current study, however, the comparison of detectability of troublesome aberrant PHD using MDCT and other modalities could not be performed, because other modalities had rarely been undergone before the surgery.

This study has some limitations. First, the false-positive case may exist at a constant rate in the population. As shown in Figure 5, it might be misdiagnosed as aberrant PHD communicating with the CD when the CD drained into the upper stream of the extrahepatic bile duct. Second, the current study includes only cases for which confluence of the common hepatic duct and CD could be detected precisely, and 30 cases were excluded due to poor visualization of the confluence.

In conclusion, MDCT could detect aberrant PHD communicating with CD, regardless of the presence or absence of bile duct dilatation.

ETHICAL APPROVAL

All procedures performed in studies involving human participants were in accordance with the ethics committee of corresponding author's institution.

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