Int Surg 2017;**102:**250–257
DOI: 10.9738/INTSURG-D-15-00049

Presence of Aberrant Anatomy Is an Independent Predictor of Bile Duct Injury During Cholecystectomy

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The aim of this study is to investigate the impact of an aberrant anatomy diagnosed with MR cholangiography on the occurrence of bile duct injury. Although many authors report that aberrant anatomy is a strong risk factor for the occurrence of bile duct injury during cholecystectomy, no reports have examined the incidence of aberrant anatomy and its association as an independent risk factor for bile duct injury while controlling for potential confounding factors. This study involved 1289 patients. All images of MR cholangiography were reviewed and the findings, including the presence of aberrant anatomy, thickening of the gallbladder wall, and cystic duct stones—which may be related to the occurrence of bile duct injury—were recorded. The surgical outcome was compared according to the presence or absence of an aberrant anatomy and the predictive factors for bile duct injury were investigated. Aberrant anatomy was present in 11.2% of cases. The incidence of bile duct injury was significantly higher in patients with aberrant anatomy compared with patients without (3.5% versus 0.3%). By multivariate analysis, the presence of an aberrant anatomy and thickening of the gallbladder wall was an independent predictor for bile duct injury occurrence [odds ratio (OR) =16.56, $P = 0.001$; OR = 10.96, $P = 0.006$, respectively]. The presence of an aberrant anatomy and thickening of the gallbladder wall is an independent risk factor for the occurrence of bile duct injury.

Key words: Bile duct injury – Aberrant anatomy – Cholecystectomy

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Bile duct injury (BDI) during cholecystectomy has severe consequences for the health of patients, in terms of mortality and morbidity. If considerable disability results, those can be costly for individual patients and the health care system.[1–3] The incidence of BDI is reported to range between 0.15% and 1.5%.[4–7] Various potential predisposing factors have been described for BDI, including, but not limited to, inflammation, biliary anomaly, surgeon's experience, older age, and male sex.[4–12] However, previous studies addressing the influence of a preexisting biliary anomaly have been limited for 2 reasons. First, as many studies included anomalies that did not influence the occurrence of BDI, the results were not pertinent to preventing BDI during cholecystectomy. For instance, a diagnosis of triple (right anterior and posterior segmental ducts and left hepatic duct) confluence pattern or right posterior segmental duct draining into the left hepatic duct had no impact on the occurrence of BDI, although it is crucial for the success of donor hepatectomy.[13–15] To prevent BDI during cholecystectomy, we must understand the incidence and pattern of aberrant bile ducts that run near Calot's triangle, an important anatomical landmark. Second, there have been no reports that have compared the operative outcome, including BDI, in the presence and absence of aberrant anatomy or have examined the impact of these anomalies on the occurrence of BDI, while controlling for potential confounding factors. Although there was only one paper which reported no differences in the incidence of BDI between cases with or without preoperative knowledge of bile duct anatomy,[16] they have not examined the impact of preoperative knowledge of "aberrant anatomy" on the occurrence of BDI.

Therefore, the aim of this study was to evaluate detailed information regarding aberrant bile ducts that might influence the occurrence of BDI during cholecystectomy and to investigate whether bile duct anomaly is an independent predictor for BDI.

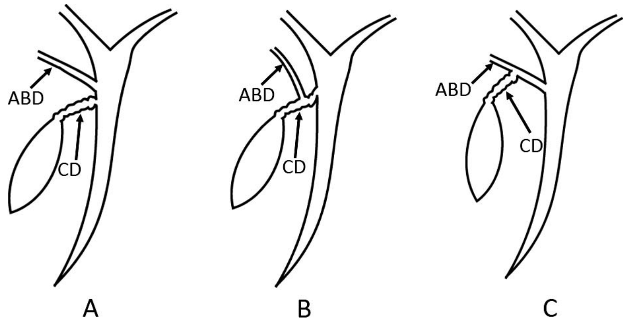

Fig. 1 Schema of the classification of aberrant bile ducts. (A) Type A anomaly consisted of an aberrant bile duct draining into the common hepatic duct or the common bile duct. (B) Type B anomaly consisted of an aberrant bile duct draining into the cystic duct. (C) Type C anomaly consisted of the cystic duct draining into an aberrant bile duct.

Materials and Methods

Patients

Between January 2006 and December 2012, a total of 1479 consecutive patients with benign disease of the gallbladder, including gallstones, adenomyomatosis, acute or chronic cholecystitis, and polyps, underwent cholecystectomy at Toyohashi Municipal Hospital. Although magnetic resonance (MR) cholangiography was routinely performed before cholecystectomy for prevention of bile duct injury at our institution, it was not performed in 190 patients preoperatively. Among these 190 patients, 136 patients underwent endoscopic retrograde cholangiography (ERC) for the treatment of bile duct stones. The remaining 54 patients who refused to be examined did not receive either of these imaging studies. Thus, 1289 patients who received MR cholangiography preoperatively formed the cohort for this study. We retrospectively collected the clinical characteristics of these patients, including sex, age, surgeon's experience, operative procedure (laparoscopic or open surgery), maximum white blood cell (WBC) count, emergency or elective operation, and occurrence of BDI. Operating surgeons were classified in 2 groups based upon having performed more than 50 cholecystectomies. Emergent operations were those performed within 48 hours after admission to our hospital for acute cholecystitis. Moreover, all MR cholangiography images were reviewed by an experienced abdominal imaging radiologist (AT) and digestive surgeon (SN) independently. The findings, including the presence of aberrant anatomy, thickening of the gallbladder wall (TGW), and cystic duct stones, which may be related to the occurrence of BDI, were recorded by consensus of 2 reviewers. The type of aberrant anatomy was also noted according to the definition described below (see "Definition of type of aberrant anatomy" and Fig. 1).

Surgical procedure

Patients in poor general condition, with sepsis, or a past history of upper abdominal surgery were subjected to open cholecystectomy (OC), whereas the remaining patients underwent laparoscopic cholecystectomy (LC). The surgical procedures were converted from LC to OC according to the operative findings, including the presence of severe adhesion due to acute or chronic inflammation, uncontrollable bleeding, or a suspicion of BDI. In the current study, such conversion cases were included in the LC group. Intraoperative cholangiography (IOC) was performed according to the surgeon's preference. Because IOC was performed mainly for the purpose of identifying the positional relationship between the cystic duct and common bile duct or common hepatic duct, intrahepatic bile ducts were not evaluated thoroughly.

Definition of BDI

Bile duct injury was defined as any tissue damage to the wall of any bile duct of the biliary tree, except for simple laceration of the cystic duct, detected during cholecystectomy or diagnosed postoperatively as a result of a bile leak or biliary obstruction not caused by a stone. In cases where BDI occurred, the following were recorded: presence or absence of aberrant anatomy, type of aberrant anatomy (if present), timing of diagnosis of BDI, severity, and clinical outcome.

Definition of MR cholangiography findings

Findings with MR cholangiography were described as follows. An aberrant bile duct was the only bile duct draining a particular segment of the liver that was joined to the common hepatic duct, common bile duct, or cystic duct. The gallbladder wall was recorded as present when the thickness was greater than 5 mm. Cystic duct stones were defined as any filling defect of the cystic duct.

Definition of type of aberrant anatomy

Aberrant anatomy was divided into 3 types (Fig. 1). Type A anomaly consisted of an aberrant bile duct draining into the common hepatic duct or common bile duct. Type B anomaly consisted of an aberrant bile duct draining into the cystic duct. Type C anomaly consisted of the cystic duct draining into an aberrant bile duct.

Setting and technique of MR cholangiography

We obtained all MR images with a 1.5 T scanner (Symphony, Siemens, Munich, Germany). All images were analyzed using the half–Fourier acquisition single-shot turbo spin echo (HASTE) sequences. We performed the fat suppression HASTE technique with a section thickness of 4 mm in a coronal or coronal oblique orientation (relaxation time, 1500 ms; effective echo time, 106 ms; image matrix, 256 $\times$ 256; field of view, 300 mm).

Statistics

Statistical analysis was carried out using statistical software (SPSS, version 21.0, IBM Corp, Armonk, New York). Normally distributed continuous variables were described as the mean values $\pm$ standard deviation, while skewed ones were described as median and interquartile range. Kolmogorov-Smirnov test was used to define a variable normally distributed. All categorical variables were expressed as numbers and percentages. The association between continuous variables and categorical variables with 2 categories was evaluated using Student's *t*-test for normally distributed continuous variables and the Mann-Whitney test for skewed variables, while the association between categorical variables was evaluated with the χ^2 test or Fisher exact probability test, where appropriate. Simple and multivariate logistic regression analysis was performed to evaluate the association between aberrant anatomy and occurrence of BDI and to identify the independent risk factors for BDI. The results were expressed as odds ratios (OR) with 95% confidence intervals (CI). A value of $P < 0.05$ was considered statistically significant.

Results

Among the 1289 patients, an aberrant bile duct anatomy was identified in 144 (11.2%), including 123 type A, 15 type B, and 6 type C. No difference was observed in the distribution of cases among sex or surgical procedures (LC or OC). The age of patients with aberrant anatomy was significantly higher than that of patients without [64 (range, 50.25–72) years versus 60 (range, 47–70.5) years, $P = 0.042$]. With regard to the surgical outcome, the volume of blood loss and operative time were similar between the two groups, although the rate of conversion to OC was significantly higher in patients with aberrant anatomy (11.8% versus 7.0%, $P = 0.044$). The incidence of BDI was significantly higher in patients with aberrant anatomy compared with those with normal anatomy (3.5% versus 0.3%, $P = 0.001$) (Table 1).

Table 1 Comparison between patients without and with aberrant bile duct

	Without aberrant bile duct (n = 1145)	With aberrant bile duct (n = 144)	*P* value
Sex			
M/F	604/541	72/72	0.537
Age, y (range)	60 (47–70.5)	64 (50.25–72)	0.039
Surgical procedure			
LC/OC	1044/101	128/16	0.357
Operative outcome			
Conversion to OC, n (%)	80 (7.0)	17 (11.8)	0.044
Blood loss, mL (range)	0 (0–11)	0 (0–9.5)	0.923
Operative time, min (range)	100 (79–137)	105 (77.5–136.5)	0.994
Incidence of BDI, n (%)	3 (0.3)	5 (3.5)	0.001

By univariate analysis, OC, the presence of aberrant bile duct, and TGW were significantly associated with the occurrence of BDI (Table 2). By multivariate analysis, the presence of an aberrant bile duct and TGW were independent predictors for BDI occurrence (OR = 16.56, 95% CI = 3.28–83.51, $P = 0.001$ and OR = 10.96, 95% CI = 1.98–60.80, $P = 0.006$, respectively; Table 3).

BDI, injury site, severity, and clinical outcome

The characteristics of 8 patients with BDI are summarized in Table 4, and diagrams of the injuries are presented in Figs. 2 and 3. Bile duct injury was diagnosed on the seventh (POD) in 1 case (12.5%; case 1), and the remaining 7 injuries were diagnosed intraoperatively. In case 1, thermal injury with electrocautery was suspected because a small perforation at the confluence of the cystic duct and the aberrant right posterior segmental duct was found on reoperation. An aberrant anomaly was present in 5 (62.5%) of the 8 cases and the aberrant bile duct was injured in 4 cases (cases 1–4). In case 6, laceration occurred at the common hepatic duct (CHD), although the patient had an aberrant bile duct. In one case (Case 5), CHD was transected, while laceration occurred in the CHD or common bile duct (CBD) in 3 cases (6–8). In all cases, a repair procedure was carried out with laparotomy, the injured site was sutured, and a stent put in place to prevent stenosis. However, because the injured bile duct was too thin, reconstruction was stopped in case 2 in which the small branch of the right anterior segmental duct draining into the common hepatic duct (BDI, type A) was severed entirely. Both of the cut stumps were ligated. As a result, bile leakage occurred and fortunately it was treated conservatively with technique of interventional radiology. In case 5, the circumference of the common hepatic duct was severed almost entirely. Postoperatively, bile leakage and stenosis of the CHD was complicated. Although he was recommended to undergo repair surgery, he refused. Therefore, even now, 7 years after cholecystectomy, he is treated with biliary stenting.

Discussion

There are many reports identifying risk factors for BDI. Older age, male sex, acute or chronic inflammation, surgeon's experience, and laparoscopic approach have all been identified as predictors of BDI in previous studies.[4–12] However, none of these earlier studies investigated whether a link existed

Table 2 Univariate analysis for predisposing factors for BDI during cholecystectomy

	BDI incidence, n (%)	Crude OR	*P* value
Male sex (n = 676)	4 (0.59)	0.91 (0.23, 3.64)	0.890
Age ≥ 65 y (n = 505)	5 (0.99)	2.60 (0.62, 1.94)	0.192
Surgeon's experience <50 (n = 590)	2 (0.34)	0.39 (0.08, 1.95)	0.254
Open cholecystectomy (n = 117)	3 (2.56)	6.14 (1.45, 26.03)	0.014
WBC ≥ 10,000/μL (n = 464)	2 (0.43)	0.39 (0.08, 1.95)	0.254
Emergent operation (n = 175)	0 (0)	0.002 (0.00, 5.06×10^{14})	0.759
Presence of ABD (n = 144)	5 (3.47)	13.69 (3.24, 57.92)	<0.001
Thickening of TGW (n = 445)	6 (1.35)	5.75 (1.16, 28.62)	0.033
Presence of CD stone (n = 59)	1 (1.69)	3.01 (0.36, 24.87)	0.306

Table 3 Multivariate analysis for predisposing factors for BDI during cholecystectomy

	Adjusted OR	*P* value
Male sex	0.69 (0.16, 3.04)	0.621
Age ≥ 65 y	1.72 (0.37, 7.98)	0.489
Surgeon's experience <50	0.25 (0.04, 1.51)	0.131
Open cholecystectomy	8.31 (1.53, 45.16)	0.014
WBC ≥ 10,000 (/μL)	0.20 (0.032, 1.32)	0.095
Emergency operation	0.001 (0.00, 2.41×10^{21})	0.798
Presence of ABD	16.56 (3.28, 83.51)	0.001
Thickening of gallbladder wall	10.96 (1.98, 60.80)	0.006
Presence of CD stone	1.38 (0.11, 17.97)	0.808

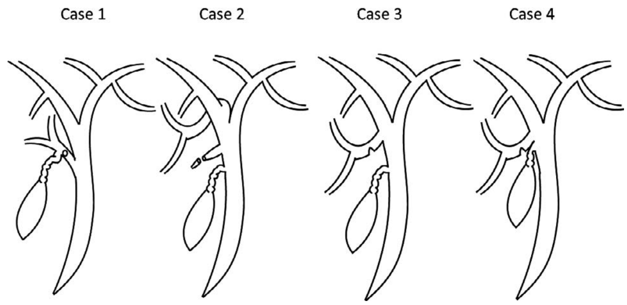

Fig. 2 Schema of aberrant bile duct injuries in cases 1 through 4. In case 1, a small perforation was detected at the aberrant right posterior segmental duct into which the cystic duct drained (BDI, type C). In case 2, the small branch of the right anterior segmental duct draining into the common hepatic duct (BDI, type A) was severed entirely. In case 3, a laceration was detected on the aberrant right posterior segmental duct draining into the common hepatic duct (BDI, type A). In case 4, a laceration was detected on the aberrant right posterior segmental duct draining into the common hepatic duct to which the cystic duct joined (BDI, type A).

between BDI and aberrant anatomy. To our knowledge, there have been no reports that have shown aberrant anatomy as an independent predictor for BDI while controlling for potential confounding factors. Using multivariate analysis, we showed that the presence of this anomaly is associated with a 16.56-fold increase in the risk of BDI occurrence. Several studies—including those from Kitami *et al*[13] (2006, n = 202); Sharma *et al*[14] (2008, n = 253); and Bageacu *et al*[15] (2011, n = 124)—have reported the frequency of bile duct anomaly as 6.9%, 12.3%, and 24.1%, respectively, according to our definition of an aberrant bile duct. We reviewed 1289 MR cholangiography images and found an incidence of 11.2% in our patient cohort. Differences among the reported frequency of this anomaly may be attributed to the different modalities used for diagnosis. We may have underestimated the frequency in our series because drip-infusion cholangiography–computed tomography has been reported to provide higher quality images than MR cholangiography (as used in our study).[17,18] Although we did not experience aberrant bile duct injury cases in which anomalies had not been diagnosed by MR cholangiography, attention should be paid to not injure aberrant bile ducts too thin to be diagnosed preoperatively.

We classified our cases with aberrant anatomy into 3 types according to the draining site of the aberrant bile duct or cystic duct. Type A was the most common, a finding that is in agreement with earlier studies.[13–15] Due to the small sample size, we could not identify which type of aberrant anomaly was associated with the greatest risk for BDI occurrence. However, it is possible that there is no association between anomaly type and the occurrence of BDI. Because the important factor for the occurrence of BDI is not the location of the aberrant bile duct or where the cystic duct drains, but whether the aberrant bile duct runs close to Calot's triangle.

Table 4 Characteristics of 8 cases of BDI

Case	Age, y	Sex	ABD	Type of ABD[a]	Timing of diagnosing BDI	Site and severity of injury	Outcome
1	50	F	P	C	POD 7	Small perforation on ABD	Uneventful
2	68	F	P	A	IO	Transection of ABD	Bile leakage
3	68	F	P	A	IO	Laceration on ABD	Uneventful
4	75	M	P	A	IO	Laceration on ABD	Uneventful
5	81	M	A	–	IO	Transection of CHD	Bile leakage, stenosis
6	69	F	P	A	IO	Laceration on CHD	Uneventful
7	58	M	A	–	IO	Laceration on CBD	Uneventful
8	79	M	A	–	IO	Laceration on CBD	Uneventful

A, absence of aberrant bile duct; IO, intraoperative; P, presence of aberrant bile duct.
[a]For an explanation of the type of aberrant anatomy, see Fig. 1.

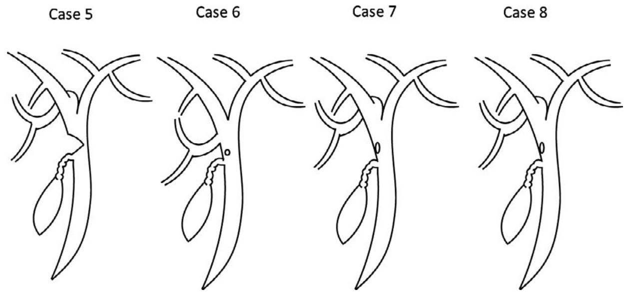

Fig. 3 Schema of injuries to the common hepatic duct or common bile duct in cases 5 through 8. In case 5, the circumference of the common hepatic duct was severed almost entirely. In case 6, a laceration was detected on the common hepatic duct. This patient had an aberrant right posterior segmental duct draining into the common hepatic duct (BDI, type A). In cases 7 and 8, a laceration was detected on the common hepatic duct.

Leukocytosis and emergency surgery did not show any significant impact on the occurrence of BDI, whereas thickening of the gallbladder wall in MRCP was identified as a predictor of BDI by multivariate analysis. This result may be because chronic inflammation (in contrast to acute inflammation): is strongly associated with the occurrence of BDI, leukocytosis reflects acute inflammation, and emergency operations have been selected for cases of acute cholecystitis. As described by some authors, chronic inflammation with fibrosis may cause difficulties during cholecystectomy.[7,12] Lukas *et al*[7] indicated that in cases of shrunken gallbladder with severe chronic inflammation, the BDI rate increased significantly to 3% because of the presence of a short cystic duct and difficult surgical dissection.

By multivariate analysis, the open surgical procedure was associated significantly with the occurrence of BDI compared with the laparoscopic approach. However, this result should be interpreted with caution as it is open to selection bias. In our institution, in principle, all patients with benign disease including cholelithiasis, adenomyomatosis, polyps, and acute or chronic inflammation were operated with the laparoscopic approach, whereas serious cases in poor general condition due to severe inflammation or adhesion from a previous operation were operated using the open approach from the start of the operation.

Surgeon's inexperience has been reported as one of the risk factors,[6–10,12] but was not associated with BDI occurrence in our study. This result may be because all operations performed by inexperienced surgeons were assisted by experienced staff surgeons. In our institute, should the initiating and responsible staff surgeon recognized the risk of BDI, he must order the inexperienced operating surgeon to be replaced by an experienced staff surgeon or to convert the operative procedure to OC if the cholecystectomy was started laparoscopically.

A repair procedure was carried out with laparotomy in all cases. One patient whose injury was diagnosed 7 days postsurgery underwent emergency laparotomy, whereas the remaining 7 patients whose injuries were detected during the initial surgery underwent repair surgery consecutively. Recently, several authors reported cases of right segmental bile duct injuries that were successfully treated with nonoperative management including percutaneous drainage and endoscopic stenting.[19–21] Although this management was used mainly for patients with delayed diagnosis of BDI, this repair strategy could be applied for injury cases detected intraoperatively. That is, if the surgeon suspected injury of the segmental bile duct during LC, drainage of the bile leakage could be performed intraoperatively. It is unnecessary to convert the procedure to OC and stenting of the injured bile duct can be performed later endoscopically if needed.

Because BDI during cholecystectomy is an important clinical problem resulting in serious morbidity, all efforts should be made to reduce its incidence. It is very important to achieve a "critical view of safety" in which the triangle of Calot is dissected free of all tissue, except for the cystic duct and artery, and the base of the liver bed is exposed.[22] No ambiguous funicular structure must be occluded or divided before confirming this anatomy. However, it is often very difficult to achieve a critical view of safety due to severe inflammation or fibrosis in Calot's triangle. We have to consider how to proceed surgically if aberrant anatomy, a strong predictor of BDI occurrence, is diagnosed preoperatively and if severe fibrosis or inflammation is present in Calot's triangle. In such cases, subtotal cholecystectomy, in which Calot's triangle is not dissected, may be one option, although adverse effects of this operative procedure have been reported, including bile leakage from the stump of the gallbladder neck or a risk of residual malignancy.[23,24]

The effect of IOC on the prevention of BDI is still under debate.[5,6,9,12,25] In the current study, the association between the performance of IOC and the occurrence of BDI was not investigated because at our institution, IOC is performed according to the surgeon's preference. Even if IOC was performed, the opacification was not enough to thoroughly reveal intrahepatic bile duct including an aberrant bile duct because this examination was performed mainly for the purpose of identifying the positional relationship between the cystic duct and the common bile duct or the common hepatic duct.

A total of 136 patients who underwent ERC but not MR cholangiography were excluded from our study. This exclusion occurred because most ERC imaging for these patients was unsatisfactory to establish whether an aberrant anomaly was present; all of these examinations were performed for the treatment of bile duct stones and not for a detailed examination of the biliary tree.

A limitation of this study is that we could not precisely know whether aberrant anatomy of 8 BDI cases was diagnosed before cholecystectomy, which should be the essential concern about this topic. According to operative records and medical chart, it was possible that aberrant anatomy which was diagnosed by authors who reviewed all images of MR cholangiography was not recognized in most BDI cases. Therefore, little understanding of aberrant anatomy might have resulted in the occurrence of BDI.

In conclusion, the incidence of an aberrant bile duct detected by MR cholangiography was 11.2% in our series. The presence of an aberrant bile duct and thickness of gallbladder wall was an independent risk factor for the occurrence of BDI. All efforts should be made to prevent BDI in cases where an aberrant bile duct and thickness of gallbladder wall have been identified.

Acknowledgments

Source of support in the form of grants, equipment, drugs, or all of these: none. The authors declare no conflict of interest.

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