Original Article

Management of Post Cholecystectomy Bile Duct Injury: Pertinent Factors Contributing to Good Surgical Outcomes

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Objective: Surgical management remains the mainstay treatment for bile duct injury (BDI) post-cholecystectomy. Achieving long-term patency and lessening anastomotic failure depends on important factors including the types of repairs, timing of repairs, and surgical expertise. The present study focused on the impact of these factors on the surgical outcomes of BDI repair.

Materials and Methods: Fifty-nine patients who were treated with BDI post cholecystectomy at the surgical department between January 2003 and December 2018 were retrospectively reviewed. The patients were categorized as 11 in-house and 48 referral patients, of which 22 patients had bile duct repairs prior to referral. Surgical outcomes and factors, including types of repairs, timing of repairs, and surgical expertise, impacting on the treatment results were analyzed.

Results: The mean age of the patients was 47.6 years. The BDI incidence in the authors' hospital was 0.14%. Complications occurred in 21 patients (35.6%), of which intraabdominal collection was the most common at 10 patients (16.9%). The median length of hospital stay was 16 days for in-house patients and 17 days for the referral group (p=0.542). The mortality rate was 1.7%. The overall patency was 93% with mean follow up 106.4 months. Concerning the primary patency rate, the partial segments IV/V liver resection and hepaticojejunostomy techniques had better long-term patency compared to primary repairs at 92.3% versus 37.5% (p=0.017), and biliary bypass at 92.3% versus 80% (p=0.44). BDI repairs performed by primary surgeons increased the risk of anastomotic failure in comparison to those done by hepatobiliary surgeons with 10-year patency at 53.3% versus 95.4% (p=0.014). Delayed repairs longer than six weeks after injury offered positive long-term outcomes compared to early repairs done within six weeks after injury, with a 10-year patency at 85.4% versus 31.3% (p<0.001).

Conclusion: Delayed repair performed by the hepatobiliary surgeon with appropriate surgical techniques decreased anastomosis stricture and achieved good overall surgical outcomes in the management of post cholecystectomy BDI.

Keywords: Bile duct injury; Cholecystectomy; Surgical management

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Operative treatments of gallstone disease a common digestive health problem have evolved over the decades[1,2]. Laparoscopic cholecystectomy (LC) is the standard treatment that has had notable impact on shortening patient recovery time and facilitating their return to normal activity[1-3]. Unfortunately, associated with this procedure has been an increase in bile duct injury (BDI), impacting not only morbidity such as recurrent cholangitis, stricture, and biliary cirrhosis but also mortality[1-3] rates, with a rise in litigation claims[4-6]. Despite recent data showing the reduced incidence of BDI after LC to 0.3% to 0.6%[1-5], down from initial reports of 0.6% to 1.3%[7], BDI continues to be an important complication after cholecystectomy.

Treatment options depend on the clinical manifestations, severity of injuries, time to recognition, inflammation in the abdominal cavity, and the availability of experienced hepatobiliary surgeons[3]. Multimodality treatments including conservative treatment, endoscopic or radiologic management and surgery have been used, however, surgical treatment is still the mainstay of intervention. Types of surgery include simple bile duct repair with or without T-tube insertion, duct-to-duct anastomosis, duct-to-

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small bowel anastomosis, liver resection, and liver transplantation.

The goal of the present study was a retrospective review of operative management factors involved in achieving good surgical outcomes for BDI patients at King Chulalongkorn Memorial Hospital (KCMH) between January 2003 and December 2018. In particular, the role of primary and hepatobiliary surgeons, time to repair, and relevant surgical techniques were analyzed. Both short and long-term outcomes were considered.

Materials and Methods

Patient characteristics and injury classifications

Fifty-nine patients treated with BDI post cholecystectomy at KCMH between January 2003 and December 2018, were analyzed. A retrospective analysis was done on patient characteristics, injury classifications and treatments, including patient demography, indications for cholecystectomy, type of BDI, time to recognition of BDI, time to repair, clinical manifestations after BDI, intervention treatments before definite operations, types of repairs, outcomes, and clinical follow-up.

Patients who developed BDI whilst in the authors' surgical department were referred to as 'in-house' patients and those from other hospitals were classified as 'referral' patients. This group was further divided into 'attempted repair' as BDI repair was performed in the referral hospitals prior to referral, and 'non-attempted repair' as no surgical intervention was attempted before referrals. Injuries to the biliary tree were classified according to Strasberg's Classification[8]. Index operations involve initial BDI repairs that were conducted in the authors' hospital. Re-repair operations refer to BDI repairs performed after the previous attempts to repair failed.

Time to repair was classified into early repairs as intraoperative repairs and repairs prior to six weeks post injury, and delayed repairs were repairs after more than six weeks of injury. In cases of the referral group, if an attempt to repair was performed, the time of repair was counted as the initial time of repair. Clinical manifestations after BDI were recorded and assessed. It included details of the following, bile leakage, jaundice, intraabdominal collection, bile peritonitis, and sepsis. Prior to BDI repair intervention, if necessary, details of percutaneous drainage (PCD), percutaneous transhepatic biliary drainage (PTBD), endoscopic management, and surgical drainage details were also recorded.

Clinical management and surgical corrective techniques

Injuries that were incurred in association with either open cholecystectomy (OC) or LC were included, regardless of whether the operation was completed laparoscopically or converted to an open procedure. Types of BDI repair depended on the types of injury, vascular injury association, index operation, or re-repair operation, and the preferred technique by the respective surgeon. In the present study hospital, in-house patients were treated by primary surgeons, except for one patient who developed a right intrahepatic duct stone and was treated by the hepatobiliary surgeon. Meanwhile, all referral patients were intervened by the hepatobiliary surgeons in the authors' unit.

The considered options of surgical management included primary repair with or without t-tube insertion, duct-to-duct anastomosis, biliary bypass, partial segments IV and V liver resection and Roux-en-Y hepaticojejunostomy (PS IV/V LRHJ), and major liver resection. PS IV/V LRHJ (Figure 1) would be offered if the biliary bypass anastomosis was considered not to be secure and safe due to anatomical distortion, marked inflammation of the hepatoduodenal ligament, sclerotic bile duct walls, or hilar bile duct injuries[9]. Major hepatectomy was performed when BDI was associated with vascular injuries. All cases involving the PS IV/V LRHJ technique or major hepatectomy were performed by the unit's hepatobiliary surgeons. Operative data including operative time, intraoperative blood loss, and blood transfusion were recorded accordingly.

Surgical outcomes

Short-term outcomes were defined as postoperative complications according to the Clavien-Dindo classification[10] and length of hospital stay (LOS). Long-term outcomes, defined by the patency of anastomosis with or without intervention, were further classified as primary patency and secondary patency according to Cho et al's[11] definition. All patients were regularly followed up with liver function tests and imaging as required. If a short segment anastomotic stricture was detected, a cholangioplasty either by endoscopic management or a percutaneous approach was performed. When the cholangioplasty procedure failed or long anastomotic strictures occurred, surgical correction was offered.

Statistical analysis

Data were presented as numbers (percentages),

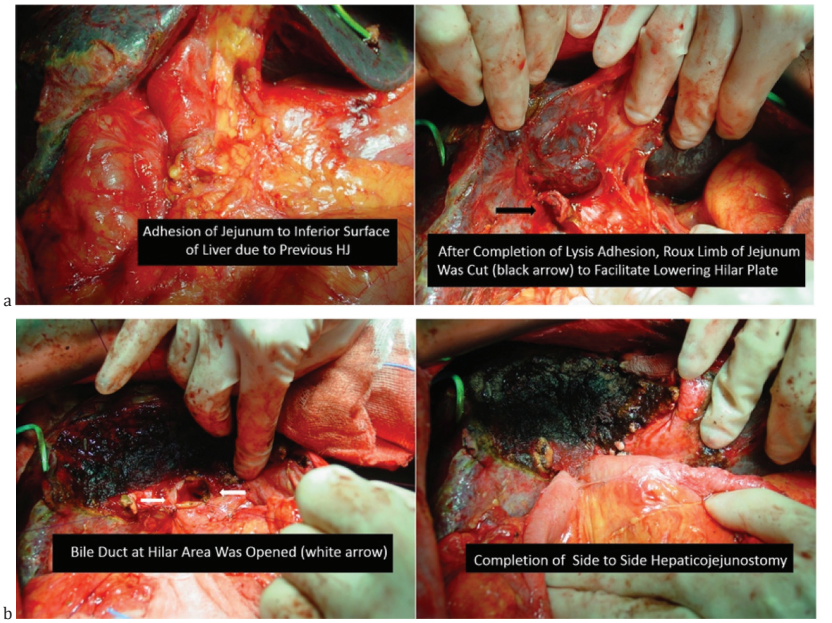

Figure 1. Operative Images of PS IV/V LRHJ for correction stricture of previous Roux-en-Y hepaticojejunostomy BDI Type E3.

(a) Adhesion of the jejunum to the inferior surface of the liver due to a previous HJ (left), after completion of lysis adhesion and division of previous Roux-limb of the jejunum, the hilar plate was lowered (right)

(b) After completion of the liver resection of the lower parts of segments IV and V, the bile duct at the hilar area was exposed and the anterior bile duct wall was opened (left); the completion of side-to-side hepaticojejunostomy was performed (right)

or mean ± standard deviation (SD), ranges, or percentages of the appropriate denominator, dependent on the data. The two groups of patients in-house and referral were compared statistically by the chi-square test or Fisher's exact test. Mann-Whitney tests were used to analyze the differences in operative time, the amount of intraoperative blood loss and length of postoperative hospital stay. Primary and secondary patency was analyzed by the Cox regression model. A p-value of less than 0.05 was considered statistically significant. Statistical analysis was performed using the Stata Statistical Software, version 15.1 (StataCorp LLC, College Station, TX, USA).

Ethics approval

Approval for the present study was obtained by KCMH's Ethics Committee (IRB number 376/62).

Results

Patient characteristics, classification of injury type, and treatment interventions (Table 1)

Seven thousand six hundred eight LC cases were performed at KCMH over a 15-year period, between January 2003 and December 2018. For this related study period, 59 patients were treated for BDI at the authors' surgical department. The 'in-house' group had eleven patients (18.6%), so incidence of BDI in the present study hospital was 0.14%. Forty-eight patients (81.3%) were accounted for the 'referral' group. The patient's mean age was 47.6 years with a range of 20 to 85 years and a median of 41 years. Notably, the mean age of patients in the referral group, at 45.2 years, was younger than that of the in-house group at 58.4 years (p=0.01). The cohort was represented by 37 females (62.7%) and 22 male patients (37.3%).

Biliary colic was the most common cholecystectomy indication, detected in seven patients (63.6%) in the in-house group and 37 patients (77%) in the referral group. Initial LC was performed in 49 cases (83%) but conversion to OC was carried out in 19 patients (39.6%) in the referral group and eight patients (72.7%) in the in-house group, respectively. Bile leakage, accounting for 54.5% for both groups, was the most common clinical manifestation of BDI, observed in six in-house patients and 26 referral patients. However, jaundice and intraabdominal collection were predominated in the referral group, with 13 cases of jaundice (27%), and seven patients (14.6%) of intraabdominal collection in comparison to one patient and none in the in-house group, respectively.

Table 1. Baseline patient characteristics, types of injury and treatment interventions

Variable	In-house patients (n=11); n (%)	Referral patients (n=48); n (%)	Total (n=59); n (%)	p-value
Age (years); mean±SD (range)	58.4±20.4 (20 to 85)	45.2±14.9 (20 to 84)	47.6±16.7 (20 to 85)	0.01
Sex: female/male	7/4 (63.6/36.4)	30/18 (62.5/32.5)	37/22 (62.7/37.3)	0.944
Indication for cholecystectomy				<0.001
Biliary colic	7 (63.6)	37 (77.0)	44 (74.6)	
Acute cholecystitis	0 (0.0)	11 (20.8)	11 (18.6)	
Gallstone pancreatitis	3 (27.3)	0 (0.0)	3 (5.1)	
Acute cholangitis	1 (9.1)	0 (0.0)	1 (1.7)	
Type of operation				0.091
LC	3 (27.3)	19 (39.6)	22 (37.3)	
LC conversion to OC	8 (72.7)	19 (39.6)	17 (45.8)	
OC	0 (0.0)	10 (28.8)	10 (16.9)	
Clinical manifestation of BDI				0.012
Bile leakage	6 (54.5)	26 (54.2)	32 (54.2)	
Bile leakage and bleeding	3 (27.3)	2 (4.2)	5 (8.5)	
Intra-abdominal collection	0 (0.0)	7 (14.5)	7 (11.9)	
Jaundice	1 (9.1)	13 (27.1)	14 (23.7)	
Intra-hepatic duct stone	1 (9.1)	0 (0.0)	1 (1.7)	
Time to diagnosis of BDI				0.024
Intra-operative diagnosis	8 (72.7)	17 (35.4)	25 (42.4)	
Post-operative diagnosis	3 (27.3)	31 (64.6)	34 (57.6)	
Time to repair of BDI				0.001
Early (≤6 weeks)	10 (90.9)	23 (47.9)	33 (55.9)	
Delayed (>6 weeks)	1 (9.1)	25 (52.1)	26 (44.1)	
Strasberg's classification, initial injuries				0.077
A	1 (9.1)	0 (0.0)	1 (1.7)	
D	3 (27.3)	6 (12.5)	9 (15.3)	
E1	0 (0.0)	8 (16.7)	8 (13.6)	
E2	6 (54.5)	28 (58.3)	34 (57.6)	
E3	1 (9.1)	1 (2.1)	2 (3.4)	
E4	0 (0.0)	5 (10.4)	5 (8.5)	
Interventions				<0.001
PTBD	0 (0.0)	19 (39.6)	19 (32.2)	
PCD + PTBD	1 (9.0)	7 (14.6)	8 (13.6)	
Open drainage + PCD	0 (0.0)	1 (2.1)	1 (1.7)	
Open drainage + PTBD	0 (0.0)	3 (6.3)	3 (5.1)	
Open drainage + PCD + PTBD	0 (0.0)	5 (10.4)	5 (8.5)	

LC=laparoscopic cholecystectomy; OC=open cholecystectomy; BDI=bile duct injury; PTBD=percutaneous transhepatic biliary drainage; PCD=percutaneous drainage

BDI in the in-house group was detected intraoperatively in eight patients (72.7%) and all of them were promptly repaired at the time of recognition. Meanwhile, intraoperative recognition of BDI was found in 17 patients (35.4%) for the referral group (p=0.024). Of the twenty-two patients in the attempted repair referral group, intraoperative repair was conducted on 14 patients (63.6%) and early repair was done in eight patients (36.4%), respectively. Of the twenty-six patients in the attempted repair referral group, 25 patients (96.2%) were repaired in the delayed repair period.

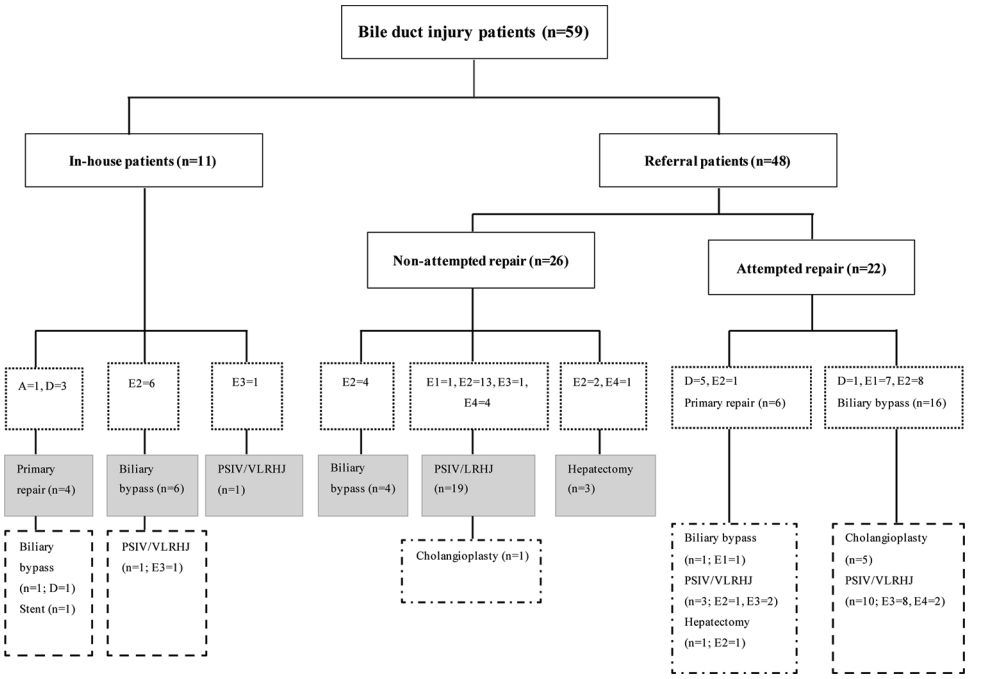

Figure 2. Bile Duct Injury Patients. Index operations are shown in solid boxes. Re-repair operations are depicted in dashed boxes. Initial injuries, as defined by Strasberg's classification, and previous repairs are presented in dotted boxes. Strasberg's classification in dashed boxes include injury types prior to surgical correction of anastomosis stricture, which are comparatively more severe than the initial injuries.

Minor BDI lesions developed in ten patients (16.9%), including one type A and three type D for in-house patients. Additionally, six patients in the referral group developed type D injuries. The most common BDI lesion was Strasberg type E2, with the in-house group accounting for six cases (54.5%) and the referral group for 28 patients (58.3%).

Intervention treatments before definitive treatments

In the authors' institution, the individual surgeons decided the appropriate treatment for BDI based on clinical presentations, considering factors of bile leakage with intraabdominal collection or jaundice, time to recognition, types of injury, index operations, or re-repair operations. Prior to performing definitive treatments, patients underwent general standards of care to stabilize their conditions, which involved elimination of any infections by draining intraabdominal collection via PCD or surgical drainage and PTBD or endoscopic management to relieve jaundice.

BDI recognition in the in-house group was detected intraoperatively in eight patients (72.7%) and intervention before any definitive treatment was rarely required. In total, intervention treatment before surgical repair was performed in only one patient (9.0%) in the in-house group, meanwhile 35 patients (72.9%) in the referral group underwent interventions prior to receiving definitive repairs, which was statistically significant, $p<0.001$. The most common intervention before definitive treatment was PTBD in 75% of patients in the referral group, performed either as a single procedure or one combined with drainage to relieve jaundice and to control bile leakage.

Operative data

Types of operation, including types of injury experienced by patients in the present study are shown in Figure 2. In the in-house group, surgical correction for BDI in four patients involved primary repair for minor BDI. Six patients with BDI Strasberg type E2 received biliary bypass and PS IV/V LRHJ was performed on one patient who further developed right intrahepatic duct stone four years after LC.

Surgical correction for BDI in the non-attempted repair referral group included PS IV/V LRHJ performed in 19 patients including Strasberg type E1 in one patient, type E2 in 13 patients, type E3 in one patient, and type E4 in four patients, biliary bypasses in four patients with BDI Strasberg type E2, and major hepatectomy in three patients including Strasberg type

E2 in two patients and type E4 in one patient.

In the attempted repair referral group, six patients including Strasberg type D in five patients and type E2 in one patient, underwent primary repairs and 16 patients including Strasberg type D in one patient, type E1 in seven patients, and type E2 in eight patients, had biliary bypasses before being referred to the authors' institute. Five patients with initial type D injuries in the primary repair group required re-repair after failed cholangioplasty. One patient had stricture development 7.6 months after the first operation and underwent biliary bypass for Strasberg type E1 strictures. Three patients required PS IV/V LRHJ for Strasberg type E2 stricture in one patient and type E3 in two patients for stricture development within 1, 1.3, and 13.2 months, respectively. One patient had a major hepatectomy 8.9 months after the first operation due to vascular injuries. Only one patient in this group, with initial Strasberg type E2 stricture, had good patency of primary repair after PCD of intraabdominal collection, with a mean follow up of 95.1 months.

In the biliary bypass group, five patients with Strasberg type E2 developed anastomotic strictures in 2.7, 4.3, 14.2, 23.3, and 81.3 months after the first operation and subsequently underwent 1 to 5 cholangioplasty procedures successfully. Meanwhile, for ten patients with initial Strasberg type D in one, E1 in seven, and E2 in two, anastomotic strictures occurred ranging from 2.0 to 186.1 months after the first operation. Of the ten patients who were intervened by the PS IV/V LRHJ technique, eight patients presented with Strasberg type E3, and two patients with Strasberg type E4 before re-repair. One patient with Strasberg type E2 had PCD for intraabdominal collection and no occurrence of biliary stricture after 154.1 months of follow up.

No significant differences were detected between the in-house group and the referral group in the following aspects, median intraoperative blood loss at 300 mL versus 500 mL, respectively (p=0.203) and operative time at 300 minutes versus 560 minutes, respectively (p=0.059). Blood transfusion was required in only one patient from the in-house group (9%) and seven patients in the referral group (14.6%), p=0.63.

Short-term outcomes

Of the 59 patients treated in the present study, one patient died (1.7%). A 65-year-old woman developed bile leakage and intraabdominal collection after biliary bypass for intraoperative recognition of BDI. However, the patient succumbed to uncontrolled sepsis and severe intraabdominal bleeding. Emergency laparotomy with abdominal packing was performed but the patient's condition, unfortunately, deteriorated and she passed away 16 days post BDI repair.

Complications ranging from one to four events for each patient with a mean of 1.7 and a median of 1, occurred in 21 patients (35.6%), with five in-house (45.5%) and 16 referral patients (33.3%) (Table 2). The most common complication was intraabdominal collection, developed in ten patients (16.9%). Bile leakage occurred in six patients (10.2%), meanwhile, superficial SSI was found in six referral patients, accounting for 10.2% of the patients. Complications by events, compared between the in-house and referral groups, were not statistically significant (p=0.07). Median LOS in the in-house group at 16 days, and referral group at 17 days, was also not statistically significant (p=0.542).

Long-term anastomosis outcome

Mean ± SD follow up in the entire study was 106.4±8.1 months with a range of 11.83 to 280.2 months. The overall ten-year patency rate was 93%. Of the 59 patients studied, anastomosis stricture occurred in four patients (6.8%) with three in-house patients (5.1%) and one from the non-attempted referral group (1.7%). Amongst the three in-house patients, anastomosis stricture was detected in two primary repair patients after the first repair at 3.7 months and 41.8 months, and were corrected by a biliary bypass and endoscopic management. One patient from the biliary bypass group developed anastomosis stricture at 60.9 months after undergoing a hepaticojejunostomy and was subsequently corrected by PS IV/V LRHJ. From the non-attempted repair referral group, anastomosis stricture developed in one patient who underwent PS IV/V LRHJ after 83.2 months and a one-time cholangioplasty was required. No stricture was reported since then, at 27.8 months after cholangioplasty. Cho et al[9] define the patency rate for re-repair surgical operations as the actuarial secondary patency rate. By following this definition, the actuarial secondary patency rate in re-repair operations for biliary bypass and PS IV/V LRHJ in attempted repair referral patients was 100%, with a mean follow up of 113.93 months.

The primary patency of BDI repairs for index patients, excluding three major hepatectomy cases, involved 34 cases. Of these cases, 11 were in-house patients and 23 were patients from the non-attempted

Table 2. Short-term outcomes

Complication and LOS	In-house patients (n=11); n (%)	Referral patients (n=48); n (%)	Total patients (n=59); n (%)	p-value
Complications*				0.07
Grade 1	0 (0.0)	0 (0.0)	0 (0.0)	
Grade 2				
• Cholangitis	0 (0.0)	4 (8.3)	4 (6.8)	
• Bile leakage	3 (27.3)	3 (6.3)	6 (10.2)	
• Stroke	0 (0.0)	1 (2.1)	1 (1.7)	
• Superficial SSI	0 (0.0)	6 (12.5)	6 (10.2)	
Grade 3				
• Intra-abdominal collection	4 (36.4)	6 (12.5)	10 (16.9)	
• Pleural effusion	2 (18.2)	1 (2.1)	3 (5.1)	
• UGIB	1 (9.1)	1 (2.1)	2 (3.4)	
• Grade 4	0 (0.0)	0 (0.0)	0 (0.0)	
• Grade 5	1 (9.1)	0 (0.0)	1 (1.7)	
LOS, median (range), days	16 (9 to 35)	17 (6 to 44)	19 (6 to 35)	0.542

SSI=surgical site infection; UGIB=upper gastrointestinal bleeding; LOS=length of hospital stay

* Complications: n represents complications that could occur in either one, or both minor or major complications. Major complications defined by Clavien-Dindo's complication grade ≥3 and minor complications referred to grade ≤2.

Table 3. Primary patency of BDI repairs (excluding attempted repair referral group and three major hepatectomy cases)

Variable	In-house group (n=11); n (%)	Non-attempted repair-referral (n=23); n (%)	p-value
Operative time (minute); median (range)	300 (105 to 450)	360 (180 to 660)	0.037
Blood loss (mL); median (range)	300 (200 to 1,600)	500 (150 to 1,500)	0.179
Blood transfusion	1 (9.1)	4 (17.4)	0.609
LOS (days); median (range)	16 (9 to 35)	20 (8 to 51)	0.359
Complications*			
Major complications	4 (36.4)	5 (21.7)	0.817
Minor complications	3 (27.3)	10 (43.5)	0.827
Anastomosis failure	3 (27.3)	1 (4.3)	0.052

LOS=length of hospital stay

* Complications: n represents complications that could occur in either one, or both minor or major complications

repair referral group, of which operative time, blood loss, LOS, and complications were not statistically different between these two groups (Table 3). An anastomosis stricture rate of 27.3% for the in-house group was higher than the 4.3% detected in the non-attempted repair referral group but was not statistically significant (p=0.052). Moreover, the actuarial primary patency for BDI index repair operations, excluding major hepatectomy, was 90% over a ten-year period.

By comparing the types of repairs, the primary patency in patients receiving PS IV/V LRHJ was significantly superior to the primary repair group (HR 19.39, 95% CI 1.7 to 222.53, p=0.017), but was not statistically different when compared to the biliary bypass group (HR 2.9, 95% CI 0.18 to 47.91, p=0.44) (Figure 3). However, anastomosis stricture occurred in 50% of the patients in the primary repair group, 10% in the biliary bypass group, and 5% in the PS IV/V LRHJ group, respectively.

Concerning patency of BDI repair performed by primary surgeons and hepatobiliary surgeons in relations to both index operation and re-repair intervention, treatments performed by general surgeons increased the risks of anastomosis stricture (HR 17.06, p=0.014, 95% CI 1.7 to 165.8) (Figure 4).

Patency was also analyzed in terms of timing of BDI repair. The survival curve in Figure 5. shows that patency in the early repair group, including both

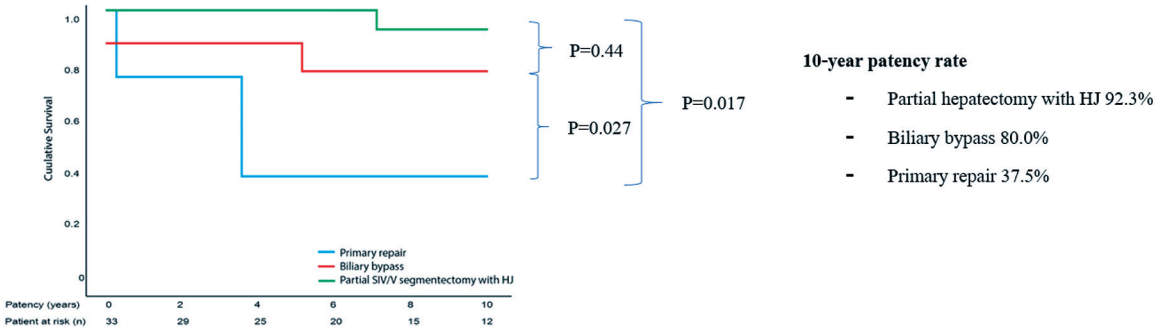

Figure 3. Survival Curve: Primary patency among types of repair (n=34) for index operation (attempted repair referral group and hepatectomy patients were excluded).

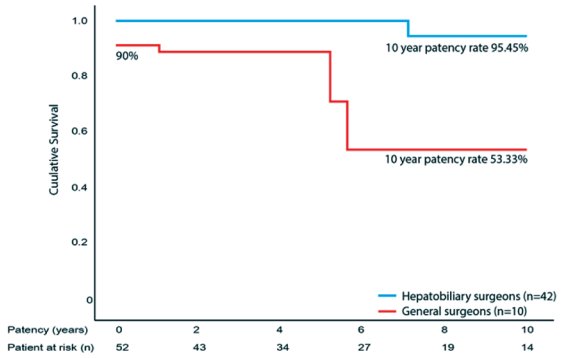

Figure 4. Survival Curve: Patency of BDI treatment repaired by hepatobiliary surgeons or primary surgeons.

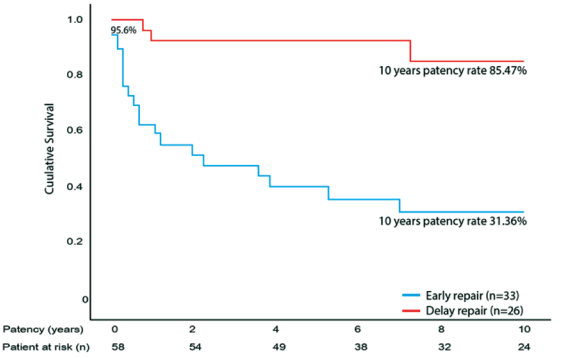

Figure 5. Survival curve: Anastomotic patency, determined by timing of repair for the entire study.

intra-operative repair and early repair of less than six weeks, was significantly inferior when compared with a delayed repair timing (HR 0.11, p<0.001, 95% CI 0.03 to 0.38).

Discussion

BDI post cholecystectomy is the most devastating complication that affects both patient morbidity and mortality[1-3]. It continues to have an impact on patients' quality of life and has also led to an increased number of patients pursuing legal remedies[4-6]. Recent data reporting incidence of BDI after LC was 0.3% to 0.6%[1-5]. Incidence of BDI in the present study cohort of 59 patients was 0.14%. This favorably reduced number may reflect the awareness of BDI because of the teaching program for surgical training residency at KCMH, although Harrison et al[12] reported that surgical residency programs did not impact the rate of BDI.

Clinical manifestation of BDI depends on the time to recognition and type of injury. Bile leakage was the most common presentation of BDI, which was discovered in half of the patients in the present series. Subsequently, this condition may lead to intrabdominal collection and abdominal sepsis, requiring drainage before intervention. Although the optimal time to repair BDI is during the intraoperative recognition of BDI[13], some centers recommend converting bile leakage into external biliary fistula to ameliorate intrabdominal infections, especially, in the event where no experienced hepatobiliary surgeons are available[1,2,14,15]. The optimal timing for fixing BDI is when inflammation in the peritoneal cavity has subsided, after getting rid of infection[13-16] which takes around 5.4 weeks after index of admission[16]. This may reflect the authors' approach to repairing BDI in a delayed repair fashion.

Management of BDI requires a multidisciplinary team including endoscopists, intervention radiologists, and hepatobiliary surgeons[16,17]. As mentioned above, general standards of care to stabilize and improve patients' conditions and rid them of any infections prior to surgical intervention are important[16]. Intervention treatments before definitive treatment including drainage of intraabdominal collection by PCD or surgical drainage, and relief of jaundice

by PTBD, mostly, are done to ameliorate patients' septic conditions. PTBD either single procedure or combined procedures, such as PCD or surgical drainage was performed in 34 of the 35 patients (97%) in the referral group who required intervention before surgical correction.

Postoperative morbidity at 35.6% and mortality at 1.7% in the present study cohort were comparable to other reports[18,19]. Although, detections of clinical presentation of jaundice and intraabdominal collection were higher in the referral patients than that reported in the in-house group, comparisons of the complication events between these two groups did not show any differences. In the present series, bile leakage after BDI repair was 10.2%, which is in line with literatures reported by Dominique-Rosado et al[20]. However, in the subgroup analysis, bile leakage was found to be 27.3% in the in-house group but 6.3% in the referral group. This event may reflect the early repair timing of BDI, which has thin, non-dilated bile ducts and the repairs were performed by the primary surgeons in the in-house group. Wound infection or superficial SSI was found in six patients in the referral group (10.2%), which is favorable in comparison to the previous literatures that reported wound infection rates of 7.4% to 10.6%[16,19]. Interventions before surgery may be one of the causes of wound infection, especially for patients in the referral group.

The most common Clavien-Dindo grade 3 complication was intraabdominal collection, which occurred in 16.9% of the cases. This may be explained by complications arising from partial hepatectomy where intraabdominal collection is detected in between 5% to 18% of the cases[21-23]. Anastomotic stricture occurred in four patients during the study period with a mean follow up of 106.4 months yielding a stricture rate of 6.8%. At the beginning of the present study, the overall patency for the entire cohort was at 98.3% and over the ten-year period, patency was reported at 93%. The present study results are in line with reports with long term outcomes varying from 85% to 95% and stricture rates from 5% to 21%[1,18,21,23,24].

Concerning the patency of the index operation, excluding major hepatectomy cases, for both in-house and non-attempted referral groups, the actuarial primary patency rate over 10 years was 90%. When comparing the types of bile duct repair in index operations, the patency of applying the PS IV/V LRHJ technique was significantly superior to the primary repair and better than the biliary bypass, though not significantly. The stricture rate of the primary repair was 50%, compared with 10% in the biliary bypass group and 5% in the PS IV/V LRHJ technique, respectively.

Primary repairs, especially duct-to-duct anastomosis, has a high risk of anastomotic stricture of up to 70% to 80%, requiring re-repair operations in most cases[25]. However, duct-to-duct repair may be optional if 1) the initial injury is less than one-third of the ductal circumference, 2) the injured duct is not located more than 2 cm below the confluence of the bile duct, and 3) the BDI is recognized intraoperatively during the primary operation[26,27].

A biliary bypass, especially Roux-en-Y hepatico-jejunostomy is the most common technique used to repair BDIs[13,18,28]. In this technique, proximal bile duct end is dissected to provide for repair. However, this technique may be troublesome if there are conditions including short proximal bile duct stumps, anatomical distortion or marked inflammation of the hepatoduodenal ligament, sclerotic bile duct wall, hilar BDI with Strasberg type E3 or E4, or re-repair operations.

In 2009, the authors reported the short-term outcomes of how "Partial segment-IV/V liver resection facilitates the repair of complicated BDI"[9]. This technique provides non-ischemic, non-scarred bile duct wall with adequate exposure for performing anastomosis. So, the authors adopted this technique for repairing BDI in the case of hilar BDI, re-repair operation, or biliary bypass considered not to be secure and safe due to anatomical distortion, marked inflammation of the hepatoduodenal ligament, or sclerotic duct walls of proximal bile duct.

The superior outcomes of applying the PS IV/V LRHJ technique in the present report may be explained and reflected in the following, 1) the wider anastomosis on vascularized healthy bile ducts provided by this technique[9], 2) the delayed repair fashion[12-15], and 3) surgery was performed by hepatobiliary surgeons[1,12-14,18].

In the present study cohort, early repair, which is based on intraoperative repair and BDI repair within six weeks after recognition, provided less long-term patency when compared to delayed repair based on longer than six weeks. This may reflect, first, on the role of a primary surgeon fixing BDI in index operations[1,13,14], and emphasizes the importance and necessity of having an experienced hepatobiliary surgeon to repair BDI[1,12-14,18]. The present study data showed that the 10-year patency of BDI repaired by hepatobiliary surgeons was 97.6%, which was better than the 53.3% 10-patency rate repaired by primary

surgeons, significantly. Second, repairs in early BDI periods may have risks of anastomosis stricture due to bile duct wall ischemia associated with BDI stemming from vascular injuries or bile duct dissection for hepaticojejunostomy and performing anastomosis on non-dilated thin bile duct[1,12-14]. Third, patients may be subjected to nutritional risks and conditions of a hostile abdomen due to inflammation during the early repair period. As a result, a delayed repair period allows the patients to recover from intrabdominal inflammation and to improve their nutritional status before operation[1,13,14].

Limitations of the present study include its retrospective design and the small number of patient inclusion. Additionally, BDI repairs were performed by both primary surgeons and hepatobiliary surgeons, which may have influenced the outcomes. Despite the restrictions, this report provides relevant information in further understanding surgical management for BDI.

Conclusion

Early referral to a multidisciplinary team and delayed BDI repair performed by an experienced hepatobiliary surgeon, particularly applying the partial segments IV/V liver resection and HJ technique, positively impacted long-term outcomes of surgical management. Anastomosis stricture decreased and long-term patency was enhanced for positive overall surgical outcomes in the management of post cholecystectomy bile duct injuries.

What is already known on this topic?

The key factors in surgical treatment of BDI post cholecystectomy depend on the timing of repair, extent of BDI, and surgical expertise.

What this study adds?

To achieve long-term patency and decrease anastomotic stricture, delayed BDI repair performed by an experienced hepatobiliary surgeon, especially applying the PS IV/V LRHJ technique, impacts the positive surgical outcomes.

Conflicts of interest

The authors declare no conflict of interest.

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