

Surgical management for bile duct injury

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Summary

The management of bile duct injury (BDI) remains a considerable challenge in hepatobiliary surgery. BDI is mainly iatrogenic, and mostly occurs in cholecystectomy. Laparoscopic cholecystectomy (LC) has been performed widely, however, the incidence of BDI associated with LC increases 2-3 times compared to that in open cholecystectomy (OC). BDI also occurs in robotic cholecystectomy. In China, the evidence-based Practice Guideline for Diagnosis and Treatment of BDI was published by the Biliary Surgery Group of Surgery Branch of Chinese Medical Association, with the purpose of reducing the incidence of BDI as well as promoting its optimal diagnosis and treatment. Surgery remains the mainstay of treatment for BDI and traumatic bile duct stricture. The definitive repair involves a series of procedures including exposing the proximal and distal bile duct, anastomotic bile duct tissue preparation, minimally invasive tissue anastomoses, and so on. Successful management is a surgical challenge requiring great specialized experience and precise surgical skill. The application of precision biliary surgery is recommended for promoting standardized management of BDI.

Keywords: Bile duct injury, traumatic bile duct stricture, surgical repair, guideline

1. Introduction

The management of bile duct injury (BDI) remains a considerable challenge in hepatobiliary surgery. Since 1905, Mayo *et al.* first reported the use of choledochoduodenostomy to repair two cases of BDI associated with cholecystectomy (1). Biliary surgeons worldwide have been committed to the prevention and treatment of BDI. BDI would not only lead to exceedingly morbid complications including biliary fistula, jaundice, and bile duct stenosis affecting the patient's long-term prognosis, but also increase the unnecessary medical burden (2,3). While long-term impact on patients is associated with a significant decrease in Quality of Life, loss of productivity in both paid and unpaid work and high rates of disability benefits use (2,4). BDI mostly occurs in cholecystectomy

(5-8). The incidence of BDI associated with open cholecystectomy (OC) is 0.125-0.3% (9-12), but the rate is up to 0.4-0.6% for cases that underwent laparoscopic cholecystectomy (LC) (13-16), as well as increasing complexity (17). With advances in technology, single-incision laparoscopic cholecystectomy and robotic cholecystectomy have been performed, but the incidence of BDI was also reported (18,19), and more rigorous training in biliary surgery may be needed (20,21).

The definitive repair surgery remains the mainstay of treatment for BDI and traumatic biliary stricture (22). However, even in a high volume biliary surgery center with extensive experience, the incidence of stricture after repair surgery of BDI still reaches 10-20% (23,24). Only 1/3-1/2 of BDI can be diagnosed in time, more than 70% of BDI is initially repaired by surgeons who do not specialize in such repair surgery (25,26). Non-definitive surgical exploration and the implementation of definitive repair surgery with inappropriate timing are ubiquitous (12,27). Moreover, delayed referral to a specialist center increases morbidity (28). In China, the evidence-based Practice Guideline for Diagnosis and Treatment of BDI was published by the Biliary Surgery Group of Surgery Branch of Chinese Medical Association, with the purpose of reducing the incidence

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Table 1. Key points for preoperative accurate assessment of bile duct injury (BDI)

- The location of bile duct injury or stenosis.
- The degree and length of bile duct loss or stenosis; Proximal bile duct with or without expansion and the expansive degree.
- Left and right hepatic duct are connected or unconnected.
- Right posterior hepatic duct with or without injury.
- Whether or not combined with vascular injury.
- Whether or not develops secondary bile leakage, abdominal infection, liver abscess, sclerosing cholangitis, biliary cirrhosis, *etc.*

of BDI as well as promoting its optimal diagnosis and treatment (29). How to improve the success rate of BDI repair, and reduce the recurrence rate of restenosis after repair is a considerable challenge in hepatobiliary surgery.

Evidence has shown that the success of definitive repair surgery on BDI relies on preoperative accurate assessment of the type of injury, selection of appropriate surgical procedures, reasonable repair methods, and the application of precision biliary surgery (30).

2. Preoperative accurate assessment

Surgeons should accurately assess all the details associated with BDI before performing a definitive repair surgery (Table 1). Based on the comprehensive assessment of the detailed information, the type of BDI can be determined (29,31). It is the basis for the development of rational treatment strategies and the selection of appropriate surgical procedures to ensure success of repair surgery.

When performing repair of BDI, location and extent of injury are clear in most cases. However, in the presence of severe inflammation or fibrous scar in the hepatic hilar region, inexperienced surgeons may not be able to correctly identify the site of injury, followed by blind suture in the Calots triangle or simply placing the T tube under the injured site. Even if location of the injury is clear, surgeons may also make a miscarriage of justice during surgery and follow the wrong treatment, such as taking the damaged right posterior segmental duct as the aberrant bile duct and make a ligation. Besides, the exact location of the injury is often difficult to determine if the pancreatic segmental bile duct is damaged during bile duct exploration or the choledochopancreato-duodenal junction is damaged during endoscopic sphincterotomy (EST) with Oddi. Although in most cases, location of the BDI is single, there may be multiple injuries, especially with traumatic bile duct injury. In these complex conditions, surgeons should pay attention to the comprehensive information of intraoperative cholangiography, bile ductal blue staining or water injection test, intraoperative choledochoscopy and other measures, then accurately determine the details of BDI.

A complete imaging of the bile duct should be obtained by radiographic examination before a definitive repair of BDI. Available methods include percutaneous transhepatic cholangiography (PTC) (32), endoscopic

retrograde cholangiopancreatography (ERCP), fistulography, computed tomography (CT), magnetic resonance cholangiopancreatography (MRCP) (33), *etc.* Indications for these inspection techniques are described in detail in the Practice Guideline for Diagnosis and Treatment of BDI published by Biliary Surgery Group of Surgery Branch of Chinese Medical Association (29). Surgeons should choose appropriate means of examination based on the combined information of patient's condition and the local medical conditions, and should not perform exploratory surgery instead of preoperative anatomical imaging assessment.

3. Appropriate timing for repair

The localized inflammatory state is one of the major determinants of the prognosis of definitive repair surgery. The ideal repair or reconstruction procedure should be carried out without inflammation (34). Based on this principle, intraoperative BDI are suggested to be repaired immediately by experienced biliary surgery specialists (35). If it cannot be performed with the support of specialists, patients should be treated with drainage and referred to specialist hospitals for early repair (36,37). For BDI detected soon after surgery, such as injury without local inflammation can be performed with primary repair (38). In cases with abdominal infection, biliary peritonitis, vascular injury, or other complicated conditions, delayed repair should be performed after the measures of controlling bile leakage and infection and improving the patient's general condition (39,40). Although the early idea holds that the timing of delayed repair should be at least 3 months away from the injury, current evidence suggests that definitive repair surgery may be performed 4-6 weeks after local inflammation and infection are effectively controlled (41,42).

4. Optimal surgical procedure for repair

Surgical procedures for definitive repair of BDI include duct-to-duct choledochostomy, bile duct jejunum Roux-en-Y anastomosis, hepatectomy, and so on (13,43,44). The optimal surgical procedure for repair should be determined by clinicians based on analysis of BDI type, biliary obstruction duration, previous biliary repair surgery history, degree of liver damage, and the patient's general condition (Table 2).

There are several classifications for BDI (45-47). We proposed a new classification of BDI. The classification

Table 2. The injury sites and repair modes of bile duct injury (BDI)

Injury types	Injury sites	Times of injury diagnosis	Repair principle	Repair modes
Type I	Pancreatic segmental bile duct and choledocho-pancreato-duodenal junction	Intraoperative or early postoperative stage	Primary repair and effective drainage	<i>i)</i> Simple BDI: Kocher incision, Repair the injury under direct vision + T-tube drainage of common bile duct <i>ii)</i> Severe injury: Transection of common bile duct + choledochojejunostomy
		Late or infected cases	Staged operation	First stage: Bile and pancreatic juice and intestinal fluid diversion Second stage: choledochojejunostomy and / or gastrointestinal anastomosis
Types III and II2	Extrahepatic bile duct and conjunctive region of bile duct	Intraoperative or early postoperative stage	"must-be" repaired or reconstructed	<i>i)</i> Slight laceration can be used for simple suture <i>ii)</i> Combined tissue defect, but proximal distal tension free, duct-to-duct anastomosis is suggested. <i>iii)</i> Large tissue defect or serious damage, difficult to repair, choledochojejunostomy could be the choice.
		Late or merge infected cases	The same as above.	See above.
Type II3	First branches of hepatic duct	Intraoperative or early postoperative stage	"should be" repaired or reconstructed	<i>i)</i> Slight laceration can be used for simple suture <i>ii)</i> Combined tissue defect, but proximal distal tension free, duct-to-duct anastomosis is suggested <i>iii)</i> Large tissue defect or serious damage, difficult to repair, choledochojejunostomy could be the performed.
		Late stage or obvious infection.		When chronic liver abscess or secondary diffused hepatolithiasis and segment atrophy, the resection of affected bile duct and affected tributary sectionectomy plus choledochojejunostomy is advised.
Type II4	Secondary braches of hepatic duct	Intraoperative or early postoperative stage	Consideration of reparation or reconstruction by condition.	<i>i)</i> For difficult reparation but with sufficient compensatory liver function, ligation of the injured bile duct. <i>ii)</i> For insufficient functional remnant liver, chose duct-to duct anastomosis or choledochojejunostomy
		Late or merge infected cases		<i>i)</i> For those asymptomatic isolated injuries, close follow-up. <i>ii)</i> Combined with bile leakage or infection, hepatectomy.
Type III	Upper branches of tertiary hepatic duct	Intraoperative or early postoperative stage	Without consideration of reparation or reconstruction	<i>i)</i> Ligation or suture of injured bile duct.
		Late or merge infected cases		<i>ii)</i> When bile leakage, PTCd or endoscopic stent placement. <i>iii)</i> Asymptomatic, localized biliary stricture, close follow-up.

includes type I involving pancreatic segmental bile duct and choledocho-pancreato-duodenal junction, types III and II2 involving extrahepatic bile duct and conjunctive region of bile duct, type II3 involving first branches of hepatic duct, type II4 involving secondary braches of hepatic duct, type III involving the upper branches of tertiary hepatic duct, and so on (29).

5. Application of precision biliary surgery

5.1. The fundamental principle of definitive repair of BDI

The surgical procedure must follow the fundamental principle of "Anastomosis and reconstruction must

build upon healthy, non-ischemic, non-inflammation and non-scarred bile duct". Many repair failures are due to failure to follow the above fundamental principles. For example, the boundaries of ischemia and devitalization of bile duct tissue caused by thermal injury are often unclear at the early stage of injury. In cases where bile duct ischemia and inactivation planes are difficult to determine accurately, surgery may be erroneously performed on ischemic bile ducts, this error is the main cause of postoperative anastomotic leakage and short-term stenosis. The scar of the bile duct wall or surrounding tissue used to try to restore the continuity of the bile duct and intestinal tract will inevitably lead to surgery failure.

5.2. Exposing the proximal and distal bile duct

The exposure of anastomotic proximal and distal healthy bile duct is the first step in injury repair. For BDI found during surgery, it is generally easier to reveal and determine the proximal and distal bile duct. When performing a staged operation to repair biliary stricture, it is possible to forward to the hepatoduodenal ligament and hilar area by separation of the liver surface adhesion or track the extrahepatic bile duct along the previous drainage fistula. In high-level bile duct stenosis, especially cases with repeated repair surgery failure, a fibrous connective tissue scar will be formed in the hepatic hilar area due to chronic inflammation, and the proximal bile duct stumps are more hidden in the deep part of the hepatic portal. In such a condition, it is very difficult to find bile duct stumps in the hepatoduodenal ligament by a conventional approach. Surgeons are suggested to find the dilated proximal dilatation of the bile duct by the following approaches.

5.2.1. Approach through hilar plate

In the posterior edge of the liver IVb along the hilar transverse groove after cutting the hilar plate the surgeon can reach the top of the hepatic duct junction, which reveals the proximal bile duct.

5.2.2. Approach through upper portion of hepatic portal

If the severe scar in the hepatic hilar area cannot be clearly dissected and is difficult to expose the bile duct by the hilar plate approach, it is suggested to go through liver IVb posterior margin and superjacent to the transverse sulcus of the hepatic portal, and dissect deeply into the liver parenchyma until confluent with the hepatic duct, and then reveal the proximal bile duct.

5.2.3. Approach through fissure of umbilical vein

If the bile duct cannot be exposed from the front area of hepatic portal, the approach of cutting off the liver

bridge in the Rex nest after dissection of the umbilical vein plate, showing the portal vein sagittal and corners, and cut umbilical vein panel in the right rear would be performed to expose the left hepatic duct.

5.2.4. Approach through posterior portion of hepatic portal

If narrow proximal bile duct cannot be exposed by the approach of anterior portion and upper portion of hepatic portal, the approach of dissecting portal vein from posterolateral hepatic duodenal ligament would be performed, and anatomy along the anterior wall of the portal vein until the right hepatic pedicle. The enlarged right proximal hepatic duct is located above the anatomical plane.

For cases with high-level bile duct injury, the most prone to error of revealing the proximal hepatic duct is missing and must independently open the bile duct. The omission of branches of a bold bile duct may cause postoperative recurrence of cholangitis and patients are forced to undergo reoperation. Following the principle of "bile duct is three rather than two" will avoid missing the right posterior hepatic duct (48). For high bile duct stenosis, there are a number of independent openings in the intrahepatic bile duct, the percutaneous transhepatic biliary drainage (PTCD) can be performed preoperatively for all the openings of the intrahepatic bile duct, and find them intraoperatively under the guidance of a drainage tube (49).

5.3. Anastomotic bile duct tissue preparation

The appropriate pruning or plastic surgery is necessary to reveal the proximal and distal bile duct, which then can be used for anastomosis. Surgical and postoperative early bile duct injury repair should be performed after removing ischemic inactivated bile duct tissue, and choosing the healthy bile duct wall for anastomosis. When performing duct-to duct choledochostomy for traumatic bile duct stricture, the narrow stenosis and scarring of the bile duct tissue should be removed, and then perform anastomosis for a healthy bile duct with a good blood supply. The key to choledochojejunostomy is to establish an adequate caliber of anastomosis in a narrow proximal bile duct with normal mucosa. Therefore, it is appropriate to remove scar tissue on the stump of the bile duct after fully revealing the proximal bile duct.

For type III of bile duct stenosis, the incision of the proximal wall of the proximal extrahepatic bile duct is usually taken; if necessary, the incision would be extended to the left hepatic duct and performing lateral-lateral anastomosis on the bile duct and jejunum. In type III of bile duct stenosis, for cases where the left and right hepatic duct is still connected, it is suggested to first reveal the anterior wall of left hepatic duct, and

then extend the incision rightwards to the anterior of the right hepatic duct. For cases, where the left and right hepatic duct is cut off, it is suggested to remove the sclera tissue of bile duct stump after the incision of the left and right hepatic duct. Forming an anastomotic stoma by suture of the medial margin of left and right hepatic duct and performing anastomosis with the jejunum, or performing the anastomosis on both sides of the hepatic duct incision and the jejunum. For type II3 of bile duct stenosis, the approach of dissecting hepatic portal, separating hilar plate, then performing incision of left hepatic duct or right hepatic duct in the narrow proximal are recommended. For type II4 of bile duct stenosis, the full exposure and incision of the right side of the secondary hepatic duct often needs to dissect the right liver pedicle Glisson sheath of the anterior wall of the gallbladder plate and resect part of liver tissue in the basilar part of S5.

5.4. Minimally invasive tissue anastomoses

For any kind of repair and reconstruction procedures, the fine coincidence technique should be performed to restore the integrity of the bile duct and its continuity with the intestinal tract, and a non-invasive suture needle should be selected for intermittent or continuous mucosal-mucosal anastomosis. The anastomotic stoma should be tight to prevent postoperative bile leakage, and it should also be observed to avoid excessive tightness damaging the blood supply of anastomotic tissues. The principles of single-layer stitching, stitching needle pitch, uniform margins, appropriate density, moderate knotting strength, and anastomosis without tension should be followed. The 6-0 fine suture needle could be used for thin bile ducts with thin walls; the 6-0 or 5-0 fine suture needle could be used for "duct-to-duct" choledochostomy in delayed repair. When performing choledochojunostomy, the 5-0 or 6-0 fine suture needle could be used according to the thickness of the bile duct wall. Both absorbable lines and non-absorbable sutures can be used, but leaving non-absorbable lines in the cavity should be avoided. The main purpose of placing biliary drainage after definitive biliary repair is not to maintain an anastomotic opening, but to provide postoperative biliary decompression to prevent bile leakage and provide access for subsequent angiographic or cholangioscopic treatments (50). Therefore, the conventional placement of bile duct drainage is not necessary. Only for cases with unsatisfied anastomosis, obvious inflammation in the bile duct wall, or intrahepatic bile duct stones, short-term drainage could be placed, with the drainage time generally not more than 3 months.

In conclusion, the management of BDI remains a considerable challenge in hepatobiliary surgery. The success of definitive repair depends on great specialized experience and precise surgical skill. The application of

precision biliary surgery is recommended for promoting standardized management of BDI.

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