Iatrogenic Biliary Injuries
Identification, Classification, and Management

Lygia Stewart, MD

KEYWORDS

• Bile duct injury • Biliary stricture • Laparoscopic cholecystectomy • Management
• Biliary-enteric anastomosis

KEY POINTS

- Laparoscopic bile duct injuries are more complex than those seen in the open era.
- The unique features of the laparoscopic environment facilitate these injuries; because of this, injuries involving misidentification of the common bile duct (CBD) for the cystic duct are the most common, resulting in a resectional injury of the main CBD and portions of the hepatic duct or ducts.
- The laparoscopic environment facilitates this illusion, so these injuries are generally not recognized intraoperatively. In addition, because many of these injuries present with a biliary fistula, as opposed to obstruction, clinical manifestations are often more subtle.
- The key to successful treatment is early recognition, control of intra-abdominal bile ascites and inflammation, nutritional repletion, and repair by a surgeon with expertise in biliary reconstruction. If these requirements are met, patients can have successful repair with long-term success in more than 90% of cases.

INTRODUCTION

More than 750,000 laparoscopic cholecystectomies are performed annually in the United States. Laparoscopic cholecystectomy offers several advantages over open cholecystectomy, including less pain, fewer wound infections, improved cosmesis, decreased activation of inflammatory mediators, and an earlier return to normal activities. Because of these advantages, laparoscopic cholecystectomy has largely replaced open cholecystectomy for the management of symptomatic gallstone disease. The only potential disadvantage to laparoscopic cholecystectomy is a higher incidence of major bile duct injury.[1–11] Several large population-based studies indicate that the incidence of major bile duct injury is 0.3% to 0.5%, which is higher than the 0.1% to 0.2% incidence reported with open cholecystectomy.[1–8] Some recent series[9,10] report a 0.2% incidence of bile duct injury with laparoscopic cholecystectomy, which approaches that seen in open series; however, single-incision laparoscopic cholecystectomy is associated with an even higher rate of bile duct injury (0.72%).[11]

Department of Surgery (112), University of California San Francisco and San Francisco VA Medical Center, San Francisco, CA 94121, USA
E-mail address: lygia.stewart@va.gov

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Obviously, prevention of these biliary injuries is ideal; however, when they do occur, early identification and appropriate treatment are critical to improving the outcomes of patients suffering a major bile duct injury. This report delineates the key factors in classification (and its relationship to mechanism and management), identification (intraoperative and postoperative), and management principles of these bile duct injuries.

CLASSIFICATION

Bismuth and Strasberg Classifications

Before the advent of laparoscopic cholecystectomy, biliary strictures were classified using the Bismuth classification (**Table 1**).[12,13] This useful classification delineated the severity of the biliary stricture based on the level of the biliary injury. The Strasberg classification[14] is similar to the Bismuth, but incorporates a few additional biliary injuries seen more commonly in the laparoscopic era (**Fig. 1**; see **Table 1**).

Stewart-Way Classification

The Stewart-Way classification incorporates the mechanism of the bile duct injury as well as its anatomy (**Table 2**). This approach is useful because it provides a means for the prevention of bile duct injury. The creators of this system found that an analysis of human error and cognitive processing provided considerable insight into the mechanisms of these bile duct injuries, the role of the laparoscopic environment in their facilitation, and improved means for their prevention.[15–19] This classification also differentiates between resectional injuries and strictures, a distinction useful in guiding preoperative evaluation and biliary reconstruction. The injury classification is as follows (**Fig. 2**A).

Class I injuries (6% of cases) involve an incision in the common bile duct (CBD) with no loss of duct. These injuries occur when the CBD is mistaken for the cystic duct, but the mistake is recognized during the initial operation (often with operative cholangiography); or when an incision in the cystic duct for a cholangiogram catheter is unintentionally extended into the CBD.

Class II injuries (24% of cases) consist of lateral damage to the hepatic duct with a resultant stenosis and/or fistula. These injuries result from unintended application of clips or cautery to the bile duct, usually during attempts to control bleeding in the triangle of Calot. For one reason or another the surgeon was working too deep in the triangle of Calot, unknowingly close to the common hepatic duct (CHD).

Class III injuries, the most common (60% of cases), involve transection and excision of a variable length of the duct, which always includes the cystic duct–common duct junction. Class III injuries result from a misperception error whereby the CBD is misidentified as the cystic duct. The surgeon transects the common duct (deliberately, thinking it is the cystic duct) early in the dissection and then transects the CHD (unknowingly) later in the process of separating the gallbladder from the liver bed. Consequently, the central portion of the extrahepatic bile duct is removed along with the gallbladder.

Class II and III injuries are subdivided based on the proximal extent of the injury as follows (see **Fig. 2**B). Class II/IIIA injuries spare the bifurcation with a remnant of CHD remaining. Class II/IIIB involves transection or stricture at the bifurcation of the CHD. Class II/IIIC results from extension of the stricture or duct excision above the bifurcation. Class IIID injuries (not seen with Class II) result from resection/transection above the first bifurcation of the lobar ducts. This last group (IIID) is uncommon and results from following the extrahepatic biliary tree into the porta with excision of all extrahepatic ducts.

Table 1
Bismuth and Strasberg classifications

Biliary Anatomy	Bismuth	Strasberg
Cystic duct leak or leak from small ducts in liver bed	—	A
Occlusion of an aberrant RHD	—	B
Transection without ligation of an aberrant RHD	—	C
Lateral injury to CBD (<50% circumference)	—	D
CHD stricture, stump >2 cm	Type 1	E1
CHD stricture, stump <2 cm	Type 2	E2
Hilar stricture, no residual CHD, confluence is preserved	Type 3	E3
Hilar stricture, involvement of confluence, loss of communication between RHD and LHD	Type 4	E4
Stricture of low-lying right sectorial duct (alone or with concomitant CHD stricture)	Type 5	—
Injury to an aberrant RHD plus injury in the hilum	Type 5	E5

Abbreviations: CBD, common bile duct; CHD, common hepatic duct; LHD, left hepatic duct; RHD, right hepatic duct.

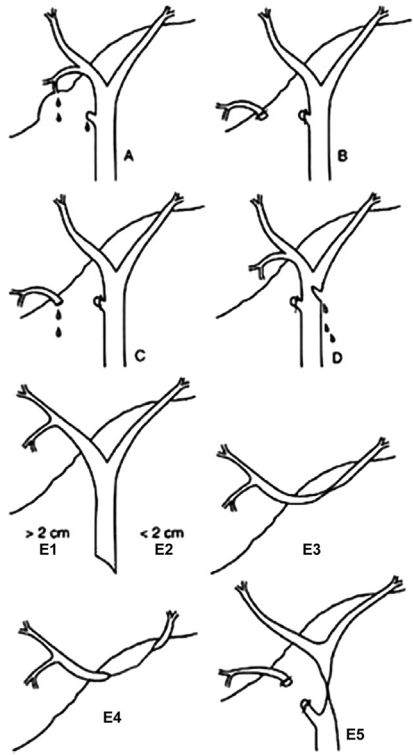

Fig. 1. Strasberg classification of bile duct injuries: injuries stratified from type A to type E. Type E injuries are further subdivided into E1 to E5 according to the Bismuth classification system. (*From* Strasberg SM, Hertl M, Soper NJ. An analysis of the problem of biliary injury during laparoscopic cholecystectomy. J Am Coll Surg 1995;180:105.)

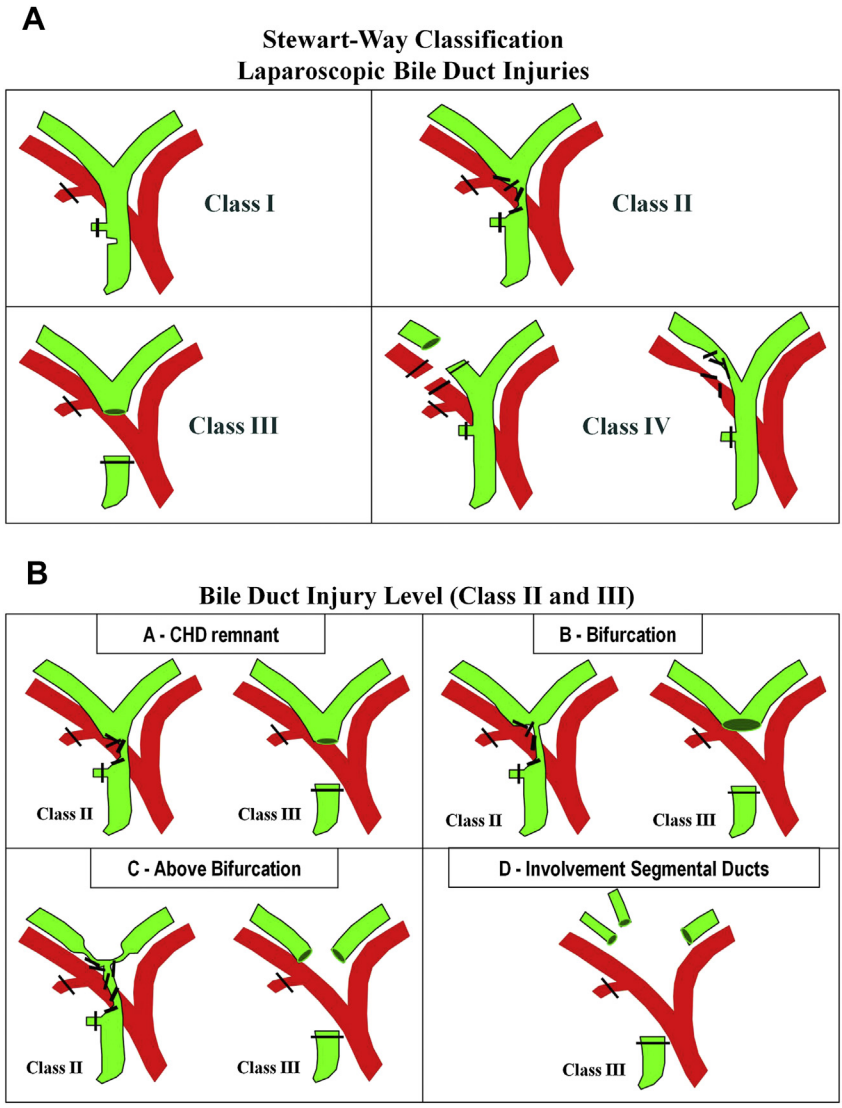

Fig. 2. (*A*) Stewart-Way classification of bile duct injuries. This classification incorporates the mechanism of injury as well as anatomic considerations. (*B*) Stewart-Way subclassification of levels of bile duct injury. This subclassification defines the levels of the Class II and Class III bile duct injuries, depending on the level of the injury. Note that the highest level, D, only occurs with Class III injuries (resectional injury with complete excision of the extrahepatic biliary tree). The Class III D injury pattern is not accounted for in the Bismuth and Strasberg classifications.

Class IV injuries (10% of cases) involve damage (transection or injury) of the right hepatic duct (RHD) (or a right sectoral duct), often (60%) combined with injury to the right hepatic artery (RHA). Class IV injuries are caused either by misidentifying the RHD (or a right sectoral duct) as the cystic duct and the RHA as the cystic artery; or from lateral injury to the RHD (or a right sectoral duct) during the dissection deep in the triangle of Calot.

Table 2
Stewart-Way classification: mechanism of major bile duct injury

	Mechanism of Laparoscopic Bile Duct Injury	Associated RHA Injury (%)
Class I	CBD mistaken for cystic duct, but recognized Cholangiogram incision in cystic duct extended into CBD	5
Class II	Lateral damage to the CHD from cautery or clips placed on duct Associated bleeding, poor visibility	20
Class III	CBD mistaken for cystic duct, not recognized CBD, CHD, RHD, LHD transected and/or resected	35
Class IV	RHD (or right sectoral duct) mistaken for cystic duct, RHA mistaken for cystic artery; RHD (or right sectoral duct) and RHA transected Lateral damage to the RHD (or right sectoral duct) from cautery or clips placed on duct	60

Abbreviations: CBD, common bile duct; CHD, common hepatic duct; LHD, left hepatic duct; RHA, right hepatic artery; RHD, right hepatic duct.

Because the RHA lies posterior to the CBD, it can be injured or even transected in laparoscopic bile duct injuries.[18] This occurrence is particularly common in cases of resectional Class IV injury whereby the RHA is thought to be a large cystic artery and is consequently divided. The association between biliary injury and RHA injury is also shown in **Table 2**.

IDENTIFICATION OF BILE DUCT INJURY

Intraoperative Bile Duct Injury

A minority of bile duct injuries are recognized during the index cholecystectomy, only about 25% in most series. There are several factors that facilitate recognition of intraoperative injury, but the most important is a change in the surgeon's awareness to suspect and/or evaluate for a bile duct injury.[15] Several features of the gallbladder dissection might indicate the possibility of major bile duct injury. It is fundamental to remember that the CBD lies medial to the gallbladder and that the RHA passes behind the CBD in 80% to 90% of cases.

Analysis of operative reports among patients with bile duct injury[15,19] revealed several possible signs that might have indicated the dissection was in the wrong plane:

- Cholangiographic abnormalities with signs that the cholangiocatheter is unintentionally in the CBD
  - Failure to opacify the proximal hepatic ducts above the catheter balloon (**Fig. 3**A, compare with **Fig. 3**B)
  - Narrowing of the CBD at the site of the cholangiocatheter insertion
  - Failure to opacify a portion of the cystic duct
    - Can also occur when the incision for the cholangiocatheter is too close to the CBD (can result in a Class I injury)
- Bile drainage (obtain a cholangiogram)
  - Drainage of bile from a location other than a lacerated gallbladder
  - Bile draining from a tubular structure
- Second cystic artery or large artery posterior to what is perceived to be the cystic duct
  - This could be the RHA, which means that the CBD is being dissected

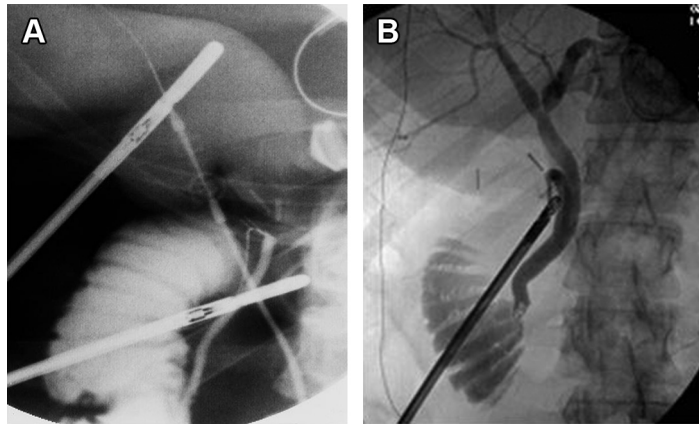

Fig. 3. (*A*) Intraoperative cholangiogram taken when the cholangiocatheter is in the common bile duct (CBD). Note that the proximal biliary radicles do not fill. In this case the CBD has been confused with the cystic duct. (*B*) Normal intraoperative cholangiogram showing opacification of the cystic duct, CBD, hepatic duct, right and left hepatic ducts, and the duodenum. Compare with panel *A*.

- Identification of an extra bile duct or tubular structure (obtain a cholangiogram)
  - This can be a sign that the CBD (rather than the cystic duct) is being dissected
  - It could be the proximal portion of a transected CHD
  - Have a high index of suspicion: resist the tendency to assign this as a second cystic artery, tubular structure, aberrant bile duct, or duct of Luschka
- Ductal abnormalities (obtain a cholangiogram)
  - Wide cystic duct: this may be the CBD
  - Accessory bile duct, duct of Luschka, second cystic duct: this may be the proximal CHD
  - Short cystic duct
    - This can be associated with bile duct injury
    - The tissue between the gallbladder infundibulum and CBD may have not been completely dissected, which can result in a bile duct injury
  - Bile duct can be traced to the duodenum: this is always the CBD
- Anomalous anatomy (obtain a cholangiogram)
  - Extra lymphatics or vessels around the cystic duct may indicate the CBD is being dissected
  - Abnormal gallbladder infundibulum may indicate the CBD is being dissected
    - Infundibulum goes deep toward the duodenum
    - Redundant infundibulum
  - Fibrous tissue in the gallbladder bed may indicate transection of the proximal CHD
  - Cystic duct structures seem more medial than usual
- Severe hemorrhage or inflammation (consider conversion to an open procedure)
  - Common mechanisms for Class II injuries

Surgeons who use clues, such as those listed, to consider the possibility of and search for a bile duct injury, can more commonly recognize the injury during the index operation.[15,19] This identification allows for prompt treatment of the injury. Recognition of a Class I injury with a cholangiogram also prevents it from being converted to a Class III injury.

Postoperative Bile Duct Injury

Unlike the open cholecystectomy era, during which patients with a biliary injury presented with the triad of jaundice, dilated bile ducts, and abdominal pain, most patients with a laparoscopic bile duct injury have an associated biliary fistula, are not jaundiced, and present in a more subtle fashion.[16,17] Most Class I and Class III injuries will have an associated biliary fistula, and about 50% of Class II and Class IV injuries also have an associated biliary fistula. Patients with a biliary fistula do not present with jaundice (liver function tests are minimally elevated) and their findings can be very subtle initially; for example, patients are sometimes treated for constipation when presenting to an emergency department. Despite large amounts of bile in the abdomen, most patients with bile collections do not present with bile peritonitis; instead they have bile ascites, with mild, relatively nonspecific symptoms including bloating and mild abdominal pain. Because of these vague symptoms, the presence of a bile collection and associated biliary injury can go unsuspected for some time. With a delay in diagnosis, bile peritonitis and serious illness can develop. In an analysis by the author's group, undrained bile for longer than 9 days was more often associated with bile peritonitis (and infected bile).[16] On the other hand, patients with biliary strictures are often recognized earlier because they present with the more classic presentation (jaundice, dilated ducts, and abdominal pain).

The key to early recognition is to suspect a problem in any patient who fails to do well following laparoscopic cholecystectomy. Because these patients usually do extremely well, any deviation from this should be recognized as a problem. A computed tomography (CT) scan should be obtained to look for bile. Ultrasonography can also be used, but is less sensitive and can lead to diagnostic delay. Cholescintigraphy scans should be avoided because they are much less reliable. In addition, nondilated bile ducts are the usual finding with laparoscopic biliary injuries, not dilated ducts. If a fluid collection is present, one should assume that it is bile and that there may be a bile duct injury, and the bile should be immediately drained percutaneously using interventional techniques.

There is no role for exploratory laparotomy, as this is associated with increased morbidity; in cases where this was used the diagnosis was often missed, and even if the injury was identified, the surgeon was generally not prepared to manage the complication.[17] In addition, patients with bile draining from an operatively placed drain should have complete evaluation for a possible biliary injury.

Complete cholangiography

Once the bile collection is drained, complete cholangiography of the biliary tree should be obtained. Complete cholangiography should also be obtained in patients with bile in an operative drain or obstructive jaundice. Cases with cystic duct leaks, Class I injuries, and most Class II injuries can generally be imaged with endoscopic retrograde cholangiopancreatography (ERCP). Both an ERCP and percutaneous transhepatic cholangiogram (PTC) are necessary to image the biliary tree in patients with Class III (**Fig. 4**) and most Class IV injuries. In all cases an ERCP should be obtained first, followed by a PTC if the entire biliary tree is not imaged.

Concomitant vascular injury

Some patients have associated injury to the RHA. These patients have a higher incidence of bleeding and hepatic abscess at presentation. Cases with an associated RHA injury more commonly have an associated hepatic abscess, bleeding, hemobilia, and right hepatic lobe ischemia.[18,20–30] As shown in **Table 2**, concurrent RHA injury was most common among patients with Class IV injuries, followed by those with Class

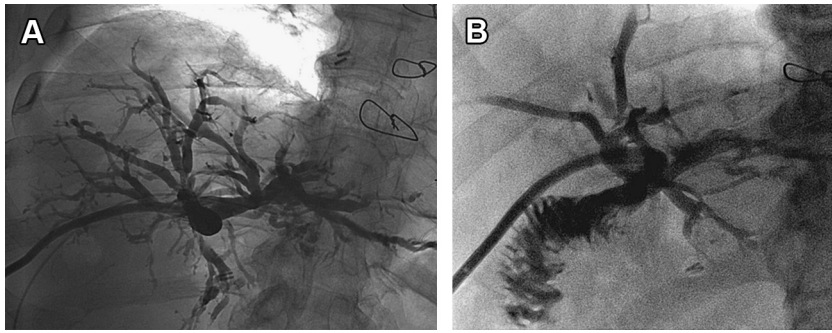

Fig. 4. (*A*) Percutaneous cholangiogram showing Class III injury. (*B*) Percutaneous cholangiogram of the patient in *A*, showing successful biliary reconstruction.

III injuries. It is important to consider this diagnosis in patients who have had a laparoscopic cholecystectomy and who present with significant hemorrhage, right hepatic ischemia, or hepatic abscess. Many of these patients require angioembolization for treatment of hemobilia and drainage of hepatic abscesses, and some require hepatectomy.[17,18,20–27] In rare cases, patients can also have associated injury to the portal vessels, and portal-vessel injury has also been reported to rarely occur following PTC.[18]

MANAGEMENT

Preoperative Evaluation

To guide surgical management, the full extent of the injury has to be defined. This evaluation requires complete cholangiography (as noted earlier). In addition, CT scan with intravenous contrast should be obtained to elucidate any evidence for vascular injuries, hepatic abscess, or presence of hepatic ischemia (generally right-sided if present).

Preoperative Patient Preparation

Before consideration of biliary injury repair, the patient needs to be stabilized and optimized for surgery. Control of intra-abdominal fluid collections, inflammation, and infection is essential, and is best achieved with percutaneous drainage. In addition, in some cases the patient presents in a debilitated state with poor nutritional status (manifested by decreased serum albumin and prealbumin) and poor functional status. Such patients require preoperative nutritional repletion and time to recover from the acute illness. Nutritional formulas that are associated with better outcomes in surgical patients can also be used preoperatively to optimize these patients.[31,32] Repair of the biliary injury is only performed once all intra-abdominal inflammation and infection has been controlled, the patient has regained functional status, and nutrition is restored. The time to achieve this depends largely on the patient's presentation and clinical course. By contrast, for patients referred early, with good control of intra-abdominal inflammation and normal nutritional state there is no need to delay operative repair.[33]

Surgical Management Principles

Bile duct injuries can be very serious complications that, if managed improperly, can result in life-threatening complications such as cholangitis, biliary cirrhosis, and portal hypertension. Even with successful management, quality of life may be diminished and survival may be impaired, especially in elderly patients.[34–37] In general, these

injuries are less commonly managed successfully by the primary surgeon who performs the initial cholecystectomy. Biliary reconstruction by the primary surgeon results in success rates of between 17% and 30%.[33,38–40] There are very good data to suggest that these injuries are best managed by a surgeon with expertise in biliary reconstruction. If these biliary injuries are managed by such surgeons, outcomes can be excellent; many expert surgical series report long-term success rates of greater than 90%.[17,18,22,23,33,39,41–75] Given that the management of these injuries often requires an experienced multidisciplinary team (including interventional radiology, gastroenterology, and surgery), they are best managed in a tertiary referral center.

The tenets of a successful biliary surgical repair include:

- Eradication of all intra-abdominal infection and inflammation
- Anastomoses to healthy bile duct tissue
- Single-layer anastomoses using fine monofilament absorbable suture (Maxon or PDS)
- Tension-free anastomoses
- Roux-en-Y hepaticojejunostomy, in most cases
  - Retrocolic Roux limb
  - 40 to 60 cm length
- Experienced biliary surgeon
- Presence or absence of a biliary stent does not influence results

Specific Biliary Injuries

Cystic duct leaks

Cystic duct leaks are well managed with ERCP, stenting (with or without sphincterotomy), and drainage of intra-abdominal bile collections. Nearly all cystic duct leaks will close with this management scheme. It is crucial to drain bile collections; the stent only acts to decrease the pressure in the biliary tree, it does not cover the leak and prevent bile drainage.

Class I injuries

Class I injuries, which are recognized intraoperatively, can be immediately repaired using fine monofilament absorbable suture. These injuries are usually recognized with cholangiography, so only the small incision used to insert the cholangiocatheter needs to be repaired. There is no need to insert a T-tube. Extension of the laceration to facilitate T-tube insertion results in progression of the injury and an increased likelihood of stricture. The best approach is simple suture of the injury.

Bile duct injuries recognized intraoperatively

If bile duct injuries, other than Class I, are recognized intraoperatively, there are 2 options. If a biliary specialist is readily available he or she should be called for immediate reconstruction. If not, a drain can be placed (to evacuate bile) and the patient immediately referred to a biliary specialist for reconstruction. In general, repair by the primary surgeon is associated with less favorable outcomes, and sometimes the attempted repair can further damage the ducts and make subsequent reconstruction more difficult. Surgeons should take into consideration the magnitude of the injury and their own experience in biliary surgery when determining the best approach for management of these biliary injuries.

Class IV injuries

Class IV injuries that involve a sectoral bile duct and that do not include transection of the duct can often be managed nonoperatively. There is a growing body of literature in

this area. Such patients can be treated with drainage and nonoperative stenting via either ERCP (preferred) or PTC, with good results in many cases.[75–78]

Class IV injuries involving transection of the bile ducts require reconstruction of the duct (either the RHD or a right sectoral duct) into a defunctionalized Roux limb. These ducts should not be sutured to the main hepatic duct, as this can increase the magnitude of the injury.

Timing of Biliary Reconstruction

Several studies reported that the timing of biliary reconstruction influences outcomes; these series reported worse outcomes for biliary reconstructions performed within 6 weeks of injury.[48,71,73] Stewart and Way[33] examined this question, using multivariate analysis, and noted that the timing of repair was not an independent predictor of successful biliary repair. Instead, success correlated with eradication of intra-abdominal infection, complete preoperative cholangiography, use of correct surgical technique, and repair by an experienced biliary surgeon. This timing issue most likely relates to the time required to eradicate intra-abdominal inflammation and to achieve nutritional repletion. In this series, good results were achieved with early biliary reconstruction in those patients with good nutrition, good functional status, and early control of intra-abdominal inflammation.[33]

SUMMARY

Laparoscopic bile duct injuries are more complex than those seen during the open era. The unique features of the laparoscopic environment facilitate these injuries and, because of this, injuries involving misidentification of the CBD for the cystic duct are the most common. This error results in a resectional injury of the main CBD and portions of the hepatic duct or ducts. The laparoscopic environment facilitates this illusion, so these injuries are generally not recognized intraoperatively. In addition, because many of these injuries present with a biliary fistula, as opposed to obstruction, clinical manifestations are often more subtle. The key to successful treatment is early recognition, control of intra-abdominal bile ascites and inflammation, nutritional repletion, and repair by a surgeon with expertise in biliary reconstruction. If these requirements are met, patients can have successful repair with long-term success in more than 90% of cases.

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