ELSEVIER

Operative Techniques in
General Surgery

Management of Common Bile Duct Injuries

John C. Haney, MD, and Theodore N. Pappas, MD

Extrahepatic biliary duct injury is a rare but potentially devastating condition associated with significant morbidity and mortality. The vast majority of these injuries occur as rare complications of the 750,000 cholecystectomies performed annually in the United States.[1] Iatrogenic injury may also occur during gastrectomy, pancreatectomy or ERCP. Trauma and duodenal ulcer are less common causes.[1-4] Improvements in length of stay, postoperative pain, and cosmetic results with the laparoscopic approach to cholecystectomy have been well documented; equally well documented has been the persistent incidence of iatrogenic extrahepatic bile duct injury. Population-based studies consistently cite an incidence of cholecystectomy-associated bile duct injury between 0.3% to 0.6% for the laparoscopic approach and 0.1% to 0.3% for open cholecystectomy.[5-7] A significant amount of literature has been dedicated to the identification of patient characteristics and intraoperative factors associated with increased risk. Conditions that confer additional risk are those that increase the degree of acute inflammation within the triangle of Calot or those that obstruct visualization and impair access to the "critical view." These include variables such as obesity and periportal fat, the presence of complex biliary disease such as choledocholithiasis, gallstone pancreatitis, or frank cholangitis, and intraoperative bleeding interfering with visualization.[8] Atypical anatomy, including aberrant right hepatic duct or complex cystic duct insertion, also predispose to intraoperative injury.[9]

Classification

Bile duct injuries may be classified by mechanism and type of injury, location of injury, effect on biliary continuity, and timing of identification. Each of these factors plays a significant role in determining the appropriate operative repair and management.

Location

Identifying the location of ductal injury and the availability of healthy proximal duct is critical; successful repair requires healthy, nonischemic duct without tension or loss of length. Bismuth and colleagues classified biliary strictures in 1982 based on their proximity to the duct confluence. Strasberg elaborated on this scheme in 1995, classifying injuries by location, mechanism, and consequence to the continuity of the system, separating leaks from occlusions (Figs 1 and 2).[10,11]

Mechanism

Laparoscopic injuries may be caused by inadvertent duct laceration or sharp transection, excessive traction or cautery injury, partial or complete clip ligation, or ligation and transection with loss of duct length. The "classic" laparoscopic injury has been described previously and mistakes the common bile duct for the cystic duct, leading the surgeon to clip and resect the common duct (Fig 3).[12] Proximal dissection and division often leads to injury of the right hepatic artery, thus the classic injury involves loss of length and occlusion of the proximal biliary tree with possible concomitant right hepatic ischemia.

Other laparoscopic injuries are possible. Clip ligation of the distal common bile duct with proximal ligation and division of the cystic duct results in bile obstruction and leak. Avulsion injury of the common bile duct during distal cystic duct transection leads to bile leakage. Thermal injury, clip application, or duct transection are all likely to cause injury to the duct or its blood supply, thus causing a loss of viable length.[15] More insidious presentations of ductal injury may occur with late biliary stricture, caused either by duct ischemia secondary to thermal or traction injury or by the various chronic inflammatory or infectious causes.

Traumatic injuries include partial or complete extrahepatic duct transection or duct avulsion, occasionally in close proximity to the pancreas.[13] The mechanism and type of injury play critical roles in patient presentation and surgical management.

Clinical Presentation and Timing of Identification

The type of biliary tract injury, as well as the timing of injury identification, determines the patient's clinical presentation. Intraoperatively, injury may be recognized by the exposure of unexpected ductal structures during the operation or by leakage of bile into the operative field from the lacerated or transected duct. If unrecognized intraoperatively, the manner of postoperative presentation will be determined by the continuity of the bile ducts and the presence or absence of a biliary leak.

Patients with a significant duct leak may present with bilious drainage from an intraoperatively placed drain. More commonly, the bile leak will cause a localized biloma or free

Department of Surgery, Duke University, Duke University Medical School, Durham, NC.
Address reprint requests to Theodore Pappas, MD, Professor of Surgery, Duke University, Duke University Medical School, DUMC 3479, Durham, NC 27710. E-mail: pappa001@mc.duke.edu

1524-153X/07/$-see front matter © 2007 Elsevier Inc. All rights reserved.
doi:10.1053/j.optechgensurg.2008.01.005

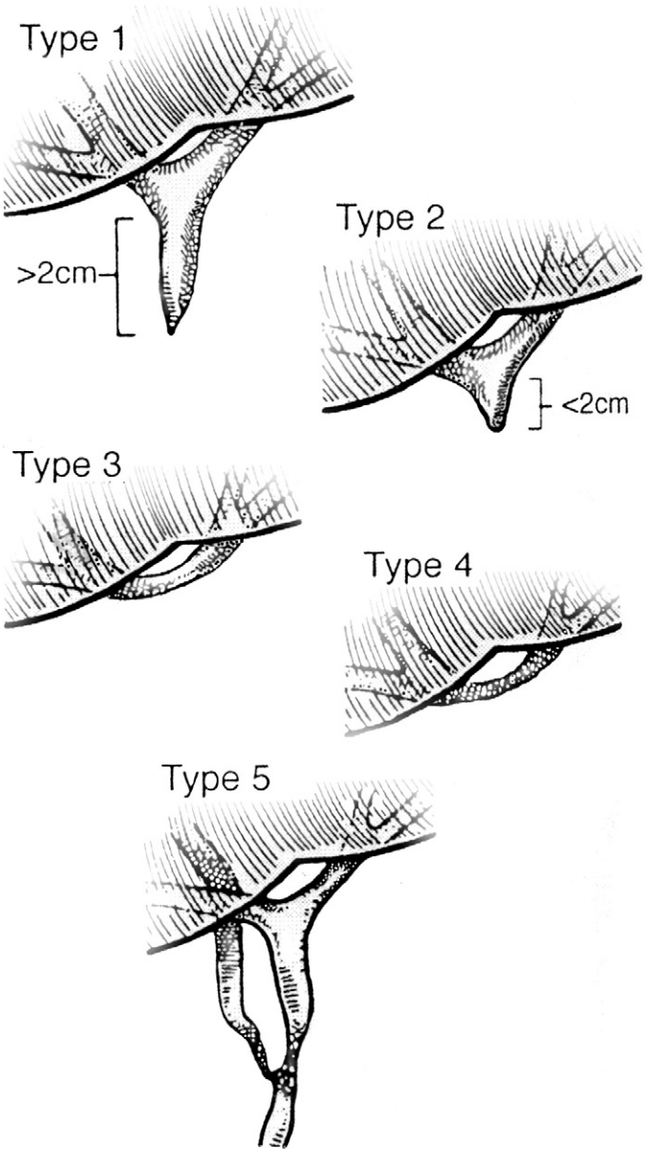

Figure 1 Bismuth classification of biliary strictures (Types 1-5) based on level relative to the hepatic confluence.

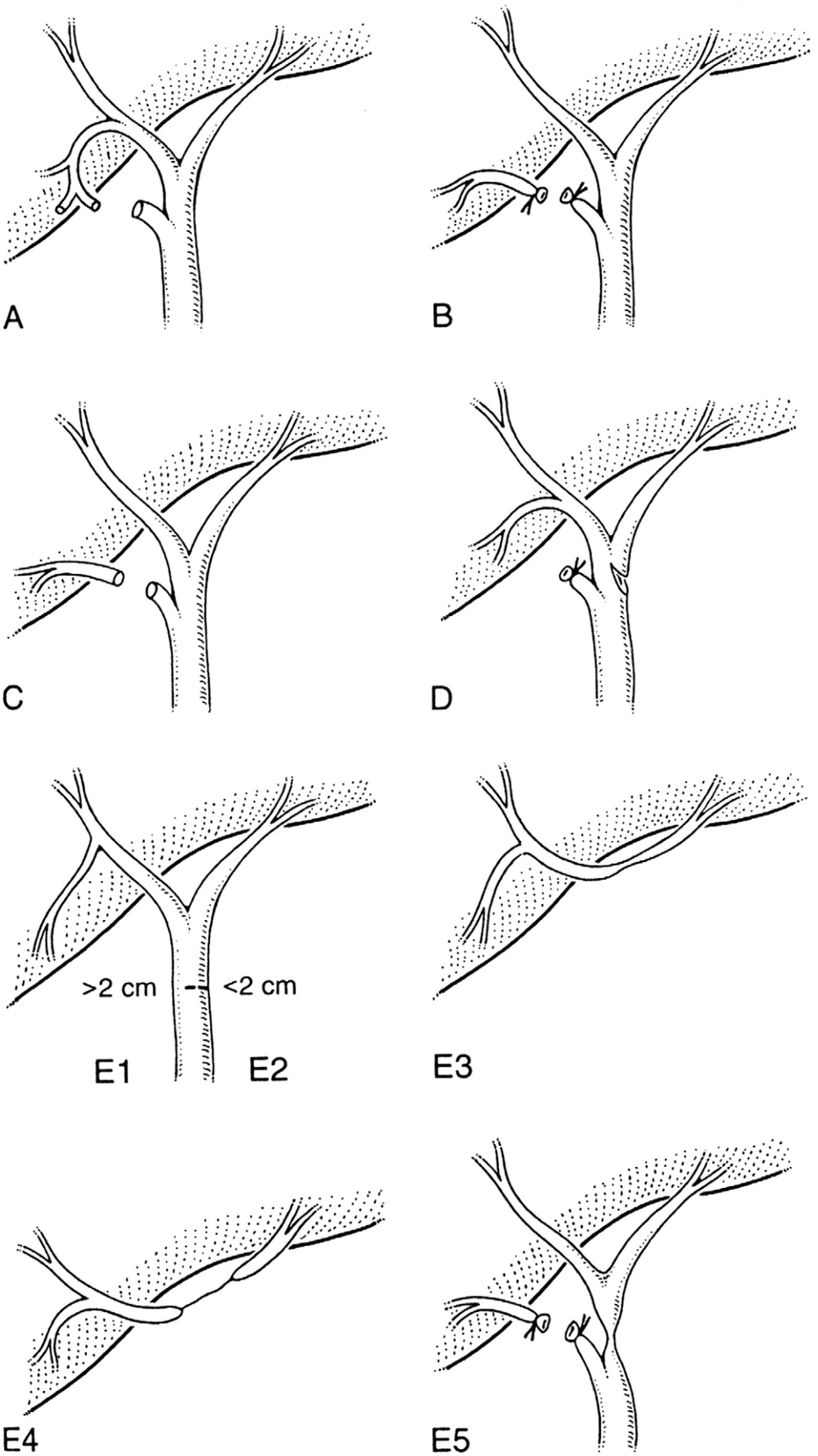

Figure 2 Strasberg classification of injury based on anatomic location and mechanism. Injuries are classified Type A-E, with Type E subdivided E1 to E5 based on Bismuth level (see Fig 1).

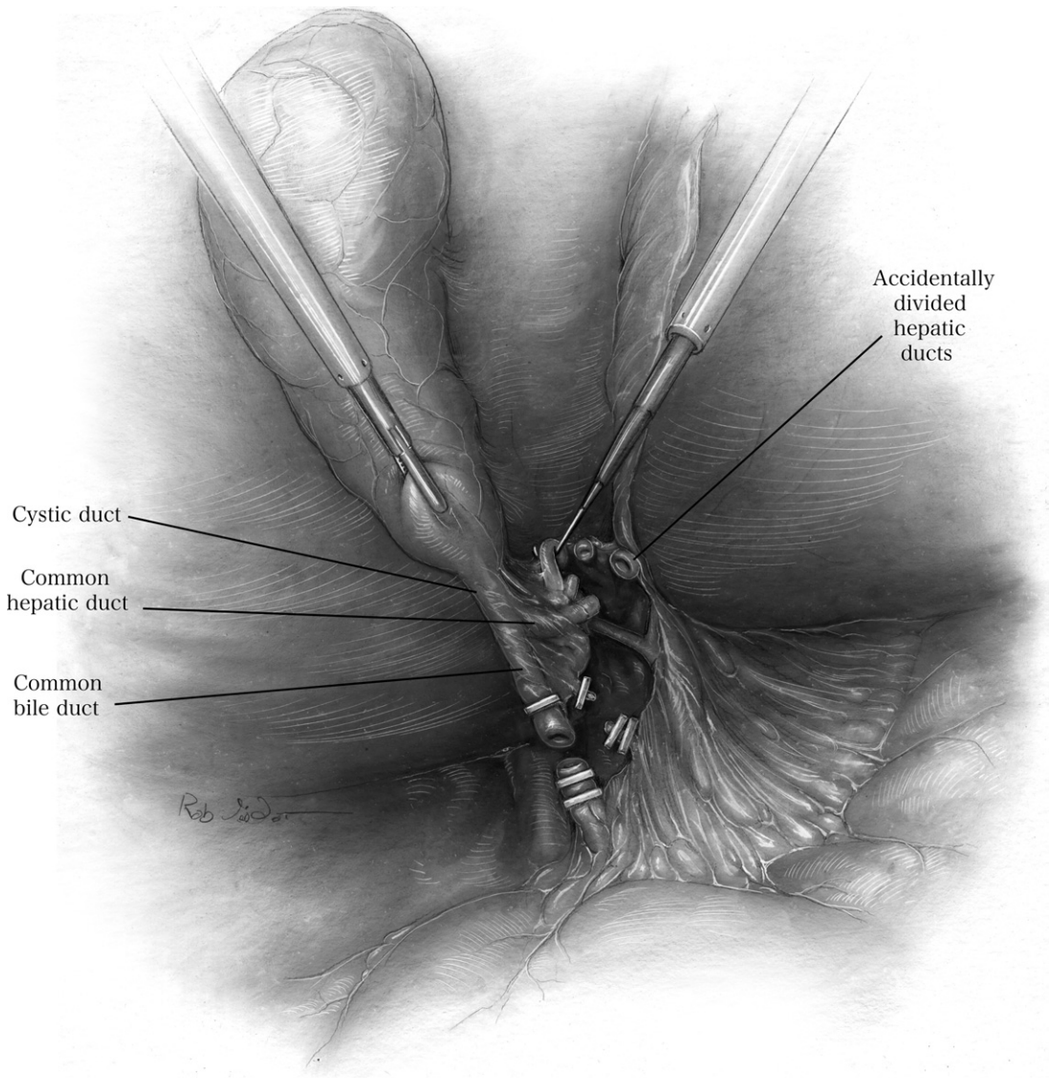

Figure 3 Classic laparoscopic bile duct injury. Misidentification leads to clipping and resection of the common bile duct as well as transection of the hepatic ducts proximally. Dissection also frequently leads to injury to the right hepatic artery.

bile ascites causing bilious peritonitis in the undrained patient. Such patients classically present with diffuse abdominal pain and persistent ileus several days postoperatively. If a biloma becomes secondarily infected, the patient may progress to fever and leukocytosis as with any intraabdominal abscess.[14] Diffuse abdominal pain after laparoscopic cholecystectomy should be met with a high index of suspicion for possible unrecognized biliary tract injury.

If the biliary injury involved clip ligation or resection of the common bile duct producing duct obstruction, the patient may present with clinical jaundice and possibly cholangitis. Aggressive decompression of an obstructed biliary tree is critical for successful management of such an injury.

Diagnostic Workup

Given the low incidence of bile duct injury after what is a very common operation, the prompt diagnosis of a postoperative biliary tract injury requires a high index of suspicion. If injury is suspected intraoperatively and early repair is to be entertained, the laparoscopic approach is converted to an open procedure and a cholangiogram is performed. If the principal surgeon is not experienced in complex hepatobiliary repair then the cholangiogram may be performed laparoscopically and, provided repair is to be deferred, adequate drains may be placed without open conversion.[15] The patient is then referred to an appropriate hepatobiliary specialist without delay.

When injuries are not diagnosed at the time of surgery, the patient's clinical presentation provides clues to the differential diagnosis, which may in turn guide diagnostic workup. Patients classically present with either persistent abdominal pain or jaundice. The presence of postoperative abdominal pain is most consistent with a biloma from duct leak, but may rarely be a result of a retained stone in the common duct or the cystic duct stump. Initial laboratory workup for every patient includes a complete blood count to evaluate for leukocytosis and liver function panel to evaluate for signs of concomitant liver injury and biliary obstruction. Transabdominal ultrasound may be utilized as an initial diagnostic

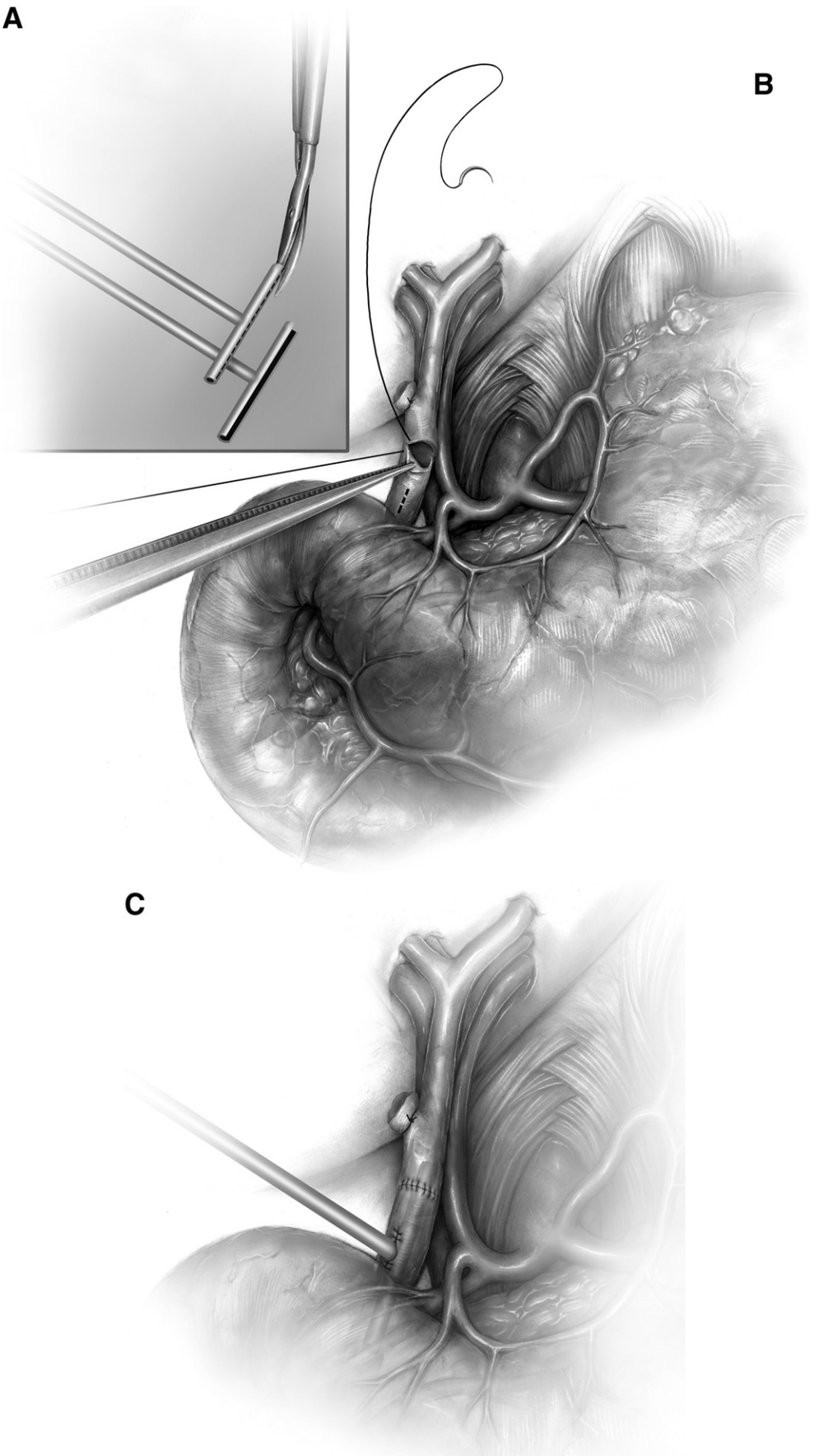

Figure 4 Primary repair of bile duct injury. (A) Transected bile duct ends are freshened and are approximated with the aid of fine stay sutures. The ducts are reanastomosed in interrupted fashion using 4-0 or 5-0 absorbable suture, taking care to approximate mucosa to mucosa. (B) Before completion of the anterior wall, a separate longitudinal choledochostomy is created, preferably downstream, for insertion of a T tube across the anastomosis. The T tube is modified by removing the back wall, reducing obstruction. (C) The choledochostomy is closed with interrupted sutures around the T tube, and the anastomosis is completed. The T tube is then brought out through a stab incision in the abdominal wall.

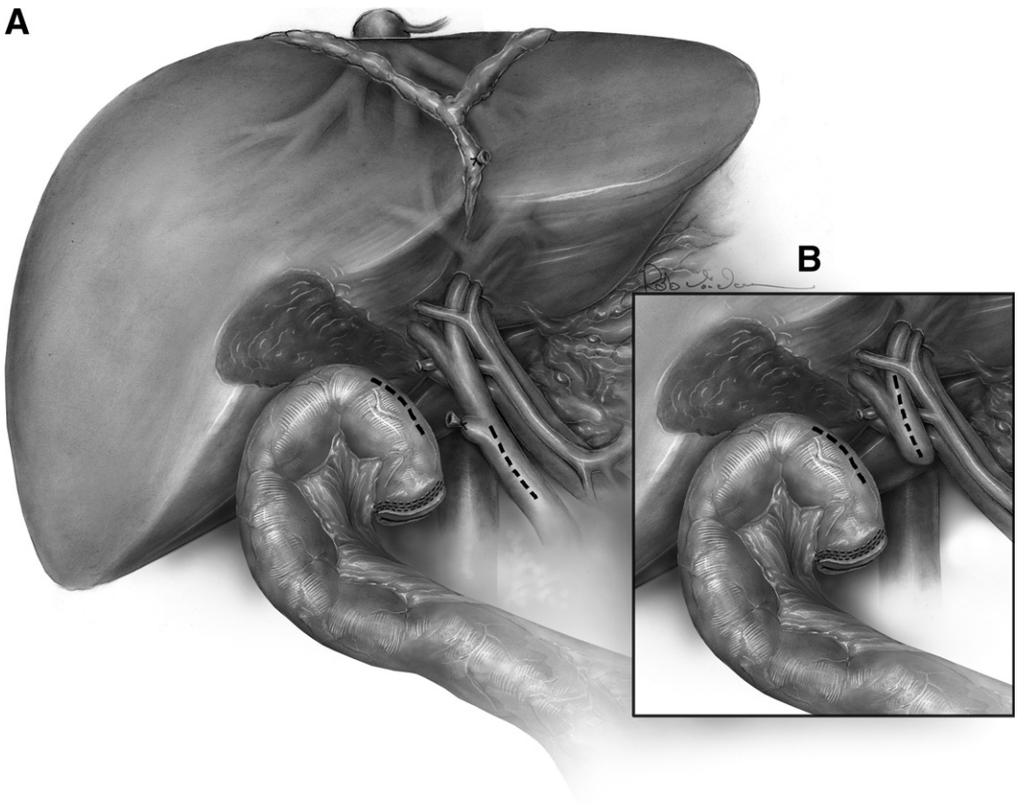

Figure 5 Side-to-side anastomotic approach for Bismuth I injuries with a sufficient common duct stump (A), or for Bismuth II or III injuries in which the anastomosis is extended into the left or right duct for sufficient length (B).

modality, but more commonly, patients will receive an abdominal computed tomography (CT) scan. Survey of the abdomen by either modality will allow for diagnosis of either free or contained biloma and may guide percutaneous drainage. Once a biliary injury is suspected and all localized or free bile is percutaneously drained, a complete cholangiogram must be performed to define the anatomical injury.[16] This may be obtained using magnetic resonance imaging or ERCP. Technetium-99 month-HIDA scintigraphy may be used as screening test for diagnosing postoperative bile leaks or as a tool for determining the adequacy of drainage.[17]

When patients present with jaundice, the differential diagnosis includes biliary obstruction from retained common bile duct stone or extrahepatic duct occlusion. In this case, ultrasound or CT scan may also be used as the initial test. If a common duct stone is suspected then ERCP is the appropriate next step, but in the event of occlusive injury endoscopic cholangiogram will be unable to provide adequate visualization of the entire biliary tract secondary to the loss of continuity.[3] In this case, percutaneous transhepatic cholangiography, which provides the most complete picture of proximal ductal anatomy and has the advantage of allowing for placement of decompressive biliary catheters as well should be performed.[18]

Preoperative Management

Once a bile duct injury has been diagnosed, a well-informed decision must be made regarding the timing and type of repair. First and foremost, this requires full appreciation for the injury and the resultant anatomy. Multiple studies have shown that early repair of biliary injury may be performed, but repair in the setting of overt inflammation is unlikely to be successful.[1,19]

In addition to defining anatomy, a major principle of preoperative therapy is the treatment of existing ductal inflammation. This entails biliary decompression for complete obstruction, aggressive drainage of bilomas, and intravenous antibiotics guided by culture of bile if cholangitis is present.

Drains may be placed in the open biliary tract intraoperatively if the injury is diagnosed immediately and repair is deferred. When complete obstruction is diagnosed postoperatively, decompression should be accomplished by the placement of percutaneous biliary catheters through a transhepatic approach. When the injury is located at least 2 cm distal to the duct confluence a single drain is sufficient, but if the injury is within 2 cm of the confluence, repair is likely to involve the confluence and thus drains should be left in both the left and right sides. If the tract is in continuity with a biloma, the transhepatic biliary catheters should be placed across the injury into the collection to facilitate drainage and identification of the ducts. Preoperative, temporary stenting of strictures is somewhat controversial, but may be utilized to restore continuity and decompress the tract.[20] In cases with a dilated duct ($>$1 cm) no stent is required. Pre-reconstruction management usually involves aggressive multidisciplinary therapy and usually does not require an operation to control bile drainage. The amount of time required to quiet existing inflammation or infection varies depending on the severity of

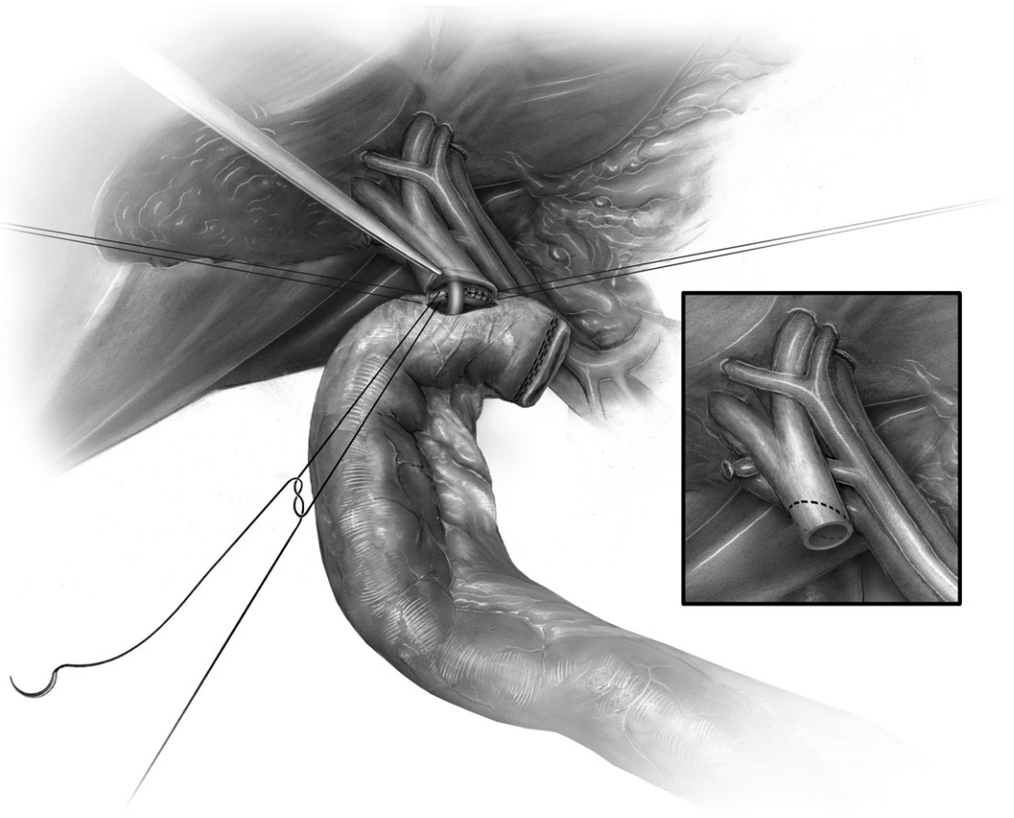

Figure 6 End-to-side choledochojejunostomy. The common bile duct is spatulated and anastomosed to the antimesenteric enterotomy using interrupted 4-0 or 5-0 mucosa-to-mucosa sutures with knots tied on the inside.

the presenting illness, which may range from a mild inflammatory response when detected early to overwhelming ascending cholangitis and sepsis in the event of complete obstruction and infection.[5]

Repair

Nonoperative Management

In select cases, nonoperative interventions may be able to provide durable and definitive biliary drainage, and multiple groups report high success rates with either percutaneous or endoscopic techniques.[21-23] Definitive nonoperative management requires intact bilioenteric continuity. Frequently this occurs when a small bile leak is detected postoperatively and treated with stent placement. Short biliary strictures may also be appropriate for a trial of nonoperative therapy. In general, strictures <2 cm in length within an intact bile duct may be balloon dilated and stented.[24] This management often requires multiple reinterventions over several months. Percutaneous management often requires at least three attempts at dilation whereas endoscopic management may prompt the placement of 2 to 3 side-by-side plastic stents left in place for many months.

Operative Management

When an injury is diagnosed at the time of initial surgery, the decision of whether or not to attempt repair, be it primary or bilioenteric, depends primarily on the experience and comfort level of the surgeon with what is a technically challenging procedure in a nondilated biliary system. Multiple studies supporting early tertiary referral have shown improved outcomes with repair by experienced hepatobiliary specialists.[16,25]

When operative repair is performed, the options include primary repair over a T tube and bilioenteric diversion. The critical principles producing a durable repair are the creation of a tension-free, mucosa-to-mucosa anastomosis with healthy, nonischemic bile duct.[19,20,26,27] Although the blood supply to the hilar and retropancreatic bile ducts is substantial, the remainder of the extrahepatic system is supplied by two tenuous axial arteries at the 3 o'clock and 9 o'clock positions, and this supply is easily compromised.[28] As a result, it is imperative to minimize unnecessary dissection whereas at the same time removing any nonviable duct length back to healthy tissue. Primary repair of partial or complete bile duct transection may be performed but should be viewed as the exception rather than the rule.[10,15] The presence of any tension on the anastomosis is a contraindication to primary repair, and the use of a Kocher maneuver to gain length on the duodenal side, while advisable, is generally not sufficient to relieve tension.[15] Irregular edges or ischemic tissue should be trimmed but the duct should not be routinely cleaned in either direction. Clamps should be avoided, and fine temporary stay sutures may be used to approximate the ends.[29] Simple, noncircumferential lacerations may be repaired in interrupted fashion using fine (4-0 or 5-0) absorbable suture. Care should be taken to approximate mucosa to mucosa, taking small, precise bites of the tissue. If

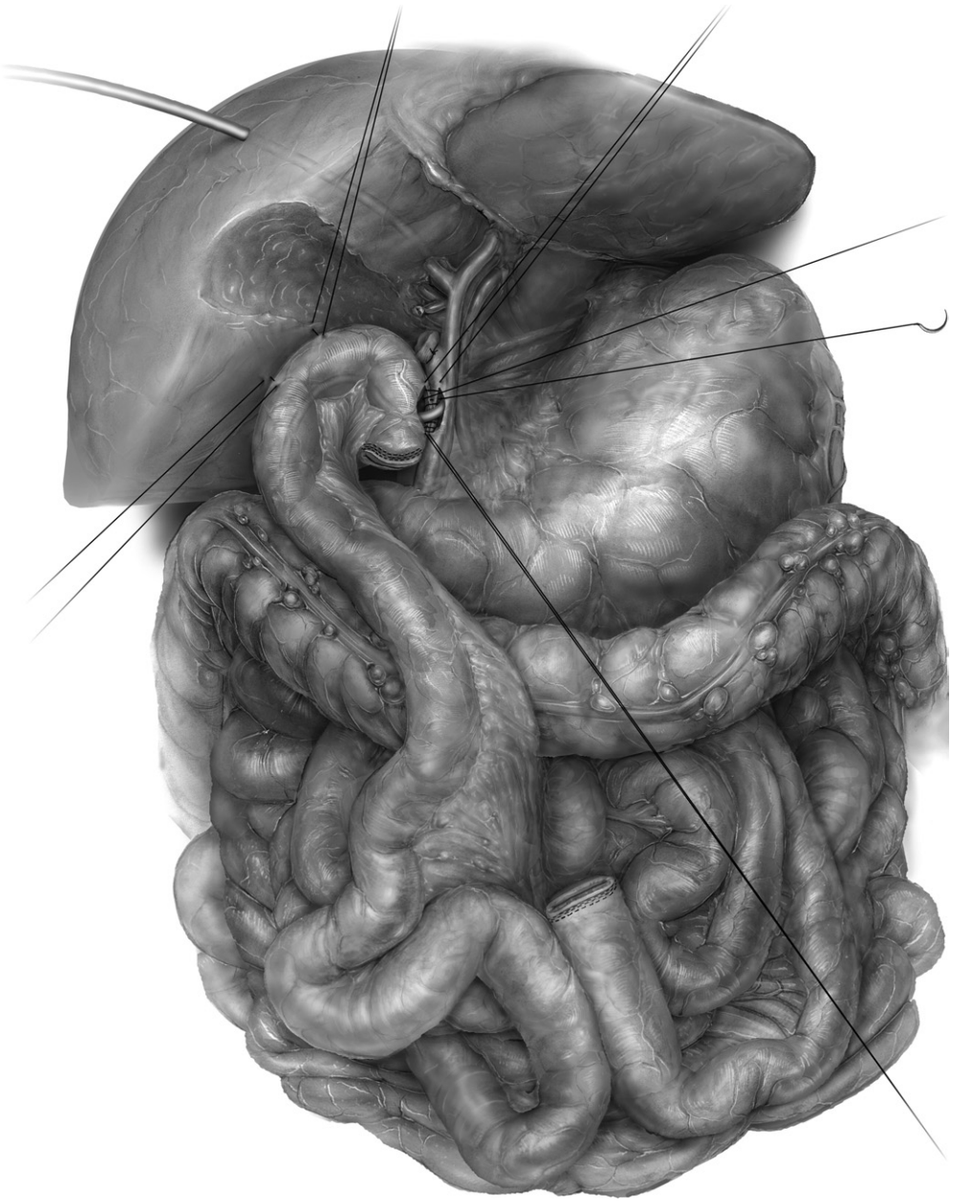

Figure 7 Roux-en-Y hepaticojejunostomy. Biliary stent(s) are brought out through the anterior incision in the bile duct. A 3 to 4 cm antimesenteric enterotomy is created in the Roux limb and the stents are passed into the Roux limb. Stay sutures are placed at either end of the anastomosis. The edges are approximated in interrupted fashion with fine absorbable suture, tying the knots within and approximating the biliary and jejunal mucosa.

simple primary repair is attempted a T tube may be placed through the repair site. If the primary involves any complexity the T tube should be placed through a separate choledochostomy, preferably below the site of injury, with the proximal end of the tube across the repair (Fig 4). A closed-suction drain is placed in Morrison's pouch and brought out through the skin. After completion, the T tube is flushed and an intraoperative cholangiogram is taken to determine adequacy of the repair.

By far the more common reconstructive technique is to restore biliary continuity by way of a new bilioenteric anastomosis. This may be accomplished with a choledochoduodenostomy, choledochojejunostomy, or hepaticojejunostomy. Although choledochoduodenostomy can be an acceptable repair, its utility is limited. For the vast majority of cases, a Roux-en-Y choledochojejunostomy or hepaticojejunostomy is the most durable reconstructive option. A 40 to 50 cm retrocolic Roux limb is brought in proximity to the common bile duct or common hepatic duct in anticipation of the anastomosis. Side-to-side anastomosis is preferable, as it has been shown to maintain better patency than end-to-side reconstruction.[3] For Bismuth I injuries this may involve the common bile duct only, but for injuries adjacent to or involving the confluence, the anastomosis may need to be extended into one of the hepatic duct limbs to achieve adequate length (Fig 5). The anterior bile duct wall is opened sharply in longitudinal direction to a distance of 3 to 4 cm. The preoperatively placed biliary catheter (used routinely in elective reconstructions) is brought through the opening. For end-to-side anastomoses, the distal end of the common bile duct is freshened and spatulated to increase its cross-section (Fig 6). A 3 to 4 cm enterotomy is made in the antimesenteric side of the Roux limb several centimeters from the terminal staple line. The biliary drain is passed through the enterotomy into the bowel lumen several centimeters. Several stay sutures may be placed to approximate the bile duct and jejunum. The anastomosis is then sewn with fine (4-0 or 5-0) absorbable suture in interrupted fashion, taking care to approximate mucosa to mucosa (Fig 7). Following completion of the anastomosis, the Roux limb is anchored to the underside of the liver with several seromuscular interrupted sutures on either side, relieving any tension from the repair. A closed suction drain is left in the Morrison's pouch and brought out through the skin through a stab incision.

A brief comment should be made regarding traumatic injury and repair. Several studies have reported good results with primary repair of bile duct transections provided that there is a lack of tension and presence of viable tissue. In the case of tissue loss a bilioenteric bypass should be created in standard fashion. In instances of distal avulsion injuries involving the retropancreatic bile duct, the proximal duct should be managed in standard fashion, and no efforts should be made to expose the pancreatic side of the transected duct; these very distal ends do not produce enteric leaks.[13]

Postoperative Care

Patients undergoing biliary reconstruction should be managed as with any upper gastrointestinal reconstruction, with diet resumed following resolution of postoperative ileus. Patients should be monitored with liver function tests. T tube or percutaneous biliary drains are internalized once diet is resumed. Operative drains should remain in place until PBD or T tube internalization and then, in the absence of output after internalization, should be removed. Drains are typically left across the anastomosis for 6 weeks, at which time a cholangiogram is performed. If the anastomosis appears widely patent the drain is removed at that time; if the anastomosis appears tight, the PBD or T tube is left longer. In extreme circumstances where the anastomosis was made to a strictured segment of the duct, the stent should be left in place for approximately 8 to 10 months to allow scar tissue to form.

Complications after biliary reconstruction are not uncommon. In the largest single-center experience from Johns Hopkins, postoperative complications were experienced by 42% of patients and consisted most frequently of wound infection, biloma, biliary stent complication, or anastomotic leak.[1] Of note, all complications were managed nonoperatively, and it has been the experience of other authors that, while complications such as cholangitis or PBD occlusion are not uncommon, they rarely require reoperation.[30] Over the long term, patients must be monitored for stricture at the anastomosis, most commonly heralded by a rising alkaline phosphatase. As many of these patients have a chronic, low-level elevation in alkaline phosphatase, the more concerning feature is a consistent upward trend. In the event of suspected anastomotic stricture, cholangiogram and possible balloon dilation and stenting are preferred. If the bile duct is in continuity with the duodenum, ERCP and stenting is the preferred approach. In the case of jejunal reconstructions where the bile duct is not in communication with the duodenum, all interventions must be accomplished via percutaneous transhepatic access.

Conclusion

In summary, bile duct injury is a rare complication of laparoscopic cholecystectomy. Pain or jaundice after laparoscopic cholecystectomy should prompt an evaluation of liver function tests (bilirubin and alkaline phosphatase) followed by computerized imaging to rule out extra-biliary tract bile. Bile duct imaging with MRCP or ERCP is required if the index of suspicion is high or if common duct appears obstructed. If the duct is intact but injured, ERCP plus stenting may control the process (after all extra-biliary bile is drained). If the injury occludes or divides the duct then bile flow should be controlled percutaneously (transhepatically). Reconstruction should be accomplished in a minimally inflamed field, most commonly with a Roux-en-Y hepaticojejunostomy. Successful operative repair requires a tension-free, mucosa-to-mucosa anastomosis using viable bile duct. These reconstructions are best performed by experienced hepatobiliary surgeons. While the complication rate including anastomotic stricture remains fairly high, most can be managed nonoperatively with a low reoperation rate and good long-term patency.

References

1. Sicklick JK, Camp MS, Lillemoe KD, et al: Surgical management of bile duct injuries sustained during laparoscopic cholecystectomy: Perioperative results in 200 patients. Ann Surg 241:786-792, 2005

2. Sawaya DE, Johnson LW, Sittig K, et al: Iatrogenic and noniatrogenic extrahepatic biliary tract injuries: A multi-institutional review. Am Surg 67:473-477, 2001
3. Saber K, El-Manialawi M: Repair of bile duct injuries. World J Surg 8:82-84, 1984
4. Hall JG, Pappas TN: Current management of biliary strictures. J Gastrointest Surg 8:1098-1110, 2004
5. Z'graggen K, Wehrli H, Metzger A, et al: Complications of laparoscopic cholecystectomy in Switzerland. A prospective 3-year study of 10,174 patients. Surg Endosc 12:1303-1310, 1998
6. Krähenbühl L, Sclabas G, Wente MN, et al: Incidence, risk factors, and prevention of biliary tract injuries during laparoscopic cholecystectomy in Switzerland. World J Surg 25:1325-1330, 2001
7. Flum DR, Cheadle A, Prela C, et al: Bile duct injury during cholecystectomy and survival in medicare beneficiaries. JAMA 290:2168-2173, 2003
8. Davidoff AM, Pappas TN, Murray EA, et al: Mechanism of major bile duct injuries during laparoscopic cholecystectomy. Ann Surg 215:196-208, 1992
9. Meyers WC, Peterseim DS, Pappas TN, et al: Low insertion of hepatic segmental duct VII-VIII is an important cause of major biliary injury or misdiagnosis. Am J Surg 171:187-191, 1996
10. Bismuth H, Majno PE: Biliary strictures: Classification based on the principles of surgical treatment. World J Surg 25:1241-1244, 2001
11. Strasberg SM, Hertl M, Soper NJ: An analysis of the problem of biliary injury during laparoscopic cholecystectomy. J Am Coll Surg 180:101-125, 1995
12. Branum G, Schmitt C, Baillie J, et al: Management of major biliary complications after laparoscopic cholecystectomy. Ann Surg 217:532-540, 1993
13. Melton SM, McGwin G, Cross JM, et al: Common bile duct transection in blunt abdominal trauma: Case report emphasizing mechanism of injury and therapeutic management. J Trauma 54:781-785, 2003
14. Bauer TW, Morris JB, Lowenstein A, et al: The consequences of a major bile duct injury during laparoscopic cholecystectomy. J Gastrointest Surg 2:61-66, 1998
15. Ahrendt SA, Pitt HA: Surgical therapy of iatrogenic lesions of biliary tract. World J Surg 25:1360-1365, 2001
16. Stewart L, Way LW: Bile duct injuries during laparoscopic cholecystectomy. Factors that influence the results of treatment. Arch Surg 130:1123-1128, 1995
17. Shinhar S, Nobel M, Shimonov M, et al: Technetium-99m-HIDA scintigraphy versus endoscopic retrograde cholangiopancreatography in demonstrating bile leaks after laparoscopic cholecystectomy. J Nucl Med 39:1802-1804, 1998
18. Lillemoe KD, Melton GB, Cameron JL, et al: Postoperative bile duct strictures: Management and outcome in the 1990s. Ann Surg 232:430-441, 2000
19. Mercado MA: Early versus late repair of bile duct injuries. Surg Endosc 20:1644-1647, 2006
20. Robinson TN, Stiegmann GV, Durham JD, et al: Management of major bile duct injury associated with laparoscopic cholecystectomy. Surg Endosc 15:1381-1385, 2001
21. Misra S, Melton GB, Geschwind JF, et al: Percutaneous management of bile duct strictures and injuries associated with laparoscopic cholecystectomy: A decade of experience. J Am Coll Surg 198:218-226, 2004
22. Misra S, Melton GB, Geschwind JF: Percutaneous management of bile duct strictures and injuries associated with laparoscopic cholecystectomy: A decade of experience. J Am Coll Surg 198:218-226, 2004
23. Kassab C, Prat F, Liguory C, et al: Endoscopic management of post-laparoscopic cholecystectomy biliary strictures. Long-term outcome in a multicenter study. Gastroenterol Clin Biol 30:124-129, 2006
24. Gazzaniga GM, Filauro M, Mori L: Surgical treatment of iatrogenic lesions of the proximal common bile duct. World J Surg 25:1254-1259, 2001
25. Thompson BNJ, Parks RW, Madhavan KK, et al: Early specialist repair of biliary injury. Br J Surg 93:216-220, 2006
26. Mercado MA, Chan C, Orozco H, et al: Acute bile duct injury. Surg Endosc 17:1351-1355, 2003
27. Quintero GA, Patino JF: Surgical management of benign strictures of the biliary tract. World J Surg 25:1245-1250, 2001
28. Terblanche J, Allison HF, Northover JMA: An ischemic basis for biliary strictures. Surgery 94:52, 1983
29. Zollinger RMJ, Zollinger RMS: Zollinger's atlas of surgical operations (8th ed). New York, McGraw Hill, 2003
30. Walsh RM, Vogt DP, Ponsky JL, et al: Management of failed biliary repairs for major bile duct injuries after laparoscopic cholecystectomy. J Am Coll Surg 199:192-197, 2004