Chapter 28
Operative Repair of Common Bile Duct Injury

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Abbreviations

CBD	Common bile duct
CHD	Common hepatic duct
LHD	Left hepatic duct
RHD	Right hepatic duct
CHA	Common hepatic artery
PHA	Proper hepatic artery
RHA	Right hepatic artery
LHA	Left hepatic artery
BDI	Bile duct injury
VBI	Vasculobiliary injury
HRQOL	Health-related quality of life

Introduction

This chapter addresses the operative repair of acute bile duct injury (BDI), in particular, that sustained at laparoscopic and open cholecystectomy. More specifically, the chapter focuses on repair of iatrogenic BDI as an unintended consequence of

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cholecystectomy. Deliberately not discussed in this chapter is the management of bile duct injuries due to blunt or penetrating trauma, or injury sustained at elective hepatectomy or gastroduodenal surgery, although the management issues are not dissimilar to those involved in bile duct injury related to cholecystectomy. The most important factor for patients undergoing laparoscopic cholecystectomy is prevention of BDI through safe surgical practice and surgical awareness, and this most important aspect of surgery to the gall bladder is covered elsewhere.

Incidence of Bile Duct Injury

More than 750,000 laparoscopic cholecystectomies are performed annually in the United States [1] and 80,000 annually in the United Kingdom [2, 3]. Prior to the widespread adoption of laparoscopic cholecystectomy, BDI occurred in an estimated 0.2 % of cholecystectomies [4]. With the introduction of laparoscopic cholecystectomy, the incident rate of iatrogenic BDI has increased approximately twofold, to 0.3–0.5 % incidence in most large series although even with large prospective studies, the true incidence varies due to a lack of consensus in agreeing what constitutes bile duct injury and an incidental bile leak.

Mechanisms of Injury

In nearly all cases, BDI results from an error in cognition during the initial phases of anatomical orientation, when the operating surgeon, corroborated or unchallenged by the assistant, misidentifies the key anatomical landmarks to allow safe dissection to achieve the critical view [5]. This fundamental "root cause" of error can progress into any type of BDI, from a lateral injury to the common bile duct (CBD) whilst attempting intraoperative cholangiogram (Strasberg type D) [5], to completed excision of the hepatic duct confluence (Garden's Type E6 addition [6] to Bismuth E1–5 classification [7]). It is important to understand the mechanisms of injury since this will impact on subsequent management. There are numerous variations, combinations, and permutations in the pattern of injury seen, which have been exhaustively covered by a series of classification systems. The main classification system in common use is that of Strasberg [5], which incorporates in its types E1–5 the original classification system of Bismuth [7] (Fig. 28.1).

The classical CBD injury, described by Davidoff [8], occurs where the surgeon initiates anatomical orientation too medially or commences dissection too low below the anatomical landmark provided by Rouviere's sulcus and the inferior border of segment IV [9, 10], misidentifies the CBD for the cystic duct, clips and divides it, proceeds proximally towards the hilum, injuring the RHA in the process as it passes under the CBD, encounters an "accessory cystic duct" (this being the CHD), dividing it and thus excising a segment of CBD with the gall bladder (Figs. 28.2 and 28.3).

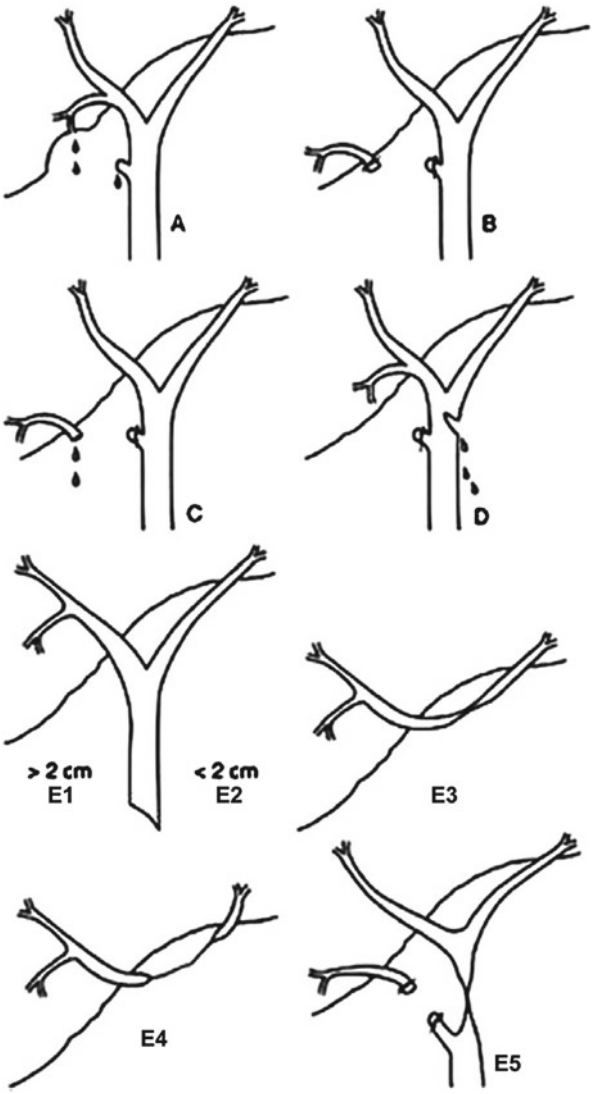

Fig. 28.1 Strasberg classification of iatrogenic bile duct injury. This figure was published in J Am Coll Surg, 180, Strasberg, S.M., Hertl, M. & Soper, N.J., *An analysis of the problem of biliary injury during laparoscopic cholecystectomy*, 101–125, Copyright Elsevier (1995) [5]

Complete excision of a portion of the bile duct has occurred in the pattern of the classical bile duct injury. The biliary confluence has been excised, leaving exposed right hepatic duct (RHD) and left hepatic duct (LHD) orifices. The main portal vein (MPV) is exposed. The right hepatic artery (RHA) has been mistaken for the cystic artery and clipped and divided as it passed behind the common hepatic duct

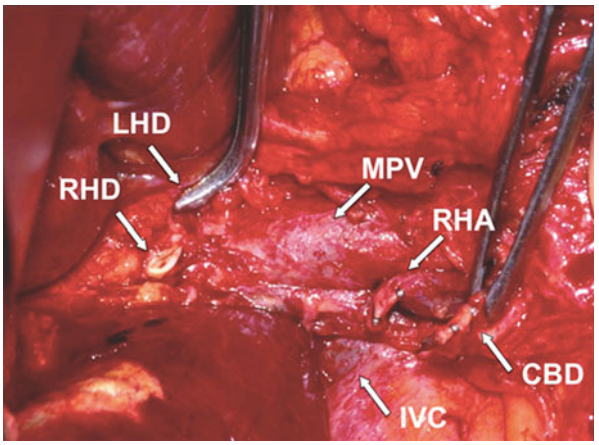

Fig. 28.2 Intraoperative photograph of a major bile duct injury with concomitant vasculobiliary injury (Strasberg E5)

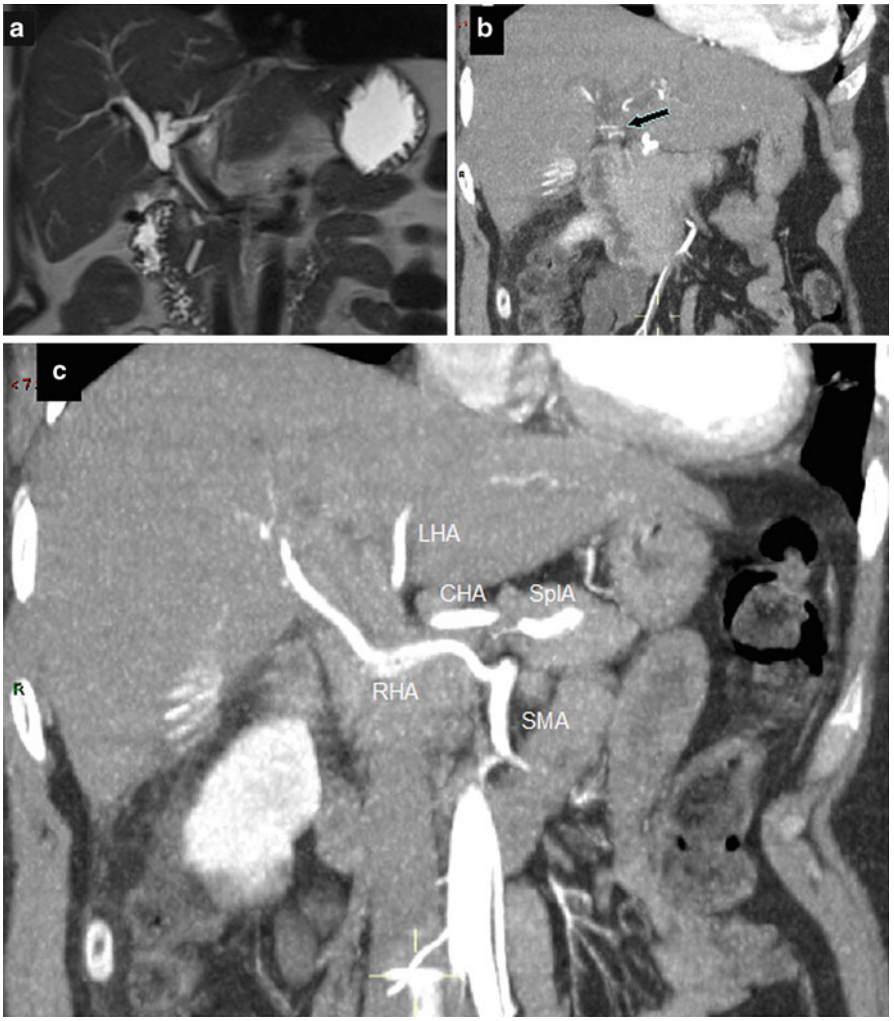

Fig. 28.3 The classical CBD injury as described by Davidoff, Strasberg E2. A segment of the CHD was excised between clips. The injury was not suspected intraoperatively. Bile leakage in the first 2 postoperative days was minimal but right upper quadrant pain and a rising bilirubin prompted an MRI scan.

(no longer present). The distal common bile duct has been mistaken for the cystic duct and has been doubly clipped and divided. The inferior vena cava (IVC) is visible posteriorly to what remains of the hepatic pedicle.

Physical Mode of Injury

The physical mode of injury is also critical to the strategic planning of the surgeon planning bile duct repair, as this will greatly influence the timing and choice of repair technique. A cold, sharp incision, for example, such as that made by scissors, is likely to be associated with far less collateral tissue damage than a high-energy injury inflicted by prolonged dissection, diathermy, ultrasonic shears, or other energy dissector. Similarly, a shredding-type injury caused by repeated forceful passages of a stone retrieval basket or a rupture-type injury caused by overinflation of a balloon during transcystic CBD exploration will result in a less discrete injury that may not lend itself to direct repair at the time of surgery. The degree of generalized tissue disruption will also influence the likelihood of subsequent stricturing of either the residual ductal tissue or the anastomotic repair.

Comprehensive Recording of BDI: The ATOM Classification

There are now multiple classifications for BDI each with their own merits. However, so many systems lead to complexity and an inability to compare injury severity and outcome between series. Therefore, the European Association for Endoscopic Surgery achieved consensus in formulating a multi-parameter template for recording BDI. Using semantics, the anatomy (A), time of injury (To), and mechanism of injury (M) are recorded as the ATOM classification [11]. The anatomical record includes the level of injury, and whether the lesion is partial or complete, with division or occlusion. The presence of VBI is recorded. Whether the injury was detected intraoperatively in the early postoperative period or detected late is recorded. Lastly, whether the injury was energy-driven or mechanical is recorded. The system is comprehensive and ensures that all relevant attributes of a BDI are recorded. It also serves as a reminder to the surgeon to consider each of the various attributes during the strategic planning phase of bile duct repair. Unfortunately, it is probably not sufficiently simple to be employed routinely by most surgeons in day-to-day practice but nonetheless is useful for the specialist surgeon in considering the nature of the injury and the optimal management approach.

Fig. 28.3 (continued) (**a**) Primovist-enhanced MRI scan showing complete occlusion of the CHD within 2 cm of the confluence (E2 injury). (**b**) CT confirms two clips placed across the CHD (*black arrow*). (**c**) Arterial phase contrast CT shows a replaced right hepatic artery arising from the superior mesenteric artery. This anatomical variant may well have saved the patient from a major arterial injury had there been a normally sited right hepatic artery

Assess the Patient and the Injury

In the event of a suspected iatrogenic BDI, particularly at the time or subsequent recognition of the injury, the absolute priority must be patient safety. If the BDI is recognized intraoperatively and there is not ongoing life-threatening hemorrhage, further dissection by the primary operator to establish the extent of the injury is generally ill-advised even if the primary operator is an experienced surgeon. Further dissection at this stage risks an extension of the injury or an additional vascular injury that will considerably worsen the situation. It is recommended that a second senior surgical colleague (who ideally is an expert hepatobiliary surgeon) be called into the operating theater to provide an objective assessment and give advice. The initial temptation is for the primary operator to perform an immediate repair, which is not always the correct course of action. Similarly, many would recommend that the primary operator who caused the BDI is not best placed to carry out the best repair. Apart from the fact that the primary operating surgeon at that moment in time is by definition error-prone (for whatever reason), in the maelstrom of emotions that may be present at the time of iatrogenic BDI, the judgment of the primary operator is unlikely to remain uncompromised.

Concomitant Vascular Injury: The Vasculobiliary Injury (VBI)

It is well recognized that concomitant vascular injury at the time of BDI, termed vasculobiliary injury (VBI), is associated with a significantly worse outcome [12, 13]. The right hepatic artery is most commonly injured (in 12–61 % of BDI [12]) due to its usual anatomical location passing behind the CHD. If injury to the RHA occurs in isolation, in other words without BDI, then there are a few long-term consequences. The reason for this is the potential for the development of collateral arterial circulation through the smaller arteries that run vertically alongside the CBD at the 3 o'clock and 9 o'clock positions, and the important transverse arterial anastomosis across the hilar plate at the main biliary confluence at the hilum [13] (Fig. 28.4).

Angiographic flow studies have demonstrated a return to near normal arterialization of the right liver after interruption of the RHA through these important potential collaterals. However, although an increase in flow across the transverse hilar network is seen after 10 h, flow is not completely compensated for at least 4 days [14]. Therefore, in the presence of acute VBI, immediate repair may in fact result in an inferior long-term outcome due to recurrent stricture because early surgery and immediate anastomosis may further disrupt this collateral arterialization. Many units expert in tertiary management of BDI [12], including the authors' unit, will preferentially delay biliary repair in the context of VBI to allow adequate collateralization across the hilar plate with the aim of achieving a better long-term outcome.

In the immediate intraoperative setting, the continuity and flow in the RHA can be established by the second expert surgeon, with care being taken to avoid exacerbating any injury. In this setting, intraoperative ultrasound, duplexed with

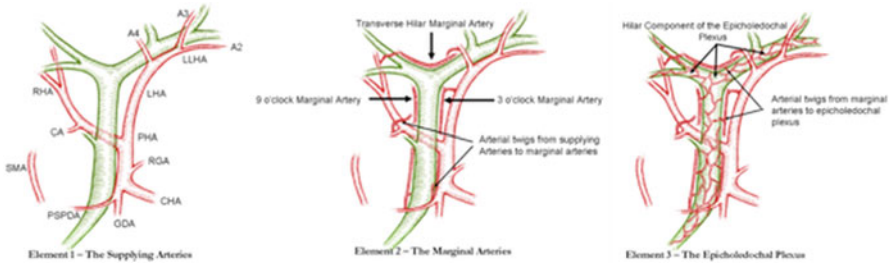

Fig. 28.4 (**a**–**c**) The blood supply of the bile duct. (**a**) Element 1 is comprised of the major named arterial vessels (SMA, superior mesenteric artery; CHA, common hepatic artery; GDA, gastroduodenal artery; PSPDA, posterior superior pancreaticoduodenal artery; RGA, right gastric artery; PHA, proper hepatic artery; RHA, right hepatic artery; LHA, left hepatic artery; LLHA, left lateral hepatic artery; A2, A3, and A4, arteries to liver segments 2, 3, and 4; CA, cystic artery). (**b**) Element 2 is comprised of the marginal arteries running in the 3 and 9 o'clock positions on both sides of the common bile duct and transversely across the hilar aspect of the bifurcation of the common hepatic duct. (**c**) Element 3 is the epicholodochal plexus forming a network in and on the wall of the ductal system. This figure was published in HPB, 13, Strasberg, S.M. & Helton, W.S., *An analytical review of vasculobiliary injury in laparoscopic and open cholecystectomy*, 1–14, Oxford (2011) [13]

color flow Doppler, may be helpful. If a concomitant significant arterial injury is detected which involves the right hepatic artery, the hilar plate, and biliary confluence, primary reconstruction of the biliary tree should be deferred to allow adequate collateralization to occur over a period of time. A delay of approximately 3 months is optimal in the authors' practice. Controversy exists over whether a primary repair of the artery, with an excision of the injured segment and primary anastomosis, or with the use of an interposition vein graft or jump graft, will lead to improved outcomes, and there is insufficient case volume reported in the literature to make a clear assessment [15]. Often there is a loss of vessel extending into the liver substance. Arterial reconstruction in this context is technically demanding, likely to failure, and risks worsening an already suboptimal situation. Therefore, if arterial revascularization is attempted, this should only be undertaken by surgeons highly experienced in the technique. The majority of centers will adopt a deferred approach to bile duct repair in the context of VBI to establish whether the vascular component of the injury will result in ischemic damage to the affected liver and biliary tree. In the context of a delayed early presentation (e.g., postoperative day 1) or late presentation (beyond 7 days), the arterial tree should be imaged, ideally with CT angiography, to confirm the arterial anatomy and define the precise extent of VBI.

Underestimating the Extent of Injury

A significant practical pitfall exists in underestimating the extent of the injury in cases of BDI and VBI. In the majority of injuries, surgery has occurred in the incorrect anatomical framework and the usual caution regarding careful dissection,

gentle tissue handling of critical structures, and judicious use of energy devices, particularly diathermy, has been misapplied. Furthermore, because operations in which a BDI has occurred are frequently reported to have been "more difficult than usual," with "more bleeding than usual," the extent of the injury can go beyond that initially expected from the exact site of the bile leak or transection point. Similarly, due to radial dissipation of energy applied during diathermy injuries of the CHD, what initially appears to be a pinpoint diathermy injury to the CHD may in fact progress into an extensive ischemic and thermal injury to a larger section of duct that may take several days to declare [6].

Immediate Repair

Many would advocate an attempt at primary repair of the BDI in the patient in whom BDI is recognized intraoperatively and a suitable second expert surgeon is available to attend the operating theater for advice and preferably take over as operator, and in whom there is no likelihood of significant vascular injury. If this is to be undertaken, exactly what surgery is required is dependent on the level and extent of injury, and the repairing surgeon should be aware of the high failure rate of immediate repair (63 % in one large series [16]) and the need to perform a Hepp-Couinaud repair, ensuring a wide hepaticojejunostomy extending up the left main hepatic duct. If a significant injury to the RHA is identified, as discussed above, the authors recommend delaying the repair to allow adequate collateralization through the transverse hilar network. However, in certain circumstances, it is acceptable for an experienced hepatobiliary surgeon to undertake a satisfactory repair, if this can be achieved without excessive dissection of the hilar plate, and therefore without further compromising the arterial supply.

Management of Strasberg Type A to C Injuries

Cystic duct stump leaks and accessory duct (of Luschka) leaks (Strasberg Type A) are usually diagnosed in the early postoperative period, often with the patient reattending hospital after discharge. These minor leaks are best managed by ERCP and biliary stenting with good outcomes. It is unusual for an isolated injury to an aberrant posterior sectoral duct (Strasberg Type B (occluded) and C (leaking)) to require reconstruction, and, if suture control of the leaking duct at the lateral edge of the gall bladder fossa is not immediately and easily achievable, the authors' recommendation is to perform laparoscopic washout and ensure the correct placement of an adequately sized tube drain in the subhepatic space to allow the segmental bile leak to dry up over a period of several weeks (Fig. 28.5). Surgical reconstruction is technically demanding and the risk-benefit assessment of Roux-en-Y hepaticojejunostomy to a nondilated isolated posterior sectoral duct orifice does not make

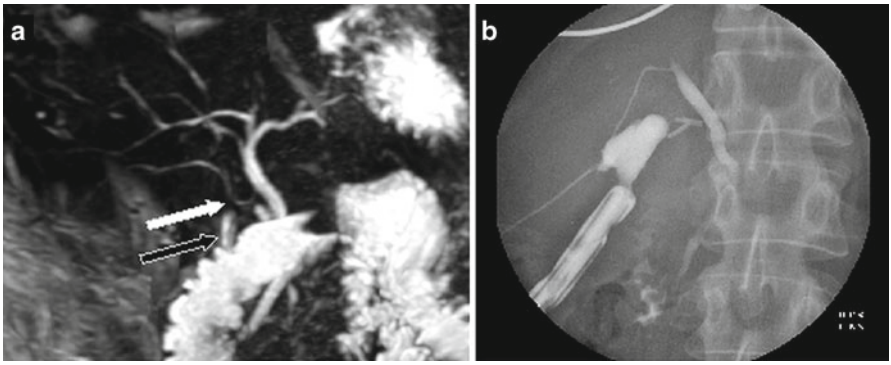

Fig. 28.5 Isolated posterior sectoral duct injury sustained at laparoscopic cholecystectomy. The patient had been discharged home and presented 1 week postoperatively with biliary peritonitis. Laparoscopy and washout was performed with placement of a tube drain in the subhepatic space. A tangential injury at the right-hand (lateral) edge of the gall bladder bed was identified. (**a**) MRCP showing an accessory posterior sectoral duct (*white arrow*) with low insertion into the CBD. The tip of the tube drain is visible (*black arrow*). (**b**) Tubogram at 2 weeks post-washout with contrast introduced retrogradely down the drain demonstrating communication with both portions of the accessory duct via a small volume reservoir. Clips on the cystic duct stump are visible in a satisfactory position. Normal anterograde flow of bile is seen in the main CBD and into duodenum. Sepsis and bile leakage were controlled and the leak was successfully managed conservatively. The leak resolved spontaneously in approximately 6 weeks after which the drain was removed

surgical sense in the context of an uninjured remaining biliary tree. ERCP and stenting are not helpful in isolated posterior sectoral duct injury as there is not usually communication with the main biliary tree. In this situation, the right posterior sector may atrophy over time. There is, however, a risk of developing recurrent sepsis in the undrained sector, and in time this may require resection, as discussed below.

Management of Strasberg Type D Injuries

Lateral injuries to the CHD or CBD without transection, affecting <50 % of the circumference of the duct, are associated with a concomitant vascular injury in 20 % of cases [4]. In a report of 10,123 laparoscopic cholecystectomies performed at a single center, the incidence of BDI was 0.2 %, and 70 % of those were Strasberg Type D [17]. The decision to perform a primary suture repair of the injured duct and arrange biliary drainage (through ERCP or T-tube) in addition to peritoneal drainage will depend largely on whether there was a thermal component to the injury. If the lesion has been made using diathermy or any other energy device, it is unlikely that the repair will be effective either in the short term as the injured tissues fibrose and retract, or in the long term, due to stricturing. In cases of thermal injury, particularly if extensive, it is recommended to completely excise the injured portion of duct

trimming back to healthy tissue and reconstruct the biliary tree by hepaticojejunostomy including the left duct. Technical recommendations for this are given below. In cases of a cold injury, i.e., partial section with scissors for example whilst attempting a cholangiogram, it is reasonable to attempt a primary suture repair, with adequate biliary drainage by ERCP and intra-abdominal covering drains. Placement of a supporting T-tube across the anastomosis is unnecessary and likely to be harmful. If immediate direct repair is undertaken, the surgeon should be aware that the failure rate is reported as 64.3 % in a large retrospective series [16].

Management of Strasberg Type E Injuries

The intraoperative recognition of a major BDI should initiate an immediate call for specialist expert assistance. The critical steps that need to be taken quickly and accurately are to, (1) define the level and type of BDI, (2) recognize the presence of associated VBI, (3) rapid appraisal of the general state of the patient in terms of comorbidity and intraoperative instability from sepsis or significant hemorrhage, and, most importantly, (4) decide whether the most appropriate personnel are present in the operating theater to make this assessment, make the decisions, and effect any repair.

All Type E injuries and thermal injuries to the CHD or CBD will eventually require biliary reconstruction. The decision to reconstruct the bile duct at the same operation as the BDI occurred is dependent on having a physiologically stable patient, free from sepsis, without an associated vascular injury. In the absence of these preferred conditions, immediate repair is not recommended due to a high chance of early failure. The revision rate of immediate Roux-en-Y hepaticojejunostomy reconstruction during the index operation in which BDI occurred is 62.9 % [16].

Hepp-Couinaud Hepaticojejunostomy: Technical Aspects

The technique of biliary reconstruction ensuring a wide and long hepaticojejunostomy using the left hepatic duct was described by Hepp and Couinaud in 1956 [18] but did not enter the published literature in English until 1985 [19]. The Hepp-Couinaud technique remains the gold standard for biliary reconstruction. An inverse J-shape incision or bilateral subcostal incision gives excellent exposure. A fixed retractor (e.g., Omnitract™ or Thomson Retractor™) is invaluable for facilitating this. An operating headlight and surgical loupes will enhance the accuracy of dissection and repair. Careful dissection of the undersurface of the liver is performed, and in particular the base of segment 4b is dissected clear so “lowering the hilar plate.” In the acute setting, clips on the cystic artery may be removed and the artery formally ligated. The distal CBD should be identified, and if it has been transected,

any clips should be removed and the distal duct sutured with an absorbable suture, for example, polydioxanone. In the delayed setting, this area will be significantly adherent and fibrosed, and it is not usually necessary or straightforward to identify the distal CBD remnant.

Careful dissection is continued on the anterior surface of the proximal CHD and the peritoneal reflection at the base of segment 4 identified overlying the hilar plate. With gentle traction on the hepatic pedicle (facilitated by a finger in the foramen of Winslow), the hilar plate is lowered to define the left hepatic duct. This may also require opening up of the gallbladder bed and dividing adhesions or any bridge of liver between segments III and IV. The goal is to achieve wide exposure of the damaged ducts and to perform a long wide choledochotomy, which is achieved by incising the CHD and extending it upwards and to the left side along the left hepatic duct. The incision is continued as far the arterial branch to segment 4b crossing from the LHA, but with great care not to injure this small branch. The small segment 4 arterial branch may be dissected free and retracted to the left to allow a further extension along the LHD to achieve a choledochotomy measuring 1.5–2 cm. Excessive extension to the left should not be undertaken as this risks ending up in multiple small subsegmental ductal orifices in the left portion of the hepaticojejunostomy. The right hepatic duct can be visualized through this orifice, and the choledochotomy may be extended towards the RHD if required, although this is rarely necessary given the long transverse lie of the extrahepatic portion of the proximal LHD. Careful dissection to free any adhesions and scar tissue is facilitated by a Cavitron Ultrasonic Surgical Aspirator (CUSA) which will accurately define ductal structures.

A 70 cm retrocolic Roux limb is fashioned to lie tension-free adjacent to the anastomosis. The key to successful repair is a careful accurate mucosa-to-mucosa anastomosis. The authors use a standard Bismuth-type interrupted biliary anastomosis with 5.0 polydioxanone sutures. Many centers advocate the retention of transanastomotic percutaneously placed biliary drains to stent the newly made anastomosis, but in the authors' practice this is not performed routinely, and certainly no new percutaneous biliary drains are placed if none are present at the time of reconstruction. The placement of an intra-abdominal tube drain in the subhepatic space behind the Roux limb is usual but is becoming less favored in the authors' current practice if the anastomosis appears sound/secure.

Although some centers advocate the use of the duodenum for reconstruction [20], this technique is not widely adopted, and in the case of an early leak results in more immediate problems. The authors have observed patients who have experienced significant symptoms from enteric reflux through this anastomosis in patients whose injury was repaired before referral. Secondary cholangitis and biliary cirrhosis have been observed in referred patients. The available literature on outcomes using this technique does not separate BDI from other elective liver operations requiring biliary reconstruction, and until long-term outcome data are available, it is not possible to recommend using the duodenum as a suitable alternative.

Delayed Early Repair

Even with routine use of the Hepp-Couinaud anastomosis, outcomes of immediate (intraoperative or within 7 days), especially with an associated VBI, may leave the patient exposed to recurrent biliary symptoms. It is highly advisable to delay any attempts at repair in the acutely unwell patient with sepsis or other significant organ dysfunction, and particularly in the event of VBI. Surgery in the acute stage will add further to an already stressed physiology and likely lead to a poor outcome, and an anastomosis that will ultimately require revision. Therefore it is advisable to gain control of bile leakage with external intra-abdominal drains, percutaneous transhepatic biliary drains, and adequately treat sepsis. A short general anesthetic for peritoneal washout, completion of the cholecystectomy, and placement of good drains should be considered as part of the surgical resuscitation and stabilization, but the surgeon should avoid the temptation to perform the definitive biliary reconstruction in the acute setting in the unwell patient. This approach is often useful in the patient in whom the BDI has not been recognized intraoperatively, and who may even have got home for a short period before being readmitted acutely unwell with biliary peritonitis and sepsis. A critical care environment is most appropriate for this patient group.

Late Presentation

The long-term consequences of BDI can present over the course of many years [21]. Recurrent episodes of sepsis due to inadequately drained segments may be the presenting features, and in more severe cases, secondary biliary cirrhosis may occur. Recurrent cholangitis can result in intrahepatic lithiasis. The undrained segments will atrophy over time, and this is exacerbated by a VBI [13]. A revision procedure for biliary reconstruction is commonly required and, in particular, for those BDI reconstructed in the early phase [16]. This is technically demanding surgery and not to be undertaken lightly.

Preoperatively, sepsis should be controlled as much as possible, which will often require antibiotic therapy and percutaneous biliary drainage of the affected segments, and attention paid to the nutritional state of the patient and requirement for parenteral vitamin K supplementation. In cases of suspected secondary biliary cirrhosis, Childs-Pugh scoring of liver function to assess risk should be performed, and the presence of esophageal varices excluded by endoscopy. Cross-sectional imaging to define ascites and examine the portal system to document cavernous transformation and the extent of intra-abdominal varices should be performed. Because some revisional surgery will require liver resection, it is critical to define the extent of cirrhosis preoperatively.

Liver Resection Following BDI

Certain situations arise following BDI for which the best treatment option is liver resection. The initial BDI is usually a Strasberg Type E4 or E5 injury [22], or E6, and most often a VBI with injury to the RHA. The indication for liver resection may be largely anatomical, for example if the confluence is so disrupted that a long distance intervenes between the left and right biliary systems (Fig. 28.6), or stricturing extends into the secondary biliary divisions on the right side, or may be because a portion of the liver is either nonfunctioning, ischemic, or becoming a risk to health from recurrent sepsis (Fig. 28.7). The latter situation arises from atrophy due to a combination of chronic biliary obstruction coupled with arterial ischemia, from recurrent sepsis due to undrained segments, abscess formation from arterial injury, or later on, consequences of recurrent cholangitis, for example intrahepatic lithiasis with chronic sepsis. Where the liver damage affects the entire organ and has caused significant secondary biliary cirrhosis with portal hypertension, liver transplantation may be the best option. However, where liver resection is possible, this should be considered, particularly in the non-cirrhotic liver.

The decision to proceed to right hepatectomy may be made easy by the findings of compromised vascular supply, inaccessible right sectional or segmental ducts, and right liver atrophy when the left liver is hypertrophied and/or the left duct is easily accessible allowing a wide bilioenteric anastomosis. Conversely, the finding of a small left liver may require a left duct approach with either drainage of the left ducts or a compromised anastomosis to the right ductal system which if it fails in the longer term would still allow an option of a delayed right hepatectomy.

The frequency of liver resection after BDI ranges from 1 % to 16 % [22–24]. Right hepatectomy is by far the most commonly performed resection, accounting for 80 % of hepatectomies [22]. Mortality is higher than in most series of liver resection, at 11.1 % overall in published cases, with some series reporting mortality as high as 27 % [25], and the biliary fistula rate in published studies ranges from 25 % to 39 %. Long-term outcome is good; for example in the patient series of Laurent et al. 13 of 18 patients were symptom free after a median of 8 years after hepatectomy [23].

Outcomes

Operative morbidity and mortality after BDI depends on age, comorbidity, untreated sepsis, and underlying liver disease. In particular, liver cirrhosis is associated with a high operative (within 30 days) mortality, ranging between 5 and 23 % [26]. The rate of recurrent biliary stricture is approximately 11–19 % in most series [27], and risk factors include biliary cirrhosis at the time of hepaticojejunostomy and sepsis

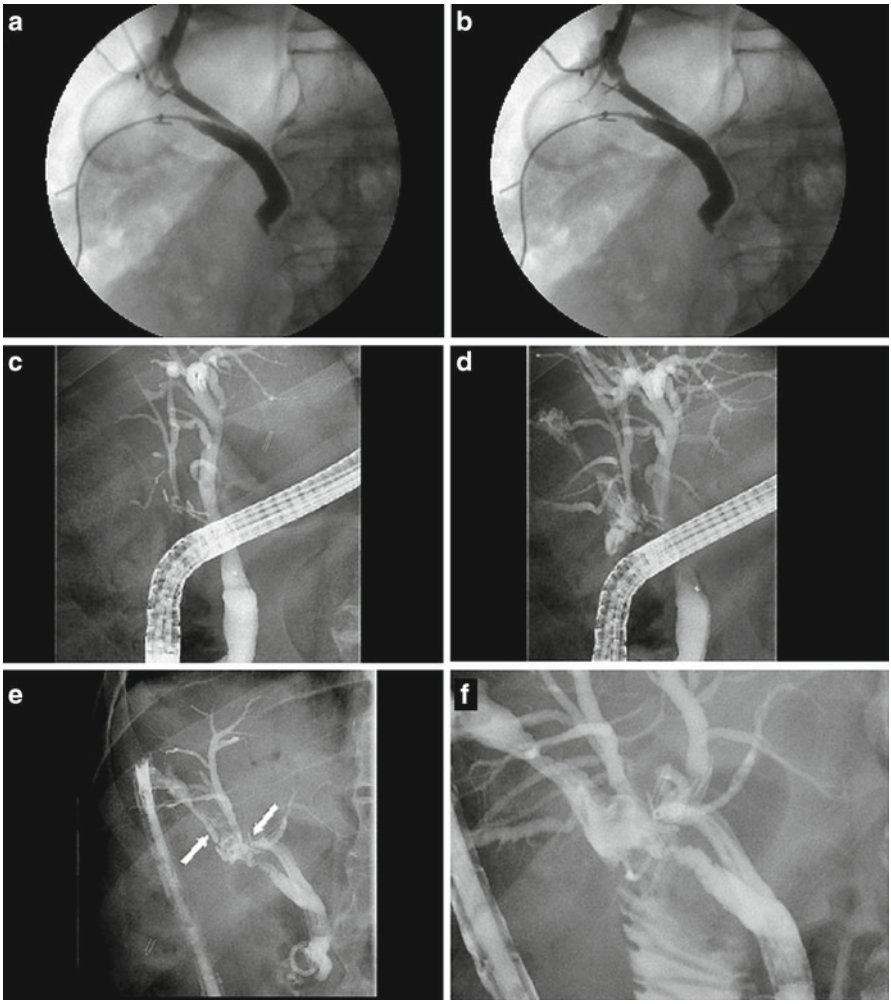

Fig. 28.6 A significant right main hepatic duct injury (Strasberg E5) likely to require right hepatectomy. This injury was recognized intraoperatively at laparoscopic cholecystectomy and the operation converted to open but the extent of the injury was underestimated at that time. (**a**) Initial image from the intraoperative cholangiogram performed via the cystic duct. Two clips ("X marks the spot") overlay the right main hepatic duct near its origin. The right anterior sectoral duct partially fills but is suggestive of injury or partial occlusion. (**b**) The next IOC image taken shows retrograde filling of some right posterior sectoral ducts which drain into the left main duct but no further filling of the anterior sector. Drains were placed. (**c** and **d**) ERCP on day 4 showing the left ductal system in continuity and clips at the origin of the right main duct with partial retrograde filling of the right anterior sectoral ducts. Further contrast injection shows leakage out of the duct with secondary filling of right-sided ducts no longer in continuity. (**e**). Tubogram filling the right ductal system demonstrating clips in an abnormal position (*white arrows*). (**f**) Close-up tubogram image showing an absent portion of the right hepatic duct between the incorrectly sited clips. This patient is being managed by drainage and sepsis control with a plan for interval right hepatectomy in 3 months

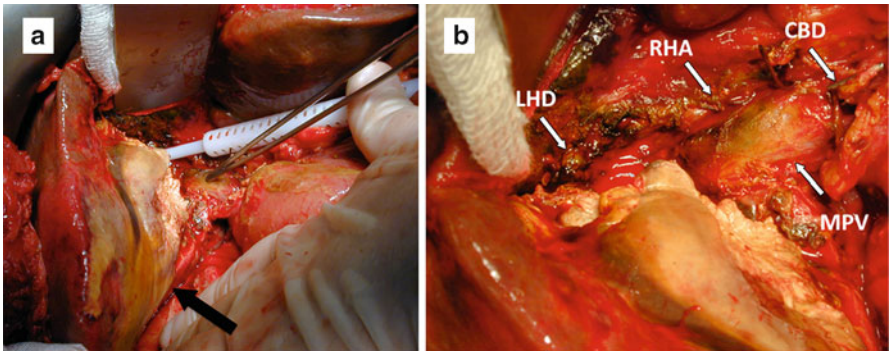

Fig. 28.7 A major vasculobiliary injury with complete excision of the extrahepatic bile duct (Garden E6). (**a**) Initial operative view shows obvious devascularization of the right hepatic lobe with necrosis (*black arrow*). (**b**) Careful exposure and identification of the extent injury shows a complete excision of the extrahepatic biliary tree. Indicated by *white arrows* are the left hepatic duct orifice (LHD), the right hepatic artery which has been clipped and divided (RHA), the distal remnant of the common bile duct which has been clipped and divided (CBD), and the entire length of the main portal vein that has been denuded (MPV). This patient proceeded to right hepatectomy and Roux-en-Y biliary reconstruction

at the time of primary repair are associated with increased long-term stricture rates [28]. These data include Hepp-Couinaud reconstructions done by experts at high volume centers. Although many reconstruction failures requiring revision occur within 2 years, 20–40 % present beyond 5 years after the initial surgery [26]. Long-term follow-up is therefore an important part of management, as the development of secondary biliary cirrhosis missed due to lack of follow-up may preclude revisional surgery and mandate liver transplantation. The rate of liver transplantation after BDI is low (5.7 % of patients in one series [29]), but not negligible, and always in the setting of secondary biliary cirrhosis.

It should be borne in mind that late development of cholangitic symptoms may result from reflux from a Roux limb that is compromised by adhesions favoring reflux of intestinal content into the biliary tree, or from a short Roux limb. The authors have also observed some patients whose recurrent cholangitis pursues a nocturnal pattern and has been found to be due to stasis in a redundant end of a previously constructed Roux limb. Investigation of these patients with CT or barium studies may be helpful in establishing whether revisional surgery short of resection or transplantation can be considered.

Medicolegal Considerations

In a large series of patients who had undergone BDI and surgical repair at Johns Hopkins Hospital, 62 of 167 patients responded to a quality of life questionnaire, 70.5 % sought litigation for their injury, and a similar proportion felt that they had

"won" their case [30]. In the United Kingdom, the majority of BDI for which the patients seeks redress through litigation are settled prior to court. It would be good practice in most healthcare organizations for a surgeon who injures the bile duct during elective laparoscopic cholecystectomy to inform his or her clinical director. Good practice and an institutional culture of safe patient care should include some form of audit of BDI and a reappraisal of the laparoscopic surgical technique employed to ensure that any one process, team, or individual is not an outlier with regard to BDI. Because in most occurrences of BDI the injury arises as a misperception of anatomy and errant anatomical orientation, the surgeon will find it difficult to avoid being deemed culpable for the injury. It is important to be clear that a mistake does not necessarily imply negligence on the part of the operator, although there are now accepted anatomical orientation strategies to minimize the risk of BDI and undertake safe laparoscopic cholecystectomy.

Quality of Life

All patients who sustain unexpected complications as a result of surgery are at risk of a decrease in health-related quality of life (HRQOL). Patients who sustain a BDI during the course of elective laparoscopic cholecystectomy are particularly at risk, although there are conflicting reports and opinions in the literature and among surgical profession and the medicolegal community. In a large series, patients reported negative effects of biliary drains on intimacy, appearance, practical activities of daily living, and embarrassment. Half of patients reported low mood and lassitude. Chronic pain is an issue, and more so in the longer-standing injuries [30]. Interestingly, mental QOL scores were worse overall in comparison to physical components of the scores [31]. Certainly, an effective biliary reconstruction appears to improve HRQOL compared to the preoperative state in one study examining exclusively Type E injuries, but whether scores ever return to those present prior to BDI is not known [32]. In a meta-analysis of six HRQOL studies after BDI, Landman et al. confirmed a long-term detriment on mental HRQOL after BDI [31].

Practical Considerations: SCARF

In summary, the key practical considerations when faced with a BDI are to do no further harm, evaluate the injury, and ensure that the most appropriate repair strategy is followed that is likely to result in the best long-term outcome for that patient. Specific considerations are summarized in Table 28.1 and follow the mnemonic, SCARF.

Table 28.1 SCARF: a practical approach to management of bile duct injury

S is for	Safety	Is the patient safe from further immediate harm?	Ensure adequate control of life-threatening hemorrhage
	Sepsis	Are adequate measures in place to treat sepsis?	Administer appropriate antibiotic therapy. Resuscitate appropriately
	Surgeon	Is the surgeon in charge of care the most suitable individual?	Consult an expert hepatobiliary specialist who was not involved in the primary injury
C is for	Containment	Have steps been taken to limit further extension of the injury?	Avoid further unnecessary or uncontrolled dissection which may cause or exacerbate vasculobiliary injury
	Control	Is there adequate and effective control of bile leak?	Place suitable external drains in the peritoneal cavity. Consider the requirement for percutaneous or endoscopically placed biliary drains
A is for	Artery	Is there an associated vascular injury?	Obtain CT angiogram to define the hepatic arterial system
	Anatomy	What is the precise anatomical extent of the biliary injury?	Obtain cholangiogram, either intraoperatively if safe to do so, or postoperatively by MRCP, by ERCP, or via percutaneous transhepatic biliary drain
R is for	Repair	Is the repairing surgeon experienced in the Hepp-Couinaud technique?	Perform a Hepp-Couinaud biliary reconstruction, extending along the left hepatic duct
	Revision	Is the previous biliary repair satisfactory?	With careful consideration to optimum timing, perform an expert revision by the Hepp-Couinaud technique
F is for	Follow-up	Are adequate follow-up arrangements scheduled?	Serial clinical assessment and imaging by MRCP and serum liver function tests should be in place
	Further surgery	Is there recurrent sepsis? Risk of secondary biliary cirrhosis? Other complications, e.g., intrahepatic lithiasis	Consider liver resection of the affected segments. Be aware that liver transplant is a recognized consequence of BDI

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