Symposium
Management of post-cholecystectomy bile duct injury: Review
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Key Words: Bile duct injuries, Management, Surgical reconstruction

Introduction
Bile duct injuries (BDI), occurring most commonly after cholecystectomy, present a formidable challenge that requires a multidisciplinary approach for optimum management. If unrecognized or managed inappropriately these injuries may not only lead to potentially serious complications such as cholangitis, biliary cirrhosis, and portal hypertension but also entail considerable cost, loss of work, and litigation. The advent of laparoscopic cholecystectomy (LC) and its rapid establishment as the gold standard for management of gallstone disease has refocused attention on BDI, their incidence, and management. The incidence of BDI during open cholecystectomy is reported to be approximately 0.1-0.2% [13]. The exact incidence of BDI following LC is not known, but is definitely higher than that following open cholecystectomy and reportedly varies between 0.4-0.6% [4-10]. It is also felt that biliary injuries following LC are more severe and complex than that encountered during an open cholecystectomy [11,12].

Classification of Bile Duct Injury
In order to define the types of BDI, several classifications of BDI have been proposed, but none is universally accepted as each of them has its own limitations. Of these, Bismuth's classification and Strasberg's classification are most commonly used by clinicians. Bismuth's classification [13] addresses the group of patients presenting with established biliary stricture and stratifies patients based on the level of injury, which is an important determinant of outcome. Sikora et al [14] modified the type 3 strictures into type 3a/3b depending on the floor of the confluence being intact or destroyed. Strasberg's classification [10] is applicable for acute injuries with bile leak, lateral injuries, and transection. The transection subgroup (type E) incorporates the Bismuth's classification. The major drawback of these classifications is that some important factors that influence the outcome are not accounted for, such as vascular injuries; timing of recognition of injury; presence of biliary fistula (external/internal); portal hypertension; atrophy/hypertrophy complex; and previous repairs, if any. The Hannover classification [15] is the most refined in terms of combining the Bismuth's and Strasberg's classification and has also addressed the vascular injuries. Hopefully, a universally accepted comprehensive classification system will be seen in the near future encompassing all the relevant parameters influencing long-term outcome [16].

Evaluation of patients
A detailed work-up and a meticulous preoperative preparation are important determinants of a successful management of a patient with BDI. The aim of preoperative work-up is to document the extent of liver dysfunction, establish the exact level and type of stricture, and to investigate for possible complications such as secondary biliary cirrhosis (SBC) and portal hypertension or an atrophy/hypertrophy complex. It is also equally important to diagnose associated medical risk factors, especially coexisting liver disease, and to detect and correct any existing nutritional, fluid-electrolyte, and coagulation disorders and control infection.

A complete hematological profile, liver and renal function tests, and a coagulation profile are obtained. Radiological imaging with ultrasound (US) and computed tomography (CT) are helpful in the initial evaluation of patients with biliary injuries. In the early period after injury, intra-abdominal collections can be demonstrated (and drained under US or CT guidance). In the later period, proximal biliary dilatation, level of biliary obstruction, and intrahepatic sludge/stones are well shown and CT may also show evidence of
vascular injury and reveal atrophy/hypertrophy complex, if present. However, the cross-sectional imaging modalities do not provide the detailed anatomical information on the type and extent of stricture, for which a cholangiographic examination is mandatory.

**Cholangiography**

The aim of cholangiographic evaluation is to define the Bismuth type of the stricture and document the extent of ductal dilatation. The entire biliary tree (all branches of the right and left intrahepatic biliary tree and the confluence intact) must be outlined for a complete assessment. This is accomplished by either a fistulogram, if there is an external biliary fistula or by a percutaneous transhepatic cholangiography (PTC). PTC should be performed either a day prior to or on the day of surgery under strict asepsis and parenteral antibiotic cover. All segmental ducts should be delineated (if required by multiple punctures) in order to define the type of stricture. Magnetic resonance cholangiopancreatography (MRCP) has now been accepted as the gold standard for noninvasive cholangiographic assessment of the biliary system. MRCP can diagnose biliary obstruction with a high sensitivity and specificity [17]. The sensitivity for the detection of biliary strictures is lower (67%), although the specificity remains high (98%) [18]. The ability of MRCP to provide anatomical details of the biliary as well as the vascular tree, along with a cross-sectional imaging to assess for atrophy/hypertrophy, etc. in a noninvasive manner makes it a potentially valuable tool in the evaluation of BDI [19,20]. In the era of MRCP, an invasive PTC is recommended in complex biliary strictures, especially Bismuth type 4 or 5 stricture with undilated ducts for a complete delineation of all ductal systems.

**Timing of Surgical Intervention**

The timing of repair of BDI is critical, especially when one realizes that the first attempt at repair is the best in terms of success and long-term results. In an elective situation, a minimum period of 46 weeks between injury and repair is desirable for resolution of tissue edema and inflammation and for dilatation of the proximal ductal system [21,22]. In patients with an external biliary fistula EBF, the injuryrepair interval may be extended to 8-12 weeks provided management of EBF is not complicated by fluid and electrolyte disturbances and skin problems. Undue haste in trying to deal with the injury by repair at an early stage is fraught with a high risk of bile leak (30%), stricture formation (25%), and even death (30%) [23].

**Surgical Reconstruction**

The definitive management of biliary stricture involves restoration of bile flow into the proximal gastrointestinal tract in a manner that prevents further cholangitis, sludge/stone formation, re-stricture, or progressive liver injury. Surgical reconstruction remains the gold standard against which other techniques such as percutaneous or endoscopic balloon dilatation and stenting need to be compared. Hepaticejunoanastomosis is the common method of repair for BDI. The key surgical principles associated with a successful repair of BDI are exposure of healthy, well-vascularized proximal bile ducts that drain the entire liver, and preparation of a suitable segment of intestine (most often a Roux-en-Y limb of jejunum >60 cm) for a mucosa-to-mucosa, tension-free anastomosis between the well-vascularized proximal bile duct/s and the jejunum.

The Hepp-Couinaud technique [24,25] of accessing the left duct under the base of quadrate lobe, where it runs a rather long extrahepatic course, provides a satisfactory and reliable method of locating the proximal duct. Lowering of the hilar plate by incising the Glisson's capsule at the base of quadrate lobe (segment 4) and incising the vasculobiliary sheath expose the main left hepatic duct, the confluence, and the origin of the right hepatic duct. It is not necessary to dissect and identify the distal bile duct or to resect the strictured segment (unless there is a suspicion of a malignant stricture), as it entails a potential risk for injury to the portal vein and hepatic artery. A side-to-side hepaticejunoanastomosis made by a longitudinal incision of extrahepatic left hepatic duct produces a wide anastomosis, minimizes dissection behind the biliary ducts, and decreases the risk of devascularization of the ducts [26,27]. Other procedures, which may be very rarely required in complex strictures where the conventional approach has failed, include the intrahepatic hepaticejunoanastomosis described by Longmire and Sanford [28] and the Smith's mucosal graft [29]. In difficult strictures with confluence involvement, excision of the base of segment 4 to access the healthy, vascularized proximal duct to perform a tension-free intrahepatic anastomosis has yielded excellent results [30,31]. The use of transanastomotic stents remains controversial. Some groups [32] use them routinely in
all cases (starting with preoperative placement to facilitate intraoperative duct dissection and identification). The premise being that in the early postoperative period, stents provide decompression of biliary tree, access for cholangiography or percutaneous interventional procedures, and over long term ensure a stable biliary anastomosis during the period of healing and scar contracture. Most groups [33,35] reserve stenting for difficult repairs. We do not routinely stent our bilioenteric anastomosis. In case of undilated system (duct diameter <5 mm), high strictures with unhealthy tissues, and unsatisfactory mucosa-to-mucosa anastomosis, we prefer to stent the patients for a period of 6-12 months. For long-term stenting, a transhepatic, transanastomotic stent placement is preferred, since the transjejunal stents are prone to migration and slipping [36].

Partial hepatic resection may be required in a proportion of patients (12-15%) to manage complex biliary injuries, liver atrophy secondary to associated vascular injuries, and multiple failed previous repairs [37-41]. Liver resection removes the fibrotic, atrophic segment and the diseased biliary confluence, thereby providing good access to the remnant bile duct for a safe healthy anastomosis [39,40]. Resections can be performed successfully with low/zero mortality, although with significant morbidity (50-60%) with excellent long-term success of 94% [39-41].

Liver transplantation is rarely indicated in patients with SBC and decompensation or in those with acute vascular injury and acute liver failure [41]. Several small series and case reports of transplant in the setting of biliovascular injury have been reported with mixed results [42-44]. Liver transplant in the setting of biliary injury is a complex exercise associated with significant morbidity and mortality [40,41].

**Associated Arterial Injury**

The incidence of hepatic arterial injury after cholecystectomy has been estimated to be 7% in an autopsy series of cadavers who had undergone an uneventful open cholecystectomy [45]. The incidence of arterial injury is higher, ranging between 12-39% [6,46,47], in patients who also have a concomitant BDI. Chapman et al [33] showed in a large study that combined hepatic arterial injury was demonstrated in 18 of 130 (13.8%) patients with BDI after “open cholecystectomy”. Routine celiac and superior mesenteric angiography in patients with major BDI reported 47% incidence of hepatic arterial injuries [48]. Right hepatic artery, or the replaced right hepatic artery, is the most common artery to be disrupted. Injuries may present either as occlusion, pseudoaneurysm, or complete disruption and a combined biliovascular injury may result in hepatic lobar ischemia, necrosis, and sepsis, with catastrophic outcome [49,50].

There is no consensus on whether to perform preoperatively a selective angiography or whether or not to perform arterial reconstruction for combined biliovascular injury in patients with major BDI. Gupta et al [51] reported three patients with right hepatic arterial occlusion combined with BDI during LC in whom arterial reconstruction was not performed. They showed that the arterial occlusion is a crucial risk factor for postoperative morbidity because liver necrosis, liver abscess, or ischemic injury of the intrahepatic bile duct can occur after reconstructive hepaticojejunostomy. They and others [27, 52] also reported that combined right arterial injury causes not only recurrent stenosis of hepaticojejunostomy but also delayed stricture of the intrahepatic bile tract in long-term outcome. Alves et al [48] and Stewart et al [53] observed combined biliovascular injury in 47% and 32% of patients, respectively, but there was no difference in the morbidity and long-term outcome in patients with or without concomitant vascular injury.

Preoperative angiography should be routinely performed to investigate combined arterial injury in patients with complex or high biliary injury during LC. In acute injuries, arterial reconstruction should be performed when the distal right hepatic artery can be exposed and can be reconstructed to prevent re-stenosis and ischemic complications. Biliary repair in this scenario is associated with a high morbidity and mortality [54-57]. In patients with delayed presentation, high anastomosis to the left duct and confluence ensures excellent long-term patency, as there is good revascularization by a robust collateral circulation via the hilar plate [48,49].

**Portal Hypertension and Bile Duct Injury**

Portal hypertension is seen in 720% of patients with BDI. Prolonged biliary obstruction leading to secondary biliary fibrosis/cirrhosis is the most common cause of portal hypertension [33,36,58,59]. Occasionally, portal vein injury with cavernoma formation or portal vein thrombosis due to recurrent cholangitis may lead to portal hypertension (PH). SBC is uncommon and incidence varies from 8-18% in various series [36,58]. Risk factors for the development of portal hypertension and/or SBC in patients with benign biliary stricture include long duration of obstruction as indicated by a long
symptomatic period, a long interval between cholecystectomy and hepaticojejunostomy, a history of cholangitis (especially recurrent attacks), and previous attempts at repair [36,58,60,61]. The approach to patients with BDI and PH is dictated by the level of injury, severity of portal hypertension, and hepatoduodenal collaterals and whether there is portal vein injury with thrombosis of cavernoma formation. In patients with portal vein cavernoma and extensive collaterals in the hepatoduodenal ligament, a staged approach with portasystemic shunt followed by a hepaticojejunostomy is the preferred approach. In majority of patients with SBC and mild-to-moderate PH, single-stage approach with a Roux-Y hepaticojejunostomy can be safely performed with excellent long-term results [36,58,59].

Results of Surgical Reconstruction

Operative Morbidity and Mortality

Compared with earlier reports, where the mortality ranged from 58% [62,63], in the last decade there has been a considerable decline in the operative mortality with many large series reporting zero perioperative deaths [64-67]. Considering that these results are from tertiary care centers where more severe injuries would be referred, usually after one or more previous attempts at repair, surgical reconstruction is a safe procedure in experienced hands. The factors that adversely affect survival [63,68] following repair include advanced age, significant comorbid medical conditions, biliary sepsis, and significant underlying liver disease. In patients with coexisting portal hypertension, mortality has been reported to be as high as 23% [33]. The morbidity is usually in the form of postoperative bile leak, cholangitis, intra-abdominal abscess, hemorrhage, and wound infection.

Long-Term Results

Several factors need to be considered when discussing long-term results following stricture repair. Duration of follow-up: The need for prolonged follow-up cannot be over-emphasized. It has been seen that although two-thirds of failure occur within 2 years and 80% within 5 years, as many as 20% of failures may occur after 5 years [68]. In one series [67], 40% of re-strictures were identified more than 5 years following the initial surgery. Hence, a minimum follow-up of 5 years or even more is required for assessment of results. Thus, the duration of follow-up is important when comparing results of different series as well as different treatment modalities.

Methods of follow-up: Although the exact system of evaluation may vary, most authors take into consideration the patients' symptoms, liver function tests, and the need for repeat intervention while categorizing the results. McDonald et al [67] have suggested a system of grading, incorporating the symptoms, liver function tests, and the need for further intervention. In this system, the results are classified as grade A (normal liver function tests (LFT) results, asymptomatic); grade B (mild elevation LFT results, asymptomatic); grade C (abnormal LFT results, cholangitis, pain); and grade D (surgical revision or dilatation required). Chapman et al [33] have also incorporated HIDA scan in assessment of these patients. Although the need for repeat intervention for re-stricture is taken as a poor result, subsequent salvage by surgery or nonsurgical methods is finally included as a good result by many. A triad of criteria incorporating symptoms, biochemistry, and radiology has been proposed to facilitate comparison of results between series as well as different treatment modalities [69].

Sikora et al [61] have proposed a modification in the follow-up grading system by suggesting that in addition to the above parameters, liver biopsy and grading of fibrosis should be an integral part of the grading algorithm. Patients with varying degrees of liver fibrosis and cirrhosis may have derangement of liver function tests despite a patent bilioenteric anastomosis documented on HIDA scan. These patients should be classified as good outcome and not be condemned as fair/poor outcome.

Most large series from tertiary care centers report a satisfactory outcome in 80-90% of patients (Table). Important factors reported in various series as predictors of adverse outcome include proximal strictures (Bismuth type 3 and 4), multiple prior attempts at repair, presence of hepatic parenchymal disease, portal hypertension, end-to-end biliary anastomoses, surgeon's inexperience, and biliary sepsis.

Quality-of-Life

Psychosocial repercussions of BDI are immense considering the fact that these patients are in the most productive years of their lives and often have nondisabling symptoms. They are prepared for a minimally invasive, perhaps daycare, quick-recovery procedure and then when faced with a serious complication requiring a major surgical repair by a specialist, it takes its toll. Despite excellent results of
surgery with good long-term patency, the quality-of-life (QOL) outcomes have not been well documented. Few studies reporting the QOL outcomes suggest paradoxical results; endoscopic treatment and long duration of treatment [72], and patients involved in litigation [73] have poor mental QOL results. Although nonsurgical treatment is touted as a less invasive, efficacious option, QOL results suggest that a good surgical repair is associated with as good results as that following a cholecystectomy [74].

Conclusions

Prevention is the best treatment of biliary strictures.

Table 1. Long-term results in patients with postcholecystectomy benign bile duct strictures

<table>
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<th>Overall failure (%)</th>
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References

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