Surgical Management of Bile Duct Injury

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Abstract

As the main cause of BDI is due to misidentification of the CBD/CHD being the cystic duct, the goal of dissection is a conclusive identification of the cystic duct. A few strategies have been proposed for this: (1) Dissection of the main bile ducts so that the uniting point of the CBD and cystic duct is identified; (2) The infundibular technique. (3); The critical view of safety technique and (4) Intraoperative cholangiography. (1) Laparoscopic dissection of the main bile ducts in order to identify the junction of the CBD and the cystic duct has been a method for reliable identification of the cystic duct prior to division. However, this method should not be encouraged as it is potentially very dangerous and the risk of damage to the CHD/CBD during dissection is increased. (2) In the infundibular technique, the cystic duct is isolated and followed into the gallbladder by dissecting the front and back of the triangle of Calot. When the cystic duct gradually becomes the gallbladder infundibulum, it is taken as evidence of identification and the structure may be divided. Although the infundibular technique have been commonly used and taught, it has disadvantages. The cystic duct may be hidden, especially in cases of inflammation and suboptimal lateral traction of Hartmann's pouch. This may lead to a false infundibulum with subsequent misinterpretation of the CBD as the cystic duct.

Keywords: Bile Duct Injury, surgical management

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Introduction

A BDI is associated with substantial morbidity [1]. The expected short hospital stay or planned day-care surgery of an uncomplicated cholecystectomy is in sharp contrast to the often complicated, prolonged and uncertain recovery after a BDI.

The majority of BDI are not detected during the initial cholecystectomy and the diagnosis is preceded by symptoms and complications due to bile leakage or stricture formation. Undiagnosed or improperly handled post-operative bile leakages have a high risk of subsequent generalized peritonitis. Biliary peritonitis has been shown to be an independent risk factor for death in comparison to other causes of secondary peritonitis, emphasizing the need for early diagnosis and intervention in this group of patients [2]. Percutaneous, endoscopic or surgical interventions and re-interventions add complexity and further risks, making the patients often committed to a decade of post-operative follow-up [1].

The morbidity and mortality risks associated with BDI are serious, but to fully comprehend the impact on afflicted patients, further studies with more carefully adopted selection criteria are needed.

Quality of life

In one of the first studies addressing quality of life, Boerma et al. assessed the impact of BDI on physical and mental quality of life (QOL) using the standardized questionnaire SF-36 [3]. Despite excellent functional outcome after repair, 106 patients sustaining BDI reported reduced QOL compared to non-injured controls.

De Reuver et al. reported a longitudinal QOL study of 403 patients that suffered BDI [4]. They compared QOL after, on average, 5.5 and 11 years following the BDI. Their results suggested that QOL was impaired compared to non-injured and no improvement during the follow-up period was observed. Further studies have confirmed these findings mainly regarding psychological factors, associating a worse outcome with prolonged treatment period and legal procedures. Patients suffering BDI are often disappointed and feel neglected by many surgeons' reluctance to admit their own mistakes, emphasizing the need for an honest doctor-patient communication and thorough information following BDI events.

Economic aspects

Surgery with complications goes with a need for substantial resources. An operation that leads to BDI adds not only hospital days, diagnostic radiology, expensive endoscopic or surgical interventions but also the costs of prolonged sick-leave and loss of production. A few studies have been conducted to estimate the economic impact of BDI. Andersson et al. calculated the annual costs per 1 000 000 inhabitants in Sweden by analyzing actual in-hospital costs and loss of production of minor and major BDI [5]. The average cost per patient was €21 837 for minor BDI and €107 568 for major BDI. After adjusting the figures by BDI incidence, the costs were estimated to be within the range of €136 787-€159 585 for minor BDI and €473 690-€608 789 for major BDI per million inhabitants.

In an American study, Savader et al. showed that for 49 BDI patients at the Johns Hopkins Hospital, Baltimore, Maryland, the average in-hospital costs associated with the complete treatment of the patients was $51 411 (€66 976), excluding the costs for sick-leave and loss of production [6].

From the medico-legal point of view, financial compensation is a measurement of the estimated economic burden associated with BDI. Statistically, surgeons are more at risk of litigation following laparoscopic cholecystectomy than they are after any other general surgical procedure, although with great differences between countries. In the UK, Roy et al. evaluated 83 claims following BDI during laparoscopic cholecystectomy between the years 2000 and 2005 [7]. An average of €64 681 were rewarded the patients and delayed recognition of the injury was correlated to increased risk of litigation.

Prevention of bile duct injury

By far the best way to treat BDI is by prevention. But is this possible?

Should a BDI be regarded as an unfortunate complication or is it a preventable error? In a Canadian survey, the majority of questioned surgeons felt that BDI could not be anticipated and as such is an inherent risk of the procedure. On the other hand, many surgeons have reported large series of laparoscopic cholecystectomies without a single BDI. To properly address this question, it is essential to understand the underlying mechanism of how BDI occur, most commonly by a misidentification or misinterpretation of biliary anatomy.

Way et al. analyzed 252 laparoscopic cholecystectomies with major bile duct injuries and came to the conclusion that in the vast majority of BDI, the CBD or CHD were misidentified for the cystic duct or the surgeon dissected too close to the CHD [8]. It was not faulty decision-making, lack of knowledge or plain clumsiness that caused the injury. Way et al. concludes that when surgeons inspect the gallbladder, the subconscious brain seeks a recognizable pattern to match the mental model of the biliary tree. The brain makes a subconscious identification of the cystic duct (an illusive decision in the case of a BDI) and it is extremely difficult to change this perception. In laparoscopy, the perception is mainly visual in contrast to open surgery, in which haptic feedback can guide the surgeon to a correct interpretation of underlying structures. This difference in perception may to some extent explain the increased BDI incidence with the laparoscopic approach.

To prevent BDI we thus have to find strategies aiding surgeons to make correct interpretations of the biliary anatomy; Risk factor identification makes the surgeon aware of patients or situations where the risk of misinterpretation is increased.

Development of surgical techniques that emphasize on making the few risky parts of a cholecystectomy more standardized and safe as well as the proper use of technology, e.g. IOC used in order to verify the anatomy.

Risk factors for bile duct injury

Advanced age

Old age has been suggested as a risk factor for BDI. Physiologic tissue changes with ageing may be a possible explanation for some of the increased risk. However, even though these studies controlled for confounding factors, it is likely that they suffer from residual confounding. Older individuals more commonly have higher comorbidity, and are thus more likely to develop complications such as acute and chronic inflammation and more frequently have adhesions obscuring the surgical field [9].

Gender

Male gender has been associated with difficult surgery during many abdominal procedures. The few population-based studies with sufficient power associate male gender to increased risk of BDI, although with questionable confounder adjustment.

However, the mechanism of such association is not fully understood. It is possible that the male abdomen is more difficult when it comes to laparoscopic surgery, as significant higher conversion rates have been reported among men. Furthermore, male gender has been associated with a higher rate of acute cholecystitis or sequele from previous acute cholecystitis which increases the surgical difficulties [10].

Another explanation might be that the proportion and distribution of obscuring intra-abdominal fat differs between genders.

Inflammation

As acute cholecystitis is associated with increased conversion rates and overall complications compared to uncomplicated gallstone disease, it has been almost generally accepted as a risk factor for BDI. However, the evidence for an association between acute cholecystitis and BDI is weak. Considering larger population-based studies addressing risk factors for BDI, no difference in BDI rates was observed between patients with and without inflammation. However, methodological limitations make the results less powerful. Giger et al. suggested that acute cholecystitis should not be regarded as a risk factor when comparing to a heterogeneous control group consisting of patients with symptomatic gallstone disease or chronic cholecystitis [1]. The only studies with reported significant increased BDI rates associated with acute cholecystitis are relatively small case series from single institutions with the most dramatic impact of acute cholecystitis seen during the first years of the laparoscopic technique [1].

Anatomical variations

Biliary tree anomalies have been reported to occur in 19-25% of patients, and constitute a risk factor for BDI [11]. Most commonly, a right hepatic segmental or sub-segmental duct drains separately into the CHD between the hepatic confluence and the cystic duct or directly into the cystic duct. These anomalies increase the possibility of misidentifying the aberrant duct as the cystic duct. If IOC is performed through an aberrant right segment or sub-segment duct, very few surgeons would recognize the “missing” segmental duct on the cholangiogram. It is thus the use of safe surgical technique that is most important in the prevention of BDI in cases of anatomical variations [12].

Surgeon-related risk factors for bile duct injury

The experience and characteristics of surgeons causing BDI have been addressed by many researchers. During the period of open cholecystectomy, Andrén-Sandberg noticed that the majority of surgeons causing the BDI were doing their residency [13]. In 1995, Moore et al. reported that 90% of BDI occurred within the first 30 operations performed by an individual surgeon [14]. Similarly, Gigot et al. reported a twofold incidence of BDI among surgeons with less than 50 cholecystectomies compared to surgeons with experience of more than 50 operations [15].

In their analysis of Medicare beneficiaries, Flum et al. showed that BDI occurred mainly during a surgeon’s first 20 cholecystectomies [16]. In addition, a survival analysis on the same cohort of patients showed slightly decreased mortality after BDI if the surgeon performing the cholecystectomy was a surgical specialist. However, a proper and dedicated laparoscopic training program has the potential to reduce this increased BDI incidence among inexperienced surgeons [17].

The association between BDI and inexperience was most noticeable in the early years of the laparoscopic technique and has diminished since laparoscopic cholecystectomy became standard of care. It is furthermore obvious that experience is not a guarantee against BDI, as many injuries are caused by surgeons with more than 100 laparoscopic cholecystectomies [18].

Safe surgical technique

As the main cause of BDI is due to misidentification of the CBD/CHD being the cystic duct, the goal of dissection is a conclusive identification of the cystic duct. A few strategies have been proposed for this: (1) Dissection of the main bile ducts so that the uniting point of the CBD and cystic duct is identified; (2) The infundibular technique. (3); The critical view of safety technique and (4) Intraoperative cholangiography.

(1) Laparoscopic dissection of the main bile ducts in order to identify the junction of the CBD and the cystic duct has been a method for reliable identification of the cystic duct prior to division. However, this method should not be encouraged as it is potentially very dangerous and the risk of damage to the CHD/CBD during dissection is increased.

(2) In the infundibular technique, the cystic duct is isolated and followed into the gallbladder by dissecting the front and back of the triangle of Calot. When the cystic duct gradually becomes the gallbladder infundibulum, it is taken as evidence of identification and the structure may be divided. Although the infundibular technique has been commonly used and taught, it has disadvantages. The cystic duct may be hidden, especially in cases of inflammation and suboptimal lateral traction of Hartmann's pouch. This may lead to a false infundibulum with subsequent misinterpretation of the CBD as the cystic duct [19].

(3) The critical view of safety technique, described by Strasberg in 1995, deals with the potential problems of the infundibular technique [20]. The method requires complete dissection of the triangle of Calot and separation of the base of the gallbladder from the liver bed prior to division of the suspected cystic duct. After proper dissection, only two structures enter the gallbladder, the cystic duct and the cystic artery, which can be divided safely. The critical view of safety should be considered as the golden standard technique of laparoscopic cholecystectomy with a likely reduction of misidentification injuries if properly used.

(4) With the introduction of laparoscopic cholecystectomy and the subsequent increase in BDI, IOC, formerly used mainly for CBD stones detection, was introduced as a "road-map" in order to avoid major BDI. Today, more than two decades since the laparoscopic procedure was introduced, the use of IOC to prevent BDI is probably one of the most debated and controversial topics in this field of surgery. It thus deserves a thorough analysis [21].

Intraoperative cholangiography

A search of intraoperative cholangiography and cholecystectomy in the online bibliographic database PubMed renders 1420 results, of which 260 have been published during the last 20 years. Despite the immense research on this topic, the level of scientific evidence is generally poor and the key questions of whether IOC prevents BDI and if it should be routinely or selectively used, are being far from settled.

Surgeons who do not use IOC, claim it to be unnecessary, costly and time consuming and that BDI can be avoided without using IOC. Selective users believe they can identify the subgroup of patients at high risk of BDI and apply IOC selectively on them. Furthermore, selective IOC users consider the patient's benefit, from the detection of unexpected common bile duct stones by IOC, to be limited not justifying the added costs. Routine users argue that it is not possible to identify patients with no risk of BDI and thus routine use is safer [22].

Alternatives to intraoperative cholangiography

A few alternatives to IOC have been suggested. The performance of a cystocholangiogram, through a catheter placed in the gallbladder, has been shown to accurately delineate the bile tree and has been proposed as a safer alternative to IOC [23]. However, occlusive stones in the gallbladder pouch or cystic duct, not uncommon in acute cholecystitis, substantially limit the usefulness.

Laparoscopic ultrasonography has the advantage of noninvasively being able to demonstrate the biliary anatomy and possible CBDS at least as good as IOC [24]. However, the technique is very user dependent with a need for ultrasonography skills. It is furthermore not readily available and is unlikely to become part of the toolbox of a general surgeon.

Intraoperative studies of the biliary tree have been achieved using Indocyanine Green (ICG). ICG is a water-soluble tricarbocyanine molecule that is almost completely protein-bound following intravenous injection. ICG is metabolized by the liver and excreted in bile. The angiographic feature of ICG is based on its fluorescent character in the near-infrared range between 790 and 805 nm, which can be detected by specialized infrared video cameras. The fact that ICG is metabolized in the liver and excreted via bile makes it an excellent medium for biliary tree imaging [25].

Detection and treatment of bile duct injury

A BDI is discovered during the primary cholecystectomy (approximately 30%), early after surgery or late, weeks to months after injury. A variety of treatment options are available ranging from simple draining to highly advanced reconstructive biliary and vascular surgery. It is important to do things right from the start, and the early involvement of hepatobiliary expertise cannot be emphasized enough [26].

Peroperatively detected bile duct injury

If not discovered during IOC, a peroperatively suspected BDI should be confirmed with IOC if this can be performed safely. Conversion and a subsequent primary repair should be performed by surgeons with experience in biliary reconstructive surgery, and further dissection, for confirmation of injury extent, should never be performed [27].

If no hepatobiliary expertise is available, it is preferable to not convert, insert a sub-hepatic drain laparoscopically and then refer the patient to a hepatobiliary unit for delayed repair. Primary repair by the same surgeon who caused the injury has been associated with poor outcome.

Stewart and Way reported only 17% successful repairs and Flum et al. reported an 11% increased mortality rate associated with repair attempted by the injuring surgeon [28].

The optimal strategy for an early repair still remains controversial. Small incisional injuries to the CBD or CHD are commonly repaired with direct closure and a T-tube. It may be successful but have also been reported to form strictures in almost every second case [29].

Completely transected ducts require more extensive reconstructive surgery. End-to-end repair has been reported to be unsuccessful in the vast majority of cases, even though the early reported devastating results may be somewhat exaggerated. The preferred reconstructive method is without doubt Roux-en-y hepaticojejunostomy, especially if the injury involves loss of ductal tissue or associated thermal or vascular injury. It is of great importance to delineate the extent of the injury and perform the anastomosis on vital, well vascularized ductal tissue, minimizing the risk of stricture formation within the anastomosis.

Postoperatively detected bile duct injury

Patients with postoperative symptoms as persisting pain, fever, nausea, jaundice or elevated laboratory findings (CRP, WBC and liver samples) should be evaluated with ultrasonography or abdominal CT, bearing a possible BDI in mind. A BDI not detected during the cholecystectomy may be revealed postoperatively either as a bile leakage and biloma or later, due to stricture formation, with jaundice and dilated bile ducts. The goal of the initial management is control of sepsis and on-going bile leakage with antibiotics and the placement of radiologically guided drains into fluid collections [30].

Once biliary drainage has been achieved and sepsis controlled, it is often preferable to allow the local inflammation to resolve, usually for several weeks, before the definitive repair.

A cholangiogram, either by endoscopic retrograde cholangiography (ERCP) or percutaneous transhepatic cholangiography (PTC), is of fundamental importance prior to injury repair as attempts for such without a preoperative cholangiogram have been reported to be unsuccessful in 96% of the cases [31]. Moreover, cystic stump leakages and minor leakages from peripheral ducts in the liver bed can, in the majority of cases, be handled endoscopically by down-stream control with sphincterotomy or/and stent placement. Additionally, ERC or PTC with dilatation and stenting is a treatment alternative when a BDI presents with jaundice due to stricture formation and with the bile ducts still in continuity [27].

MRCP is now commonly used as a noninvasive diagnostic tool in visualization of the pancreaticobiliary tree without injection of contrast media, exposure to ionizing radiation or the injurious puncture of PTC. It can be used to establish the presence and severity of biliary and pancreatic ductal dilatation, detect the length of the stricture as well as the exact cause and location of the obstructing lesion.

MRCP was first used in the 1990s. Since then it has undergone considerable technical evolution and maturation and has reached the stage at which MRCP has become an alternative to ERCP.

MRCP is based on heavily T2 weighted sequence that presents static or slowly moving fluids including bile as bright (hyperintense) structures against a dark (hypointense) back ground of surrounding organs. The initial MRCP studies were performed with gradient ECHO sequences by using 2D or 3D steady state free prescession sequence [32].

Concomitant vascular injuries

Vascular injuries are commonly associated with BDI with incidence estimates approximating 25% [33]. The most common injury affects the right hepatic artery (>90%) [33], with isolated portal vein injuries and combined portal vein and arterial injuries being rare but with the addition of substantial complexity.

Castaing [27] described the surgical anatomy of the biliary tract, highlighting the complexity and potential for misinterpretation. Hundt et al. [28] provide a detailed overview of biliary duct anatomy in StatPearls. Kafle et al. [29] conducted a cadaveric study focusing on anatomical variations of the right hepatic duct, emphasizing the importance of recognizing these variations during surgery. Sarawagi et al. [30] explored cystic duct variations in Magnetic Resonance Cholangiopancreatography (MRCP), illustrating the significance of imaging in understanding biliary anatomy. Skandalakis' Surgical Anatomy [31] offers a comprehensive resource for understanding the embryologic and anatomical basis of modern surgery, particularly relevant for grasping the intricacies of biliary anatomy and potential sources of BDI.

Mischinger et al. [32] discussed the limitations of the "critical view of safety (CVS)" technique and explored alternative strategies to avoid BDI. Mahadevan [33] reviewed the anatomy of the liver, providing essential context for understanding biliary anatomy and its relevance to BDI. Seeras et al. [34] reviewed bile duct repair, outlining different approaches and emphasizing the need for specialized expertise. Chun [35] analyzed different classifications of common bile duct injury, providing a framework for understanding the complexity of BDI.

Stewart and Way [36] conducted a detailed analysis of 300 cases of laparoscopic bile duct injuries, employing human factors and cognitive psychology to identify contributing factors and recommend preventative measures. Dolan et al. [37] examined the national volume of bile duct injuries requiring operative repair over a 10-year period, highlighting the persistent occurrence and need for ongoing research. Pucher et al. [38] conducted a systematic review and pooled data analysis of 30 years of laparoscopic cholecystectomy, providing valuable insights into the evolution of the procedure and the ongoing efforts to minimize complications like BDI.

Strasberg et al. [39] conducted a seminal analysis of biliary injury during laparoscopic cholecystectomy, providing valuable insights into the causes, prevention, and management of BDI. Bektas et al. [40] investigated the surgical treatment and outcomes of iatrogenic bile duct lesions after cholecystectomy, exploring the impact of various classification systems and highlighting the need for standardized approaches to management.

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