Post-cholecystectomy Bile duct injuries: A Retrospective Study

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Research Article

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Abstract

Background:

Bile duct injury (BDI) is still a major worrisome complication that is feared by all surgeons undergoing cholecystectomy. The overall incidence of biliary duct injuries still falls between 0.2–1.3%. BDI classification remains an important method to define the type of injury conducted for investigation and management. In recent years, a Consensus has been taken to clearly define BDI using the ATOM classification. Early management brings better results than delayed management. The current perspective in biliary surgery is the laparoscopic role in diagnosing and managing BDI. Diagnostic laparoscopy has been conducted in various entities for diagnostic and therapeutic measures in both minor and major BDIs.

Methods:

35 cases with iatrogenic BDI following cholecystectomy (after both open and laparoscopic approaches) both happened in or were referred to Alexandria Main University Hospital surgical department from January 2019 till May 2022 and were analyzed retrospectively. Patients were classified according to the ATOM classification. Management options undertaken were mentioned and compared to the timing of diagnosis, and the morbidity and mortality rates (using the Clavien-Dindo classification).

Results

35 patients with BDI after both laparoscopic cholecystectomy (LC) (54.3%), and Open cholecystectomy (OC) (45.7%) (20% were converted and 25.7% were Open from the start) were classified according to ATOM classification. 45.7% were main bile duct injuries (MBDI), and 54.3% were non-main bile duct injuries (NMBDI), where only one case 2.9% was associated with vasculobiliary injury (VBI). 28% (n = 10) of the cases were diagnosed intraoperatively (Ei), 62.9% were diagnosed early postoperatively (Ep), and 8.6% were diagnosed in the late postoperative period (L). LC was associated with 84.2% of the NMBDI, and only 18.8% of the MBDI., compared to OC which was associated with 81.3% of MBDI, and 15.8% of NMBDI. By the Clavien-Dindo classification, 68.6% fell into Class IIIb, 20% into Class I, 5.7% into Class V (mortality rate), 2.9% into Class IIIa, and 2.9% into Class IV. The Clavien-Dindo classification and the patient's injury (type and time of detection) were compared to investigation and management options.

Conclusion

Management options should be defined individually according to the mode of presentation, the timing of detection of injury, and the type of injury. Early detection and management are associated with lower morbidity and mortality. Diagnostic Laparoscopy was associated with lower morbidity and better outcomes.

Introduction

Post-cholecystectomy Bile duct injury (BDI) is associated with morbidity and mortality making it the most feared complication of cholecystectomy [1, 2]. BDI is in direct correlation with surgical experience and knowledge of cholecystectomy. Past studies in the last three decades stated that the incidence of BDI after laparoscopic cholecystectomy (LC) was significantly greater than that after open cholecystectomy (OC) (0.4–0.6% and 0.1–
0.2%, respectively). This was corresponding to the emergence of the laparoscopic technique in that era [3, 4]. However, later studies found a considerable decline in the incidence of BDIs after LC, to around 0.2%, due to the improved surgical laparoscopic experience [5].

Prevention of BDI remains the most important aspect in the application of the surgeon's learning curve. Prevention of BDI is through thorough knowledge of the mechanism by which a BDI occurs, understanding the critical view of safety, and a proper selection of patients [6–8]. The World Society of Emergency Surgery (WSES) guidelines in 2020, advocates the implementation of a “Bailout” surgery in cases of obscure anatomy, to prevent BDI [9]. Bailout surgeries include Subtotal Cholecystectomy, or Cholecystostomy insertion followed by interval cholecystectomy [9, 10]. Although Conversion to OC is an option to enhance visualization, there is no sufficient evidence to support the fact that conversion decreases the rate of BDI [9].

The timing of detection of BDI remains the most important variable in managing BDI, which significantly affects the outcome of the patients, regarding morbidity, general well-being, and mortality. Many studies were formulated to interpret the timing of injury detection in correspondence with the mortality rates, these data concluded that the time of BDI detection is important, but that there are very few cases of BDIs recognized intraoperatively, despite the wide ranges (25–92%) reported in the literature [11, 12].

To reduce major morbidity, it is crucial to identify BDI as soon as possible in patients who experience an unusual course after cholecystectomy. As a result, imaging techniques like ultrasound and computed tomography (CT) are very helpful during the initial assessment of a patient with a BDI. Intraoperative findings, clinical evidence, Diagnostic Laparoscopy (DL), and post-operative imaging, including Endoscopic Retrograde Cholangiopancreatography (ERCP), Magnetic Resonance Cholangiopancreatography (MRCP), Computed Tomography (CT), and Percutaneous Transhepatic Cholangiography (PTC) can all be used to identify BDI [9, 13].

Although re-laparoscopy is not yet advocated by the current guidelines, this modality is helpful in not only assessing and identifying the injury but also in managing BDIs. Re-laparoscopy can rule out duodenal injuries, treat minor BDIs, and extensively irrigates and drains the abdomen [14–16]. This method can be used to treat the injury conservatively or to stabilize the patient while the definitive repair is planned. Early post-operative referred patients with suspected BDI in the first 72 hours, are good candidates to relaparoscopy. Surgeons can be given the choice of whether to proceed with immediate repair or to delay the repair of the injury, depending on the location and extent of the injury, the patient's overall stability, and local expertise [16].

Nonetheless, classifying BDI remains an important aspect of the management of BDI. Surgeons have long struggled to define and categorize BDIs. Various approaches have been employed throughout the surgical literature, but no consensus was reached until the WSES guidelines of 2020, which advocated the use of the ATOM classification as a comprehensive classification [9, 17].

Although Surgical reconstruction of the biliary continuity is the mainstay of treatment, management options should be customized based on variables such as the timing of BDI diagnosis, and the presence of sepsis, or coagulopathy. Management of BDI is discussed according to the type of injury and the time of detection of BDI.

Patients and Methods
A retrospective cohort study analyzed 35 patients with post-cholecystectomy biliary duct injuries. All cases either happened in or were referred to Alexandria Main University Hospital surgical department, Egypt from January 2019 till May 2022. All patients complained of post-cholecystectomy biliary tract injuries encountered with different presentations and different timings from the surgical intervention. Careful examination was done with thorough clinical data taken. Data collected was carefully stated under a checklist designed by our department in 2020 and left for further reviews and studies. Older databases missed some data; however, most data were recovered through phone calls to the patients.

Post-operative methods for diagnosing BDI undertaken were both objective and subjective presentations followed by a thorough workup. Subjective presentations included abdominal pain, distension, nausea, fever, and malaise. Objective presentations included evidence of bile leakage from a post-operative drain, obstructive jaundice, sepsis, septic shock, and signs of biliary peritonitis. Ultrasound was done routinely in all cases with a suspected injury. However, highly suspected cases underwent a more rigorous workup, including MRCP, PTC, or ERCP. “Drain tube cholangiography” was also an option in patients with BDI diagnosed intra-operatively by a non-biliary surgeon who drained the biliary system with a tube (e.g., T-tube) and referred the patient to our hospital. CT scan was not done routinely, except in cases with prolonged control, to assess intraperitoneal collections and biloma or in cases that developed pancreatitis following ERCP. DL was chosen in certain cases to both diagnose the underlying disease and as an imperative therapeutic agent.

An intra-operative diagnosis of the Main Biliary Duct (MBD) injury, Strasberg E1-5, was managed by both conventional and laparoscopic bilioenteric anastomosis. Non-Main Biliary Duct (NMBD) injury, Strasberg A-D, was managed intraoperatively by either ligation of the leaking structure, or direct repair.

Managing options of BDI depended on the anatomic level, type, extent of injury, timing of detection, and the presence or absence of the vascular-biliary system. Patients were classified according to the Strasberg classification; However, in the recent year 2022, our department has changed its way of looking into biliary injuries to use the ATOM classification to define all biliary injuries. Thereby, Previous records in this study were re-classified by the ATOM classification.

Reconstructive surgery is the most definitive treatment for bile duct injury cases; however, not all BDIs need reconstructive surgery. Bilio-enteric bypass surgery was decided to treat intra-operatively detected BDI immediately and electively 6 weeks after drainage of both early postoperative and late diagnosed BDIs. Open and laparoscopic approaches have been done on different occasions in our facility. Our preferred method of bilio-enteric anastomosis was Roux-en-Y hepaticojejunostomy. Laparoscopic Roux-en-Y hepaticojejunostomy was fashioned one time in this study. Post-bilioenteric bypass leakage was either managed by pharmacological treatment and follow-up, or drainage, and interventional radiology.

we reviewed our cases and classified them according to Clavien-Dindo Classification [18], to assess and evaluate management modalities and their effect on patients with morbidity and their general well-being. The classification and comparison were based on the type of therapy required to treat the complication. The rationale to preserve this approach was to eliminate subjective interpretation of serious adverse events and any tendency to down-grade complications. To avoid imprecision in reporting complications, we avoided using qualitative terms, such as “major” and “minor” complications. We retained these terms to only classify BDIs and not their sequel.
Statistical analysis

Data was fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). The chi-square test was used in the comparisons of the managing options between groups, and the difference was considered to be statistically significant at $P \leq 0.05$.

Results

Patient demographics and pre-operative data

A total of 35 patients with bile duct injuries were identified and their clinical data was reviewed. Female to male ratio was 1.97:1, and the median age was 37.97 (range, 19–57). Patients were identified according to the type of operation, operative time, and method of cholecystectomy. 13 cases (37.1%) of bile duct injuries occurred at our hospital of Alexandria Main university hospital, and 22 cases (62.9%) were referred from secondary hospitals with suspicion of BDI, or a definitive diagnosis.

Indications of cholecystitis were identified retrospectively, where 65.7% had dyspeptic symptoms or a history of biliary colic, 20% had acute cholecystitis, and 25.8% had other modes of presentation.

MBD injury was identified in 16 cases, and NMBDI was identified in 19 cases. LC was responsible for only 18.8% of MBD injuries, compared to OC and converted cases which were responsible for 43.8% and 37.5% of MBD, respectively. However, the rate of NMBD injuries was much higher in LC (83%) compared to OC (10.5%) and converted cases (5.3%).

The conversion was recorded in 20%, where justifications of conversions were recorded, including obscured anatomy in 28.6%, previous multiple abdominal surgeries in 28.6%, previous cholecystostomy drainage in 14.3%, failure to control bleeding in 14.3%, and stone impaction at the neck in 14.3%.
Patients according to ATOM classification

Minor bile duct injuries (NMBD) were more detailed in the EAES classification (ATOM). We have identified 1 case (2.9%) with cystohepatic accessory duct injury (also called aberrant cystic duct), 8 cases (22.8%) were classified as the accessory duct of Luschka or aberrant Subvesical bile ducts, 7 cases (20%) with a leak from the cystic
stump due to a slipped clip, 1 case (2.9%) with an aberrant right hepatic duct, and 2 cases (5.7%) with lateral injury to the biliary tree without tissue loss. The type and extent of injuries were classified into partial division (37.1%), partial occlusion (14.3%), complete division (40.0%), and complete occlusion (8.5%). There was only one case reported with Vasculo-biliary injury (VBI) and hepatic abscess formation (2.9%).

Timing of detection was classified into three main groups: Intraoperative identification (Ei) (28.6%), early postoperative identification (Ep) (identified up to 3 weeks post-cholecystectomy) (62.9%), and late postoperative identification (L) (identified more than 3 weeks post-cholecystectomy) (8.6%). Ei was subdivided by the method of identification by either intraoperative cholangiography (2.9%), identification of duct injury by vision (devisu) (5.7%), or evidence of bile leak (bile leak) (20%). Ep was subdivided into cases identified within the first 72 hours (25.7%), and cases identified in the window between 72 hours and 3 weeks (74.3%).

The mechanism of injury was defined by the ATOM classification into either mechanical injury (Me) or energy-driven (ED); However, in our study, the mechanism of injury in 54.3% of the cases was unknown. We reported 37.1% were due to a mechanical injury (Me), and 8.6% were energy-driven (ED).
Table 3
Classification of bile duct injuries in 35 patients according to ATOM [17]

<table>
<thead>
<tr>
<th>ATOM Classification (n = 35)</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anatomical Level</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MBD (Major)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• MBD 1</td>
<td>6</td>
<td>17.1</td>
</tr>
<tr>
<td>• MBD 2</td>
<td>6</td>
<td>17.1</td>
</tr>
<tr>
<td>• MBD 3</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td>• MBD 4</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td>• MBD 5</td>
<td>2</td>
<td>5.7</td>
</tr>
<tr>
<td>• MBD 6</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>NMBD (Minor)</td>
<td>19</td>
<td>54.3</td>
</tr>
<tr>
<td>• Cystohepatic accessory duct</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td>• The duct of Luschka (hepatico-cholecystic bile duct) / Aberrant Subvesical bile duct</td>
<td>8</td>
<td>22.8</td>
</tr>
<tr>
<td>• A leak from the cystic stump (slipped cystic duct clip)</td>
<td>7</td>
<td>20.0</td>
</tr>
<tr>
<td>• Aberrant right hepatic duct</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td>• Lateral injury to CHD</td>
<td>2</td>
<td>5.7</td>
</tr>
<tr>
<td><strong>Type and extent of the injury</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial division</td>
<td>13</td>
<td>37.1</td>
</tr>
<tr>
<td>Complete division</td>
<td>14</td>
<td>40.0</td>
</tr>
<tr>
<td>Partial occlusion</td>
<td>5</td>
<td>14.3</td>
</tr>
<tr>
<td>Complete occlusion</td>
<td>3</td>
<td>8.5</td>
</tr>
<tr>
<td><strong>Vasculobiliary injury</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>34</td>
<td>97.1</td>
</tr>
<tr>
<td>Right hepatic artery</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td><strong>Time of detection</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intraoperative (Ei)</td>
<td>10</td>
<td>28.6</td>
</tr>
<tr>
<td>• Devisu</td>
<td>2</td>
<td>5.7</td>
</tr>
<tr>
<td>• bile leak</td>
<td>7</td>
<td>20.0</td>
</tr>
<tr>
<td>• IOC</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td>Early Postoperative (Ep)</td>
<td>22</td>
<td>62.9</td>
</tr>
<tr>
<td>ATOM Classification (n = 35)</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>----------------------------</td>
<td>-----</td>
<td>----</td>
</tr>
<tr>
<td>Anatomical Level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MBD (Major)</td>
<td>16</td>
<td>45.7</td>
</tr>
<tr>
<td>• &lt; 72 hrs.</td>
<td>9</td>
<td>25.7</td>
</tr>
<tr>
<td>• &gt; 72 hrs. &lt;3 weeks</td>
<td>13</td>
<td>74.3</td>
</tr>
<tr>
<td>Late (L)</td>
<td>3</td>
<td>8.6</td>
</tr>
<tr>
<td>Mechanism of damage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>19</td>
<td>54.3</td>
</tr>
<tr>
<td>Mechanical (Me)</td>
<td>13</td>
<td>37.1</td>
</tr>
<tr>
<td>Energy-driven (ED)</td>
<td>3</td>
<td>8.6</td>
</tr>
</tbody>
</table>

### Management of Intra-operatively detected BDI

BDI was diagnosed intraoperatively in 10 cases (28.6%); of which, 4 cases (11.4%) were MBD injuries, and 6 cases (17.14%) were NMBD injuries. Intraoperative detection was done by Intraoperative cholangiogram (IOC) in one case, after evidence of bile leak in 7 cases, and after noticing a defect (devisu) in 2 cases.

Triaging surgeries are surgeries done in cases where there are no experienced hepatobiliary surgeons. Two intraoperatively diagnosed MBD injuries were triaged: one by a T-tube inserted at the injury site to facilitate tube cholangiography and further repair, and another case was triaged by ligature of the common hepatic duct without marking of the biliary duct, which prolonged the postoperative management and entailed further biliary stenting with a PTD. ERCP with sphincterotomy was conducted on the T-tube triaged patient, to decrease the intra-biliary pressure, and facilitate biliary drainage. The two triaged cases were eligible for delayed hepaticojejunostomy 6 weeks later as a definitive reconstructive procedure.

There were two cases of intraoperatively diagnosed major BDI's that were reconstructed in the same setting by two different experienced hepatobiliary surgeons (who were also responsible for the BDI). One of the two definitive reconstructive surgeries was done laparoscopically and the other was conventional Roux-en-Y hepaticojejunostomy. The laparoscopically performed Roux-en-Y hepaticojejunostomy had good results with no leakage and needed no further intervention in follow-up; However, the conventional hepaticojejunostomy was followed by a biliary leak that was managed by an external PTD. At follow up the patient was well for 3 weeks and removed the PTD. There were 6 cases of the intraoperatively diagnosed duct of Luschka (hepatico-cholecystic bile duct) and aberrant Subvesical bile duct injuries, that were clipped or ligated using a 4/0 Vicryl or PDS suture, all six cases did well during the postoperative period and needed no further management.

### Management of post-operatively detected BDI

Postoperative diagnosis of a patient with a BDI was analyzed in 25 patients, 22 patients were diagnosed in the early postoperative period, and 3 cases were diagnosed in the late postoperative period. Subjectively, these patients reported nausea, fever, and malaise in 60%, and abdominal pain in 64%. Objectively, they have shown evidence of obstructive jaundice in 20%, sepsis in 8%, and documented bile leak in 72%.
Post-operative investigations were undertaken on all clinically suspected patients. Non-invasive investigations were the first investigations conducted in most cases. Abdominal ultrasonography was the initial investigation of choice, in 88%, Magnetic resonance cholangiopancreatography (MRCP) in 72%, and Computed tomography with intravenous contrast (CT-IV) in 60%.

Invasive investigations were chosen with caution, as they further affect the morbidity and outcome of the patients. The choice of intervention was implemented to not only diagnose, but also to manage the cases; therefore, it is important to carefully choose the intervention at hand to both plan for biliary drainage, and abdominal drainage.

Early postoperative (Ei) diagnosed bile duct injuries are further classified into two subgroups according to the urgency of intervention needed. MBD injury Cases diagnosed in the first 72 hours are liable for bilioenteric anastomosis if referred promptly to a tertiary hospital with hepatobiliary expertise, NMBD injury patients diagnosed in the same subgroup are also amenable to definitive repair.

9 patients (25.7%) were diagnosed in this subgroup (< 72 hours), all of which (100%) were treated with re-laparoscopy (p = < 0.001). ERCP was conducted on 33.3% of these cases as a supplementary modality of treatment in the same setting of anesthesia with re-laparoscopy (hybrid technique). Sphincterotomy was done in 22.2% to decrease the intra-biliary pressure and improve healing, and stent insertion, and sphincterotomy via endoscopy was conducted in 11.1% to bypass the site of injury.

13 patients (37.1%) were diagnosed after 72 hours from the primary operation. Delayed hepaticojejunostomy was the definitive treatment for 84.7% (n = 11) of the patients in this subgroup, and relaparoscopy was definitive in 7.7% (n = 1). However, one 46-years old case (7.7%) died in this subgroup due to severe post-ERCP pancreatitis. Percutaneous transhepatic biliary drainage (PTBD) was the main modality of investigation, and biliary drainage in 11 cases of this subgroup (84.6%), all of which were later amenable for bilioenteric anastomosis. ERCP was done in 23.1% of the cases, with stent insertion undergone in 7.7% and sphincterotomy only in 15.4%. Pigtail insertion was inserted in 53.8% of the cases in this timeframe for abdominal drainage of bilomas.

There were 3 cases (8.6%) diagnosed in the late postoperative period. Biliary drainage and abdominal drainage were needed in all 3 cases in this subgroup. 2 cases needed abdominal drainage with pigtail insertion and biliary drainage with PTBD, and one case (33.3%) was diagnosed with septic shock and was surgically explored to both drain the abdomen and insert a biliary stent. Surgically drained biliary stent was used to both decrease biliary spillage and enhance "tube cholangiography," for follow-up radiology before reconstruction. 66.7% of the patients in this timeframe needed pigtail insertion for abdominal drainage. Delayed hepaticojejunostomy was the definitive treatment for 66.7% of this subgroup. Mortality was recorded in one 22-years old case in this subgroup, due to delayed intervention, which led to electrolyte imbalance, and death, even after pigtail insertion and PTBD. ERCP with sphincterotomy was used to ensure low pressure in the biliary tract in one case.

ERCP was done in 12 cases, 4 of which (33.3%; n = 12) had failed, 1 case (8.3%; n = 12) had died after ERCP with sphincterotomy due to post-ERCP pancreatitis, 5 cases underwent sphincterotomy only (41.7%; n = 12), and 2 cases did sphincterotomy with stent insertion (16.7%; n = 12).
Table 4. Management procedures in 35 patients with bile duct injuries following cholecystectomies in respect of the timing of detection.

<table>
<thead>
<tr>
<th>Management options undertaken</th>
<th>Time of detection</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Early intraoperative (Ei) (n = 10)</td>
<td>Early Postoperative (Ep) (n = 22)</td>
<td>Late (L) (n = 3)</td>
<td>c²</td>
<td>MCp</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>PTBD</td>
<td>2</td>
<td>20.0</td>
<td>0</td>
<td>0.0</td>
<td>11</td>
<td>84.6</td>
<td>2</td>
</tr>
<tr>
<td>Successful ERCP</td>
<td>1</td>
<td>10.0</td>
<td>3</td>
<td>33.3</td>
<td>3</td>
<td>23.1</td>
<td>1</td>
</tr>
<tr>
<td>Sphincterotomy Only</td>
<td>1</td>
<td>10.0</td>
<td>2</td>
<td>22.2</td>
<td>2</td>
<td>15.4</td>
<td>1</td>
</tr>
<tr>
<td>Sphincterotomy + Stent</td>
<td>0</td>
<td>0.0</td>
<td>1</td>
<td>11.1</td>
<td>1</td>
<td>7.7</td>
<td>0</td>
</tr>
<tr>
<td>Surgical Exploration</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>1</td>
</tr>
<tr>
<td>Re-Laparoscopy</td>
<td>0</td>
<td>0.0</td>
<td>9</td>
<td>100</td>
<td>1</td>
<td>7.7</td>
<td>0</td>
</tr>
<tr>
<td>Primary bilioenteric anastomosis</td>
<td>2</td>
<td>20.0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>Delayed Hepaticojejunostomy</td>
<td>2</td>
<td>20.0</td>
<td>0</td>
<td>0.0</td>
<td>11</td>
<td>84.6</td>
<td>2</td>
</tr>
<tr>
<td>Ligature/clipping of Duct of Luschka</td>
<td>6</td>
<td>60.0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>T-tube Insertion</td>
<td>1</td>
<td>10.0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>Ligature of a main duct as a method of triaging</td>
<td>1</td>
<td>10.0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>Pigtail drainage</td>
<td>1</td>
<td>10.0</td>
<td>0</td>
<td>0.0</td>
<td>7</td>
<td>53.8</td>
<td>2</td>
</tr>
</tbody>
</table>

(PTBD) Percutaneous Transhepatic Biliary Drainage; (ERCP) Endoscopic Retrograde cholangiopancreatography; (χ²): Chi-square test; (MC) Monte Carlo; (p) p-value; *ligature of a main duct during intra-operative diagnosis is not recommended by current literature.

The severity of the injury was classified according to Clavien-Dindo. Of the injuries, 68.6% were classified as IIIb, 20% as I, 5.7% as V (mortality rate), 2.9% as IIa, and 2.9% as IV. The follow-up of patients surviving the post-operative period was 6 months. Both cases classified as V were NMBD injuries.

Hepaticojejunostomy was done in 17 cases (48.6%) of all cases diagnosed with BDI. Complications related to hepaticojejunostomy were wound infection 11.4% (4/17), and leakage in 20% (7/17), of which two cases...
needed further intervention.

Discussion

Biliary duct injury remains the most perilous complication of cholecystectomies, despite the increasing knowledge of gallbladder surgeries. Since 1996, LC has sought its trending course to become the gold standard technique. On the contrary, many reviews depicted a lower rate of BDI after OC (0.1–0.2%) compared to LC (0.4–1.5%) \[19\]. However, according to The Swedish Registry of Gallstone Surgery and Endoscopic Retrograde Cholangiopancreatography, the skills acquired to perform LC increased throughout the years, thus the rate of BDI following OC (2.8%) was more than that after LC (1.3%) \[20\]. In account of the increased surgical skills in LC, Halbert et. al. concluded that the overall rate of LC has declined to around 0.2% \[5\].

We agreed in a way with recent studies, in that 81.3% of our major BDI cases followed OC or converted cases; however, LC was responsible for 84% of minor BDIs. Overall, LC was responsible for 54.3% of all cases. We concluded that the rate of major BDI was more in OC, as the surgical skills of OC had been in a decline in recent years as advances in the laparoscopic surgical skills had been on the rise, and that the rate of minor BDI is in a rise hence the rate of LC has increased. We suggest that more studies should carefully aim to depict the incidence, and prevalence of BDI and compare the current rate of BDI after LC, OC, and robotic cholecystectomy.

Many studies in the literature agreed that the most important factor that decreases the rate of BDI is surgical skill and knowledge in the prevention of BDI. All surgeons must be oriented with a critical view of safety (CVS), respect the calot’s triangle during dissection of the calot’s triangle, and be oriented and prepared with all possible biliary tree and hepatic artery anomalies. Disregarding the CVS, the use of thermal hemostats close to the main biliary system, or strenuous traction on the cystic duct is associated with high rates of BDI \[6, 7\]. All surgeons should choose their patients, and the ideal timing of cholecystectomy, putting in mind the possible risks that would be encountered; for instance, performing a cholecystectomy for a patient with acute cholecystitis should be within 48 hours and no more than 10 days after the onset of symptoms \[9\]. Therefore, the choice of the proper timing for performing a cholecystectomy is advised.

WSES guidelines recommended the use of CVS during LC and advised bailout surgeries whenever the CVS is not achievable. Bailout surgeries include Subtotal Cholecystectomy, or Cholecystostomy insertion followed by interval cholecystectomy \[9, 10\]. Conversion to OC is an option in challenging cholecystectomies; Although, conversion was weakly evidenced to decrease the rate of BDI \[9\]. We found that 28.6% of BDI cases were due to misperception of anatomy and thus the CVS was not properly identified.

Difficult cholecystectomy is a subjective term used by surgeons to indicate the difficulties encountered during cholecystectomies. Although there is no clear definition in the current literature for the term, surgeons have long used the term for the prediction of hard cholecystectomies that entails higher surgical skills \[21, 22\]. As such, Difficult cholecystectomy is a major cause of biliary duct injuries \[21\]. However, referring that most BDIs are due to a difficult cholecystectomy without objective evidence creates bias. It is not clear whether surgeons prefer to associate their complications with the fact that it was a hard cholecystectomy. It does not matter how hard a cholecystectomy is, surgeons must be able to carefully detect the CVS before ligating any structure. Respect to the CVS significantly decreases the rates of BDI. In circumstances where CVS cannot be depicted, the surgeon must undergo a “bailout” surgery \[9\] (we have not recorded any case which had undergone a bailout surgery,
which may agree with the fact that bailout surgeries indeed avoid BDI). It is also important to note the importance of proper reporting of BDI, referring to the “ideal report” proposed by the WSES, which aims to facilitate proper identification of the hardships encountered during the procedure [9].

BDIs are detected in different frames of time. The earlier the timing of detection, the better the outcomes for the patient [9]. Intraoperative detection of BDI is not an easy task; however, if occurred, surgeons must be aware of what to be done next. The use of intraoperative cholangiography (IOC), and Indocyanine green-fluorescent cholangiography (ICG-C), have been proven to facilitate the detection of challenging biliary anatomy and detect BDI intraoperatively. However, there is no consensus, on the routine usage of these techniques in cholecystectomies [8, 9, 23]. A Meta-analysis undergone on 2,059 articles to evaluate the use of IOC, stated that BDI rates are lower with IOC than without IOC (depending only on the anatomical description) [24]. IOC was used in two cases in our study to help diagnose BDI.

WSES recommends that once a BDI is detected intraoperatively, an experienced biliary surgeon must be consulted to assess and evaluate the condition and undertake a repair. However, if no biliary surgeon is available, it is recommended to “triage” the patient with a biliary drain and refer the patient immediately to an experienced center for further management [9].

Intraoperatively diagnosed major BDI (Strasberg E1-E5) is best definitively managed by a hepaticojejunostomy, either open or laparoscopic, if and only if, an experienced biliary surgeon is available, as this is believed to decrease the risk of post-operative leakage. Minor BDI (Strasberg A-D) diagnosed intraoperatively can be definitively managed in various ways. Injury to the subhepatic bile ducts, for instance, is managed by ligation/clipping. A lateral injury without loss of tissue to a Common hepatic duct can be managed, after assessment by an IOC, by direct sutures, with or without a biliary tube (e.g. T-tube) [9].

Triaging surgeries aim to postpone the repair until an experienced biliary surgeon is available. Sadly, not all surgeons are aware of the technicality of triaging a patient diagnosed with BDI. Triaging BDI intraoperatively must only be aimed to drain the biliary system and place a drain in the subhepatic region, then immediately referring the patient [9]. It is not justified to ligate the main biliary duct, as originally believed in old literature. Ligating the BD prolongs the hospital stay, entails more intervention to drain the bile, puts the patient at risk for cholangitis, and makes it more difficult to identify the injured bile duct during repair, due to adhesions [9].

The mainstay of treatment of Bile duct injuries is the restoration of the biliary continuity. Ligation of the BD does not treat, yet it converts one type of injury to another. Furthermore, ligation of the biliary duct disrupts the vascular supply to the retained bile duct, as the blood supply of the biliary tree is downward-upward via the ascending marginal vessels from the posterior branch of the superior pancreaticoduodenal artery [25].

28.6% (n = 11) of cases in this study were diagnosed intraoperatively, of which, 2 cases undergone primary biloenteric repair (one laparoscopic hepaticojejunostomy, and another open hepaticojejunostomy), 7 cases were found to be minor injuries to the subhepatic ducts and were ligated, and 2 cases were triaged (one by a T-tube biliary drainage, another by ligation of CBD).

Unfortunately, none of the triaged patients were referred immediately to our center. Ligation of the CBD had further put the patient in a prolonged management pattern, as the patient developed hyperbilirubinemia, cholangitis, fever, and abdominal pain. Furthermore, the definitive bypass was delayed long enough, to treat the
sequel of such a maneuver. The patient was referred after 4 days of surgery, and PTBD was used to drain BD, to
treat jaundice and cholangitis. The patient was operated on for bypass after 10 weeks, after improvement of the
general condition, and surgery was even harder than anticipated, due to the recurrent attacks of cholangitis the
patient encountered. Thus, ligating BDs after the diagnosis of BDI intraoperatively delays rather than promotes
the patient’s health and well-being.

Postoperative diagnosis of BDI is an obligatory skill for all surgeons. Symptomatology of BDI may vary from
one patient to another, according to the type of injury and its extent. Subjectively, these patients often report
abdominal pain, nausea, fever, and malaise. Objectively, they may show evidence of obstructive jaundice, sepsis,
biliary peritonitis, or documented bile leakage from drains [26].

For patients with suspected BDI postoperatively, ultrasound remains the most used initial investigation as it
diagnoses intraperitoneal collections, and biliary and intrahepatic dilatation [13]. In this study, ultrasound was
conducted on 89% of patients, as a primitive scanning technique. Abdominal Computed Tomography (CT)
scans, on the other hand, were not conducted routinely (59.3%), except for patients with suspected vascular
injuries, or with signs of fever, to exclude intrahepatic abscesses. CT is usually conserved for cases where
Magnetic Resonance Cholangio Pancreatography (MRCP) is contraindicated, or for cases with suspected
vasculobiliary injury [13].

There is a general agreement toward the use of MRCP, as the gold standard, diagnostic modality in BDIs [9]. 74%
of our cases underwent MRCP and were classified accordingly. MRCP can be sufficient in most cases to
diagnose BDI and implement the management plan.

Tube cholangiography is an efficient non-invasive modality. Tube cholangiography is cholangiography via an
intraoperatively placed drain inside the biliary tree, conducted in properly triaged cases. It provides a feasible
diagnostic, and follow-up modality in cases with BDI. Tube cholangiography can delineate the biliary tree,
without the need for further investigations. In this study two cases had a tube cholangiography, one had it
inserted as an intraoperative triaging method (T-Tube), and the other was inserted in a surgical Exploration
conducted on a patient in septic shock. In both cases, tube cholangiography decreased the need for further
interventions.

Invasive diagnostic methods such as Endoscopic Retrograde Cholangiography (ERCP), Percutaneous
transhepatic cholangiogram (PTC), and Diagnostic Laparoscopy (DL) are not the preferred first options.
Although they provide efficient therapeutic add-ons. They are usually left as second options in investigating
BDIs. The literature encourages the use of ERCP, over Percutaneous Transhepatic Biliary Drain (PTBD) as its
insertion can be technically difficult because intrahepatic bile ducts are usually not dilated; moreover, PTBD is
advised if ERCP has failed [9]. However, our results disagree with this statement. Out of the 12 cases that have
undergone ERCP, 4 cases have failed, and 1 case has died due to post-ERCP pancreatitis, indicating the high
failure rate of ERCP in comparison to PTBD. Moreover, the complications of ERCP are irreversible, and moribund
(pancreatitis, and duodenal perforation), in comparison to the reversible complications of PTBD (bleeding,
cholangitis). PTBD is not only used as a diagnostic method to perform a cholangiogram but also a therapeutic
measure to drain and stent the biliary tree and bypass partial BDI to give it a chance to heal, reserving further
interventions. ERCP, however, has one advantage over PTBD, in that it has treated minor BDIs efficiently post re-
laparoscopy by sphincterotomy, as a modality to decrease intra-biliary pressure. Furthermore, PTC can delineate
the bile ducts more clearly and can be used in all cases, in comparison to ERCP, where discontinuity of the biliary tree, such as in cases of segment loss, hinders the performance of ERCP. Clinical trials should be conducted to compare both modalities in investigating and treating BDIs.

Relaparoscopy and diagnostic laparoscopy (DL), are two terms we used interchangeably; however, DL was used to indicate the technique used to diagnose BDI, while relaparoscopy was used to indicate the procedure to treat BDI. However, all 10 cases which underwent DL, had undergone a therapeutic intervention, which permits the usage of both terms interchangeably. Relaparoscopy has diverse uses as it allows intra-abdominal lavage, drainage of biloma, and intra-abdominal collection with the placement of a drain, clipping/ligating of any accessory ducts or an insecure cystic duct, inspection of the biliary anatomy with potential treatment (i.e., releasing a clipped CBD), performing cholangiogram, or placement of a biliary tube to facilitate tube cholangiography, which can be useful in identifying whether a persistent fistula remains in the biliary tree [16]. More trials should be undertaken to assess relaparoscopy in the management of BDI, as it seems an effective modality.

Relaparoscopy was used in 10 cases in the early postoperative period, no further intervention was obligatory; however, complementary ERCP and sphincterotomy were done to enhance the biliary drainage by decreasing the intra-biliary pressure. One case had ERCP, and a stent inserted before re-laparoscopy. It is recommended by the WSES, that cases presented in a tertiary hospital with major BDI, proceed for hepaticojejunostomy [9]. However, recent guidelines do not answer the role of re-laparoscopy, especially in the management of minor BDI, and its role in the early detection of BDI. In our study, we noticed that cases managed by re-laparoscopy in the early postoperative period avoided further sequel, in comparison to minor cases that were not managed by re-laparoscopy and were left for PTBD. Relaparoscopy was aimed not only for diagnosis, but also for lavage, drainage of the abdominal cavity, and definitively managing minor injuries.

In our study, relaparoscopy was not associated with further complications; furthermore, relaparoscopy was associated with faster diagnosis and better surgical outcomes than other modalities in the treatment of minor BDIs. The fact that the mortality rate was recorded in two minor injuries, raises the concern that minor BDIs should be studied more efficiently and that the role of relaparoscopy should be highlighted.

Managing cases with ERCP and stenting as the first modality should be evaluated in further clinical trials and studies. In our study, ERCP has been associated with a high failure rate (33.3%; n = 4) and was responsible for death in one case. On the contrary, ERCP was conducted as a first modality in one case that helped diagnose cystic stump ligature slippage and was used in its management by stent insertion; however, relaparoscopy aided in further management by applying a ligature to the cystic stump. Comparative clinical trials between ERCP and PTBD in the management of BDI should be conducted.

Classifying BDI remains the most important aspect in defining the injury, planning the management, and predicting the outcome of the proposed management. The ATOM is a thorough classification compared to all other classifications mentioned in the literature. Although it needs more knowledge, and practice to fully define a BDI using an ATOM classification, it remains a strong method that carefully depicts the type, extent, vascular association, timing of Injury, and mechanism of injury [17]. We have used both the Strasberg classification and the ATOM classification in defining our cases; Although it was harder to depict our cases using the ATOM classification, it was more apothegmatic and compact.
We reviewed our cases regarding the Clavien-Dindo classification [18], to assess and evaluate management modalities and their effect on patients with morbidity and their general well-being. The classification and comparison were based on the type of therapy required to treat the complication. Our justification was to eliminate subjective interpretation of serious complications.

Intraoperative primary repair has many advantages over delayed primary repair in that: it is performed under the same anesthesia, avoids referring the patient to another institution, shorter hospital stays, requires less intervention, causes less psychological trauma, and families are less likely to make malpractice litigations [27]. In our study, we noticed that intra-operative primary biliointestinal bypass was associated with lower Clavien-Dindo classes, as patients needed fewer postoperative interventions. hepaticojejunostomy is not confined to conventional surgeries, laparoscopic hepaticojejunoscopy is a useful modality that is condoned and undertaken to treat BDIs with less hospital stay and transfusion rates [28].

In this study delayed biliointestinal anastomosis, was fashioned by Roux-en-Y hepaticojejunoscopy. Hepaticojejunoscopy was constructed in 48.6%, 45.7% did not need any reconstruction, and 5.7% died before definitive management. Hepaticojejunoscopy is the mainstay treatment of BDIs in most scenarios [29]. Cases that did not need reconstruction were either because they were managed by other modalities such as relaparoscopy (28.6%) or were minor BDI and were managed intraoperatively (17.1%). Leakage was recorded in 20% of the cases, and 5.7% needed further intervention after biliary leakage. Biliary leakage post-biliointestinal anastomosis is a common complication, that can be resolved with proper drainage and medications. A retrospective cohort study in 2015 conducted on 120 cases showed a biliary leakage rate of 19.2% [30]. Management of biliary “failed” Roux-en-Y hepaticojejunoscopy can entail various surgical and interventional options. Patients with failed hepaticojejunoscopy may be amenable to liver transplantation [29].

**Conclusion**

Managing BDI remains a concern for all surgeons, and updates in the technologies should be properly utilized in managing BDI. Surgeons must be aware of primary triaging techniques and improve their knowledge regarding triaging bail-out surgeries, both to prevent BDI and avoid the accumulation of the risk of patient morbidity and mortality in the pre-reconstructive period. The role of re-laparoscopy should gain more interest in research, as it showed preliminary value in managing BDI.

**Declarations**

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Consent for publication

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References


**Figures**
Figure 1

An intraoperatively diagnosed BDI managed by laparoscopic Roux-en-Y hepaticojejunostomy. (a) shows the transected biliary duct, (b) A catheter inserted in the bile ducts for performing an IOC. (c) shows an IOC image taken with good flow to both lobes. (d), (e), and (f) show sutures being taken in the bile duct, preparing for hepaticojejunostomy. (g) primary hepaticojejunostomy performed, jejunal loop seen in the image adhering to the previously mentioned bile duct.
intraoperatively diagnosed patient with BDI that was triaged by ligation of the BD. PTBD was then inserted to drain the BD, and a reconstructive bilioenteric bypass was undergone after 10 weeks. (a) shows a PTD on the right side of the patient which was inserted weeks earlier and the previous scar of the operation. (b) shows a CHD after dissection and is ready for hepaticojejunostomy
Figure 3

A case of delayed management of BDI. (a) shows a Chiba needle inserted for dye insertion and PTC showing a lateral leak and stricture in the CHD. (b) Percutaneous transhepatic drain (PTD) was inserted external to internal to reach the duodenum and showed no extravasation of dye with positive contrast at the duodenum. (c) Follow-up PTC 10 days after the insertion of the PTD showing no extravasation of dye. Note a Pigtail in all 3 images transecting the view to a previously mentioned collection.
Figure 4

The Pie chart shows all cases of ERCP n=12 conducted in our study: (a) Failed ERCP 33.33 (b) Mortality caused by ERCP and sphincterotomy (8.33%) (c) Sphincterotomy only, after excluding the mortality case (41.67%) (d) Sphincterotomy and stent (16.67%). The right small pie chart demonstrates the stented cases where (d1) a Combined regimen of ERCP stenting and PTBD, and (d2) a solitary regimen of ERCP sphincterotomy and stenting alone.
Figure 5

Pie chart shows Types of PTD conducted to Manage BDI (n=14)

Figure 6
Figure 7

Pre-operative Cholangiography of a major bile duct injury, Strasberg E2
Figure 8

Intraoperatively detected bile leak – Strasberg A
relaparoscopy in a minor BDI. (a) lavage and exploration of the gallbladder bed revealed residual biloma that had been aspirated. (b) clipping of a small duct with a suspected biliary leak at the Subvesical region. (c) drain insertion.