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Evaluation of Bile Duct Injury Managements: Surgery and Endoscopy

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Abstract: Bile duct injuries (BDI) are serious complications following cholecystectomy, requiring careful management to ensure optimal outcomes. This study compares biliodigestive surgery and minimally invasive procedures, including ERCP, PTBD, and EUS-BD, to guide clinical decision-making. A retrospective analysis was conducted on 44 patients who experienced BDIs post-cholecystectomy from January 2023 to February 2025. Patients were grouped based on their treatment modality, and outcomes were assessed in terms of recovery time, complications, and long-term functional results. Statistical analyses using the SPSS Chi-Square test were performed to evaluate differences between the two groups.
Among the 44 patients, 10 died, while 34 clinically improved. ERCP emerged as the most successful minimally invasive procedure, with 20 successful interventions and only 5 failures. PTBD and EUS-BD showed moderate success, while biliodigestive surgery had a higher failure rate, with 8 out of 12 procedures unsuccessful. However, the statistical analysis revealed no significant correlation between treatment modality and improved clinical outcomes.
In conclusion, while minimally invasive procedures, particularly ERCP, offer lower morbidity and faster recovery, they do not demonstrate a statistically significant advantage over surgical interventions in terms of overall clinical outcomes. Biliodigestive surgery remains essential for managing complex injuries. Therefore, treatment selection should be tailored based on injury severity and individual patient conditions, emphasizing the importance of personalized treatment strategies.

Keywords: Bile Duct Injury, Cholecystectomy, Minimally Invasive Procedures, Biliodigestive Surgery

INTRODUCTION

The biliary system includes bile ducts, which are divided into intrahepatic (within the liver) and extrahepatic (outside the liver) structures. The intrahepatic common hepatic duct (CHD) is formed by the convergence of the left and right hepatic ducts, while the extrahepatic common bile duct (CBD) arises from the union of the CHD and the cystic duct. These ducts transport bile to the gallbladder, where it is stored until needed for digestion (Dave, H. D., Shumway, K. R., & Obaidi, N. M. Al., 2025). Bile plays a critical role in eliminating harmful lipophilic substances and serves as the primary pathway for

cholesterol removal from the body (Boyer, J. L., 2013). Biliary obstruction, a global health concern, occurs when bile flow from the liver to the intestines is disrupted, often due to conditions like gallstones (Elkin, D. C., 1924, Kruis, T., et al., 2020).

Gallstones, hardened deposits of cholesterol, bilirubin, and bile components, frequently remain asymptomatic but can trigger symptoms such as right upper quadrant pain followed by nausea and also vomiting. Symptomatic cases are typically managed through laparoscopic cholecystectomy, supplemented by endoscopic retrograde cholangiopancreatography (ERCP) or laparoscopic CBD exploration to remove stones (Jones, M. W., et al., 2025). Despite its benefits, laparoscopic cholecystectomy carries risks, including iatrogenic bile duct injury (BDI), a serious complication associated with significant morbidity and mortality (Kalyanashanmugam, S., et al., 2019).

BDI often stems from surgical challenges like misidentifying ducts due to anatomical variations, inflammation, scarring, or bleeding obscuring the surgical field (Kalyanashanmugam, S., et al., 2019) (Moghul, F., & Kashyap, S., 2025). Approximately 25–40% of BDIs are detected during surgery, while postoperative signs may include fever, abdominal pain, jaundice, or bile leakage. Severe cases can progress to sepsis or acute abdomen if untreated (Moghul, F., & Kashyap, S., 2025).

Current management strategies prioritize minimally invasive approaches. ERCP, combining endoscopy and imaging, is often the first-line intervention. Alternatives like percutaneous transhepatic biliary drainage (PTBD) or endoscopic ultrasound-guided drainage (EUS-BD) are considered if ERCP fails or is unavailable. Surgical options, such as biliodigestive anastomosis, are reserved for complex cases due to their invasiveness (Kalyanashanmugam, S., et al., 2019, Mishra, A., & Tyberg, A., 2019, Verma, N., et al., 2022, Pesce, A., et al., 2019).

RESEARCH METHOD

This retrospective analysis included 44 cholecystectomy cases of iatrogenic bile duct injury (BDI). These cases were either treated at or referred to the Internal Medicine or Digestive Surgery departments of Moewardi Regional General Hospital Surakarta between January 2023 and April 2025. Patients were categorized based on the type of cholecystectomy performed (open/laparotomy or laparoscopic), the severity of BDI according to the Strasberg classification, and the repair method utilized—including minimally invasive approaches (ERCP, PTBD, EUS-BD) or invasive surgical interventions

(biliodigestive surgery, Whipple procedure). Additional parameters analyzed included procedural success rates, mortality, time to BDI onset, and the timing of repair relative to injury detection.

Classification

To determine the BDI classification, Strasberg classification was used, dividing the range from major (Strassberg E) and minor (Strassberg A-D).

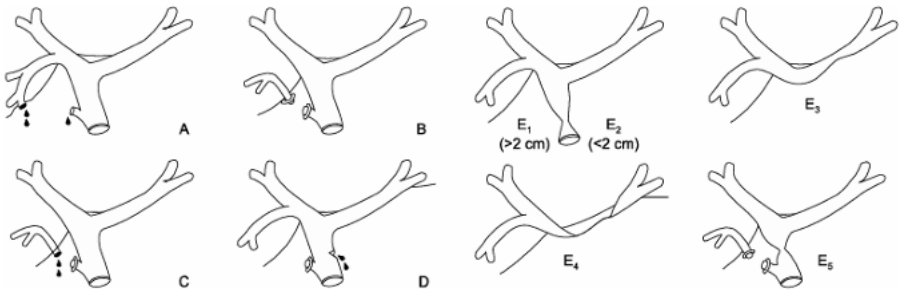

Figure 1. Strasberg classification

Repair procedure

The collected data will be grouped into whether the patient had laparoscopy cholecystectomy or laparotomy cholecystectomy.

BDI Intervention

The collected data will be grouped accordingly based on the intervention patients received, be it ERCP, PTBD, EUS-BD, or biliodigestive surgery and compared to the outcome of the surgery, whether the patient had clinical improvement or the patient died.

Onset of BDI and timing of procedure

Onset of BDI is classified into under and over 2 weeks and the timing of procedure is classified into under and over 1 week after diagnosis of BDI.

RESULT AND DISCUSSION

Table 1. Classification and Success Rates of Biliary Procedures and BDI Onset

Category	Type / Procedure / Outcome	N (%)

Classification of BDI	A	10 (22,73%)
	B	2 (4,55%)
	C	0
	D	9 (20,45%)
	E1	6 (13,64%)
	E2	6 (13,64%)
	E3	0
	E4	0
	E5	1 (2,27%)
	Unknown	10 (22,73%)
Classification of Initial Procedure	Laparoscopic Cholecystectomy	27 (63,64%)
	Laparotomic Cholecystectomy	16 (36,36%)
	Laparotomic Whipple Procedure	1 (2,27%)
Success rate of PTBD	Success	10 (22,73%)
	Failure	2 (4,55%)
	Unknown	32 (72,73%)
Success rate of ERCP	Success	22 (50,00%)
	Failure	5 (11,36%)
	Unknown	17 (38,64%)
Success rate of Biliodigestive Surgery	Success	5 (11,36%)
	Failure	9 (20,45%)
	Unknown	30 (68,18%)
Onset of BDI	< 2 weeks	16 (36,36%)
	> 2 weeks	28 (63,64%)
Time of Intervention	< 1 week	26 (59,09%)
	> 1 week	12 (27,27%)
	No Intervention	6 (13,64%)

This retrospective analysis examined medical records of patients who developed bile duct injuries (BDI) following cholecystectomy at Dr. Moewardi Hospital between January 2023 and April 2025. The study protocol was approved by the hospital's ethical committee. All referred cases were assessed by either a digestive surgeon or gastroenterologist, with the attending specialist determining the treatment plan. Due to the lack of standardized institutional protocols for managing post-cholecystectomy BDI, treatment decisions were based on the clinical judgment of the evaluating physician. The study included only patients who underwent cholecystectomy (via laparotomy or laparoscopy) and subsequently developed BDI, regardless of the initial reason for surgery.

Among the 44 cases reviewed, the majority were classified as Strasberg A injuries (10 patients), followed by 7 cases of type D, 6 cases of type E2, and 6 cases of type E1. Two patients were categorized as type B, and only one case was classified as type E5. Ten cases lacked a definitive classification due to insufficient clinical or imaging data.

In terms of surgical procedures, 27 patients had laparoscopic cholecystectomy, 16 had laparotomic cholecystectomy, and 1 underwent a laparotomic Whipple procedure. Of the 44 cases, 12 patients had percutaneous transhepatic biliary drainage (PTBD), with 10 successful procedures and 2 failures. Additionally, 27 patients underwent endoscopic retrograde cholangiopancreatography (ERCP), with 22 successes and 5 failures, while 14 patients had biliodigestive surgery, with 5 successful interventions and 9 failures. Regarding the onset of BDI, 16 patients developed BDI within 2 weeks, while 28 had an onset beyond 2 weeks. In terms of intervention timing, 12 patients had interventions within 1 week, 26 after 1 week, and 6 patients did not receive any intervention.

Table 2. Outcome of PTBD, ERCP, EUS-BD and Biliodigestive Surgery

	Success	**Failure**	**Not Done**	**P-value**
Outcome of PTBD	10	2	32	1.0
Outcome of ERCP	20	5	19	1.0
Outcome of EUS – BD	1	1	42	1.0
Outcome of Biliodigestive Surgery	4	8	32	0.576

Among the 12 percutaneous transhepatic biliary drainage (PTBD) procedures performed, 10 were successful, with 5 patients showing clinical improvement and 5 patients deceased. In the 2 failed PTBD procedures, 1 patient improved clinically and 1 patient died. Of the 32 patients who did not undergo PTBD, 28 demonstrated clinical improvement and 4 died. The statistical significance of the correlation between PTBD and patient outcomes was $p > 0.05$, indicating no significant relationship between PTBD and patient outcomes. In the 25 endoscopic retrograde cholangiopancreatography (ERCP) procedures conducted, 20 were successful, with 16 patients showing clinical improvement and 4 patients dying. Among the 5 failed ERCP interventions, 4 patients improved clinically and 1 patient died. Of the 19 patients who did not undergo ERCP, 15 patients improved clinically and 4 died. The significance of the correlation between ERCP and

patient outcomes was $p > 0.05$, suggesting no significant relationship between ERCP and clinical outcomes.

There were 2 endoscopic ultrasound-guided biliary drainage (EUS-BD) procedures performed, 1 of which was successful, with the patient showing clinical improvement. The other EUS-BD procedure failed, but the patient showed clinical improvement. The statistical significance of the correlation between EUS-BD and patient outcomes was $p > 0.05$, indicating no significant relationship between EUS-BD and the clinical outcomes. Among the 12 biliodigestive surgeries performed, 4 were successful, with 3 patients clinically improving and 1 patient dying. Of the 8 failed biliodigestive surgeries, 4 patients improved clinically and 4 patients died. Of the 32 patients who did not undergo biliodigestive surgery, 27 patients showed clinical improvement and 5 died. The correlation between biliodigestive surgery and patient outcomes was not statistically significant, with a p-value > 0.05, indicating no significant relationship between biliodigestive surgery and clinical outcomes.

The growing adoption and standardization of laparoscopic cholecystectomy have coincided with a rise in bile duct injury (BDI) rates. In the U.S., approximately 0.3–0.7% of 750,000 annual laparoscopic cholecystectomies result in BDI, translating to 2,250–5,250 cases. Over time, various classifications and interventions for BDI have emerged, underscoring the importance of early detection, injury severity assessment, and patient clinical status (Pesce, A., et al., 2019).

Endoscopic retrograde cholangiopancreatography (ERCP), a procedure combining endoscopy and fluoroscopy, involves advancing an endoscope to the duodenum and accessing the biliary/pancreatic ducts via the major duodenal papilla. Contrast agents are often used for radiologic imaging. Originally a diagnostic tool, ERCP has evolved into a therapeutic intervention (Adler, D. G., et al., 2020). It is now pivotal in BDI management, enabling leak localization and internal biliary drainage for minor injuries. ERCP is widely endorsed as first-line therapy (de'Angelis, N., et al., 2021), with repeat ERCP recommended if initial attempts fail (Sayed, M. M., et al., 2024).

Percutaneous transhepatic biliary drainage (PTBD) remains the gold standard when ERCP is contraindicated or unsuccessful (Pedersoli, F., et al., 2021). By diverting bile flow, PTBD promotes healing at injury sites and is advised for cases involving biliodigestive failure or biliobiliary anastomosis (Deniz, S., et al., 2023). PTBD, performed via percutaneous transhepatic cholangiography (PTC), involves needle insertion into the

biliary tree followed by catheter placement, serving both diagnostic and therapeutic roles (Glenn, F., et al., 1962).

Endoscopic ultrasound-guided biliary drainage (EUS-BD), a newer intervention for BDI, is indicated for benign or malignant obstructions when ERCP fails or is unavailable (Karagyozov, P. I., et al., 2021). Unlike ERCP, EUS-BD differs in biliary access location and stent deployment methods (Mishra, A., & Tyberg, A., 2019). Biliodigestive surgery requires anastomoses to be constructed using healthy, non-ischemic, and non-inflamed bile ducts. Surgical failures often stem from non-adherence to this principle (Feng, X., & Dong, J., 2017). Techniques include hepaticojejunostomy, hepatojejunostomy/portoenterostomy, and hepaticoduodenostomy (Goessmann, H., et al., 2012).

In this study of 41 cases, ERCP—the least invasive approach—proved most effective for BDI repair. At Dr. Moewardi General Hospital, 18 ERCPs succeeded and 5 failed. Chi-square analysis ($p > 0.05$) indicated a statistically significant correlation between ERCP intervention and patient outcomes, including clinical improvement or mortality.

CONCLUSION

This study aimed to evaluate the effectiveness of various interventions for bile duct injuries (BDI) following cholecystectomy, specifically comparing minimally invasive methods (ERCP, PTBD, EUS-BD) with biliodigestive surgery. The objective was achieved through a retrospective analysis of 44 patients, with clinical outcomes assessed using Chi-square statistical tests.

Among the interventions, ERCP demonstrated the highest clinical improvement rate (20 successes out of 25), while PTBD and EUS-BD showed moderate effectiveness. Biliodigestive surgery had the highest failure rate (8 failures out of 12). However, statistical analysis revealed that none of the intervention modalities had a significant correlation with clinical outcomes (p-values > 0.05 for all procedures), indicating that no single approach was superior in a statistically significant manner.

In conclusion, although ERCP showed promising clinical outcomes, the lack of statistical significance suggests that treatment success is influenced by factors beyond the intervention method alone. Therefore, we recommend that treatment decisions be personalized based on the patient's clinical status, injury complexity, and available expertise. Minimally invasive techniques like ERCP should be prioritized for simple injuries, while surgical interventions remain vital for managing complex cases.

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