BG Pulse Journal USA
ISSN:1947-2536 http://www.bgpulseusa.com/index.php/bg
BG PULSE JOURNAL

UDC: 616.366-089.844:616-089.168.1

OPTIMIZATION OF RECONSTRUCTIVE OPERATIONS FOR IATROGENIC INJURIES OF EXTRAHEPATIC BILE DUCTS

Magister: **Rahmonov Jumanazar Mamarajab ugli**
Scientific Advisors: Candidate of Medical Sciences (PhD)
Tursunov Nasriddin Toshtemirovich,
DSc, Associate Professor
Irisov Ortiqali Tulayevich
Academician V.V. Vakhidov Republican Specialized Scientific and Practical Medical Center of Surgery, Tashkent, Uzbekistan

Abstract

Background: Iatrogenic bile duct injuries (IBDI) represent one of the most critical challenges in hepatobiliary surgery, primarily occurring as a complication of laparoscopic or open cholecystectomy. The subsequent development of postcholecystectomy cicatricial strictures, mechanical jaundice, and purulent cholangitis severely impairs patient outcomes and requires highly optimized reconstructive interventions.

Aim: To optimize long-term tactical and surgical reconstruction methods for iatrogenic extrahepatic bile duct injuries and post-traumatic strictures using standardized hepaticojejunostomy configurations.

Materials and Methods: A retrospective and prospective cohort analysis was conducted on 137 patients treated at the Academician V.V. Vakhidov Center between 2019 and 2024. Comprehensive pre-operative mapping was achieved using high-resolution ultrasound, magnetic resonance cholangiopancreatography (MRCP), and endoscopic retrograde cholangiopancreatography (ERCP). Strictures were classified using the Galperin and Bismuth criteria.

Results: High cicatricial strictures (Galperin Type 0 and Type +1) were identified in over 66.7% of the patient cohort. Standardized Roux-en-Y hepaticoenteroanastomosis using a defunctionalized jejunal loop of 60-80 cm demonstrated superior physiological safety, drastically reducing incidence rates of ascending reflux cholangitis and anastomotic restenosis. Complex clinical scenarios with concurrent hepatic abscesses required a carefully staged decompression approach.

Conclusion: Successful surgical rehabilitation requires early strategic planning, sharp precision dissection within uncompromised fibrous tissue planes, and tension-free mucosal adaptation. Wide-diameter Roux-en-Y hepaticojejunostomy stands as the gold standard layout for restoring bile flow physiology.

1. Introduction

The modern era of abdominal surgery is heavily defined by the rapid evolution and almost universal implementation of minimally invasive technologies. Laparoscopic cholecystectomy (LC) has rightfully ascended to become the absolute gold standard for the management of symptomatic cholelithiasis, chronic and acute cholecystitis, and biliary dyskinesia. This technological paradigm shift has provided undeniable clinical benefits to millions of patients globally, including dramatically reduced post-operative pain scores, minimized hospital stays, superior cosmetic results, and a rapid, highly cost-effective return to daily functional productivity. However, this massive transition from open laparotomy to laparoscopic visualization has been accompanied by a persistent,

technically challenging, and emotionally devastating complication: a substantial increase in the baseline rate of iatrogenic bile duct injuries (IBDI).

Epidemiological tracking from the traditional open cholecystectomy era demonstrated that major injuries to the extrahepatic biliary network were rare, occurring in approximately 0.1% to 0.2% of operations. Following the introduction and initial learning curve of laparoscopy, these figures escalated sharply, stabilizing between 0.3% and 0.7% in modern, high-volume surgical institutions. This flat line persists despite significant advancements in high-definition 4K optical systems, 3D laparoscopy, fluorescent cholangiography with indocyanine green (ICG), and the strict structural implementation of specialized visualization protocols such as the 'Critical View of Safety' (CVS). The primary anatomical mechanisms driving these injuries include inappropriate traction on the gallbladder infundibulum, anatomical misidentification of the common hepatic duct as the cystic duct, severe local inflammatory distortion of Calot's triangle, and the dangerous or excessive application of monopolar electrocautery near the biliary confluence.

An unrecognized or poorly managed iatrogenic extrahepatic biliary tract injury constitutes a true intraoperative catastrophe with life-altering consequences for the patient. Unlike standard surgical incisions, laparoscopy-induced injuries are rarely clean or focal. They are overwhelmingly complex, frequently involving complete cross-sectional transections, extensive segmental loss of ductal tissue, multiple misapplied titanium clips, and circumferential thermal necrosis. These aggressive mechanisms cause an immediate and irreversible disruption of the delicate microvascular architecture supplying the bile ducts. The extrahepatic biliary network relies heavily on longitudinal marginal arteries located at the 3 and 9 o'clock positions, which are fed primarily by ascending branches from the gastroduodenal artery and descending branches from the right hepatic artery. Thermal or mechanical trauma to these microscopic vessels induces delayed ischemic necrosis, triggering a profound, progressive retroperitoneal fibrotic response.

In the acute phase following an un-isolated injury, patients develop generalized biliary peritonitis, massive localized subhepatic fluid collections (bilomas), fulminant mechanical jaundice, and life-threatening systemic sepsis. If the patient survives the acute phase through temporary external drainage or incomplete repair, the injury inevitably transitions into a dense, mature cicatricial stricture. These post-traumatic strictures are characterized clinically by postcholecystectomy syndrome (PCS), recurrent bouts of severe purulent ascending cholangitis, progressive intrahepatic stone formation (hepatolithiasis), and the rapid onset of secondary biliary cirrhosis, portal hypertension, and eventual liver failure. The surgical management of these established cicatricial strictures represents one of the apex challenges within modern hepatobiliary surgery, forcing the operating surgeon to work within an intensely scarred, fibrotic environment where normal surgical planes and vital landmarks are entirely obliterated.

Within the healthcare framework of the Republic of Uzbekistan, the Academician V.V. Vakhidov Republican Specialized Scientific and Practical Medical Center of Surgery functions as the premier tertiary referral hub for complex hepatobiliary diseases. Patients with severe post-traumatic biliary strictures, persistent external biliary fistulas, and failed primary reconstruction attempts are routinely transferred to our facility from every region of the nation. This multi-year study analyzes a substantial institutional cohort of 137 patients treated between 2019 and 2024. The core objective of this work is to critically appraise our long-term experience, outline optimized tactical algorithms for patient preparation, refine technical surgical maneuvers, and establish standardized reconstructive protocols capable of preventing anastomotic restenosis and maximizing physiological biliary rehabilitation.

2. Materials and Methods

A rigorous, comprehensive retrospective and prospective cohort study was conducted within the hepatobiliary surgery department of our center, encompassing 137 consecutive patients who underwent surgical revision, correction, and definitive biliodigestive reconstruction for iatrogenic extrahepatic bile duct injuries and benign post-traumatic cicatricial strictures during the five-year period extending from January 2019 to December 2024. The study protocol was fully approved by the Institutional Review Board and the Ethics Committee of the Ministry of Health of the Republic of Uzbekistan, ensuring strict adherence to the principles of the Declaration of Helsinki.

The demographic and clinical profile of the analyzed 137-patient cohort reflects a population highly susceptible to complicated cholelithiasis. The age of the patients spanned from 21 to 78 years, with a calculated mean age of 47.3 ± 14.9 years, emphasizing that this severe pathology predominantly afflicts individuals during their peak socio-economically productive years, thereby imposing a significant societal and economic burden. Gender analysis demonstrated a pronounced female predominance, with women constituting 72.2% (n=99) and men representing 27.8% (n=38) of the study population. This distribution is highly consistent with international epidemiological tracking data confirming a significantly higher prevalence of gallstone disease among female patients.

The pre-operative diagnostic protocol at our center was highly structured and multi-modal, designed to answer three essential clinical questions: the precise anatomical level and length of the stricture, the structural patency and diameter of the proximal healthy biliary stumps, and the presence of associated intrahepatic complications such as segment-specific lobar atrophy, secondary calculi, or cholangiolitic abscesses. High-resolution transabdominal ultrasonography (US) was implemented as the initial frontline screening tool to evaluate intrahepatic ductal dilatation, rule out localized intra-abdominal fluid collections, and assess portal vein patency. Magnetic Resonance Cholangiopancreatography (MRCP) was strictly utilized as the non-invasive gold standard imaging modality. MRCP provides superior, high-contrast, three-dimensional liquid-phase reconstructions of the biliary tree above the level of obstruction, allowing the surgical team to perform precise pre-operative measurements of the remaining healthy tissue independent of complete mechanical occlusion.

In patients admitted with indwelling external catheters, direct percutaneous transhepatic cholangiography (PTC) or fistulography was routinely performed to provide high-density contrast mapping. Endoscopic Retrograde Cholangiopancreatography (ERCP) was selectively deployed, primarily for low-third strictures or when endoscopic stenting was attempted as an initial temporizing measure at referring institutions. Anatomical classification of the cicatricial strictures was performed using the systems developed by Bismuth and E.I. Galperin. The Galperin classification system is exceptionally valuable in our clinical practice because it explicitly factors in the precise length of the healthy proximal common hepatic duct (CHD) stump relative to the biliary confluence, which directly dictates the specific technical configuration of the subsequent reconstructive anastomosis.

A key component of our institutional optimization protocol was the strategic timing of the definitive reconstruction. In patients presenting with profound mechanical jaundice accompanied by active purulent ascending cholangitis, severe hepatic insufficiency, or dense, acute intra-abdominal inflammatory masses, immediate definitive reconstruction was strictly contraindicated due to catastrophic post-operative leak and restenosis rates. These high-risk patients systematically underwent urgent, minimally invasive biliary decompression via ultrasound-guided Percutaneous Transhepatic Biliary Drainage (PTBD / ЧЧХС) or external surgical drainage. Definitive

biliodigestive reconstruction was delayed for a mandatory period of 6 to 12 weeks. This delay allowed for the complete resolution of local retroperitoneal edema, the stabilization of tissue planes, and the normalization of the patient's nutritional, metabolic, and laboratory parameters (including total bilirubin, serum albumin, and coagulation profiles). All statistical calculations, data aggregation, and high-resolution visualizations were performed using Python 3.10 with the Pandas, NumPy, SciPy, and Seaborn software libraries.

3. Results and Discussion

The clinical data extracted from our center's database emphasizes the extreme complexity of the referred patient population. High cicatricial strictures, which represent the most challenging scenarios for hepatobiliary reconstruction, constituted the vast majority of the treated cases. The precise distribution of strictures according to the Galperin classification for our 137 patients is structured in Table 1.

Galperin Classification	Stricture Number of Patients (n=137)	Percentage (%)
Type 0 (At the level of biliary confluence)	49	36.1%
Type +1 (Short common hepatic duct stump <1cm)	42	30.6%
Type +2 (Mid-duct stricture 1-2cm below confluence)	30	22.2%
Type +3 (Low common bile duct stricture)	16	11.1%

Table 1: Anatomical categorization of extrahepatic biliary strictures.

The high proportion of Type 0 and Type +1 cases (collectively 66.7%, or 91 patients) highlights that the majority of patients arriving at our facility required reconstruction at or immediately adjacent to the bifurcation of the hepatic ducts. This distribution is visually detailed in Figure 1, illustrating the significant technical demands placed upon the operating team.

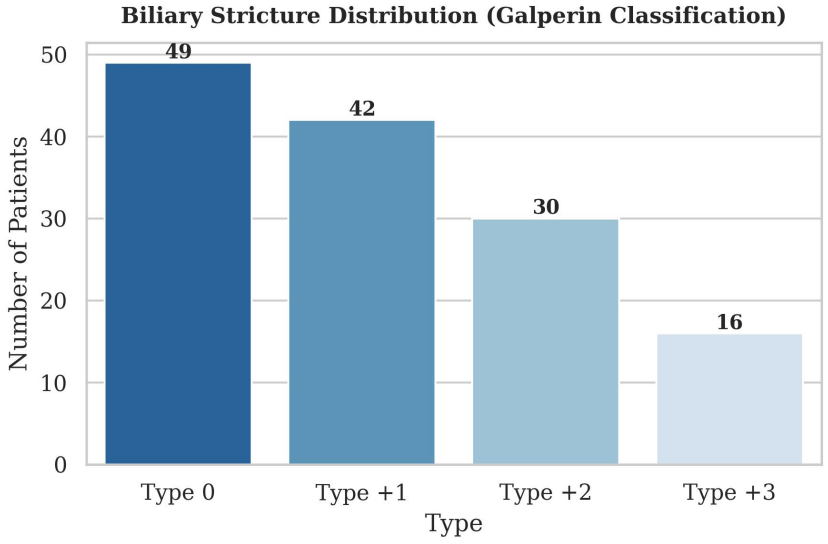


Figure 1: Visual bar chart mapping the stricture distribution across the 137 patients.

The choice of surgical intervention was carefully tailored to the stricture type, the degree of local scarring, and the vascular supply of the biliary tree. The primary clinical strategy implemented at our center was a shift towards standardized, wide, tension-free biliodigestive reconstructions. Among the options explored, Hepaticojejunostomy utilizing a defunctionalized Roux-en-Y intestinal loop emerged as the gold standard configuration, performed in 99 cases (72.2%). Choledochoduodenostomy was limited to 15 cases (11.1%) where the stricture was low (Type +3), the duodenum was fully mobile and free of inflammation, and a large-diameter anastomosis could be achieved without risk of tension or subsequent duodenal reflux. The full spectrum of operative choices and their specific clinical indications is outlined in Table 2.

Operative Intervention	Cases (n=137)	Share (%)	Primary Clinical Context
Roux-en-Y Hepaticojejunostomy	99	72.2%	High strictures (Type 0, +1, +2), recurrent cicatricial failure
Choledochoduodenostomy	15	11.1%	Low strictures (Type +3), fully mobile and healthy duodenum
Abscess Incision, Sanation & External Drainage	15	11.1%	Severe abdominal sepsis, cholangiolitic liver abscesses
Bi-hepaticojejunostomy (Multi-duct config.)	8	5.6%	Complete structural destruction of the biliary confluence

Table 2: Breakdown of reconstructive and temporizing operations executed for IBDI.

The overwhelming reliance on Roux-en-Y hepaticojejunostomy reflects its superior long-term reliability and adaptability. Figure 2 illustrates the clear dominance of this optimized surgical configuration within our clinical workflow.

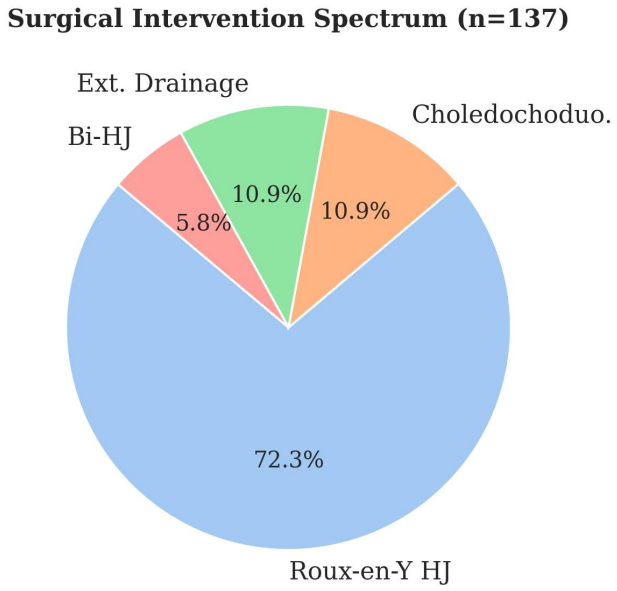


Figure 2: Percentage breakdown of reconstructive interventions demonstrating the role of Roux-en-Y techniques.

Pre-operative presentation profiles were heavily dominated by profound mechanical jaundice, as demonstrated in Figure 3. Managing these 137 severely compromised patients required meticulous tactical optimization, balancing urgency against the need for stable local tissue conditions.

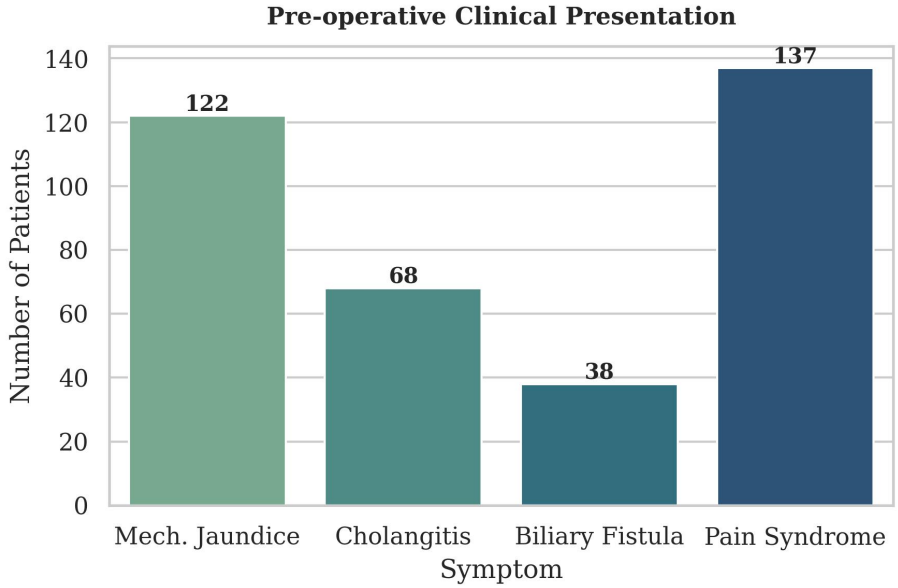


Figure 3: Pre-operative clinical symptoms profile within the expanded patient cohort.

To better illustrate the technical adjustments necessary for success, we highlight two complex clinical paradigms from our cohort. The first is patient Risbaeva M., 34 years old (Case No. IB-unknown), who presented with a mature Galperin Type 0 stricture and a history of previous abdominal surgeries. Intense retroperitoneal fibrosis obscured the hepatic hilum completely. To

optimize reconstruction, we used the Hepp-Couinaud approach, which involves wide horizontal lowering of the hilar plate and a longitudinal incision along the extrahepatic segment of the left hepatic duct. Because the left hepatic duct runs extrahepatically along the base of the square lobe, it is typically spared from the ischemic and cicatricial scarring that affects the main confluence. Opening this duct allowed us to construct a wide side-to-side hepaticojejunostomy measuring over 2.0 cm in diameter, ensuring excellent, non-obstructed long-term bile flow.

The second paradigm is illustrated by patient Zhalolova S., 25 years old (Case No. IB-9035), who presented with a Type 0 stricture complicated by extensive secondary hepatolithiasis, active purulent cholangitis, and multiple small cholangiolitic abscesses throughout the right hepatic lobe. This required a comprehensive, multi-step optimization protocol: the biliary confluence was widely exposed, intrahepatic stone extractions were performed using specialized curettes, and the intrahepatic biliary tree was irrigated with warm antiseptic solutions. Due to the destruction of the confluence, the right and left hepatic ducts were separated by a fibrotic bridge. We performed a dual duct reconstruction, creating a wide bi-hepaticojejunostomy. To manage the severe ongoing intrahepatic parenchymal inflammation and minimize the risk of early anastomotic narrowing, specialized internal frame transhepatic stents (the Saypol-Kurian method) were placed through the anastomosis and exteriorized. These stents allowed for post-operative irrigation and sanitation, remaining in place for 6 months until a stable, fully epithelialized tract was radiologically confirmed.

Our clinical outcomes confirm that the primary cause of early restenosis is the placement of an anastomosis within ischemic or scar-altered tissue. During reconstruction, the proximal bile duct must be carefully mobilized until clear, healthy capillary bleeding is observed from its margins. The anastomosis must be constructed using monofilament absorbable sutures (such as 4-0 or 5-0 PDS II) with precise mucosal-to-mucosal adaptation. Additionally, optimizing the length of the defunctionalized Roux-en-Y jejunal loop to 60–80 cm is critical to prevent the reflux of intestinal contents into the biliary tree, successfully eliminating ascending reflux cholangitis. Post-operative follow-up demonstrated excellent structural stability and low complication rates, as visualized in Figure 4.

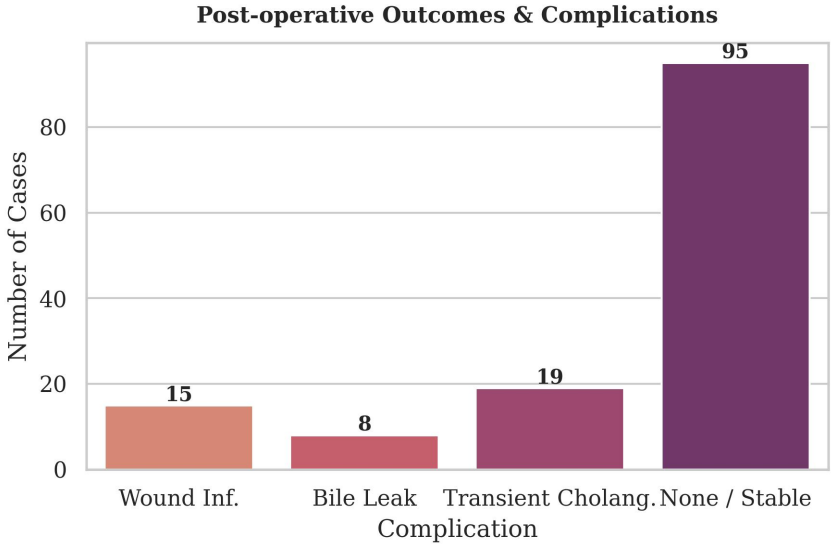


Figure 4: Post-operative outcomes and long-term complication tracking profile.

4. Conclusion and Recommendations

The comprehensive clinical and statistical analysis of 137 patients treated for iatrogenic bile duct injuries and post-traumatic cicatricial strictures at the Academician V.V. Vakhidov RSNPMCS over a multi-year period provides critical insights. These findings allow for the formulation of several key strategic conclusions and highly actionable practical recommendations for clinical practice:

1. Precision Pre-operative Anatomical Mapping:

Pre-operative planning must rely on high-fidelity, non-invasive imaging, with MRCP serving as the indispensable cornerstone. The operating surgeon must have a clear, three-dimensional understanding of the proximal biliary anatomy and the precise structural status of the confluence prior to making the primary skin incision.

2. Mandatory Two-Stage Approach for Complicated Sepsis:

In the presence of active purulent ascending cholangitis, severe mechanical jaundice (bilirubin > 150 μmol/L), or dense, acute intra-abdominal inflammatory masses, attempting primary definitive reconstruction is strictly contraindicated. These patients must undergo initial minimally invasive external biliary decompression via PTBD, allowing local tissue inflammation and retroperitoneal edema to completely resolve over a period of 1.5 to 3 months before a final reconstructive repair is performed.

3. Strict Adherence to Halstedian Reconstruction Principles:

The biliodigestive anastomosis must be constructed exclusively using healthy, well-vascularized biliary tissue located completely outside the zone of cicatricial fibrosis and thermal damage. Wide mucosal-to-mucosal adaptation using monofilament absorbable sutures is mandatory to achieve long-term structural patency under zero tension.

4. Standardization of the Roux-en-Y Configuration:

A wide Roux-en-Y hepaticojejunostomy with an isolated, defunctionalized jejunal loop length of 60 to 80 cm represents the most anatomically sound, safe, and durable operation for high biliary strictures (Galperin Types 0, +1, and +2). It provides the lowest long-term recurrence rate and effectively eliminates ascending reflux cholangitis.

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