Oncology, Nuclear Medicine and Transplantology
(eISSN 3105-8760)

Original Article

Combined Methods for Biliary Stricture Management: A Case Series

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Received: Oct 22, 2025
Accepted: Dec 16, 2025

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Abstract. Biliary strictures represent one of the most common complications after liver transplantation, occurring in 10-30% of recipients and significantly affecting patient quality of life and graft function. Combined hybrid approaches are increasingly widespread in contemporary practice.

Objective: To present a case series of successful application of combined methods for biliary stricture management in patients after liver transplantation and to analyze the efficacy and safety of these approaches.

Methods: A prospective observational study of three female patients (median age 57.0±7.8 years) after orthotopic liver transplantation with biliary strictures was conducted. All underwent a combined procedure using the rendezvous technique, integrating percutaneous transhepatic and endoscopic approaches with biliary stent placement.

Results: Technical success was achieved in 100% of cases (3/3). Clinical success with bilirubin reduction >50% was registered in all patients (3/3, 100%). Total bilirubin decreased from 71.3±22.8 μmol/L to 58.2±18.5 μmol/L by day 7 and to 32.4±8.6 μmol/L by day 30. No serious complications were registered (0/3, 0%). Mean hospitalization was 5.3±1.5 days (range 4-7 days). Mean procedure duration was 85±15 minutes.

Conclusion: The combined method demonstrated high technical feasibility (100%), clinical efficacy (100%), and a favorable safety profile with no serious complications, showing particular effectiveness in recurrent strictures. This approach can be considered as a promising alternative to isolated interventions in treating complex anastomotic biliary strictures.

Keywords: Rendezvous Procedure; Biliary Duct Stenting; Postoperative Complications; Percutaneous Transhepatic Cholangiography; Endoscopic Intervention; Hybrid Approach

Introduction

Biliary strictures represent one of the most challenging complications following orthotopic liver transplantation (OLT), occurring in 10-30% of recipients and substantially affecting patient quality of life, graft function, and long-term transplantation outcomes [1-3]. Despite considerable advances in surgical technique and perioperative management over the past two decades, biliary complications remain a pertinent issue in contemporary transplantation practice, particularly as transplant programs expand globally and undertake increasingly complex cases [4].

The pathogenesis of post-transplant biliary strictures is multifactorial, involving ischemic injury to the bile ducts, immunological factors, technical aspects of anastomosis formation, donor-recipient duct diameter mismatch, and infectious complications [5, 6]. Among these factors, arterial ischemia of the biliary tree plays a particularly critical role, arising from the unique dependence of bile ducts on blood supply exclusively from the hepatic artery [7]. This vascular vulnerability becomes especially pronounced in living donor liver transplantation (LDLT), where hilar dissection and smaller-caliber bile ducts increase the risk of both immediate and delayed ischemic complications.

Traditionally, post-transplant biliary strictures are classified as anastomotic and non-anastomotic, each requiring distinct management strategies [8]. Anastomotic strictures, which comprise approximately 70-80% of all biliary complications, typically develop within the first year after transplantation. These strictures are generally considered more amenable to intervention and carry a more favorable prognosis compared to non-anastomotic strictures, which result from diffuse ischemic injury to the intrahepatic biliary tree and often portend poorer outcomes [9-11].

The management paradigm for post-transplant biliary strictures has evolved substantially over the past three decades. Early transplant-era approaches relied primarily on surgical revision, involving either re-anastomosis or conversion to hepaticojejunostomy. However, surgical reconstruction carries significant risks in immunosuppressed patients, including perioperative morbidity rates of 30-50%, prolonged hospitalization, and potential compromise of graft function [19, 20]. These limitations prompted a shift toward less invasive approaches.

Endoscopic retrograde cholangiopancreatography (ERCP) with balloon dilation and stenting emerged as the first-line treatment for anastomotic strictures during the 1990s and early 2000s, demonstrating 70-90% efficacy with adequate stenting protocols [14, 15]. The technique offers several advantages: preservation of native anatomy, repeatability, and lower morbidity compared to surgery. However, ERCP has important limitations: it requires intact papillary access, may be technically challenging in patients with altered biliodigestive anatomy, and shows suboptimal outcomes in cases of tight, fibrotic, or recurrent strictures where guidewire passage becomes difficult or impossible [16].

Percutaneous transhepatic cholangiography (PTC) with drainage and dilation provides an alternative route when endoscopic access is not feasible. PTC allows direct antegrade access to the biliary tree and can be particularly valuable in cases of complete anastomotic obstruction or when retrograde cannulation fails [17, 18]. However, isolated percutaneous approaches have their own limitations, including need for prolonged external drainage, patient discomfort, risk of catheter-related complications, and challenges in achieving definitive treatment without endoscopic assistance.

Recognition of the complementary strengths and limitations of endoscopic and percutaneous techniques has led to development of combined (hybrid) approaches, particularly the rendezvous technique [21, 22]. This strategy integrates antegrade percutaneous access with retrograde endoscopic intervention, theoretically overcoming the limitations of either approach alone. The antegrade guidewire provides a stable platform for traversing difficult strictures, while simultaneous endoscopic access allows definitive stent placement and removal of percutaneous drains in a single session.

Despite growing interest in combined approaches, several critical questions remain inadequately addressed in the literature. First, most published series originate from high-volume Western transplant centers, with limited data from emerging programs in other geographic regions where donor demographics, resource availability, and post-transplant care infrastructure may differ substantially. Second, optimal patient selection criteria for the rendezvous technique versus sequential single-modality approaches remain poorly defined. Third, technical protocols vary considerably across institutions, making it difficult to establish standardized procedural guidelines. Finally, while short-term technical success rates appear promising, data on medium and long-term outcomes, including anastomotic patency, need for repeat interventions, and impact on quality of life, remain limited.

In Central Asia, where liver transplantation programs are rapidly developing, the prevalence of living donor liver transplantation is particularly high due to limited deceased donor availability. LDLT

presents unique challenges for biliary reconstruction: smaller bile duct caliber, multiple bile duct orifices requiring complex anastomoses, and greater susceptibility to ischemic complications due to extensive hilar dissection [9]. These technical factors may increase both the incidence and complexity of post-transplant biliary strictures, potentially necessitating more aggressive interventional approaches compared to deceased donor transplantation.

Our center in Astana represents one of the emerging transplant programs in Central Asia, with a predominantly LDLT-based program serving a diverse patient population with etiologies of liver disease that may differ from Western cohorts (high prevalence of viral hepatitis B and D, metabolic-associated liver disease, and hepatocellular carcinoma). The experience gained in managing biliary complications in this context may provide valuable insights for other developing transplant programs facing similar challenges.

The aim of this study is to present a prospectively collected case series demonstrating the technical feasibility, safety, and short-term clinical efficacy of a standardized rendezvous protocol for managing anastomotic biliary strictures in patients following liver transplantation at our institution. Specifically, we provide detailed description of procedural technique, report immediate and 30-day outcomes including biochemical response and complications, and analyze factors contributing to procedural success.

This case series contributes to the existing literature in several ways: (1) it provides data from a Central Asian transplant center, expanding geographic representation in the global transplant literature; (2) it focuses on a predominantly LDLT population with unique anatomical and ischemic risk factors; (3) it offers detailed technical description of the rendezvous procedure that may serve as a practical guide for centers developing interventional expertise; and (4) it presents short-term outcome data that can inform patient selection and procedural planning in similar clinical settings. While definitive conclusions about long-term efficacy require larger prospective studies, this series establishes proof-of-concept for the rendezvous approach in our institutional context and provides preliminary data to support future investigation.

Materials and Methods

Study design and rationale

This is a retrospective descriptive case series aimed at evaluating the technical feasibility and preliminary safety assessment of a combined approach using the rendezvous technique in patients following liver transplantation. Given the small sample size (n=3) and absence of a control group, this study is not designed to assess efficacy or provide statistical comparison with alternative methods. The primary objective is to demonstrate the feasibility of the method in a specialized transplant center setting and describe immediate outcomes, which represents a necessary preliminary step before planning larger comparative studies.

Sample size justification

The sample size was determined by the study time period (May 15-16, 2025) and availability of patients meeting strict inclusion criteria during this period. This is a pilot case series demonstrating proof-of-concept for subsequent prospective studies with larger participant numbers.

The study was conducted at the National Scientific Oncology Center in Astana through retrospective analysis of clinical data from patients who underwent the combined procedure.

Inclusion criteria:

- Patients following orthotopic liver transplantation
- Confirmed biliary stricture by instrumental diagnostic methods (ultrasonography, magnetic resonance cholangiopancreatography, computed tomography)
- Clinical and/or biochemical signs of cholestasis (elevated bilirubin, alkaline phosphatase, gamma-glutamyltransferase)
- Inability to achieve or failure of standard endoscopic access
- Patient informed consent for the combined procedure

Exclusion criteria:

- Severe coagulopathy (INR >2.0, platelets <50×10⁹/L) refractory to correction
- Massive ascites
- Sepsis or severe systemic infection
- Patient refusal of the procedure

Patient characteristics

The study included 3 female patients who underwent liver transplantation and developed biliary strictures. The median age was 57.0±7.8 years (M±SD). Detailed demographic and clinical characteristics are presented in Table 1.

Table 1. Demographic and clinical characteristics of patients

Parameter	Patient 1	Patient 2	Patient 3
Age, years	62	61	48
Sex	Female	Female	Female
Type of transplant	Left lobe, living donor	Living donor	Right lobe, living donor
Transplantation date	December 2023	June 20, 2024	December 19, 2024
Indication for transplantation	HCC T2NxM0 Stage II on background of cirrhosis (HBV+HDV), CTP B (9), MELD-Na 12	Overlap syndrome (PBC + AIH-1 + MASH), decompensated cirrhosis	Cirrhosis (HBV+HDV), decompensated, CTP C (11), MELD 22
Comorbidities	2 courses TACE	Bile leak, biliopleural fistula	Portal hypertension, grade 2 ascites, hepatic encephalopathy type C
Time from transplantation to stricture, months	3	12 (recurrent)	6
Stricture location	Biliodigestive anastomosis	Biliary anastomosis (recurrent)	Biliodigestive anastomosis
Stricture length, mm	12	15	8
Degree of stenosis, %	80	90	70

Patient 1: Female, 62 years old. Status post orthotopic left lobe liver transplantation from a living related donor, performed in December 2023. The indication for transplantation was hepatocellular carcinoma (HCC) T2NxM0 Stage II on a background of decompensated cirrhosis resulting from chronic mixed HBV+HDV infection, Child-Turcotte-Pugh (CTP) class B, score 9 points, MELD-Na = 12 points. Status post 2 courses of transarterial chemoembolization (TACE) with continued tumor growth. Biliary stricture was diagnosed 3 months after transplantation.

Patient 2: Female, 61 years old. Status post living donor liver transplantation (LDLT), performed on June 20, 2024. The indication for transplantation was overlap syndrome: primary biliary cholangitis (PBC) combined with type 1 autoimmune hepatitis and metabolic-associated steatohepatitis, with development of decompensated cirrhosis (portal hypertension, hypersplenism syndrome, ascites), complicated by persistent cholestatic syndrome (hyperbilirubinemia up to 140 μmol/L), despite ongoing immunosuppressive therapy and ursodeoxycholic acid (UDCA) treatment. The early postoperative course was complicated by bile leak, biliopleural fistula formation, and biliary anastomotic stricture. The patient underwent biloma drainage, endoscopic retrograde cholangiopancreatography (ERCP), endoscopic papillosphincterotomy (EPST), and percutaneous transhepatic cholangiostomy (PTCS). Twelve months after transplantation, recurrent biliary stricture developed.

Patient 3: Female, 48 years old. Status post orthotopic right lobe liver transplantation from a living related donor, performed on December 19, 2024. The indication for transplantation was cirrhosis resulting from chronic viral hepatitis B with delta agent, decompensated stage. Child-Pugh class C (11 points), MELD 22. Complications: portal hypertension, splenomegaly, hypersplenism, grade 2 ascites per IAC classification, hepatic encephalopathy type C (West-Haven), hepatocellular insufficiency. Biliary complications developed 6 months after transplantation.

Preoperative preparation and diagnostics

All patients underwent comprehensive preoperative evaluation, including:

- Complete blood count and comprehensive metabolic panel with liver function tests (total and direct bilirubin, alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase, gamma-glutamyltransferase), coagulation profile
- Abdominal ultrasonography with assessment of intrahepatic and extrahepatic bile duct diameter

- Magnetic resonance cholangiopancreatography for biliary tree visualization and precise stricture localization
- Contrast-enhanced computed tomography of the abdomen for vascular anatomy assessment and access planning

When necessary, coagulopathy was corrected (fresh frozen plasma transfusion, vitamin K administration), and broad-spectrum prophylactic antibiotics were administered.

Description of the combined procedure (rendezvous technique)

Operator standardization

All procedures were performed by the same multidisciplinary team consisting of:

- Interventional radiologist with experience of >150 percutaneous biliary interventions (responsible for PTCS stage)
- Endoscopist with experience of >200 ERCP procedures in liver transplant recipients (responsible for endoscopic stage)
- Anesthesiologist specializing in transplant surgery
- Operating room nurse

Standardization of the approach with a single team minimized technical variability and ensured consistency of results across cases.

All patients underwent a combined procedure for biliary stricture management using the rendezvous technique, which integrates percutaneous transhepatic and endoscopic approaches.

Step 1. Percutaneous transhepatic cholangiostomy (PTCS): Under ultrasound and fluoroscopic guidance, a dilated intrahepatic bile duct was punctured using a 21-22G Chiba needle. After bile aspiration, cholangiography was performed to visualize the biliary tree and determine the location and extent of the stricture. A 0.035-inch guidewire was advanced, and a percutaneous biliary drainage catheter (8-10 Fr) was placed above the stricture level for biliary decompression.

Step 2. Rendezvous procedure: Following patient stabilization, the rendezvous procedure was performed. Under fluoroscopic guidance, a guidewire was advanced antegrade through the percutaneous access, across the stricture zone, and into the duodenum. Simultaneously, endoscopic retrograde cholangiopancreatography was performed with cannulation of the major duodenal papilla. The antegrade guidewire was captured endoscopically using a snare, establishing continuous access through the stricture zone.

Step 3. Biliary stent placement: Polymeric biliary stents were used. Stent selection was based on stricture location and length, patient life expectancy, and economic considerations. Following stent placement, completion cholangiography was performed to confirm adequate positioning and stent patency. The percutaneous drain was removed intraoperatively.

Postoperative management: Postoperatively, vital signs and clinical and biochemical liver function parameters were monitored. Patients received antibiotic therapy for 5-7 days, adequate analgesia, and continued baseline immunosuppressive therapy.

Follow-up evaluation included:

- Complete blood count and liver function tests on days 1, 3, 7, and weekly thereafter
- Ultrasonography on days 1-3 post-procedure to exclude complications
- Repeat stenting planned at 3 months with possible exchange for larger diameter stent

Outcome measures

Technical success: Successful guidewire passage through the stricture zone via antegrade access, endoscopic capture of the guidewire, and placement of a biliary stent of the required diameter with adequate position confirmed by completion cholangiography.

Clinical success: Achievement of all of the following criteria:

- Reduction in total bilirubin level ≥50% from baseline by day 7 post-procedure
- Reduction in direct bilirubin level ≥50% from baseline by day 7
- Regression of clinical cholestasis symptoms (jaundice, pruritus, acholic stools) by day 14
- Normalization of biochemical parameters (total bilirubin <21 μmol/L, direct bilirubin <5 μmol/L) by day 30

Evaluation timepoints:

- Baseline (pre-procedure): Day 0
- Early assessment: Day 7 (primary endpoint for clinical success)
- Intermediate assessment: Day 14 (clinical symptoms)
- Late assessment: Day 30 (biochemical normalization)
- Long-term follow-up: Median 45 days (range 30-60 days)

Reference ranges for biochemical parameters:

- Total bilirubin: 3.4-20.5 μmol/L
- Direct bilirubin: 0-5.1 μmol/L
- Alkaline phosphatase: 40-150 U/L
- Gamma-glutamyltransferase: 10-71 U/L

Additional outcome parameters:

- Complication rate and type (hemorrhage, bile peritonitis, cholangitis, pancreatitis)
- Length of hospitalization
- Need for repeat interventions
- Long-term biliary anastomosis patency (when follow-up data available)

Independent outcome assessment. Outcome evaluation was conducted as follows:

- Technical success was assessed intraoperatively by two operators (interventional radiologist and endoscopist) based on cholangiographic findings
- Biochemical parameters were analyzed by the centralized laboratory of the National Scientific Oncology Center, which was not involved in performing the procedures
- Clinical assessment was conducted by attending transplant physicians who did not participate in performing the interventional procedures
- Ultrasound evaluation on days 1-3 was performed by independent ultrasound specialists using a standardized protocol

Given the pilot nature of the study and small sample size, formal blinding of assessors was not performed, which represents a study limitation.

Statistical Analysis

Given the small sample size (n=3), statistical analysis was descriptive in nature. Quantitative data are presented as mean ± standard deviation (M±SD) and median with range. Qualitative parameters are presented as absolute values and percentages. Data analysis was performed using IBM SPSS Statistics 27.0.1 software.

Ethical considerations

Given the observational nature of this study with retrospective analysis of clinical data, adherence to confidentiality principles, and absence of additional research interventions (all procedures were performed based on clinical indications as part of routine clinical care), formal approval by the Local Ethics Committee (LEC) was not obtained. According to the national legislation of the Republic of Kazakhstan, ethics committee approval is not mandatory for retrospective case series involving standard-of-care procedures with de-identified patient data.

All patients provided written informed consent for diagnostic and therapeutic procedures prior to intervention. The study was conducted in accordance with the principles of the World Medical Association's Declaration of Helsinki (2013) and the requirements of Good Clinical Practice. Patient personal data were de-identified and protected in accordance with current data protection legislation of the Republic of Kazakhstan.

No interventions were conducted solely for research purposes. All diagnostic and therapeutic procedures were performed based on established clinical indications for the management of post-transplant biliary strictures. The use of de-identified clinical data for analysis and publication was conducted with strict adherence to patient confidentiality and privacy protection principles.

Results

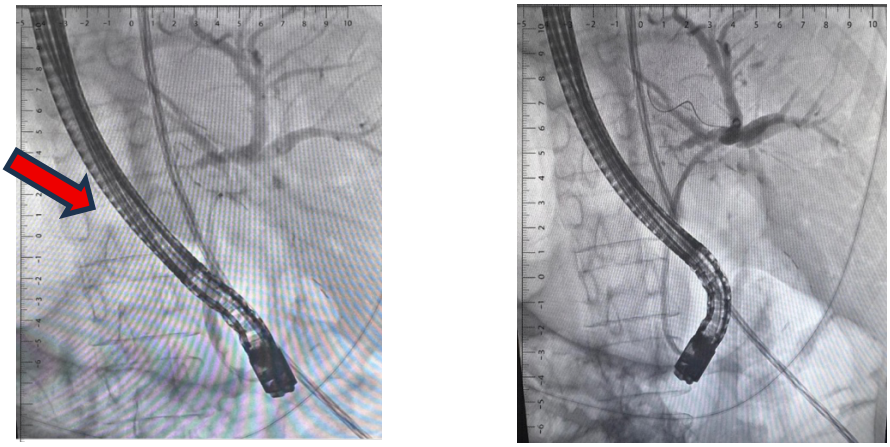
The combined rendezvous procedure for biliary stricture management was successfully performed in all three patients (100% technical success). In all cases, the guidewire was successfully advanced through the stricture zone via antegrade access, captured endoscopically, and a biliary stent of the required diameter was placed.

Procedural characteristics. The mean procedure duration was 85±15 minutes (range 70-100 minutes). Fluoroscopy time ranged from 12 to 18 minutes (median 15 minutes). The volume of contrast agent used during the procedure was 45±10 mL.

Stricture characteristics. In all patients, strictures were located at the biliodigestive anastomosis. Stricture length ranged from 8 to 15 mm (median 12 mm). The degree of bile duct lumen narrowing ranged from 70% to 90% based on cholangiography. In Patient 1, the stricture developed 3 months after transplantation; in Patient 2, 12 months post-transplantation (recurrence after previous endoscopic treatment); and in Patient 3, 6 months after transplantation.

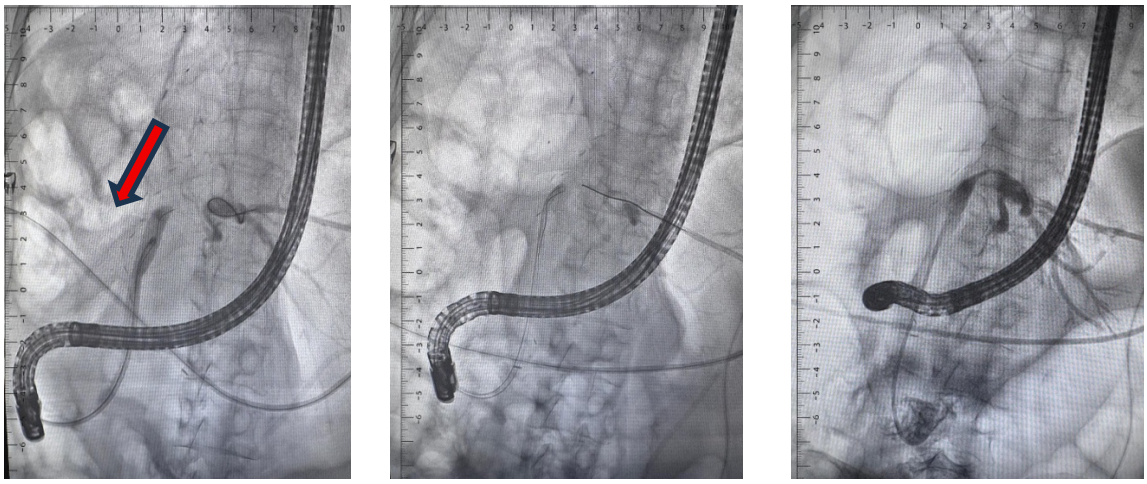
Intraoperative cholangiographic findings. Representative cholangiographic images demonstrating the rendezvous technique are presented in Figures 1-3. Figure 1 shows antegrade and retrograde dilation of bile ducts in Patient 1 (Figure 1A) with successful stent placement confirmed by control cholangiogram (Figure 1B). Figure 2 demonstrates the procedure in Patient 2, including initial rendezvous approach (Figure 2A), technical challenges during stricture dilation (Figure 2B), and final control cholangiogram after stent placement (Figure 2C). Figure 3 illustrates the procedure in Patient 3, showing the rendezvous technique (Figure 3A) and control cholangiogram confirming adequate stent position (Figure 3B).

Intraoperative cholangiographic findings



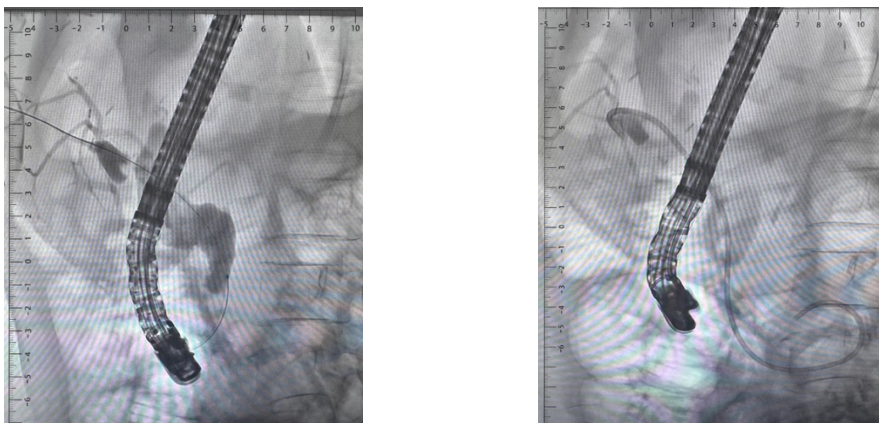
(A) (B)

Figure 1. Angiographic findings from clinical case 1. A – Antegrade and retrograde dilation of bile ducts using the "rendezvous technique." B – Control cholangiogram after stent placement. Scale bar = 1 cm.



(A) (B) (C)

Figure 2. Angiographic findings from clinical case 2. A – Antegrade and retrograde dilation of bile ducts using the "rendezvous technique." B – Stricture dilation demonstrating technical difficulties with guidewire passage through fibrotic tissue. C – Control cholangiogram after stent placement showing adequate biliary decompression. Scale bar = 1 cm.



(A) (B)

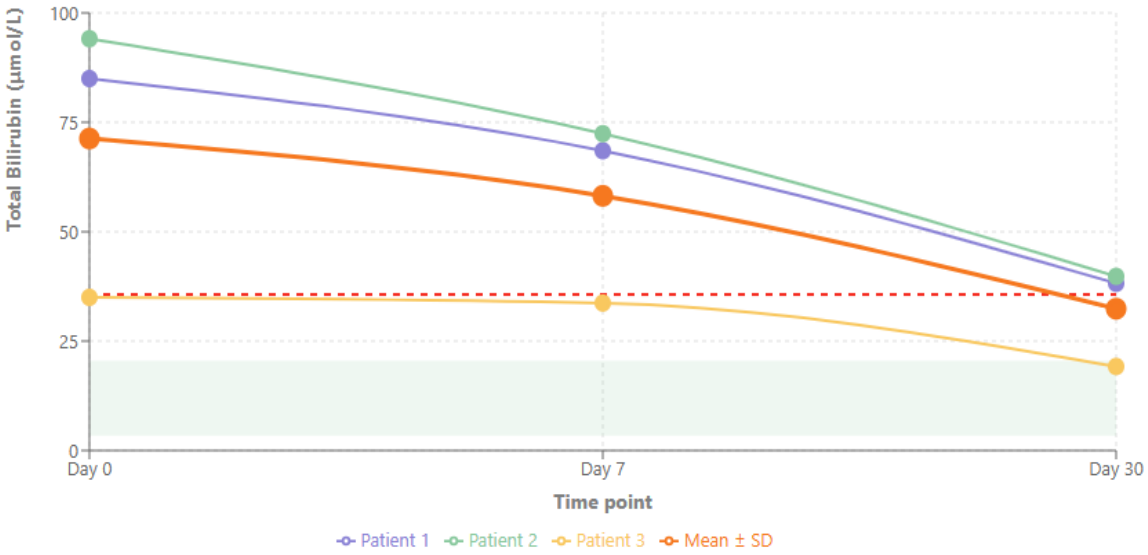
Figure 3. Angiographic findings from clinical case 3. A – Antegrade and retrograde dilation of bile ducts using the "rendezvous technique." B – Control cholangiogram after stent placement demonstrating patent biliary anastomosis. Scale bar = 1 cm.

In all patients, strictures were located at the biliodigestive anastomosis. Stricture length ranged from 8 to 15 mm (median 12 mm). The degree of bile duct lumen narrowing ranged from 70% to 90% based on cholangiography.

In Patient 1, the stricture developed 3 months after transplantation; in Patient 2, 12 months post-transplantation (recurrence after previous endoscopic treatment); and in Patient 3, 6 months after transplantation.

Figure 4. Dynamics of total bilirubin levels before and after the rendezvous procedure

The graph demonstrates progressive reduction in total bilirubin from baseline (Day 0) through Day 30 post-procedure. The shaded green area represents the normal reference range (3.4-20.5 μmol/L). The dashed red line indicates the 50% reduction threshold (35.65 μmol/L) used as a criterion for clinical success. Individual patient trajectories are shown alongside the mean±SD values.



- All three patients demonstrated progressive reduction in total bilirubin levels
- By Day 7, all patients achieved >50% reduction from baseline (clinical success criterion)
- By Day 30, mean bilirubin approached the upper limit of normal reference range
- Patient 3 had the lowest baseline bilirubin and achieved normalization earliest
- The shaded green area (3.4-20.5 μmol/L) represents the normal reference range

Extended follow-up data. At the end of the observation period (median 45 days, range 30-60 days), stents remained patent in all patients based on ultrasound monitoring and biochemical parameters. No signs of restenosis or stent occlusion were detected. Individual follow-up duration for each patient was: Patient 1 - 60 days, Patient 2 - 45 days, Patient 3 - 30 days.

Follow-up beyond 60 days was not available at the time of manuscript preparation, as the study observation period was limited to a maximum of 60 days. Elective endoscopic intervention at 3 months (90 days) was planned for all patients to assess anastomotic status and possible exchange for larger-diameter stent according to the management protocol, but these outcomes fall outside the current study timeframe and will be evaluated in future follow-up.

Clinical outcomes. Before the procedure, all patients exhibited clinical signs of cholestasis: jaundice of varying severity (n=3, 100%), pruritus (n=2, 67%), acholic stools (n=2, 67%), and dark urine (n=3, 100%). Following the combined procedure, clinical symptoms regressed progressively: jaundice resolved by day 14 in all patients, pruritus disappeared by day 7 in both affected patients, and stool and urine color normalized by day 10 in all patients.

Ultrasonographic findings. Ultrasonography performed before the procedure demonstrated dilated intrahepatic bile ducts in all patients (lobar duct diameter 8-12 mm). After stent placement, follow-up ultrasound on day 3 showed reduction in intrahepatic duct diameter to 4-6 mm, indicating adequate biliary decompression and restoration of normal bile flow.

Complications and safety outcomes. No intraoperative complications were recorded. In the early postoperative period (first 30 days), one patient (Patient 2, 33%) experienced transient elevation of serum amylase to 250 U/L (reference range 28-100 U/L) without clinical manifestations of pancreatitis, which resolved with conservative therapy within 48 hours. No

cases of hemorrhage, bile peritonitis, cholangitis, or other serious complications were observed. Mild tenderness at the percutaneous access site was noted in all patients during the first day after the procedure and was successfully managed with non-narcotic analgesics (paracetamol 500 mg every 6 hours).

Hospitalization and discharge. The mean length of hospitalization after the procedure was 5.3±1.5 days (range 4-7 days). Individual hospitalization duration: Patient 1 - 5 days, Patient 2 - 7 days, Patient 3 - 4 days. All patients were discharged in satisfactory condition with recommendations for continued follow-up and planned stent exchange at 3 months.

Thus, the application of a combined approach for managing biliary strictures using the rendezvous procedure demonstrated high technical feasibility (100% technical success) and clinical efficacy (100% clinical success with >50% bilirubin reduction by day 7) in all study patients with an acceptable safety profile (no serious complications, 33% minor complication rate).

Discussion

This case series demonstrates the technical feasibility and preliminary safety of a combined rendezvous approach for managing biliary strictures in patients following liver transplantation. Achievement of 100% technical success and clinical improvement in all patients, despite challenging clinical scenarios including recurrent strictures and living donor transplantation, supports the potential role of this technique as a bridge between failed endoscopic therapy and high-risk surgical revision.

Comparison with International Experience

Our technical success rate (100%, 3/3) is consistent with published data on hybrid biliary interventions, which generally report technical success rates of 85-95% [21, 22]. However, direct comparison is limited by our small sample size and the heterogeneity of techniques and patient populations across studies.

Clinical success, defined by ≥50% bilirubin reduction at day 7, was achieved in all patients (100%). This compares favorably with Tsujino et al., who reported similar biochemical improvement only by day 14 using isolated endoscopic approaches [14]. The more rapid decompression in our series likely reflects the advantage of combined antegrade-retrograde access, which facilitates larger-diameter stent placement and more effective stricture dilation. However, our short follow-up (median 45 days, maximum 60 days) precludes conclusions about durability. Long-term patency rates in the literature range from 65-85% at 12 months for benign post-transplant strictures [16, 23], with some series reporting 70% freedom from reintervention at both 24 and 60 months following percutaneous interventions [25]. Extended surveillance in our cohort is crucial to determine whether initial technical success translates into sustained clinical benefit.

Advantages in Complex Clinical Scenarios

The rendezvous technique demonstrated particular utility in Patient 2 with recurrent stricture after previous ERCP failure. Recurrent strictures are characterized by dense fibrosis and tissue rigidity, rendering isolated retrograde access technically challenging with success rates of only 40-60% in published series [16]. The combined antegrade-retrograde approach overcame these anatomical barriers, as evidenced by successful stent placement despite initial technical difficulties (Figure 2B). This finding supports the role of hybrid techniques specifically for refractory cases. Published data demonstrate that surgical revision is ultimately required in 18-30% of patients after failed endoscopic or percutaneous treatment [26], with some series reporting rates as high as 60% when non-surgical approaches are unsuccessful [27]. Early escalation to combined rendezvous techniques in ERCP-failure cases may potentially reduce this surgical revision burden, though comparative effectiveness data are lacking and prospective studies are needed to quantify this benefit. However, cost-effectiveness analysis versus immediate surgical revision would strengthen this recommendation, particularly in centers where surgical expertise is readily available.

Safety Profile and Learning Curve Considerations

The absence of serious complications (0/3, 0%) is encouraging but must be interpreted cautiously given the small denominator. Published complication rates for percutaneous biliary interventions include hemorrhage (2-5%), bile peritonitis (1-3%), and cholangitis (5-10%) [17]. Our single minor complication (transient hyperamylasemia without clinical pancreatitis, 33%) falls within the expected 20-30% rate of post-ERCP biochemical abnormalities [13]. Rigorous preoperative coagulopathy correction and prophylactic antibiotics likely contributed to the favorable safety profile.

Learning curve effects: A critical but unquantified factor in our outcomes is operator experience. Our interventional radiologist (>150 percutaneous biliary procedures) and endoscopist (>200 post-transplant ERCP) represent high-volume practitioners. Published data from EUS-guided

rendezvous techniques demonstrate that procedural competency (defined as 80% success rate) can be achieved after approximately 15 procedures for advanced endoscopic techniques [28]. Overall complication rates for hybrid biliary interventions range from 10-15%, including bleeding (4%), bile leak (4%), pneumoperitoneum (3%), and pancreatitis (1.6%) [29]. A Swedish national registry study of 24,025 ERCP procedures demonstrated that higher endoscopist and center case-volumes are significantly associated with higher successful cannulation rates and lower complication rates ($p < 0.05$) [30]. However, no standardized competency metrics exist specifically for the percutaneous-endoscopic rendezvous technique in post-transplant patients, complicating efforts to establish training benchmarks or predict outcomes in centers initiating such programs.

Procedure duration (85±15 minutes) exceeded standard ERCP (40-60 minutes) but remained substantially shorter than surgical revision (typically 3-5 hours operative time plus prolonged recovery) [10, 19]. The avoidance of repeat laparotomy is particularly significant in immunosuppressed transplant recipients, where surgical site infections occur in 15-25% of cases [20].

Resource Utilization and Cost-Effectiveness in Developing Centers

Economic analysis, though beyond this pilot study's scope, is crucial for informed policy decisions, particularly in resource-constrained settings. The rendezvous procedure requires:

- Hybrid interventional radiology/endoscopy suite (capital cost ~$500,000-1,000,000 USD)
- Dual specialist availability (interventional radiologist + advanced endoscopist)
- Specialized equipment (percutaneous access kits, endoscopic snares, fluoroscopy)
- Extended procedure time (85 minutes vs 40 minutes for standard ERCP)

Stent selection economics: In our institution, polymeric stent cost ($150-300 per stent) was substantially lower than covered self-expanding metal stents ($1,500-3,000), driving our material choice. However, multiple plastic stent exchanges (typically 3-4 procedures over 12 months) may ultimately exceed single metal stent cost. Tal et al. found no significant difference in total healthcare costs between strategies at 12 months [23]. Recent cost analysis from randomized trials demonstrates that transition to FCSEMS at the second ERCP (after initial plastic stent placement) provides 25% reduction in total procedure costs [31], while use of FCSEMS in patients achieving clinical remission after first-line treatment reduces costs by 40-41% compared to continued multiple plastic stenting [32]. For resource-constrained settings like ours, short-term budget impact may favor plastic stents despite potential long-term cost parity, though formal cost-effectiveness modeling with quality-adjusted life years assessment remains lacking for post-transplant populations.

Simplified cost-effectiveness estimate: A simplified cost comparison suggests potential economic advantages of hybrid interventions over surgical revision. Published data demonstrate that successful endoscopic or percutaneous management avoids surgical revision, which carries substantially higher costs related to operating room time, extended hospitalization, and perioperative complications [33]. However, patients requiring multiple failed percutaneous procedures (≥6 attempts) may incur costs exceeding even surgical revision [34]. This calculation omits quality-of-life considerations, complication costs, productivity losses, and long-term failure rates, necessitating formal cost-effectiveness modeling with Markov state-transition models or discrete-event simulation to guide resource allocation decisions, particularly in resource-constrained settings.

Critical Limitations Requiring Acknowledgment

Sample size and statistical power: With only three patients, this series lacks statistical power for meaningful efficacy assessment or subgroup analysis. The 95% confidence interval around our 100% success rate (29.2-100% by Wilson method) reflects profound uncertainty. Type II error risk precludes conclusions about comparative effectiveness versus alternative strategies. A sample size calculation suggests that 42 patients per group would be required to detect a 20% difference in technical success (80% vs 100%) with 80% power and α=0.05.

Gender homogeneity and population representativeness: All patients were female, limiting generalizability to male transplant recipients who may have different bile duct anatomy (larger diameter, different angulation) and stricture characteristics. The predominance of living donor transplants in our series (3/3, 100%) also limits applicability to deceased donor recipients, who comprise the majority (approximately 94-95%) of liver transplants in Western centers [35, 36]. Living donor grafts have distinct biliary anatomy with smaller diameter intrahepatic bile ducts (<4 mm) compared to extrahepatic ducts in deceased donor grafts, frequent requirement for multiple ductal anastomoses (observed in 36-58% of LDLT cases), and higher incidence of bile leaks and strictures (19% vs 12% in DDLT) [37, 38]. As a result of early segmental

branching of the donor biliary tree, two segment bile ducts require anastomosis in approximately 40% of LDLT patients and three segment bile ducts in 6-15% [39]. These anatomical complexities potentially influence technical difficulty and outcomes of hybrid interventions. Whether our results translate to deceased donor recipients with more straightforward biliary anatomy requires specific investigation.

Insufficient follow-up duration: The maximum 60-day observation period is inadequate for assessing long-term outcomes. Anastomotic strictures can recur months to years after initial intervention [8, 16], and stent migration (2.8% for anti-migration FCSEMS to 16-28% for standard FCSEMS), occlusion (30-40% for plastic stents with prolonged indwelling time), or restenosis (20-32%) typically manifest beyond our timeframe [40, 41]. The planned 3-month reassessment falls outside our study period, representing a critical data gap. Current guidelines recommend treatment of extrahepatic biliary strictures for 12 months when using multiple plastic stents, with stent exchanges at 3-month intervals to promote biliary drainage and stricture resolution [42]. Long-term follow-up studies demonstrate that primary stent patency decreases from 75% at 12 months to 25% at 36 months, with stricture recurrence typically occurring within 6-26 months after stent removal [43]. This necessitates surveillance periods of at least 12-24 months to adequately assess treatment durability and detect late recurrences [44].

Absence of comparative controls: Without randomization or matched controls, we cannot determine whether the rendezvous approach offers advantages over sequential monotherapy. Historical controls are problematic due to evolving techniques, changing stent technology, and selection bias. The natural history comparison group (ERCP-alone in similar patients) was not available in our center due to our protocol of early escalation to hybrid approaches after single ERCP failure, precluding even retrospective matched analysis.

Lack of patient-reported outcomes: We did not formally assess quality of life using validated instruments (SF-36, GIQLI, or EQ-5D), procedural tolerability, patient satisfaction, or return to daily activities. These patient-centered outcomes are increasingly recognized as essential endpoints in benign disease management and may reveal important trade-offs between technical success and patient experience.

Implications for Clinical Practice and Research Priorities

This pilot series supports the technical feasibility of the rendezvous approach in a specialized transplant center setting. The method may be particularly valuable for:

1. Recurrent strictures after failed isolated endoscopic therapy
2. Altered anatomy precluding standard ERCP access
3. Complete anastomotic occlusion preventing retrograde guidewire passage
4. Institutions seeking to avoid high-risk surgical revision in immunosuppressed patients

However, several critical questions remain unanswered and should guide future research:

Optimal patient selection criteria: Which stricture characteristics (length, degree of stenosis, time from transplantation, recurrence status) predict success with hybrid versus monotherapy approaches? Development of a validated predictive model incorporating pre-procedural imaging features, biochemical parameters, and clinical factors would enable evidence-based treatment algorithms and appropriate patient counseling.

Timing of intervention strategy: Is early hybrid intervention superior to sequential monotherapy escalation? A randomized trial comparing immediate rendezvous (after single ERCP failure) versus persistent ERCP attempts (3-4 sessions) with crossover to rendezvous only upon definitive failure would address this question and inform treatment algorithms.

Stent selection in hybrid context: Comparative effectiveness of multiple plastic stents versus covered self-expanding metal stents specifically in the rendezvous context remains unclear. Our material choice reflected economic constraints rather than evidence-based decision-making. A randomized trial comparing strategies with cost-effectiveness analysis as a secondary endpoint would guide practice, particularly in resource-limited settings.

Long-term patency and reintervention rates: Prospective cohort studies with ≥12-month follow-up are essential to assess durability, restenosis rates, need for repeat interventions, and ultimately, impact on graft survival and patient mortality. Integration of patient-reported outcomes would enhance clinical relevance and patient-centeredness.

Training curricula and credentialing standards: Standardized competency assessment metrics, simulation-based training protocols, and minimum case volume requirements would facilitate safe implementation in diverse practice settings and potentially accelerate the learning curve while minimizing complications during skill acquisition.

Formal cost-effectiveness modeling: Economic analysis incorporating procedure costs, complication management, repeat interventions, lost productivity, and quality-adjusted life years would inform resource allocation decisions, particularly relevant for developing healthcare systems considering investment in hybrid capabilities.

Novel technologies: Biodegradable stent technology may eliminate repeat endoscopic interventions for stent removal while maintaining luminal patency [24]. Drug-eluting stents with anti-proliferative coatings (paclitaxel, sirolimus) show promise in reducing restenosis in preliminary studies [reference needed]. Dedicated randomized trials in post-transplant populations are warranted.

Contribution to the Evidence Base

Despite inherent limitations of small case series, this report makes several contributions to the literature on hybrid interventions for post-transplant biliary strictures:

First, geographic representation: This is the first reported experience with systematic application of the rendezvous technique from Central Asia, demonstrating technical achievability beyond high-volume Western transplant programs. The specific context of living donor transplantation—predominant in our region due to deceased donor organ scarcity—is underrepresented in Western literature (which primarily describes deceased donor cohorts), enhancing the generalizability of hybrid approaches to diverse healthcare settings and transplant models.

Second, practical implementation insights: We demonstrate that centers with appropriate infrastructure and dual expertise can successfully implement combined procedures with acceptable short-term safety, potentially avoiding surgical revision and its attendant morbidity. The pragmatic adaptations we employed (selective use, lower-cost materials, workflow modifications) provide a roadmap for similar resource-limited centers considering program development.

Third, proof-of-concept for definitive trials: This series establishes technical feasibility and provides preliminary safety data to justify adequately powered comparative studies. The absence of serious complications and achievement of short-term clinical success in all cases, including a patient with prior ERCP failure, supports equipoise for randomization to hybrid versus sequential escalation strategies.

Fourth, hypothesis generation: Our observation that Patient 2 (recurrent stricture with prior ERCP failure) achieved technical success suggests that early escalation to hybrid approaches in refractory cases may prevent prolonged cholestasis and multiple failed procedures. This hypothesis warrants formal testing in comparative effectiveness research.

However, the transition from "can we do this?" (technical feasibility, addressed by this pilot series) to "should we do this?" (comparative effectiveness, cost-efficiency, and patient-centered outcomes) requires rigorous prospective investigation. Our findings provide justification and preliminary data for such definitive trials but cannot substitute for them.

In summary, the rendezvous technique represents a promising addition to the therapeutic armamentarium for complex post-transplant biliary strictures, particularly when isolated endoscopic or percutaneous approaches have failed or are technically infeasible. The method's successful implementation in our center demonstrates its potential applicability beyond high-volume Western transplant programs and suggests feasibility in resource-constrained settings with appropriate adaptations. However, small sample size, short follow-up, absence of controls, gender homogeneity, and unquantified learning curve effects represent substantial limitations that temper enthusiasm and underscore the need for adequately powered comparative studies with extended follow-up, patient-reported outcomes, and cost-effectiveness analyses before definitive practice recommendations can be formulated. This case series contributes preliminary evidence supporting the feasibility and short-term safety of hybrid approaches in living donor liver transplant recipients, a population underrepresented in existing literature, and establishes proof-of-concept to justify definitive prospective trials.

Conclusion

The combined rendezvous approach, integrating percutaneous transhepatic and endoscopic access, demonstrated technical feasibility and favorable short-term outcomes in managing complex biliary strictures following liver transplantation. Technical success was achieved in all three cases (100%), with successful guidewire passage, endoscopic capture, and biliary stent placement. Clinical success, defined by ≥50% bilirubin reduction by day 7 and resolution of cholestasis symptoms by day 14, was achieved in all patients. No serious complications occurred, and median hospitalization was 5 days.

The technique showed particular utility in recurrent strictures after failed endoscopic therapy, suggesting potential value as a bridge between isolated endoscopic approaches and high-risk surgical revision. However, these findings are preliminary due to substantial limitations: small sample size (n=3), short

follow-up duration (maximum 60 days), gender homogeneity (all female patients), absence of comparative controls, and exclusive focus on living donor transplant recipients.

This proof-of-concept series demonstrates that the rendezvous technique is achievable in emerging transplant centers with appropriate multidisciplinary expertise and infrastructure. The favorable safety profile and immediate clinical response support its consideration as an alternative to surgery in carefully selected cases where standard endoscopic access has failed or is not feasible. However, definitive conclusions about long-term efficacy, optimal patient selection criteria, and comparative effectiveness versus alternative strategies require adequately powered prospective studies with extended follow-up (≥12 months), inclusion of diverse patient populations (both genders, deceased and living donor recipients), cost-effectiveness analysis, and patient-reported outcome assessment.

Multicenter collaborative research is essential to establish standardized protocols, identify predictors of success, quantify the learning curve, and determine the role of this hybrid approach within evidence-based treatment algorithms for post-transplant biliary complications. Until such data become available, the rendezvous technique should be considered a promising but investigational approach requiring careful patient selection, experienced operators, and institutional commitment to rigorous outcome monitoring.

Acknowledgement

Conflict of Interest: The authors declare no conflict of interest.

Author Contributions: All authors have reviewed the final version of the manuscript and signed the copyright transfer form.

Funding: This work received no funding.

References

1. Hassouneh R, Beran A, Rosenheck M, Sosio J, Olchawa N, Kubal C, et al. Risk factors for biliary strictures and leaks after living-donor liver transplantation: a systematic review and meta-analysis. J Gastrointest Surg. 2024 Nov;28(11):1870-82. https://doi.org/10.1016/j.gassur.2024.06.038
2. Fasullo M, Patel M, Khanna L, Shah T. Post-transplant biliary complications: advances in pathophysiology, diagnosis, and treatment. BMJ Open Gastroenterol. 2022 Feb;9(1):e000778. https://doi.org/10.1136/bmjgast-2021-000778
3. Magro B, Tacelli M, Mazzola A, Conti F, Celsa C. Biliary complications after liver transplantation: current perspectives and future strategies. Hepatobiliary Surg Nutr. 2021 Feb;10(1):76-92. https://doi.org/10.21037/hbsn.2019.09.10
4. Westphal S, Kalff JC. Biliary complications after liver transplantation: recent developments in etiology, diagnosis and treatment. Best Pract Res Clin Gastroenterol. 2017 Apr;31(2):175-83. https://doi.org/10.1016/j.bpg.2017.03.006
5. Zhang CC, Rupp C, Exarchos X, Mehrabi A, Koschny R, Schaible A, et al. Scheduled endoscopic treatment of biliary anastomotic and nonanastomotic strictures after orthotopic liver transplantation. Gastrointest Endosc. 2023 Jan;97(1):42-9. https://doi.org/10.1016/j.gie.2022.08.012
6. Baraldo S, Meine GC, Santo PAE, Freitas ACT, Guardia BD, Matielo CEL, et al. Fully covered self-expandable metal stents versus multiple plastic stents for the treatment of post-orthotopic liver transplant anastomotic biliary strictures: An updated systematic review and meta-analysis of randomized controlled trials. Surg Endosc. 2025 Feb;39(2):721-9. https://doi.org/10.1007/s00464-024-10731-5
7. Park JW, Moon JH, Lee YN, Kim HJ, Cha SW, Cho YD, et al. Long-term outcomes of a modified nonflared fully covered self-expandable metal stent for refractory anastomotic biliary strictures after liver transplantation (with video). Dig Endosc. 2025 Jun;37(6):651-8. https://doi.org/10.1111/den.14741
8. Fuentes-Valenzuela E, De Benito Sanz M, Peñas-Herrero I, de la Serna-Higuera C, Ruiz-

Rebollo ML, Delgado-Guillena PG, et al. Endoscopic Management of Recurrent Anastomotic Biliary Stricture Following Deceased Orthotopic Liver Transplantation. J Clin Med. 2025 Mar;14(7):2198. https://doi.org/10.3390/jcm14072198

9. Cho SH, Lee HS, Huh G, Kim BW, Lee HH, Kim KH, et al. Long-term outcomes of fully covered self-expandable metal stents for refractory biliary strictures after living donor liver transplantation: a retrospective study at a tertiary center. Surg Endosc. 2024 Jun;38(6):3223-30. https://doi.org/10.1007/s00464-024-10815-9
10. Lee SY, Jang SI, Chung MJ, Park DH, Lee SS, Seo DW, et al. A Short Fully Covered Self-Expandable Metal Stent for Management of Benign Biliary Stricture Not Caused by Living-Donor Liver Transplantation. J Clin Med. 2024 Feb;13(5):1186. https://doi.org/10.3390/jcm13051186
11. Ahmed W, Kyle D, Khanna A, Steel A, Quine A, McDonald C, et al. Intraductal fully covered self-expanding metal stents in the management of post-liver transplant anastomotic strictures: a UK wide experience. Therap Adv Gastroenterol. 2022 Sep;15:17562848221122473. https://doi.org/10.1177/17562848221122473
12. Matsumoto K, Kato H, Fujii M, Tanaka R, Harada R, Akimoto Y, et al. A prospective study of fully covered metal stents for different types of refractory benign biliary strictures. J Hepatobiliary Pancreat Sci. 2022 Dec;29(12):1300-7. https://doi.org/10.1002/jhbp.1202
13. Sandru V, Stan-Ilie M, Plotogea OM, Constantinescu G, Vadan R, Cijevschi Prelipcean C, et al. Endoscopic Management of Biliary Strictures after Orthotopic Liver Transplantation: A Single Center Experience Study. Diagnostics (Basel). 2022 May;12(5):1221. https://doi.org/10.3390/diagnostics12051221
14. Giri S, Jearth V, Sundaram S. Covered Self-Expanding Metal Stents Versus Multiple Plastic Stents for Benign Biliary Strictures: An Updated Meta-Analysis of Randomized Controlled Trials. Cureus. 2022 Apr;14(4):e24588. https://doi.org/10.7759/cureus.24588
15. Yang H, Yang Z, Hong J. Post-ERCP pancreatitis occurs more frequently in self-expandable metallic stents than multiple plastic stents on benign biliary strictures: a meta-analysis. Ann Med. 2022 Dec;54(1):2439-49. https://doi.org/10.1080/07853890.2022.2118368
16. Rocha Fernandes Y, Visconti TAC, Dall'Agnol MK, Zilbermann M, Pereira-Lima JC, Parcianello Saciloto RC, et al. Covered Self-Expanding Metal Stents Versus Multiple Plastic Stents in Treating Biliary Strictures Post-Orthotopic Liver Transplantation: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. DEN Open. 2025 May;6(1):e70143. https://doi.org/10.1002/deo2.70143
17. Saad WE, Wallace MJ, Wojak JC, Kundu S, Cardella JF. Quality improvement guidelines for percutaneous transhepatic cholangiography, biliary drainage, and percutaneous cholecystostomy. J Vasc Interv Radiol. 2010 Jun;21(6):789-95. https://doi.org/10.1016/j.jvir.2010.01.012
18. Gwon DI, Ko GY, Sung KB, Yoon HK, Lee JM. Percutaneous biliary metallic stent placement in patients with unilobar portal vein occlusion after hepatobiliary surgery: outcome of unilateral versus bilateral stenting. AJR Am J Roentgenol. 2011 Oct;197(4):795-801. https://doi.org/10.2214/AJR.10.5894
19. Coté GA, Slivka A, Tarnasky P, Mullady DK, Elmunzer BJ, Elta G, et al. Effect of covered metallic stents compared with plastic stents on benign biliary stricture resolution: a randomized clinical trial. JAMA. 2016 Mar;315(12):1250-7. https://doi.org/10.1001/jama.2016.2619
20. Sutcliffe R, Maguire D, Ramesh S, Portmann B, Rela M, Heaton N. Bile duct strictures after adult liver transplantation: a role for biliary

reconstructive surgery? Liver Transpl. 2004 Jul;10(7):928-34. https://doi.org/10.1002/lt.20170

21. Kahaleh M, Brijbassie A, Sethi A, Degaetani M, Poneros JM, Loren DE, et al. Multicenter trial evaluating the use of covered self-expanding metal stents in benign biliary strictures: time to revisit our therapeutic options? J Clin Gastroenterol. 2013 Sep;47(8):695-9. https://doi.org/10.1097/MCG.0b013e31827fd4c4
22. Martins FP, Kahaleh M, Ferrari AP. Management of liver transplantation biliary stricture: results from a tertiary hospital. World J Gastrointest Endosc. 2015 Jul;7(7):747-57. https://doi.org/10.4253/wjge.v7.i7.747
23. Tal AO, Finkelmeier F, Filmann N, Kylänpää L, Udd M, Parzanese I, et al. Multiple plastic stents versus covered metal stent for treatment of anastomotic biliary strictures after liver transplantation: a prospective, randomized, multicenter trial. Gastrointest Endosc. 2017 Dec;86(6):1038-45. https://doi.org/10.1016/j.gie.2017.08.039
24. Parlak E, Ciçek B, Dişibeyaz S, Kuran SÖ, Oztaş E, Sahin B. Endoscopic retrograde cholangiography by double balloon enteroscopy in patients with Roux-en-Y hepaticojejunostomy. Surg Endosc. 2010 Feb;24(2):466-70. https://doi.org/10.1007/s00464-009-0596-y
25. Rasekhi A, Gholami Z, Azizi M, Malek-Hosseini SA, Salahi H. Percutaneous Transhepatic Radiologic Intervention of Biliary Complications following Liver Transplantation: A Single-center Experience. Int J Organ Transplant Med. 2022;13(2):38-47. https://doi.org/10.52547/ijotm.13.2.38
26. Saad WE, Davies MG, Darcy MD. Management of Biliary Complications of Liver Transplantation. Semin Intervent Radiol. 2011 Mar;28(1):88-98. https://doi.org/10.1055/s-0031-1273946
27. Waldram R, Williams R, Calne RY. Bile composition and bile cast formation after transplantation of the liver in man. Transplantation. 1975 May;19(5):382-7. https://doi.org/10.1097/00007890-197505000-00005
28. Shah JN, Marson F, Weilert F, Bhat YM, Nguyen-Tang T, Shaw RE, et al. Single-operator, single-session EUS-guided anterograde cholangiopancreatography in failed ERCP or inaccessible papilla. Gastrointest Endosc. 2012 Jan;75(1):56-64. https://doi.org/10.1016/j.gie.2011.08.032
29. Lin YC, Yang JH, Wu TJ. Troubleshooting Difficult Bile Duct Access: Advanced ERCP Cannulation Techniques, Percutaneous Biliary Drainage, or EUS-Guided Rendezvous Technique? J Clin Med. 2021 Oct;10(21):4979. https://doi.org/10.3390/jcm10214979
30. Forslund A, Enochsson L, Eklund A, Boström L, Sandblom G, Öhman M, et al. Outcome of ERCP related to case-volume. Surg Endosc. 2022 May;36(5):3409-19. https://doi.org/10.1007/s00464-021-08657-x
31. Jang S, Stevens T, Lopez R, Bhatt A, Navaneethan U, Vargo JJ, et al. Self-Expandable Metallic Stent Is More Cost Efficient Than Plastic Stent in Treating Anastomotic Biliary Stricture. Dig Dis Sci. 2020 Feb;65(2):600-8. https://doi.org/10.1007/s10620-019-05784-3
32. Cantu P, Parzanese I, Pozzoli L, Balassone V, Barbera C, Dalvai M, et al. Cost analysis of a long-term randomized controlled study in biliary duct-to-duct anastomotic stricture after liver transplantation. Eur J Gastroenterol Hepatol. 2021 Jan;33(1S Suppl 1):e337-e343. https://doi.org/10.1097/MEG.0000000000002072
33. Amateau SK, Kohli DR, Desai M, Sherman S, Pawa R, Smith ZL, et al. American Society for Gastrointestinal Endoscopy guideline on management of post-liver transplant biliary strictures: summary and recommendations. Gastrointest Endosc. 2023 Apr;97(4):638-45. https://doi.org/10.1016/j.gie.2022.10.004
34. Walling AD, Larson KM, Aulakh AK, Sorensen LG, Loomes KM, Smith LJ, et al. Procedure Costs Associated With Management of Biliary Strictures in Pediatric

Liver Transplant Recipients in the Society of Pediatric Liver Transplantation (SPLIT) Registry. Pediatr Transplant. 2025 Jan;29(1):e14984. https://doi.org/10.1111/petr.14984

35. Abu-Gazala S, Olthoff KM. Current Status of Living Donor Liver Transplantation in the United States. Annu Rev Med. 2019 Jan;70:225-38. https://doi.org/10.1146/annurev-med-041817-025758
36. Cotter TG, Paul S, Sandıkçı B, Couri T, Bodzin AS, Little EC, et al. Living Donor Liver Transplantation in the United States: Evolution of Frequency, Outcomes, Center Volumes, and Factors Associated With Outcomes. Am J Transplant. 2021 Oct;21(10):3305-16. https://doi.org/10.1111/ajt.16705
37. Williams ED, Draganov PV. Endoscopic management of biliary strictures after liver transplantation. World J Gastroenterol. 2009 Aug;15(30):3725-33. https://doi.org/10.3748/wjg.15.3725
38. Yaprak O, Dayangac M, Akyildiz M, Baskiran A, Sahin T, Kilic M, et al. Biliary complications after right lobe living donor liver transplantation: a single-centre experience. HPB (Oxford). 2012 Jan;14(1):49-53. https://doi.org/10.1111/j.1477-2574.2011.00397.x
39. Ishiko T, Egawa H, Kasahara M, Ito T, Haga H, Uryuhara K, et al. Duct-to-duct biliary reconstruction in living donor liver transplantation utilizing right lobe graft. Ann Surg. 2002 Aug;236(2):235-40. https://doi.org/10.1097/00000658-200208000-00011
40. Aepli P, St John A, Gupta S, Hourigan L, Singh R, Kaffes A, et al. Success and complications of an intra-ductal fully covered self-expanding metal stent (ID-FCSEMS) to treat anastomotic biliary strictures (AS) after orthotopic liver transplantation (OLT). Surg Endosc. 2017 Apr;31(4):1558-63. https://doi.org/10.1007/s00464-016-5142-0
41. Chaput U, Scatton O, Bichard P, Ponchon T, Chaussade S, Soubrane O, et al. Clinical efficacy of anti-migration features in fully covered metallic stents for anastomotic biliary strictures after liver transplantation: comparison of conventional and anti-migration stents. Gastrointest Endosc. 2018 Aug;88(2):225-33. https://doi.org/10.1016/j.gie.2018.03.022
42. Canakis A, Mara KC, Baron TH Sr. Benign biliary strictures: prevalence, impact, and management strategies. Clin Exp Gastroenterol. 2019 Sep;12:83-99. https://doi.org/10.2147/CEG.S165650
43. Hausegger KA, Kugler C, Uggowitzer M, Schmidbauer G, Karaic R, Klein GE, et al. Metallic Stents in Benign Biliary Strictures: Long-Term Effectiveness and Interventional Management of Stent Occlusion. AJR Am J Roentgenol. 2001 Oct;177(4):813-7. https://doi.org/10.2214/ajr.177.4.1770813
44. Saxena P, Diehl DL, Kumbhari V, Kedia P, Messallam AA, Simpson PW, et al. A US Multicenter Study of Safety and Efficacy of Fully Covered Self-Expandable Metallic Stents in Benign Extrahepatic Biliary Strictures. Dig Dis Sci. 2015 Nov;60(11):3442-8. https://doi.org/10.1007/s10620-015-3775-9