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Percutaneous tandem modified plastic stenting for post-transplant duct-to-duct biliary anastomotic strictures: long-term outcomes from a single-center cohort

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PURPOSE

This study aimed to evaluate the feasibility, safety, and long-term outcomes of a percutaneous technique using tandem modified plastic biliary stents (MPBSs) for benign duct-to-duct biliary anastomotic strictures after liver transplantation (LT).

METHODS

This retrospective single-center study included 48 recipients who underwent treatment between January 2011 and January 2025 after failure or ineligibility for endoscopic therapy. All patients underwent percutaneous placement of two MPBSs through a single transhepatic access. Technical success, symptomatic and biochemical response, procedure-related complications classified according to the Cardiovascular and Interventional Radiological Society of Europe system, and patency were evaluated. Patency was analyzed using the Kaplan–Meier method, and laboratory parameters were analyzed using the Wilcoxon signed-rank test.

RESULTS

Patients' mean age was 33.3 ± 22.0 years. Technical success was achieved in all patients (100%), and symptomatic and biochemical improvement was documented in 46 of 48 patients (95.8%); assessment timing was not standardized. The mean stent indwelling time was 159 ± 42.9 days. Stent migration occurred in 3 patients (6.2%), and cholangitis in 5 patients (10.4%), with no major complications observed. The median primary patency was 1,689 days (95% confidence interval: 311–3,067 days). During follow-up, 29 of 48 patients (60.4%) required at least one additional biliary intervention. Total bilirubin levels decreased after the procedure (3.3 ± 1.9 vs. 0.8 ± 0.5 mg/dL, $P < 0.01$).

CONCLUSION

Percutaneous tandem MPBS placement is a reversible, metal-free salvage option for duct-to-duct biliary anastomotic strictures after LT. However, 60.4% of patients required additional biliary interventions during follow-up, underscoring the substantial reintervention burden associated with this approach. Its comparative efficacy relative to established alternatives, including biodegradable and removable covered metallic stents, remains undetermined.

CLINICAL SIGNIFICANCE

Percutaneous tandem modified plastic biliary stenting is a feasible metal-free salvage option for post-transplant anastomotic strictures when endoscopic treatment fails or is unfeasible. Further studies are needed to establish its efficacy relative to biodegradable and removable covered metallic stents.

KEYWORDS

Biliary stricture, plastic stent, liver transplant, percutaneous transhepatic cholangiography

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Benign biliary anastomotic strictures that develop after liver transplantation (LT) remain among the most frequent and challenging complications despite substantial advances in surgical techniques. According to the literature, they account for approximately 40% of all post-transplant biliary complications and may adversely affect long-term graft survival.[1]

In patients undergoing duct-to-duct reconstruction, the first-line treatment typically involves the endoscopic placement of plastic biliary stents (PBSs).[2-5] Using multiple and large-caliber stents has been shown to produce better outcomes.[1] However, endoscopic therapy is not always possible due to severe strictures, anatomical differences, or previous unsuccessful attempts. In such cases, percutaneous therapy offers an alternative.[6,7] Current percutaneous options include balloon dilatation, metallic and biodegradable stent placement, and internal–external drainage catheters; however, data on the use of percutaneous plastic stents remain limited in the literature.[7-9]

Although percutaneous plastic biliary stenting has been described in limited case series,[1] the simultaneous placement of two large-caliber modified plastic stents through a single percutaneous transhepatic access in patients with duct-to-duct reconstruction has not been systematically investigated. The tandem modified configuration deployed via a single access route and the long-term follow-up period together represent a clinically meaningful addition to the existing literature.

Main points

- Percutaneous placement of tandem modified plastic biliary stents (MPBSs) through a single transhepatic access achieved 100% technical success in patients with post-liver transplant anastomotic strictures; however, 29 of 48 patients (60.4%) required additional biliary intervention during follow-up.
- This metal-free approach demonstrated a median primary patency of 1,689 days (95% confidence interval: 311–3,067 days), with stent migration in 3 patients (6.2%), cholangitis in 5 (10.4%), and no major procedure-related complications observed in this cohort.
- Tandem MPBS placement may represent a metal-free salvage option for patients in whom endoscopic treatment has failed or is not feasible; its comparative efficacy and safety relative to biodegradable and removable covered metallic stents remain undetermined.

This study aims to assess the feasibility, safety, and long-term outcomes of this tandem modified plastic biliary stent (MPBS) approach for managing benign duct-to-duct biliary anastomotic strictures after LT.

Methods

Study design and ethical approval

This retrospective single-institution study was approved by the Başkent University Institutional Review Board of the University (approval number: KA25/412; date: 12.05.2025) and conducted in accordance with the Declaration of Helsinki. The need for written informed consent was waived due to the retrospective design and anonymized data analysis.

Patients

Patients who consecutively underwent LT with duct-to-duct biliary anastomosis between January 2011 and January 2025 and subsequently developed benign biliary strictures were retrospectively reviewed. Endoscopic failure was defined as the inability to achieve adequate biliary drainage or stricture traversal despite at least one attempted endoscopic retrograde cholangiopancreatography (ERCP) session. Endoscopic ineligibility included cases where ERCP was precluded by unfavorable anatomy, prior surgical alterations of the upper gastrointestinal tract, inaccessible papilla, or prior adverse events during endoscopic procedures. Exclusion criteria included hepaticojejunostomy reconstruction, malignant biliary obstruction, and incomplete clinical data. A total of 48 patients met the inclusion criteria (Figure 1). Given the relatively limited number of patients and the rarity of percutaneous tandem plastic stenting in post-transplant biliary strictures, pediatric and adult recipients were included within the same cohort to evaluate the overall technical feasibility of the technique. Nevertheless, subgroup analyses comparing pediatric and adult recipients were predefined and performed for patency and reintervention outcomes. Clinical, laboratory, imaging, procedural, and follow-up data were collected from electronic medical records.

Description of the technique

All interventions were performed independently by one of two interventional radiologists, each with > 15 years of experience in hepatobiliary interventions, under ultrasound and fluoroscopic guidance and conscious sedation.

In all patients, the procedure was performed via a pre-existing percutaneous transhepatic biliary drainage tract. After stabilization of clinical and infectious parameters, a 10F introducer sheath (Radifocus Introducer II; Terumo; Tokyo; Japan) was placed via the existing percutaneous biliary access, followed by cholangiography to define biliary anatomy and stricture characteristics. Balloon dilatation was performed selectively when the stricture could not be adequately traversed or expanded with the stent delivery system alone. Balloon diameters ranged from 6 to 10 mm according to bile duct caliber, with inflation maintained for approximately 30–60 seconds under fluoroscopic monitoring. Through the 10F sheath, a 6F, 45-cm sheath (Destination; Terumo Interventional Systems) was advanced, with an additional 0.035-inch stiff guidewire placed into the duodenum. Precise measurements were taken to ensure the stents would fully span the stricture, from the intrahepatic bile ducts to the duodenum.

Patient-specific MPBSs were created by trimming an 8–12F internal–external biliary

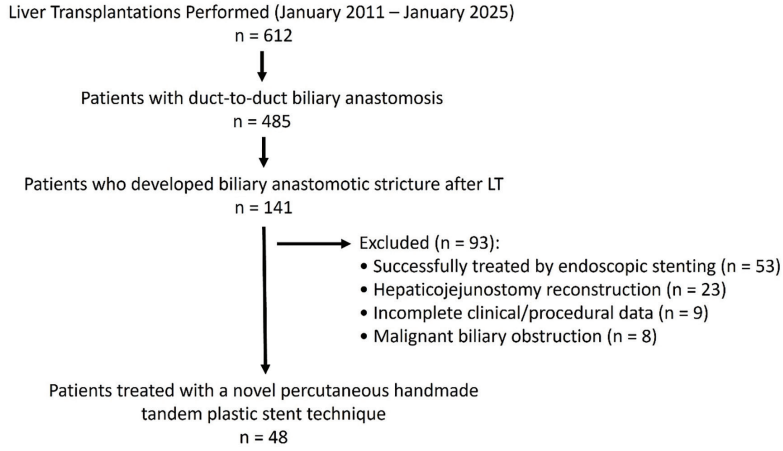


Figure 1. Flowchart. LT, liver transplantation.

drainage catheter (Flexima; Boston Scientific) (Figure 2). The tapered 1-cm distal tip of the catheter, along with the segment containing the radiopaque marker, was cut. The straight end of the MPBS was secured with 2-0 polypropylene sutures. This suture fixation was designed to allow for positional adjustment if the stent advanced distally beyond the desired location. After removing the short vascular sheath, two stiff guidewires remained in place, crossing the skin entry site, passing through the biliary ducts, and ending in the duodenum. Over the guidewires, the 1-cm tip, the MPBS with its straight end first, and finally the remaining part of the catheter (Figure 3) were sequentially advanced. The pigtail end was positioned to remain within the biliary system, preventing the catheter tip from migrating as it tried to revert to its pigtail shape. Once the stents reached the target position, the suture was removed by pulling on one end, and the stent portion used as a pusher stayed within the intrahepatic bile ducts. This dual catheter-based method enabled drainage through a single percutaneous tract. This type of double stent technique is more successful than a single stent in the treatment of biliary strictures (Figure 4).[10]

The stents were intended to be kept in place across the biliary stricture for 3–6 months; the complication rate increases when stents are left in place for extended periods without replacement.[11] Stents that reached this intended dwell time without complications were removed endoscopically. If any clinical or laboratory abnormality occurred, the stents were removed endoscopically at the discretion of the multidisciplinary hepatobiliary team.

The interventional radiology team conducted post-procedure follow-up in coordination with the hepatobiliary surgery, oncology, and endoscopy units.

The MPBSs were manually fabricated from commercially available internal–external biliary drainage catheters originally approved for biliary drainage. Their use as internal tandem stents represented an off-label modification performed at the discretion of the treating interventional radiologists within a multidisciplinary hepatobiliary practice. All patients provided procedural informed consent before intervention. Institutional review board approval included retrospective evaluation of this treatment approach.

Definitions

Technical success was defined as successful stent placement with adequate biliary drainage on cholangiography. Clinical response was assessed based on symptomatic improvement and improved liver function tests; the assessment time point was not standardized. Complications were classified according to the Cardiovascular and Interventional Radiological Society of Europe classification system.[12]

Early strictures were defined as those occurring within 3 months after LT and late strictures thereafter.

Primary patency was defined as the period from stent placement until a secondary percutaneous, endoscopic (excluding planned stent removal), or surgical intervention becomes necessary.

Secondary patency was defined as the length of time bile flows freely after percutaneous or endoscopic re-intervention, without clinical or laboratory indications of biliary obstruction.

It should be noted that stent indwelling time and primary patency are separate clinical endpoints. Stent indwelling time refers to the span from stent placement to planned or unplanned endoscopic removal, whereas primary patency indicates the period from stent placement until the need for any secondary percutaneous, endoscopic (excluding planned stent removal), or surgical re-intervention—a time that extends well beyond the initial stent dwell period in patients who remain stricture free after stent removal.

Statistical analysis

Statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation or median (range) and categorical variables as frequencies and percentages.

Pre- and post-procedural laboratory values were compared using the Wilcoxon signed-rank test. Comparisons between patients with and without stricture recurrence were performed using the Mann–Whitney U test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate. Primary patency was analyzed using the Kaplan–Meier method, with the requirement for any additional biliary intervention (excluding planned stent removal) considered an event and patients without an event censored at their last follow-up. Median primary patency and its corresponding 95% confidence intervals (CIs) were estimated using Kaplan–Meier analysis. Univariate Cox regression was performed to evaluate potential predictors of recurrence; multivariate analysis was not conducted due to the limited number of events to avoid model overfitting. The following variables

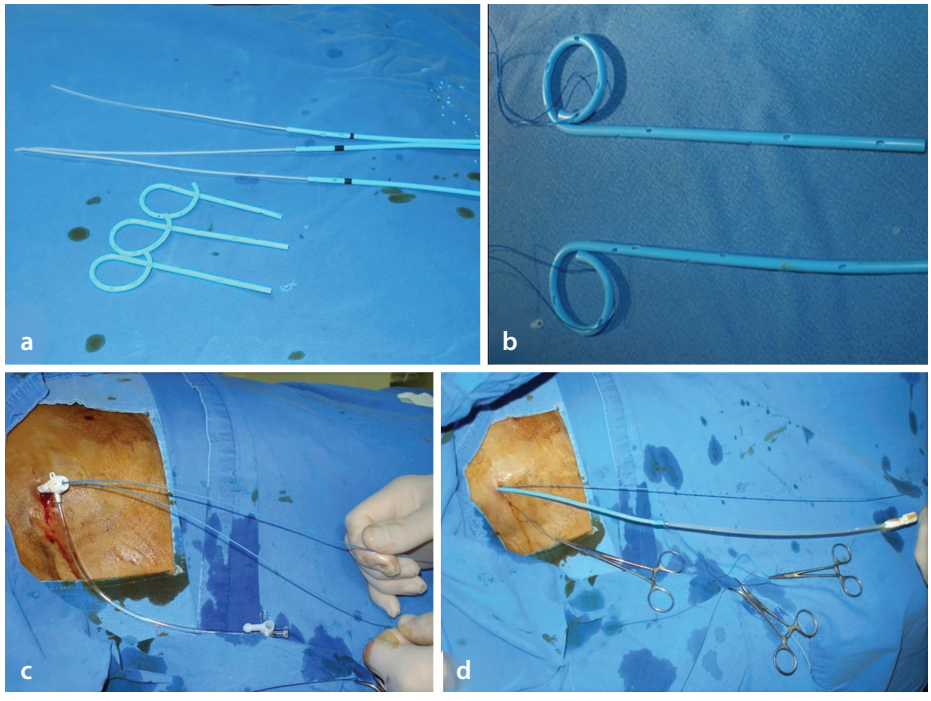


Figure 2. Preparation and placement of modified plastic stents. **(a)** Plastic stents are cut to the desired length using an internal–external biliary drainage catheter as a template. **(b)** A single 2-0 Prolene suture is placed at the hepatic end of each stent, allowing retrieval when required. **(c)** Two Amplatz guidewires are positioned, extending into the duodenum. **(d)** The plastic stents are sequentially advanced and deployed over the guidewires.

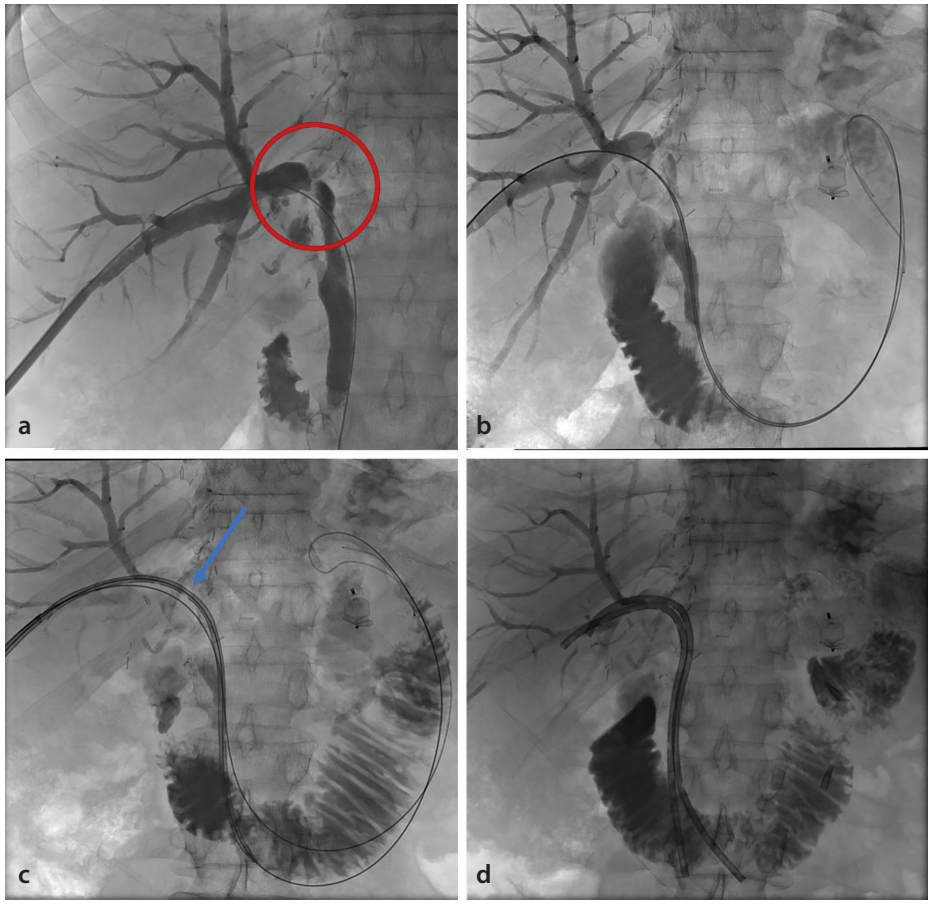


Figure 3. A 64-year-old male patient with a persistent biliary anastomotic stricture despite multiple previous balloon dilatation procedures. **(a)** Cholangiographic image demonstrating the persistent biliary anastomotic stricture. **(b)** Placement of two Amplatz guidewires extending from the intrahepatic bile ducts into the duodenum. **(c)** Deployment of two modified plastic stents, each advanced over a separate guidewire. **(d)** Final cholangiographic image obtained after removal of the guidewires and sheath, showing two plastic stents positioned across the anastomotic stricture. The red circle indicates the biliary anastomotic stricture, and the blue arrows indicate the plastic stents.

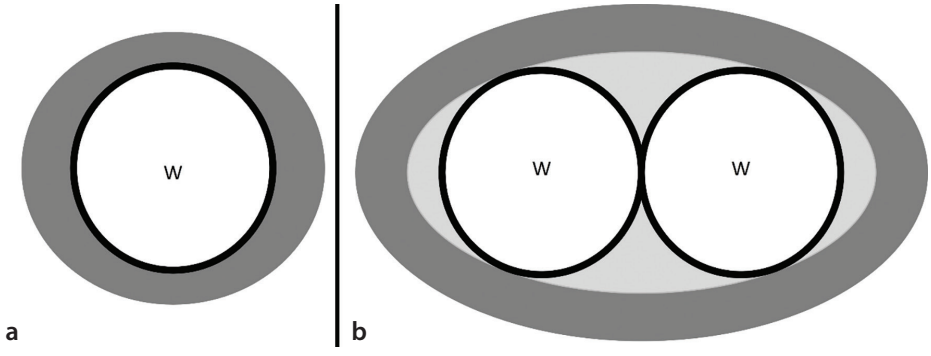


Figure 4. Schematic view of the tandem stent system at the stricture area. **(a)** When a single stent is placed across the anastomotic stricture, bile drainage is limited to the internal lumen of that stent. In contrast, the tandem stent placement technique allows for more effective biliary drainage not only through the lumens of the two stents but also through the potential spaces around the stents. **(b)** This feature helps prevent early occlusion of the drainage system. White area **(W)**: intraluminal space, dark gray area: stricture, light gray area: potential spaces around the stents.

were evaluated: age at stent placement, sex, graft type (living donor vs. deceased donor), timing of stricture onset (early vs. late), stent diameter (≤ 10F vs. > 10F), and stent indwelling time. A *P* value of < 0.05 was considered statistically significant.

Results

A total of 48 LT recipients (33 male patients and 15 female patients; mean age: 33.3 ± 22.0 years; range: 1–74 years) who developed duct-to-duct biliary anastomotic strictures underwent percutaneous placement of tandem MPBSs. The study population comprised both pediatric (age < 18 years; n = 15, 31.2%) and adult (age ≥ 18 years; n = 33, 68.8%) recipients. No statistically significant differences were observed between pediatric and adult recipients regarding technical success, symptomatic and biochemical improvement, primary patency, secondary patency, or reintervention frequency. The most common indication for LT was cirrhosis (26/48, 54.2%). In all patients, strictures were located at the biliary anastomotic level. Detailed patient characteristics and procedural data are summarized in Table 1.

Technical success was achieved in all patients (48/48, 100%). Symptomatic and biochemical improvement was documented in 46 of 48 patients (95.8%), although the assessment time point was not standardized (Table 2). Among the 2 patients without documented symptomatic and biochemical improvement, 1 developed progressive graft dysfunction requiring retransplantation despite adequate biliary drainage, whereas the other had a persistent, refractory stricture requiring surgical revision. The mean time from LT to internal stent placement was 1,395 ± 1,614 days (range: 58–6,552 days). The mean follow-up duration after the procedure was 2,397 ± 1,562 days (range: 376–6,588 days).

The mean number of reinterventions in the overall study population was 1.79 ± 1.85 (range: 0–6). In adult patients, the mean was 1.87 ± 2.02 (range: 0–6), whereas in pediatric patients it was 1.60 ± 1.45 (range: 1–4). There was no statistically significant difference between adult and pediatric patients ($P = 0.88$). Additional procedures were required in 29 patients. Of these, 19 (39%) underwent endoscopic stent replacement due to stent occlusion. In 10 patients (21%), percutaneous drainage catheter placement was necessary due to recurrence of biliary stricture after stent removal.

During follow-up, 29 of 48 patients (60.4%) required at least one additional biliary intervention and were considered to have reached the primary patency endpoint, whereas 19 patients (39.6%) were censored without an additional intervention. The Kaplan–Meier analysis demonstrated a median primary patency of 1,689 days (95% CI: 311–3,067 days). Primary patency rates are shown in Table 3. No statistically significant difference was observed between adult and pediatric patients in primary patency ($P = 0.46$). The Kaplan–Meier curve for primary patency is presented in Figure 5. Patency out-

comes did not significantly differ between patients treated with 8F tandem stents and those treated with 10F tandem stents.

Internal plastic stents with diameters ranging from 8 to 12F were selected according to the degree of biliary dilatation. The most frequently used stent size was 10F, used in 26 patients (54.2%). In all procedures, two tandem stents of identical size were deployed. The mean indwelling time of tandem internal stents was 159 ± 42.9 days (range: 80–260 days).

Spontaneous stent migration into the bowel occurred in 3 patients (6.2%), none of whom required additional intervention during follow-up. Five patients (10.4%) developed cholangitis due to stent occlusion, and stents were removed endoscopically in these cases. The mean indwelling time of the stents in patients who developed cholangitis was 168 ± 54 days (range: 90–240 days). Among these patients, 3 did not require further treatment after stent removal, whereas 2 required additional percutaneous drainage and balloon dilatation. In the remaining 40 patients, stents were removed during routine follow-up without complications.

Univariate Cox regression analysis did not identify any significant predictors of stricture recurrence.

No major procedure-related complications were observed. Five patients experienced moderate pain at the percutaneous entry site, and 1 patient developed hemobilia after the procedure. All complications were successfully managed with conservative and supportive treatment.

Table 1. Patients and procedural characteristics

Patient and procedural characteristics	n
Male/female	33 (69%)/15 (31%)
Mean age (SD; range)	33.3 years (22.0; 1–74)
Graft type	
Cadaver	8 (16%)
Live donor	40 (84%)
Biliary stricture time	
Early (< 3 months)	9 (19%)
Late (> 3 months)	39 (81%)
Total bilirubin levels (mean) (pre-post procedure)	3.3–0.8 mg/dL
Stent size	
8F and 8F	21 (44%)
10F and 10F	26 (54%)
12F and 12F	1 (2%)
Mean stent indwelling time (SD; range)	159 days (42.9; 80–260)
Follow-up time (SD; range)	2,397 days (1,562; 376–6,588)

n, number; SD, standard deviation; F, French.

Table 2. Outcomes after percutaneous plastic stent placement

Outcome parameter	Results
Patients	48
Technical success	48/48 (100%)
Symptomatic and biochemical improvement	46/48 (95.8%)
Patients requiring no additional biliary intervention*	19 (39.6%)
Median primary patency, days (95% confidence interval)	1,689 (311–3,067)
Mean follow-up duration (no additional intervention group)	2,421 ± 1,399 days (range: 433–4,823)
Patients requiring additional procedures	29
Number of additional procedures (median, range)	3 (1–6)
Re-transplantation due to graft failure	1
Referral to surgery due to a refractory stricture	1
Pre-procedural total bilirubin (mg/dL)	Mean: 3.3 ± 1.93 (range: 0.9–8.7)
Total bilirubin at 7 days post-procedure (mg/dL)	Mean: 0.8 ± 0.49 (range: 0.2–3.6)
Statistical significance (bilirubin change)	$P < 0.01$

*Patients required only endoscopic removal of internal stents without additional intervention.

Discussion

This study evaluated the technical feasibility, safety, and long-term outcomes of a percutaneous tandem MPBS technique in LT recipients, demonstrating high technical success, documented symptomatic and biochemical improvement, a favorable safety profile, and a substantial need for subsequent biliary interventions. Results suggest that this approach may be a valuable salvage option for patients for whom traditional endoscopic therapy has failed or is unsuitable.

Endoscopic PBS placement remains the first-line approach, with reported long-term resolution rates of 70%–85%.[3,4,13,14] Endoscopic failure may occur due to technical limitations, tight or tortuous strictures, or anatomic variations. Several patients in the present cohort had extremely tight strictures, altered anatomy, failed prior ERCP attempts, or an inability to traverse the anastomosis endoscopically. Therefore, the present study specifically reflects a difficult-to-treat subgroup in whom conventional endoscopic treatment was unsuccessful or technically infeasible. In such cases, percutaneous interventions become necessary. Traditional percutaneous methods, including balloon dilatation or metallic stenting, may require multiple sessions, carry a risk of stricture recurrence, or limit future surgical options.[7-9,15]

Table 3. Primary patency rates

	1 year (95% CI)	3 years (95% CI)	5 years (95% CI)	10 years (95% CI)
Primary overall	68.7 (53.6-79.8)	58.0 (42.8-70.6)	48.1 (33.0-61.7)	26.2 (11.6-43.5)
Adults	69.7 (51.0-82.4)	56.9 (38.3-71.9)	50.0 (31.7-65.8)	34.6 (16.7-53.3)
Pediatrics	66.7 (37.5-84.6)	60.0 (31.8-79.6)	43.8 (17.9-67.2)	0

CI, confidence interval.

The technique presented here addresses these challenges. The MPBSs, modified from drainage catheters, can be placed through a single percutaneous access, thereby eliminating the need for multiple percutaneous accesses. The observed outcomes are consistent with those reported for endoscopic plastic stenting and metallic stenting in post-transplant biliary strictures.[16]

Evidence suggests that the use of multiple plastic stents yields better outcomes than single-stent strategies in post-transplant benign biliary strictures.[17,18] The favorable results may be explained by several advantages of tandem MPBS placement. First, two parallel stents increase effective luminal diameter and drainage capacity, which may reduce early stent occlusion (Figure 4). Second, a single percutaneous tract eliminates the need for multiple access routes. Unlike metallic stents, MPBSs provide a removable, metal-free drainage option; however, their comparative effects on the biliary wall and long-term clinical outcomes remain undetermined.

Although the absence of a control group limits direct comparisons, the outcomes were consistent with those reported in previous studies.[7,17,19-21] Stent migration remains a potential limitation of both plastic and metallic stents. Previous studies have reported migration rates of up to 37% for self-expanding metal stents.[22] In the present study, stent migration occurred in 6% of patients, which is comparable to or lower than rates reported in the literature.[13,23,24] The absence of metal within the biliary tree may preserve flexibility for future surgical or endoscopic interventions, although this potential benefit was not specifically evaluated in our study.

The customized nature of MPBSs allows precise adaptation to individual anatomy and stricture length and may offer greater flexibility than prefabricated stents. Although derived from pigtail catheters, their final shape depends on the biliary anatomy; in narrow donor ducts, a straighter configuration may result. However, residual curvature at the proximal end still contributes to anchoring and may reduce the risk of migration. This configuration permits the treatment of complex strictures, including cases in which anastomotic and non-anastomotic strictures coexist. The predominance of living donor grafts in the present cohort is clinically relevant because these grafts frequently involve smaller-caliber and more delicate biliary anatomy. In such patients, achieving tandem drainage through a single transhepatic puncture may reduce procedural trauma and preserve future biliary access options. Additionally, the tandem configuration increases effective drainage capacity regardless of shape.

Although these patients were unsuitable for therapeutic endoscopic stenting, endoscopic bowel access for stent removal was still feasible. Endoscopic stent removal was performed when feasible; percutaneous removal was used in cases of severe duodenal stricture where endoscopic access was not possible.

Biodegradable biliary stents represent an established treatment option for benign biliary strictures, providing temporary biliary support without requiring dedicated stent retrieval procedures. Almeida and Donato[18] reported cholangitis rates of up to 24% for biodegradable stents, though most included studies used an endoscopic approach. Zhang et al.[25] and Chen et al.,[26] who specifically evaluated percutaneous implantation of biodegradable biliary stents, reported cholangitis rates considerably lower than those in the Almeida meta-analysis. The 10.4% cholangitis rate observed in our study should be interpreted cautiously in comparison with these findings because of differences in patient populations and treatment approaches. The present retrospective study did not directly compare tandem MPBSs with biodegradable biliary stents; therefore, their relative efficacy, safety, and resource requirements cannot be established from our findings. Prospective comparative studies are needed to establish the relative efficacy and safety of percutaneous tandem MPBS placement and biodegradable stents.

Although reintervention was required in a substantial proportion of patients, most secondary procedures were minimally invasive endoscopic stent exchanges or percutaneous revisions that contributed to maintaining biliary drainage during follow-up. Secondary patency therefore reflects the outcomes of subsequent biliary interventions as well as the index procedure and should not be interpreted as the long-term efficacy of tandem MPBS placement alone.

The stents are manually modified from commercially available internal–external biliary drainage catheters, constituting off-label use with implications for device liability. The manual modification and tandem placement require technical expertise and may limit reproducibility across centers. This technique should therefore be applied with caution, and the development of purpose-built devices would help standardize this approach.

Limitations include the retrospective, single-center design, the absence of a control group, and potential selection bias, which is partially mitigated by the long follow-up and comparisons with the literature. Heterogeneous stricture characteristics and limited subgroup sample sizes may have influenced results. The inclusion of both pediatric and adult recipients introduced biological and anatomical heterogeneity. However, subgroup analyses did not demonstrate significant outcome differences between the two groups. Larger multicenter studies with stratified cohorts are needed to validate these findings separately in pediatric and adult populations. Clinical response was not

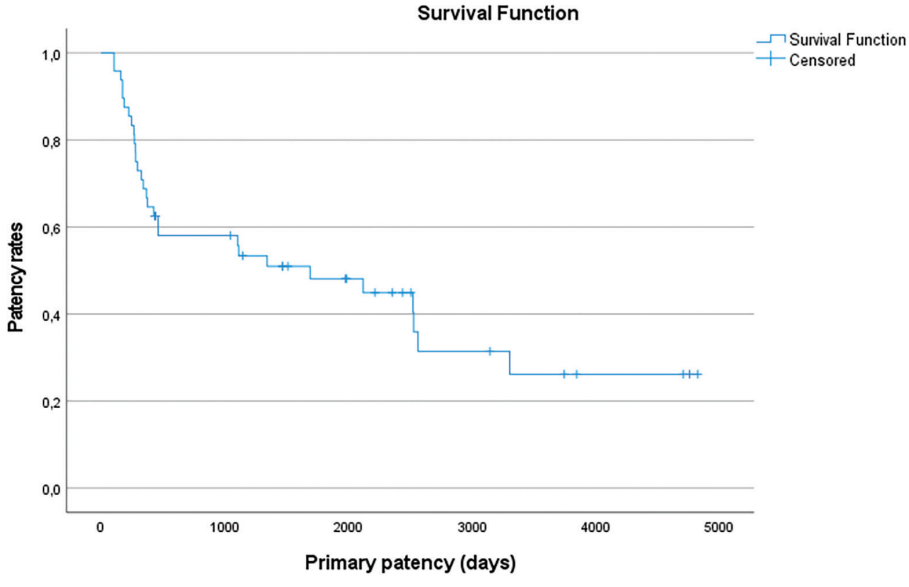


Figure 5. Kaplan–Meier curve of primary patency following tandem modified plastic biliary stent placement.

assessed at a standardized time point, and secondary patency included the effects of subsequent biliary interventions. The univariate analysis was likely underpowered due to the limited number of events, and therefore, the absence of significant predictors should be interpreted with caution. Cost-effectiveness and quality-of-life outcomes were not assessed. Larger prospective multicenter studies are needed to evaluate the efficacy, safety, and reproducibility of this technique.

Percutaneous placement of tandem MPBSs is a technically feasible salvage option for benign duct-to-duct biliary anastomotic strictures after LT, achieving high technical success and symptomatic and biochemical improvement, although subsequent biliary interventions were frequently required. This technique may represent an additional treatment option when endoscopic therapy fails. Its potential advantages over biodegradable and removable covered metallic stents remain unestablished. Larger prospective multicenter comparative studies are warranted to evaluate its long-term efficacy, safety, and reproducibility.

Footnotes

Conflict of interest disclosure

The authors declared no conflicts of interest.

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