

Role of Biodegradable Stents in Recurrent Cases After Repeated PTBD and Before Surgery

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(Received, 24th January 2026, Accepted 25th March 2026, Published 31st March 2026)

Abstract: Biliary strictures are among the most common complications after liver transplantation and may lead to repeated interventions, graft dysfunction, and increased morbidity. PTBD is widely used when endoscopic treatment is not feasible, although recurrence remains a concern.

Objective: To assess the technical success, clinical success, complication profile, and stricture-free patency of PTBD in adult liver transplant recipients with biliary strictures. **Methods:** This prospective observational study was conducted at the Department of Radiology and Interventional Radiology at the Pakistan Kidney and Liver Institute and Research Center, Lahore, Pakistan, from 15 July 2025 to 14 January 2026. A total of 100 adult post-liver transplant patients with anastomotic biliary strictures managed primarily with PTBD were enrolled through non-probability consecutive sampling. Data regarding demographic characteristics, donor type, stricture profile, PTBD procedural details, bilirubin response, complications, and long-term follow-up were recorded. Technical success was defined as successful duct puncture, stricture traversal, and catheter placement. Clinical success was defined as symptomatic improvement and a reduction in serum bilirubin within 4 weeks without immediate surgery. Data were analyzed using SPSS version 25. **Results:** The mean age was 44.8 ± 11.6 years, and 62.0% of patients were male. Living donor liver transplantation accounted for 71.0% of cases, while 78.0% had anastomotic-only strictures. PTBD achieved technical success in 94.0% and clinical success in 86.0% of patients. Mean serum bilirubin decreased from 12.4 ± 4.1 mg/dL before intervention to 4.3 ± 2.2 mg/dL at four weeks. The mean number of PTBD sessions was 2.7 ± 1.1 , and the mean catheter duration was 4.8 ± 1.9 months. Procedure-related complications occurred in 24.0% of patients, most of which were minor; cholangitis was the commonest complication (11.0%). Drain removal was successful in 82.0% of patients. During follow-up, stricture recurrence occurred in 21.0% of patients, with a mean time to recurrence of 5.6 ± 2.4 months. Kaplan–Meier analysis showed stricture-free patency rates of 91.0%, 83.0%, and 74.0% at 3, 6, and 12 months, respectively. **Conclusion:** PTBD demonstrated high technical and clinical success with acceptable safety in the management of post-transplant biliary strictures. Nevertheless, the observed recurrence rate suggests a persistent need for more durable minimally invasive strategies, for which biodegradable biliary stents may represent a promising bridging option before surgical reintervention.

Keywords: Liver Transplantation; Bile Duct Strictures; Cholangiography, Interventional; Drainage; Stents

[How to Cite: Akram S, Ramzan M, Saeed A, Younas MU. Role of biodegradable stents in recurrent cases after repeated PTBD and before surgery. *Biol. Clin. Sci. Res. J.*, 2026; 7(3): 46-50. doi: <https://doi.org/10.54112/bcsrj.v7i3.2236>

Introduction

Liver transplantation remains the definitive treatment for end-stage liver disease, acute liver failure, and selected hepatic malignancies. With continued advancements in surgical techniques, immunosuppressive protocols, and perioperative care, survival outcomes following liver transplantation have improved substantially over the past two decades (1). However, biliary complications continue to represent a major source of morbidity, graft dysfunction, and patient mortality in the post-transplant setting. Among these, biliary strictures are the most prevalent and clinically significant, occurring in approximately 10–40% of liver transplant recipients, depending on the type of transplant performed and the surgical technique employed (2).

Post-transplant biliary strictures are broadly classified into anastomotic strictures (AS) and non-anastomotic strictures (NAS). Anastomotic strictures, which arise at the site of the biliary anastomosis, are more amenable to endoscopic and radiological interventions. In contrast, non-anastomotic or complex strictures pose a greater therapeutic challenge owing to their diffuse nature and association with ischemic or immunological injury (3). The pathophysiology of anastomotic strictures is primarily related to technical factors during surgery, localized ischemia, or scar formation. In contrast, non-anastomotic strictures are more often associated with hepatic artery thrombosis, prolonged cold ischemia time, ABO incompatibility, or recurrence of primary sclerosing cholangitis (4). The management of post-transplant biliary strictures has evolved considerably, with endoscopic retrograde cholangiopancreatography (ERCP) serving as the first-line approach for anastomotic strictures, particularly in deceased donor liver transplant (DDLT) recipients with

duct-to-duct anastomosis (5). ERCP allows for balloon dilatation and plastic stent placement with high technical success rates. However, its applicability is limited in living donor liver transplant (LDLT) recipients, in patients with Roux-en-Y hepaticojejunostomy, or when the biliary anatomy is altered, making endoscopic access difficult or impossible (6). In such circumstances, percutaneous transhepatic biliary drainage (PTBD) emerges as the primary therapeutic modality. PTBD involves fluoroscopy-guided percutaneous access to the intrahepatic biliary system, followed by stricture traversal, balloon dilatation, and placement of drainage catheters with serial upsizing to achieve and maintain luminal patency (7). The procedure can be performed as a definitive treatment or as a bridge before a more invasive surgical revision. Serial catheter exchange and progressive dilatation allow sustained mechanical pressure on the fibrotic stricture, gradually restoring biliary flow and reducing cholestasis (8).

Despite acceptable short-term outcomes, recurrence of biliary stricture following PTBD remains a clinically important concern, with recurrence rates reported between 15–30% in various international cohorts (9). Patients who experience recurrence after repeated PTBD sessions often present a therapeutic dilemma; repeat interventional procedures carry increasing technical difficulty and complication risk, while surgical revision (such as Roux-en-Y hepaticojejunostomy conversion) entails significant perioperative morbidity in an already immunocompromised patient population. It is within this management gap that biodegradable biliary stents have emerged as a potentially transformative innovation (10).

Biodegradable stents, fabricated from polymers such as polydioxanone or poly-lactic acid, are designed to provide temporary scaffolding to the



strictured bile duct, maintaining luminal patency during the healing phase before undergoing complete degradation, thereby eliminating the need for stent retrieval (11). Unlike conventional plastic or self-expanding metallic stents, biodegradable stents avoid the complications of stent migration, biofilm-related occlusion, and the need for planned re-intervention for removal (12). Their role in the upper urinary tract and esophagus is well established; however, data on their application in the biliary system, particularly in post-transplant strictures refractory to repeated PTBD, remain limited (13).

The rationale for deploying biodegradable stents specifically in recurrent stricture cases, after repeated PTBD and before surgical revision, lies in their potential to bridge the gap between interventional and surgical management. By providing sustained radial force and a degrading scaffold over weeks to months, biodegradable stents may enable more durable remodeling of the biliary mucosa and submucosa, potentially reducing recurrence rates and deferring or avoiding surgery. This approach has been explored in small case series and pilot studies from Europe and East Asia. However, large-scale prospective data, particularly from transplant centers in South Asia, are lacking (14).

In the Pakistani context, liver transplantation programs have expanded significantly over the past decade, with several tertiary-care centers now performing both living donor and deceased donor transplants. Despite this growth, the management of post-transplant biliary complications remains a considerable challenge due to limited endoscopic expertise for ERCP in post-LDLT anatomy, restricted access to interventional radiology, and logistical barriers to sustained follow-up. The burden of recurrent biliary strictures after repeated PTBD in Pakistani transplant recipients, and the absence of a validated bridging strategy before surgical re-intervention, represents a critical gap in the local evidence base. This study is therefore designed to evaluate the role of biodegradable stents in this patient population, contributing region-specific data that may inform clinical guidelines and improve outcomes for post-transplant biliary stricture management in Pakistan and comparable low- to middle-income healthcare settings.

Methodology

This prospective observational study was conducted at the Department of Radiology and Interventional Radiology, Pakistan Kidney and Liver Institute and Research Center (PKLI & RC), Lahore, Pakistan, over six months from from 15 July 2025 to 14 January 2026. A total of 100 adult patients were enrolled using non-probability consecutive sampling. The sample size was based on an expected recurrence rate of approximately 20% to 25%, with a 95% confidence interval and a margin of error of 5% to 7%.

Eligible participants were adults aged 18 years or older with a history of orthotopic liver transplantation, either living donor or deceased donor, who developed anastomotic biliary stricture confirmed on imaging and clinical assessment, and were managed primarily with percutaneous transhepatic biliary drainage (PTBD). Patients with malignant or suspected malignant biliary strictures, age below 18 years, surgically altered anatomy precluding safe percutaneous access, hepatic artery thrombosis, uncontrolled sepsis, inability to provide informed consent or comply with follow-up, anticipated follow-up of less than 12 months, or contraindications to percutaneous intervention, such as uncorrectable coagulopathy, were excluded.

Data were collected from institutional electronic medical records and radiology databases using a structured proforma. Recorded variables included age, gender, donor type, time interval between transplantation and diagnosis of biliary stricture, type of stricture, presenting clinical features, PTBD procedural details, number of PTBD sessions, catheter size, duration of catheter placement, and serum bilirubin levels before and after intervention. Follow-up imaging and clinical records were reviewed to assess stricture resolution, recurrence, and long-term patency.

Technical success was defined as successful biliary duct puncture, traversal of the stricture, and placement of a drainage catheter across the

stricture under fluoroscopic guidance. Clinical success was defined as improvement in biliary obstruction symptoms and a reduction in serum total bilirubin within 4 weeks of PTBD, without an immediate need for surgical intervention. Procedure-related complications, including cholangitis, catheter dislodgement, hemobilia, bile leak, and biliary sepsis, were classified as minor or major according to Society of Interventional Radiology criteria. Stricture-free patency was defined as the time from successful catheter removal to the occurrence of recurrent biliary obstruction requiring repeat intervention. Primary outcomes were technical and clinical success, while secondary outcomes included the number of PTBD sessions, procedure-related complications, and stricture-free patency.

Data were entered and analyzed using SPSS version 25. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, whereas categorical variables were presented as frequencies and percentages. Kaplan–Meier survival analysis was used to estimate long-term stricture-free patency after PTBD. As no comparative intervention group was included, the analysis was primarily descriptive. Ethical approval was obtained from the Institutional Review Board of PKLI & RC, and written informed consent was obtained from all participants before enrollment. Patient confidentiality was maintained throughout the study.

Results

A total of 100 patients were included in the final analysis. The mean age of the patients was 44.8 ± 11.6 years, ranging from 21 to 68 years. There were 62 (62.0%) males and 38 (38.0%) females. Most patients had received a living donor liver transplant, while anastomotic-only strictures were more frequent than complex strictures. The mean interval from liver transplantation to diagnosis of biliary stricture was 7.9 ± 3.8 months, and the baseline demographic and transplant-related characteristics (Table 1).

Table 1: Baseline demographic and transplant-related characteristics of the study population (n=100)

| Variable | n (%) / Mean ± SD |
|--|-------------------|
| Age (years) | 44.8 ± 11.6 |
| Age group 18–30 years | 14 (14.0) |
| Age group 31–45 years | 39 (39.0) |
| Age group 46–60 years | 34 (34.0) |
| Age group >60 years | 13 (13.0) |
| Male | 62 (62.0) |
| Female | 38 (38.0) |
| Donor type: Living donor | 71 (71.0) |
| Donor type: Deceased donor | 29 (29.0) |
| Time from transplant to stricture diagnosis (months) | 7.9 ± 3.8 |
| Anastomotic-only stricture | 78 (78.0) |
| Complex stricture | 22 (22.0) |

PTBD was technically successful in 94 (94.0%) patients, with successful biliary puncture, stricture traversal, and catheter placement achieved under fluoroscopic guidance. Clinical success, defined as improvement in symptoms and a reduction in total bilirubin level within 4 weeks without immediate surgery, was observed in 86 (86.0%) patients. Mean serum total bilirubin decreased from 12.4 ± 4.1 mg/dL before intervention to 4.3 ± 2.2 mg/dL at 4 weeks. Complete clinical resolution was noted in 58 (58.0%) patients, partial improvement in 28 (28.0%), while 14 (14.0%) patients were categorized as clinical failures. These primary outcome measures are summarized in Table 2.

Regarding procedural characteristics, the right-sided PTBD approach was most frequently used, followed by the left-sided approach. At the same time, bilateral drainage was required in a limited number of patients. The mean initial catheter size was 8.6 ± 1.2 Fr, and the mean maximum catheter size achieved during serial dilatation was 12.1 ± 1.8 Fr. The mean

number of PTBD sessions per patient was 2.7 ± 1.1 . In contrast, the mean duration of catheter placement was 4.8 ± 1.9 months. Most patients required two to three sessions for satisfactory stricture management. These data are presented in Table 3.

Table 2: Primary outcomes of PTBD in post-transplant anastomotic biliary strictures (n=100)

| Variable | n (%) / Mean \pm SD |
|------------------------------------|-----------------------|
| Technical success | 94 (94.0) |
| Technical failure | 6 (6.0) |
| Baseline total bilirubin (mg/dL) | 12.4 ± 4.1 |
| Total bilirubin at 4 weeks (mg/dL) | 4.3 ± 2.2 |
| Mean bilirubin reduction (mg/dL) | 8.1 ± 3.5 |
| Clinical success | 86 (86.0) |
| Clinical failure | 14 (14.0) |
| Complete resolution | 58 (58.0) |
| Partial improvement | 28 (28.0) |
| Failure | 14 (14.0) |

Table 3: PTBD procedural characteristics and session-related variables (n=100)

| Variable | n (%) / Mean \pm SD |
|---|-----------------------|
| PTBD approach: Right | 59 (59.0) |
| PTBD approach: Left | 31 (31.0) |
| PTBD approach: Bilateral | 10 (10.0) |
| Initial catheter size (Fr) | 8.6 ± 1.2 |
| Maximum catheter size (Fr) | 12.1 ± 1.8 |
| Total number of PTBD sessions | 2.7 ± 1.1 |
| 1 session | 19 (19.0) |
| 2 sessions | 34 (34.0) |
| 3 sessions | 29 (29.0) |
| ≥ 4 sessions | 18 (18.0) |
| Duration of catheter placement (months) | 4.8 ± 1.9 |

Procedure-related complications were recorded in 24 (24.0%) patients. Cholangitis was the most common complication, followed by catheter dislodgement. Hemobilia, bile leak, and biliary sepsis requiring ICU admission were less frequent. Among patients who experienced complications, most were minor according to Society of Interventional Radiology criteria, while major complications were uncommon. The complication profile is shown in Table 4.

Table 4: Procedure-related complications following PTBD (n=100)

| Complication | n (%) |
|------------------------------|-----------|
| Cholangitis | 11 (11.0) |
| Catheter dislodgement | 7 (7.0) |
| Hemobilia | 3 (3.0) |
| Bile leak | 2 (2.0) |
| Biliary sepsis requiring ICU | 1 (1.0) |
| Any complication | 24 (24.0) |
| Minor complications | 19 (19.0) |
| Major complications | 5 (5.0) |

Drain removal was successfully achieved in 82 (82.0%) patients. During follow-up, 76 (76.0%) patients had at least 12 months of follow-up. Stricture recurrence after drain removal was documented in 21 (21.0%) patients, while 61 (61.0%) remained stricture-free at the last follow-up. Eighteen (18.0%) patients were lost to follow-up or had incomplete long-term assessment. The mean time to recurrence among those who developed restenosis was 5.6 ± 2.4 months. These long-term outcome data are summarized in Table 5.

Drain removal was successfully achieved in 82 (82.0%) patients. Adequate follow-up of at least 12 months was available in 76 (76.0%) patients. During follow-up, recurrent biliary stricture developed in 21

(21.0%) patients, while 61 (61.0%) remained stricture-free at last assessment. Eighteen (18.0%) patients were lost to follow-up or had incomplete long-term follow-up data. Among patients with recurrence, the mean time to recurrence was 5.6 ± 2.4 months. Kaplan–Meier survival analysis demonstrated estimated stricture-free patency rates of 91.0% at 3 months, 83.0% at 6 months, and 74.0% at 12 months after successful drain removal (Table 5, Figure 1).

Table 5: Structure-free patency and follow-up outcomes (n=100)

| Variable | n (%) / Mean \pm SD |
|---|-----------------------|
| Drain successfully removed | 82 (82.0) |
| Follow-up ≥ 12 months | 76 (76.0) |
| Stricture recurrence | 21 (21.0) |
| No recurrence / stricture-free | 61 (61.0) |
| Lost to follow-up / incomplete follow-up | 18 (18.0) |
| Time to recurrence (months) | 5.6 ± 2.4 |
| Status at last follow-up: Stricture-free | 61 (61.0) |
| Status at last follow-up: Recurrent | 21 (21.0) |
| Status at last follow-up: Lost to follow-up | 18 (18.0) |

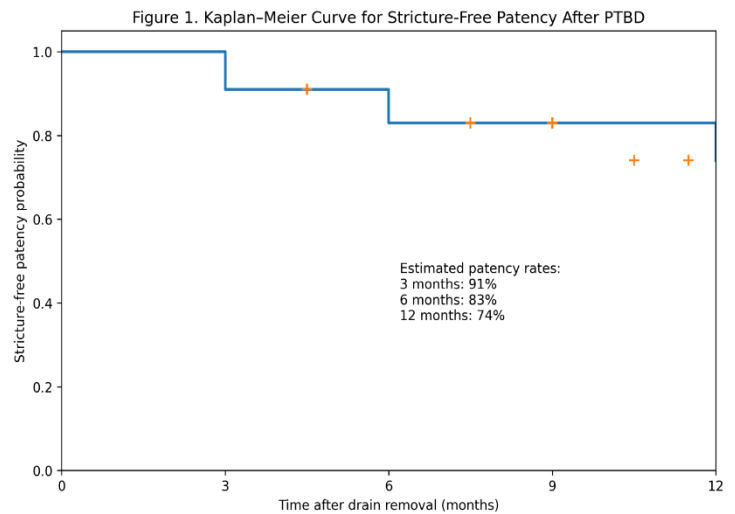


Figure 1: Kaplan–Meier curve for stricture-free patency after successful PTBD.

Discussion

This study evaluated the outcomes of percutaneous transhepatic biliary drainage (PTBD) in 100 post-liver transplant patients with anastomotic biliary strictures, with the ultimate aim of contextualizing these findings in relation to the emerging role of biodegradable stents as a bridging strategy before surgical intervention. The overall technical success rate of PTBD in our cohort was 94.0%, which is consistent with data reported in recent international literature. Moole et al. reported technical success rates of 90–96% for percutaneous biliary interventions in post-transplant strictures, underscoring the procedural reliability of this modality even in anatomically challenging scenarios (11).

Clinical success, defined as symptomatic improvement with a reduction in serum bilirubin within four weeks, was achieved in 86.0% of our patients. This figure is comparable to the findings of Zheng et al., who documented clinical success rates of 83–88% in LDLT recipients managed with PTBD for anastomotic strictures, and attributed higher success rates to early intervention within twelve months of transplantation (12). In our study, the mean interval from transplantation to stricture diagnosis was 7.9 ± 3.8 months, suggesting that most strictures were identified and treated within the critical therapeutic window.

The mean total bilirubin declined significantly from 12.4 ± 4.1 mg/dL at baseline to 4.3 ± 2.2 mg/dL at four weeks, representing a mean reduction of 8.1 ± 3.5 mg/dL. This magnitude of bilirubin reduction aligns with

outcomes described by Hu et al., who observed comparable biochemical responses following PTBD with serial balloon dilatation in post-LDLT anastomotic strictures, and highlighted serial catheter upsizing as a key determinant of sustained biliary decompression (13). In our cohort, the mean maximum catheter size achieved was 12.1 ± 1.8 Fr across a mean of 2.7 ± 1.1 PTBD sessions, consistent with established protocols for progressive stricture dilatation.

Procedure-related complications were recorded in 24.0% of patients, with cholangitis (11.0%) and catheter dislodgement (7.0%) being the most frequent. Major complications occurred in only 5.0% of patients. These complication rates are broadly in agreement with pooled data from a systematic review by Tringali et al., which reported overall complication rates of 20–30% for percutaneous biliary drainage in liver transplant recipients, with cholangitis and catheter-related events dominating the complication profile (14). The relatively low rate of biliary sepsis requiring intensive care (1.0%) in our series reflects the benefit of prophylactic antibiotic protocols and timely intervention.

Drain removal was successfully achieved in 82.0% of patients. Among those with adequate follow-up of at least 12 months (76.0%), stricture recurrence was documented in 21.0%, while 61.0% remained stricture-free at last assessment. Kaplan–Meier analysis demonstrated stricture-free patency rates of 91.0%, 83.0%, and 74.0% at 3, 6, and 12 months, respectively. These figures are comparable to results reported by Srivastava et al. from a high-volume transplant center in India, where 12-month patency rates of 71–76% were documented following PTBD with serial dilatation in LDLT recipients (15). However, the 21.0% recurrence rate in our cohort underscores a persistent challenge, particularly since the mean time to recurrence was only 5.6 ± 2.4 months, a timeframe within which repeat intervention becomes necessary.

The recurrence rate observed in our study highlights the need for a more durable therapeutic strategy in patients who fail repeated PTBD. Conventional plastic stents placed via PTBD are associated with occlusion, migration, and the need for planned exchange every three to six months, limiting their utility as a long-term solution (16). Self-expanding metal stents, while offering longer patency, are not retrievable once embedded, and their use in the post-transplant setting is associated with risks of stent-induced injury and difficulty with future endoscopic access (17). Biodegradable stents represent a conceptually elegant alternative: they provide temporary luminal scaffolding during the critical remodeling phase and subsequently degrade, precluding the need for retrieval and avoiding long-term stent-related complications (18).

Recent pilot data from European centers support the feasibility of biodegradable stents in refractory biliary strictures. Mauri et al. evaluated polydioxanone-based biodegradable stents in patients with anastomotic strictures refractory to conventional endoscopic therapy and reported a 12-month patency rate of 72%, with no stent migration and acceptable safety (19). Similarly, van Boeckel et al. demonstrated that biodegradable esophageal stent principles could be translated to biliary applications, with degradation profiles that matched the expected tissue remodeling timeline (20). These data, while preliminary, suggest that biodegradable stents may reduce recurrence rates in the post-PTBD recurrent stricture population, precisely the cohort that our study identifies as being at the highest risk.

From a Pakistani and South Asian perspective, our study's findings are particularly relevant. The predominance of LDLT recipients (71.0%) in our cohort, reflecting the regional epidemiology where deceased donor programs remain underdeveloped, means that endoscopic management via ERCP is frequently not feasible due to altered anatomy, making PTBD the primary and often only minimally invasive option. The identification of a 21.0% recurrence rate following PTBD in this setting creates a clinically significant population for whom biodegradable stent deployment may serve as a viable bridge before surgical revision, potentially reducing operative morbidity and improving quality of life. Future prospective trials from this region are warranted to validate the safety, efficacy, and cost-effectiveness of biodegradable biliary stents specifically in this high-need patient population.

Conclusion

PTBD was an effective and reasonably safe treatment for post-transplant biliary strictures in this Pakistani cohort, but recurrence remained substantial. These findings support further prospective evaluation of biodegradable biliary stents as a potential intermediate strategy between repeated PTBD and surgical revision.

Declarations

Data Availability statement

All data generated or analysed during the study are included in the manuscript.

Ethics approval and consent to participate

Approved by the department concerned. (IRBEC-GDHLH-023/24)

Consent for publication

Approved

Funding

Not applicable

Conflict of interest

The authors declared no conflict of interest.

Author Contribution

SA, MR

Contributed to study design, data collection, and initial manuscript drafting

Assisted in data acquisition, literature review, and manuscript editing

Performed statistical analysis and contributed to the interpretation of results

AS, MUY

Contributed to patient recruitment, data entry, and results compilation

Assisted in referencing, proofreading, and final revisions of the manuscript

Guided study execution and critically reviewed the manuscript

Supervised the research, coordinated among authors, finalized the manuscript, and approved the final version

All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the study's integrity.

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