

Percutaneous Cholangioplasty for Benign Biliary Strictures: Long-Term Follow-Up With Review of Technical Factors Predicting Success

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Abstract

Purpose

This study aimed to evaluate the long-term outcomes of percutaneous cholangioplasty for benign biliary strictures and characterize the technical factors associated with sustained patency.

Materials and methods

This was a retrospective single-center analysis of 48 patients (50 strictures) treated with percutaneous cholangioplasty between 2009 and 2024. Patients underwent 1-4 dilation sessions with balloon diameters of 8-12 mm and drainage catheter maintenance (median 6.8 months). Long-term patency and associations with recurrence were explored.

Results

Clinical success (drain-free status) was achieved in 96% (n=47/49, one patient currently undergoing treatment). Estimated median primary patency was 72 months, with patency rates of 84% at one year, 73% at three years, 58% at five years, and 39% at 10 years. Among 37 liver transplant recipients (74% of the cohort), outcomes were similar to non-transplant patients. Recurrence occurred in 31.9% (n= 15) and was managed percutaneously in 73% (n=11/15) of cases, with 71% (n=5/7) achieving secondary drain-free status.

Conclusion

Percutaneous cholangioplasty achieves durable long-term patency for benign biliary strictures. The high success rate in liver transplant recipients, including a predominance of living donors, provides outcomes similar to deceased-donor cohorts and supports percutaneous management as a feasible intervention.

Categories: Radiology

Keywords: benign biliary strictures, cholangioplasty, liver transplantation, long-term outcomes, percutaneous cholangioplasty

Introduction

Benign biliary strictures are an uncommon but clinically challenging complication of hepatobiliary surgery and liver transplantation [1,2]. While surgical revision can offer definitive treatment, it carries substantial morbidity (9-58%) and mortality rates up to 5% [2-4]. Minimally invasive approaches are therefore preferred, with endoscopic management typically attempted first to avoid external biliary drainage. When endoscopic management is unsuccessful or anatomically unfeasible, percutaneous biliary drainage and cholangioplasty provide an established alternative with reported one-year patency rates ranging from 36% to 95% [5-11].

Percutaneous cholangioplasty protocols vary considerably in balloon diameter, dilation frequency, and drainage catheter management. Published series demonstrate heterogeneous outcomes due to differences in patient populations (transplant vs non-transplant), stricture characteristics (anastomotic vs non-anastomotic), and technical factors, including balloon dilation of >20 minutes [11] and large-bore drainage catheter insertion [9,10]. Comparison between protocols is challenging due to the variety in patient population and treatment protocols. In addition, long-term patency data beyond five years remain limited, particularly in liver transplant recipients. This gap is clinically important because transplant-related strictures carry distinct recurrence risks and management challenges [1,9]. Additionally, most published North American series emphasize deceased-donor transplant recipients; outcomes in predominantly living-donor cohorts are underreported.

How to cite this article

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The primary objective of this study was to evaluate the long-term outcomes of percutaneous cholangioplasty for benign biliary strictures at a single institution over a 15-year period. Secondary objectives were to characterize the long-term outcomes in liver transplant recipients and to evaluate the factors associated with sustained patency.

This article was previously presented as a meeting abstract at the 2025 CIRSE Annual Congress on September 13, 2025.

Materials And Methods

Patient selection

The study was conducted at University Health Network Hospitals, Toronto, Ontario, Canada, after obtaining approval from the University Health Network Research Ethics Board (approval number: 24-5569), and the requirement for informed consent was waived. A retrospective review of consecutive patients who underwent percutaneous biliary drainage for benign strictures was performed between September 2009 and September 2024. Patients were included if they subsequently underwent percutaneous cholangioplasty for a benign biliary stricture. A total of 48 patients underwent percutaneous cholangioplasty for 50 benign strictures. Two liver transplant patients underwent a second cholangioplasty treatment for strictures occurring after re-transplantation and were counted as separate cholangioplasty cycles. Figure 1 outlines the summary flowchart.

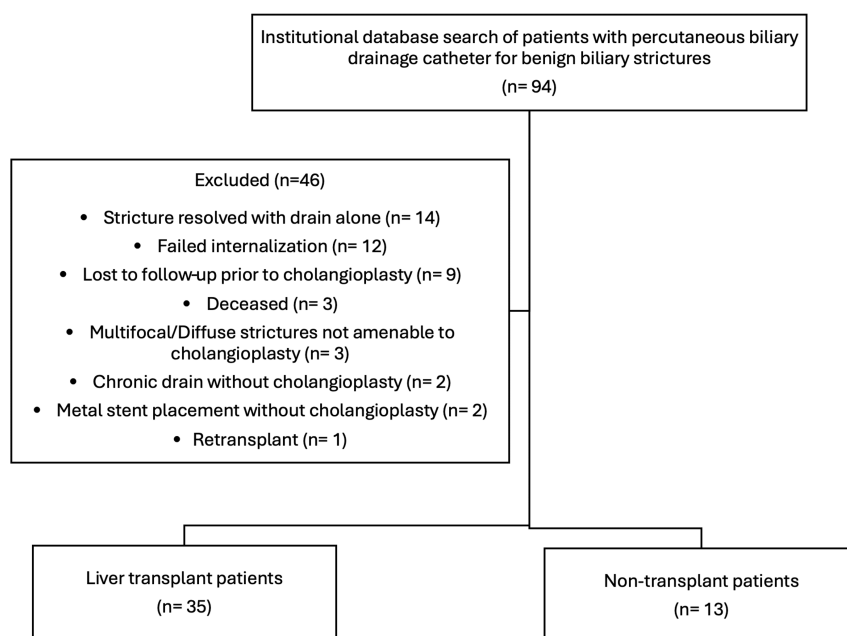


FIGURE 1: Study inclusion flowchart.

Cholangioplasty technique

Percutaneous biliary access was performed under ultrasound guidance under conscious sedation with IV fentanyl and midazolam. Pre-procedure antibiotic prophylaxis was administered per institutional protocol. The stricture was visualized with a diagnostic cholangiogram. A 6-Fr vascular sheath was placed, and the stricture was crossed with a guidewire and catheter. If unable to cross the stricture, an external biliary drain was placed, and the patient returned for a second attempt. Subsequent cholangioplasty procedures were performed as an outpatient. Cholangioplasty was performed with semi-compliant angioplasty balloons (e.g., Mustang, Boston Scientific, Marlborough, MA, USA) selected to approximate the duct diameter on cholangiogram. Balloons were inflated until effacement of the stricture waist was achieved and maintained for a duration determined by the treating radiologist (30 seconds to five minutes for standard dilation and 20 minutes for prolonged dilation). Patients returned for repeat cholangioplasty at intervals of approximately 4-12 weeks (mean 10.3±8.9 weeks). A larger balloon was used during follow-up if residual stenosis exceeded 30%. When <30% residual stenosis and prompt contrast flow into the small bowel were observed, a trial of drain removal was initiated using a capped external drain or a low-profile 4-Fr "safety catheter" to maintain biliary access using a 4-Fr Kumpe catheter (Angiodynamics, Latham, NY, USA). Catheters were removed after 6-8 weeks if no clinical or laboratory evidence of cholestasis was present. A number of safety catheters were maintained indefinitely to preserve biliary access, per patient preference, for example, in cases where biliary

drain insertion was challenging.

Definitions and endpoints

Cholangioplasty cycle was defined as the sequence of procedures from initial drain insertion to removal or capping of the biliary drain. Technical success was defined as <30% residual stenosis after balloon dilation. Clinical success (drain-free status) was defined as successful removal of internal-external drainage catheters. Catheters were removed if liver function tests remained at baseline, patients did not have signs/symptoms of cholestasis, and there was cholangiographic evidence of adequate stricture resolution and prompt contrast flow into the small bowel. Primary patency was defined as the time interval between the initiation of a successful drain removal trial and recurrence of the stricture or death. Recurrence was defined as symptomatic or biochemical evidence of cholestasis requiring imaging or repeat intervention.

Statistical methods

Demographic and procedural variables were summarized using standard descriptive statistics. Categorical variables were compared between groups using Fisher's exact test. Continuous variables were analyzed using the unpaired t-test for factors with a normal distribution; the Mann-Whitney test was preferred for continuous variables not following a normal distribution. Primary patency was assessed using Kaplan-Meier survival analysis and Cox proportional hazards regression. Patients who did not have a recurrence were censored at the time of last follow-up. The association between prolonged dilation and primary patency was assessed by univariable Cox proportional hazards regression. Given 15 events, multivariable adjustment was restricted to two pre-specified covariates, number of dilation sessions and balloon diameter, and results are reported as exploratory. A significance level of $p < 0.05$ was considered statistically significant. All analyses were performed using Microsoft Excel 2020, version 16.94 (Microsoft Corporation, Redmond, WA, USA), and IBM SPSS Statistics for Macintosh, Version 30.0 (IBM Corp., Armonk, NY, USA).

Results

Baseline characteristics are shown in Table 1. Percutaneous cholangioplasty was performed in one to four sessions (median: 2; IQR: 1-3), with balloon diameters of 8-12 mm. The maximum drainage catheter diameter ranged from 8 to 16 Fr, with 72% ($n=36$) reaching 8-10 Fr. The median catheter dwell time was 6.8 months (IQR: 8.0).

	Overall (n=50)	Transplant subgroup (n=37)	Non-transplant subgroup (n=13)	Test statistic	P-value
Age (mean±SD)	57.2±15.9	52.0±14.3	71.1±11.2	-	<0.01
Sex (n, %)					
Male	33, 66%	24, 64.9%	9, 69.2%	$\chi^2=0.08$	0.77
Female	17, 34%	13, 35.1%	4, 30.8%		
Stricture number (n, %)					
Single	35, 70%	28, 75.7%	7, 53.8%	$\chi^2=2.18$	0.14
Multiple	15, 30%	9, 24.3%	6, 46.2%		
Stricture location (n, %)					
Anastomotic	37, 74%	32, 86.4%	5, 38.5%	$\chi^2=14.28$	<0.01
Non-anastomotic	6, 12%	1, 2.7%	5, 38.5%		
Both	7, 14%	4, 10.8%	3, 23%		
Anastomosis type					
Bilioenteric	40, 93%	32, 91.4%	8, 100%	Fisher's exact test	1.00
Duct-duct	3, 7%	3, 8.6%	0		
Prior ERCP, n (%)	8, 16%	4, 10.8%	4, 30.8%	$\chi^2 = 2.55$	0.11
No. of cholangioplasties (n, %)					
Single	23, 46%	15, 40.5%	8, 61.5%	$\chi^2=1.71$	0.19
Multiple	27, 54%	22, 59.5%	5, 38.5%		

Maximum balloon diameter, mm (n, %)					
<10	27, 54%	17, 45.9%	10, 76.9%	$\chi^2=3.72$	0.05
≥10	23, 46%	20, 54.1%	3, 23.1%		
Balloon dilation, duration (minutes)					
<20	34, 68%	23, 62.2%	11, 84.6%	$\chi^2=2.23$	0.14
20	16, 32%	14, 37.8%	2, 15.4%		
Maximum drain size, French (n, %)					
≤10	36, 72%	26, 70.3%	10, 76.9%	$\chi^2=0.48$	0.92
12	9, 18%	7, 18.9%	2, 15.4%		
14	4, 8%	3, 8.1%	1, 7.7%		
22	1, 2%	1, 2.7%	0		
Duration of drain, months (median, IQR)	6.8, 8.0	8.3, 8.9	5.7, 4.8	t=-0.02	0.99
Drain-free status (n, %)	47, 94%	34, 91.9%	13, 100%	$\chi^2=1.12$	0.28
Recurrence rate (n, %)	15, 31.9%	12, 35.3%	3, 23.1%	$\chi^2=0.40$	0.52
Time to recurrence, months (median, IQR)	11.8, 43.5	28.3, 46.0	4.7, 3.0	Log-rank $\chi^2=0.062$	NS
Follow-up duration, months (mean, SD)	80.8, 66.8	91.1, 67.5	51.2, 57.3	t=2.06	0.05
Death (n, %)	6, 12%	5, 13.5%	1, 7.7%	-	-
Liver failure	2, 4%	2, 5.4%	0	-	-
Multi-organ failure	2, 4%	2, 5.4%	0	-	-
Other/unknown cause of death	2, 4%	1, 2.7%	1, 7.7%	-	-

TABLE 1: Demographics and treatment outcomes of transplant vs non-transplant subgroup.

ERCP: endoscopic retrograde cholangiopancreatography

Clinical outcomes

Clinical success, defined as achievement of drain-free status, was achieved in 96% (n=47/49) of evaluable patients. One patient remained under active treatment at the last follow-up and was not included in the clinical success outcome. Two failures occurred in liver transplant recipients, one deceased and one living donor, who underwent a single cholangioplasty session and failed a drain removal trial. Of the 47 successfully treated patients, 89% (n=42/47) were transitioned to low-profile safety catheters prior to removal. Of the 42 patients with safety catheters, 11.9% (n=5/42) were maintained indefinitely per patient preference, and 42.9% (n=18/42) had catheter dwell times exceeding two months.

Long-term patency

Stricture recurrence occurred in 31.9% (n=15/47) of patients. The median time to recurrence was 28.3 months (IQR: 46.0). By Kaplan-Meier analysis, the estimated median primary patency was 72.0 months (95% CI: 22.2-121.8). Primary patency rates were 84% at one year, 73% at three years, 58% at five years, and 39% at 10 years (Figure 2).

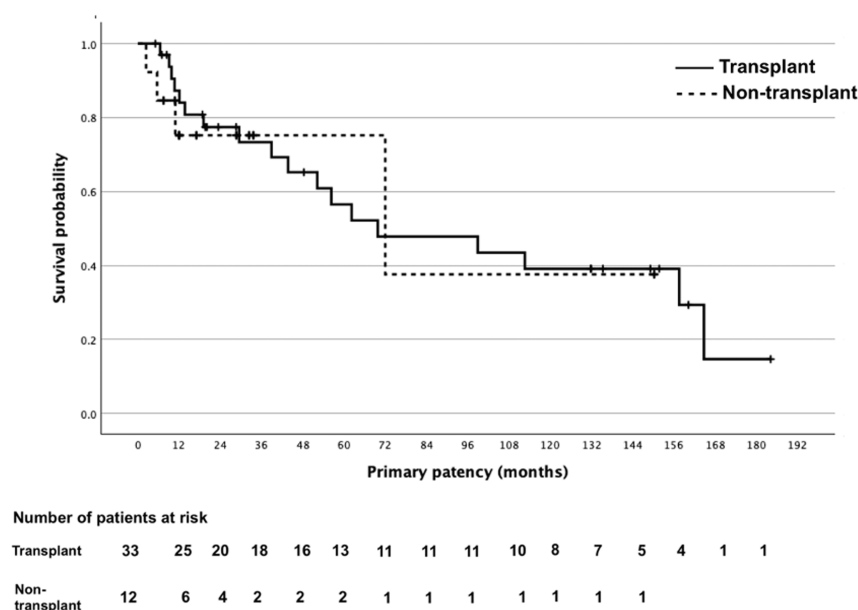


FIGURE 2: Kaplan-Meier analysis of primary patency stratified by transplant and non-transplant patients.

Recurrence management

Of 15 recurrent strictures, 11 were treated percutaneously: seven underwent repeat cholangioplasty (secondary drain-free success 71%; $n=5/7$), one received metal stent insertion, and three were managed with permanent drainage. Four patients underwent surgical intervention (three re-transplantations, one surgical revision). Five patients experienced a second recurrence (one post-stent, two post-repeat dilation, two post-retransplant). Six patients died during follow-up from causes unrelated to biliary pathology (liver failure $n=2$; multi-organ failure $n=2$; other/unknown $n=2$).

Adverse events

Overall, 40% of patients experienced adverse events. Adverse events were classified according to the 2023 Society of Interventional Radiology (SIR) adverse event classification system [12]. Minor events occurred in 28% ($n=14/50$) and major events in 12% ($n=6/50$). Minor events consisted of catheter malfunction (leaking, obstruction, migration, low-grade cholangitis) requiring catheter exchange. Major events comprised catheter fracture requiring retrieval ($n=3$), tube dislodgement ($n=1$), cholangitis requiring admission ($n=1$), and bile leak ($n=1$). Two catheter fractures involved 4-Fr Kumpe safety catheters at two and six months post-insertion; one fragment was retrieved percutaneously and the other via endoscopic retrograde cholangiopancreatography (ERCP). A third fracture occurred during exchange of a 12-Fr internal-external catheter, with percutaneous retrieval of the fractured distal loop in a subsequent procedure.

Transplant vs non-transplant outcomes

Comparative outcomes between transplant and non-transplant subgroups are shown in Table 1. Transplant recipients comprised 74% ($n=37$) of the cohort: 24 (65%) were living-donor recipients and 13 (35%) were deceased-donor recipients. Among the non-transplant subgroup, eight strictures were postoperative, four resulted from intraoperative iatrogenic injury, and one was secondary to cholangitis.

Stricture etiology differed significantly between groups. Transplant strictures were predominantly anastomotic ($n=32$; 86.4%); non-transplant strictures included iatrogenic injury post-cholecystectomy ($n=5$; 38.5%), hepaticojejunostomy strictures ($n=7$; 53.8%), and pyogenic cholangitis ($n=1$; 7.7%). Age differed (transplant 52.0 ± 14.3 vs non-transplant 71.1 ± 11.2 years; $t=-4.83$; $p<0.01$). Time from surgery to stricture diagnosis did not differ significantly ($t=-0.88$; $p=0.39$).

Clinical success rates were similar: transplant 91.9% ($n=34/37$) and non-transplant 100% ($n=13/13$). Recurrence occurred in 35.3% ($n=12/34$) of transplant patients vs 23.1% ($n=3/13$) of non-transplant patients ($\chi^2=0.40$; $p=0.52$). Kaplan-Meier analysis showed no significant difference in primary patency between transplant and non-transplant groups (log-rank $p=0.80$). Among transplant recipients, estimated primary patency rates were 87% at one year, 73% at three years, 57% at five years, and 39% at 10 years. No significant differences in patency were observed between living-donor and deceased-donor recipients.

Technical factors and subgroup analysis

A subgroup of 16 patients (32%) received several prolonged (>20-minute) dilation sessions as part of a single operator's protocol from 2011 to 2014 (Table 2). Comparison was made with the remaining 34 patients treated with standard approaches.

	Overall (n=50)	Prolonged subgroup (n=16)	Non-prolonged and no data subgroup (n=34)	Test statistic	P-value
Age (mean±SD)	57.2±15.9	53.6±13.8	59.0±16.8	t=1.10	0.28
Sex (n, %)					
Male	33, 66%	13, 81%	20, 59%	Fisher's exact test	0.20
Female	17, 34%	3, 19%	14, 41%		
Stricture number (n, %)					
Single	35, 70%	11, 68.8%	24, 70.6%	Fisher's exact test	0.89
Multiple	15, 30%	5, 31.2%	10, 29.4%		
Stricture location (n, %)					
Anastomotic	37, 74%	13, 81%	28, 82%	Fisher's exact test	0.71
Non-anastomotic	6, 12%	1, 6%	4, 12%		
Both	7, 14%	2, 13%	2, 6%		
Anastomosis type					
Bilioenteric	40, 93%	14, 93%	28, 93%	Fisher's exact test	1.00
Duct-duct	3, 7%	1, 7%	2, 7%		
Prior ERCP, n (%)	8, 16%	2, 13%	6, 18%	Fisher's exact test	0.58
No. of cholangioplasties (n, %)					
Single	23, 46%	3, 18.8%	20, 58.8%	Fisher's exact test	0.01
Multiple	27, 54%	13, 81.3%	14, 41.2%		
Maximum balloon diameter, mm (n, %)					
<10	27, 54%	1, 6.3%	26, 76%	Fisher's exact test	<0.001
≥10	23, 46%	15, 93.7%	8, 24%		
Maximum drain size, French (n, %)					
≤10	36, 72%	13, 81.3%	23, 67.6%	Fisher's exact test	0.32
12	9, 18%	3, 18.7%	6, 17.6%		
14	4, 8%	0	4, 11.8%		
22	1, 2%	0	1, 2.9%		
Duration of drain, months (median, IQR)	6.8, 8.0	4.9, 5.8	7.9, 8.3	t=0.80	0.43

TABLE 2: Patient, stricture, and treatment characteristics for prolonged vs non-prolonged subgroup.

Demographic and stricture characteristics did not differ between groups (Table 3 and Table 4). However, significant differences in treatment variables were observed. Patients receiving prolonged dilation sessions underwent a median of three treatments (IQR: 2-3) compared with one treatment (IQR: 1-2) in the single-

session group (Fisher's exact test $p=0.01$). The mean maximum balloon diameter was larger in the prolonged dilation group (9.9 ± 0.5 mm vs 8.2 ± 1.5 mm; Fisher's exact test $p<0.001$).

	Overall (n=50)	Prolonged subgroup (n=16)	Non-prolonged and no data subgroup (n=34)	Test statistic	P- value
Drain-free status (n, %)	47, 94%	16, 100%	31, 91.2%	Fisher's exact test	0.54
Recurrence rate (n, %)	15, 31.9%	7, 43.8%	8, 23.5%	$\chi^2=2.02$	0.16
Time to recurrence, months (median, IQR)	11.8, 43.5	11.8, 42.2	6.7, 0.0	Kaplan-Meier	NS
Follow-up duration, months (mean, SD)	80.8, 66.8	124.5, 41.1	60.2, 67.1	$t=4.17$	<0.001
Death (n, %)	6, 12%	1, 6.3%	5, 14.7%	-	-
Liver failure	2, 4%	1, 6.3%	1, 2.9%	-	-
Multi-organ failure	2, 4%	-	2, 5.9%	-	-
Other/unknown cause of death	2, 4%	-	2, 5.9%	-	-

TABLE 3: Outcomes for prolonged vs non-prolonged subgroup.

Outcome	Analysis	Data summaries: n/N (%)		Group difference		
		Non-prolonged	Prolonged	% difference (95% CI)	Test statistic	P- value
Treatment success	Unadjusted	31/33 (94%)	16/16 (100%)	6% (-2%, 14%)	Fisher's exact test	1.00
	Adjusted*	-	-	-	-	-
Outcome	Analysis	Data summaries: 5-year recurrence-free (95% CI)		Group difference		
		Non-prolonged	Prolonged	Hazard ratio (95% CI)*	Test statistic	P- value
Primary patency (months)	Unadjusted	73 (47, 88)	61 (33, 81)	1.03 (0.36, 2.94)	$z=0.05$	0.96
	Adjusted*	-	-	1.15 (0.28, 4.73)	$z=0.84$	0.84

TABLE 4: Outcome analysis for prolonged vs non-prolonged subgroup.

*Group differences adjusted for the number of treatments and balloon diameter.

*Hazard ratio calculated as risk of recurrence in the prolonged group relative to risk in the non-prolonged group.

Clinical success was achieved in 100% ($n=16/16$) of the prolonged dilation patients vs 94% ($n=31/33$) of the standard-approach patients (Fisher's exact test $p=0.54$). Recurrence rates were higher in the multi-session group (43.8% vs 23.5%; Fisher's exact test $p=0.16$), though this difference was not statistically significant. No statistically significant association between prolonged dilation and primary patency was demonstrated at five years with Kaplan-Meier primary patency analysis (HR: 1.15; 95% CI: 0.28-4.73; $p=0.84$; adjusted for number of sessions and balloon diameter) (Figure 3). There was no difference in the rate of adverse events between the prolonged and non-prolonged dilation groups (37.5% ($n=6/16$) and 41.2% ($n=14/34$); Fisher's exact test $p=1$).

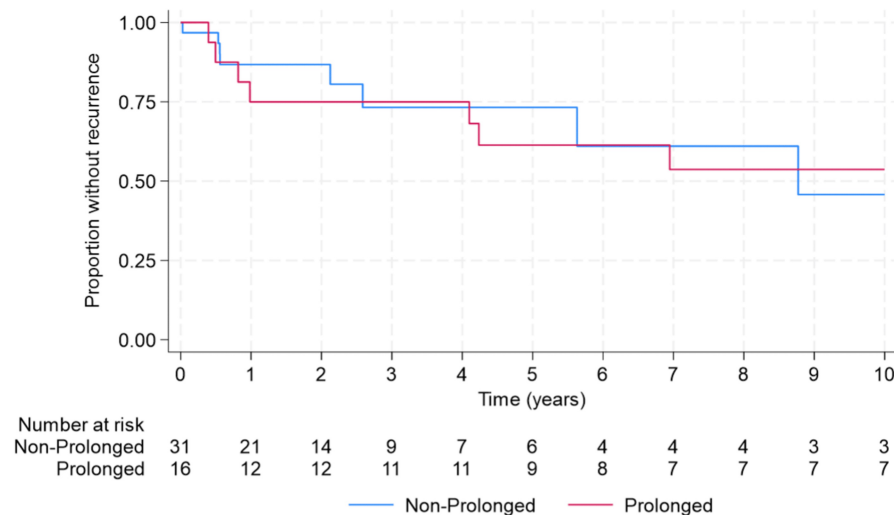


FIGURE 3: Kaplan-Meier curve of primary patency for prolonged dilation vs non-prolonged dilation.

Discussion

This study demonstrates that percutaneous cholangioplasty for benign biliary strictures is an effective treatment with high rates of clinical success and durable long-term patency. In a mixed cohort dominated by liver transplant recipients, drain-free status was achieved in 96% of evaluable patients, with an estimated median primary patency of 72 months and nearly 40% of patients remaining recurrence-free at 10 years. Cantwell et al. reported a freedom-from-restenosis rate of 49% at 10 years [13]. DePietro et al. reported a 67% 10-year primary patency rate using a large-bore catheter protocol, excluding a protocol dropout rate of 25% [9]. Notably, all recurrent strictures in the DePietro et al. series occurred in liver transplant recipients. Our results compare favorably with published reports, particularly given the high proportion of transplant patients in our cohort.

Considerable heterogeneity exists among published percutaneous cholangioplasty protocols, with variation in balloon diameter, dilation frequency, and use and caliber of biliary drainage catheters. Repeated dilations, large-bore drainage catheters, prolonged drainage, and structured protocols have been proposed as successful technical factors [5,9,11,13,14]. Comparisons across studies are challenging because of differences in patient populations, stricture characteristics, and procedural techniques, and long-term outcome data remain limited.

Prolonged dilation (>20 minutes) was used as part of an initiative in 2011-2014 based on early reports of "drain-free", prolonged dilation protocols [11]. The patients treated as part of this protocol also underwent more treatment sessions and larger balloon diameters. While patients treated with prolonged dilation achieved 100% clinical success, they also experienced higher recurrence rates compared with single-session cohorts. After adjusting for treatment-related variables, this apparent disadvantage was not explained by treatment intensity alone, suggesting that unmeasured patient-level factors or stricture characteristics may be more influential or the difference may be bias related to the longer follow-up time for this cohort. This finding aligns with studies questioning whether dilation intensity improves outcomes and supports the concept that structured protocols, rather than aggressive intervention, may be optimal [5,15], although further research is needed to determine the optimal approach. The substantial recurrence rate even in the prolonged dilation group (44%) underscores that no single technical factor reliably prevents recurrence.

The predominance of liver transplant recipients in this series (74%) provides a distinct contribution to the literature. Most published North American experience emphasizes deceased-donor transplantation, while this cohort is predominantly living-donor (65% of transplant patients). Our findings demonstrate that percutaneous cholangioplasty achieves similar long-term patency in living-donor recipients, with 87% freedom from recurrence at one year and 39% at 10 years. This compares favorably with reports from Asian centers, where living donor transplantation is more common, which demonstrated excellent short- and medium-term patency rates of 85-96% at one year and sustained patency at 3-5 years [8,10]. These outcomes support percutaneous management as an appropriate intervention in this population and are reassuring given the greater investment in living-donor transplantation and the desire to preserve graft function.

Advanced cholangioplasty techniques, including cutting balloons, retrievable biliary stents, laser

stricturotomy, and biodegradable stents, were not used in this cohort. While these approaches are promising, existing studies are limited by small sample sizes [16–18]. Implementing a structured protocol may be as important as adoption of novel techniques and devices [5,9].

This study has several limitations common to retrospective studies. Only treatments and events recorded in the medical record are reported, which may miss relevant outcomes or side effects. The single-center design and small sample size limit the generalizability of our findings. Absence of a standardized dilation protocol at the center may impact outcomes and duration of treatment. Variations in protocols over the study period and evolving clinical practices over the 15-year study period could confound outcomes. Treatment heterogeneity over 15 years, including variation in operator experience, technique, and patient selection, introduces temporal bias and limits causal inference regarding specific procedural variables such as prolonged dilation. The higher recurrence rate in the multi-session cohort, despite confounding by indication, suggests that stricture-level factors rather than procedural intensity drive outcomes.

Conclusions

Percutaneous cholangioplasty achieves high clinical success (96%) and durable long-term patency for benign biliary strictures, with sustained benefit through 10 years of follow-up. This living-donor transplant cohort demonstrated similar outcomes to non-transplant patients. Recurrent strictures are amenable to repeat percutaneous intervention in the majority of cases. These findings establish percutaneous cholangioplasty as an effective long-term treatment strategy and support its use as management for patients with ERCP-refractory strictures or anatomically unfeasible endoscopic access.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Sabreena Moosa, Cathal O'Leary

Acquisition, analysis, or interpretation of data: Sabreena Moosa, Sebastian Mafeld, Camilo Barragan-Leal, Arash Jaberi, Aziz Qazi, Eran Shlomovitz, Cathal O'Leary

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Critical review of the manuscript for important intellectual content: Sabreena Moosa, Sebastian Mafeld, Camilo Barragan-Leal, Arash Jaberi, Aziz Qazi, Eran Shlomovitz, Cathal O'Leary

Supervision: Cathal O'Leary

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. University Health Network Research Ethics Board issued approval 24-5569.

Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue.

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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