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Hepatology

Percutaneous transhepatic cholangiography and drainage for biliary strictures after pediatric liver transplantation

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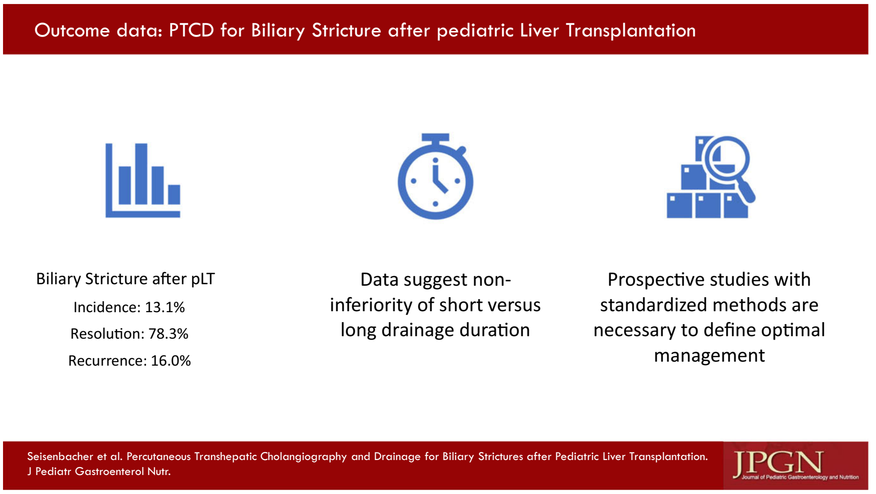
Abstract

Objectives: Biliary strictures (BS) remain frequent after pediatric liver transplantation (pLT) and best management practices are still lacking. This study systematically assesses efficacy of stricture treatment by percutaneous transhepatic cholangiography and drainage (PTCD).

Methods: Online databases were searched for studies on PTCD treatment of BS after pLT from the year 2000 to 2024. Efficacy and safety profile of PTCD were analyzed. Influence of various risk factors on outcome parameters was compared by meta-regression.

Results: Twenty-seven observational studies with 802 patients undergoing PTCD for BS met the inclusion criteria. Incidence of BS was 13.1% (95% confidence interval [CI]: 10.3–16.1) in 6543 patients reported who underwent pLT between 1989 and 2020. Overall efficacy of PTCD to achieve stricture resolution was 78.3% (95% CI: 66.5–80.4). Drainage duration longer or shorter than 109.1 days did not impact on achievement of resolution with efficacies of 76.5% (95% CI: 65.4–86.2) in short versus 75.1% (95% CI: 61.9–86.5, $p = 0.87$) in long drainage. Overall recurrence rate after stricture resolution was 16.0% (95% CI: 7.5–26.3). Drainage duration longer or shorter than 109.1 days did not affect recurrence rate which was 17.4% (95% CI: 3.3–37.3) in short versus 20.9% (95% CI: 14.0–28.5, $p = 0.68$) in long drainage duration. Overall rate of procedure-related complications was 9.9% (95% CI: 2.6–20.0, $p = 0.99$) and was not influenced by drainage duration.

Conclusions: PTCD is efficient to treat BS after pLT. Drainage time does not impact efficacy, recurrence rate, and complication rate. Randomized trials are necessary to determine the best treatment protocol concerning drainage duration and intervals between interventions.



KEYWORDS

biliary complication, meta-analysis, PTC, PTCD, systematic review

1 | INTRODUCTION

Biliary strictures (BS) occur in 3%–27% of patients after pediatric liver transplantation (pLT) and most occur in the first year after pLT.[1–3] If not diagnosed promptly and managed effectively, BS can lead to cholestasis, cholangitis, and fibrosis, significantly compromising graft survival.[3] A high level of clinical suspicion is essential for early recognition to prevent graft injury or loss. Patients may present either asymptomatically or with a variety of symptoms, including pruritus, jaundice, fever, and sepsis.[4–10] Liver transaminases and cholestatic markers can be elevated.[3–5,7,11–16] Ultrasound, magnetic resonance cholangiopancreatography, and liver biopsy may be helpful in diagnosis.[1,4,7,8,14,17–19] The gold standard for diagnosis and treatment of BS is endoscopic retrograde cholangiopancreatography (ERCP) or percutaneous transhepatic cholangiography and drainage (PTCD). Due to anatomical reasons and body size, PTCD frequently serves as the primary modality in pediatric patients.[20,21] PTCD protocols vary widely regarding duration of drainage and dilation intervals, and best management practices for PTCD in BS treatment are lacking.[2–4,11,12,22] An evidence-based algorithm for PTCD treatment in BS after pLT could relief the burden of disease, improve long-term graft survival and impact quality of life in patients after pLT. Given the limited data on the outcomes of different PTCD management strategies, this meta-analysis aims to systematically assess the efficacy of stricture treatment by PTCD after pLT.

What is Known?

- Biliary strictures (BS) are a frequent complication after pediatric liver transplantation.
- Treatment options are limited and include endoscopic retrograde cholangiopancreatography (if feasible), percutaneous transhepatic cholangiography and drainage (PTCD), and surgery.
- PTCD protocols vary widely as evidence-based algorithms are lacking.

What is New?

- Incidence of BS 13.1%, resolution rate 78.3%, recurrence rate 16.0%.
- Data suggests noninferiority of short versus long drainage duration.
- Prospective studies with standardized methods are necessary to define optimal management.

2 | METHODS

This systematic review and meta-analysis were conducted in accordance with the preferred reporting items for systematic reviews and meta-analyses reporting guidelines (PRISMA).[23]

2.1 | Ethics statement

This study was conducted in accordance with the guidelines of the Institutional Review Board of the Medical University of Innsbruck and the 1975 Declaration of Helsinki.

2.2 | Search strategy and data extraction

PubMed, Scopus, Web of Science, and Google Scholar online databases were searched to identify studies on PTCD treatment of BS after pLT from January 2000 to October 2024. No further restrictions or filter criteria were used. The search term “biliary stricture AND pediatric liver transplantation” was used. Two investigators (J.S. and G.F.V.) independently screened the mentioned databases via abstract and title search. All articles considered eligible were retrieved in full text and the predefined in- and exclusion criteria were applied. A single investigator (J.S.) extracted the data from all included studies into an Excel spreadsheet (Microsoft). These data included authorship, year of publication, type of study, patient characteristics, intervention details, and outcome measures (e.g., achievement of resolution, recurrence, complications, need for surgical revision or re-transplantation). Data were controlled, cross-checked, and confirmed by a second reviewer (G.F.V.). The included studies were checked for data consistency by both reviewers. Disagreements were resolved by discussion.

2.3 | Inclusion and exclusion

Included were studies that reported outcome data of PTCD for BS in pediatric patients with liver transplantation being performed between 0 and 18 years. PTCD treatment was defined as biliary drainage with or without dilation via the percutaneous transhepatic approach. Technical variations of percutaneous treatment such as application of stents, rendezvous technique, or experimental methods were not included in the analysis. Studies were only included if PTCD was the primary treatment modality for BS. Case reports, commentaries, editorial letters, and case series with less than five patients were excluded.

2.4 | Study quality and bias assessment

Risk of bias was assessed using the revised Cochrane risk of bias in nonrandomized studies of interventions (ROBINS-I) tool[24] and visualized with the Risk-Of-Bias VISualization (Robvis) tool (Supporting Information S1: Figure S1).[25] Publication bias was visualized via funnel plots and further assessed using the Egger test (Supporting Information S1: Figure S2A,B).

2.5 | Outcome measures

The primary outcome of this study was resolution of stricture by PTCD treatment. In addition, recurrence, peri-interventional complications, need for surgery or re-transplantation, and patient survival were assessed. Resolution of stricture was defined as technical as well as clinical success of the PTCD procedure: improvement of the stricture on cholangiography and free flow of bile into the intestine were required as well as clinical improvement of symptoms if present. Various methods of measurement in the individual study design were accepted. For this study, resolution was defined as absence of stricture of at least 6 months after interventional stricture treatment, in accordance with Valentino et al.[3] A reappearance of stricture less than 6 months after treatment withdrawal was regarded as treatment failure and not as recurrence after resolution. Recurrence was defined as reappearance of stricture on cholangiogram later than 6 months after stricture resolution and requiring at least one intervention or surgery. When these definitions for resolution and recurrence could not be applied (e.g., due to lacking data regarding time to recurrence), the primary studies definitions and case numbers were accepted. Complications were defined as reported by the individual studies. We aimed to classify these complications as minor or major according to the Clavien-Dindo classification.[26,27] However, due to incomplete reporting and the limited number of studies providing detailed information on procedure-related complications, their severity, and management, we opted to conduct a statistical analysis solely of the overall complication rate. Detailed descriptions of specific complications were reported narratively. Surgery was defined as surgical revision of the biliary anastomosis due to stricture at any time during the follow-up period. Re-transplantation was defined as transplantation for any reason after the first PTCD procedure. Deaths were all deaths for any reason after the first PTCD procedure.

2.6 | Data synthesis and statistical analysis

All statistical analyses were performed using meta, metafor, and metamedian packages in R statistical software (version 4.4.1; The R Foundation for Statistical Computing). Random-effects meta-analyses of efficacy (e.g., resolution and recurrence of BS) and safety profile of PTCD (e.g., procedure-related complications) were performed using an inverse variance method. The results were visualized via forest plots. The influence of drainage duration, intervention interval, and stricture type on resolution, recurrence, and complication rates was compared by meta-regression. Drainage duration was categorized into a long and short drainage group by the method of median-split, that is dichotomizing the continuous variable drainage time at the median. To compensate for the potential loss of information and bias caused by the median split, drainage duration was also analyzed as a continuous variable. Sensitivity analyses with exclusion of studies showing serious risk of bias were conducted. A p-value of <0.05 was considered significant.

3 | RESULTS

3.1 | Study cohort

Database screening identified 245 studies after exclusion of duplicates. 50 studies were read full-text and thoroughly examined for eligibility. Twenty-seven retrospective cohort studies published between 2000 and 2024 were included, no prospective or randomized controlled trials were identified (Figure 1).[1–5,7–9,11–18,21,22,28–36] Basic characteristics of studies are shown in Table 1 and Supporting Information S1: Table S1A,B, and excluded studies in Supporting Information S1: Table S2.

The 27 included studies comprised 802 patients undergoing PTCD for BS after pLT. Median age at LT was 3.1 (interquartile range [IQR]: 1.9–3.6) and at PTCD 5.0 years (IQR: 4.4–7.3). Of all BS patients, 48.9% were male ($n = 583$ patients). The indications for LT were biliary atresia in 61.6%, metabolic conditions in 6.8%, and other conditions in 33.4% (e.g., hepatoblastoma, hepatitis, sclerosing cholangitis; $n = 578$ patients). Deceased donor LT was conducted in 48.0%, while 52.0% were living donor LT ($n = 510$ patients). Whole liver grafts and partial liver grafts were received in 15.7% and 84.3%, respectively ($n = 465$ patients). Hepatic artery thrombosis occurred before BS in 17.3% of patients ($n = 533$ patients). Roux-en-Y hepaticojejunostomy was present in 94.3% ($n = 511$ patients). Most patients (87.6%) had single anastomotic strictures, the remaining had nonanastomotic or multiple strictures ($n = 640$ patients). Multiple strictures were defined as anastomotic stricture with concomitant nonanastomotic stricture, or multiple nonanastomotic strictures. Median time from LT to BS diagnosis was 225.5 days (IQR: 175.0–318.0, $n = 480$ patients). Patients received a median of 3.9 interventions (IQR: 3.0–4.0, $n = 336$ patients) and median drainage time was 109.1 days (IQR: 80.0–271.0, $n = 628$ patients). Median duration of follow-up after PTCD was 48.4 months (IQR: 40.3–100.0, $n = 574$ patients). Median laboratory values at BS diagnosis were as follows: Gamma-glutamyl-transferase 370 IU/L (IQR: 294.2–743.0, $n = 326$ patients) aspartate aminotransferase (AST) 91.0 IU/L (IQR: 90.4–91.0, $n = 227$ patients), alanine aminotransferase (ALT) 113.0 IU/L (IQR: 98.3–126.0, $n = 313$ patients), alkaline phosphatase 1408.0 IU/L (IQR: 333.0–1755.9, $n = 185$ patients), direct bilirubin 0.50 mg/dL (IQR: 0.30–0.50, $n = 65$ patients), and total bilirubin 1.65 mg/dL (IQR: 1.30–2.60, $n = 315$ patients).

Quality assessment, sensitivity analyses, and a transplant era subgroup analysis can be found in the Supporting Information.

3.2 | PTCD outcome

The incidence of BS was 13.1% (95% confidence interval [CI]: 10.3–16.1) in all reported patients undergoing pLT between 1989 and 2020 ($n = 6543$ patients, Figure 2A). Overall efficacy of PTCD to achieve stricture resolution was 78.3% (95% CI: 66.5–80.4, $n = 783$ patients, Figure 2B). The overall recurrence rate after stricture resolution was 16.0% (95% CI: 7.5–26.3, $n = 530$ patients, Figure 3A). The overall occurrence of procedure-related complications was 9.9% (95% CI: 2.6–20.0, $n = 355$ patients, Figure 3B). Commonly reported procedure-related complications of PTCD included catheter displacement, obstruction, leakage, cholangitis, sepsis, and biliary perforation.

3.3 | Risk factors for stricture recurrence

We examined possible factors influencing resolution and recurrence of BS through meta-regression. While acknowledging that graft type, type and number of anastomoses, vascular and immunological complications might significantly impact outcome, limited data quality did not allow for a detailed analysis regarding these factors. Procedure-related data was reported consistently. Thus, we investigated whether drainage duration and interval between interventions might influence PTCD outcome. Additionally, we explored whether the stricture type was a prognostic factor for PTCD outcome.

To analyze the effect of drainage duration, the cut-off between long and short drainage was set at 109.1 days by median-split. Moreover, that duration seemed as a clinically significant cut-off value to compare short drainage protocols to longer drainage durations, where the duration often depends on clinical decision rather than a specific protocol. In the "long" group with drainage duration longer than 109.1 days, median catheter dwell time was 271 days (IQR: 240.0–300.0). In the "short" group with drainage duration up to 109.1 days, median catheter dwell time was 80 days (IQR: 21.0–101.0). Drainage duration did not impact resolution rate with efficacies of 76.5% (95% CI: 65.4–86.2) in short versus 75.1%

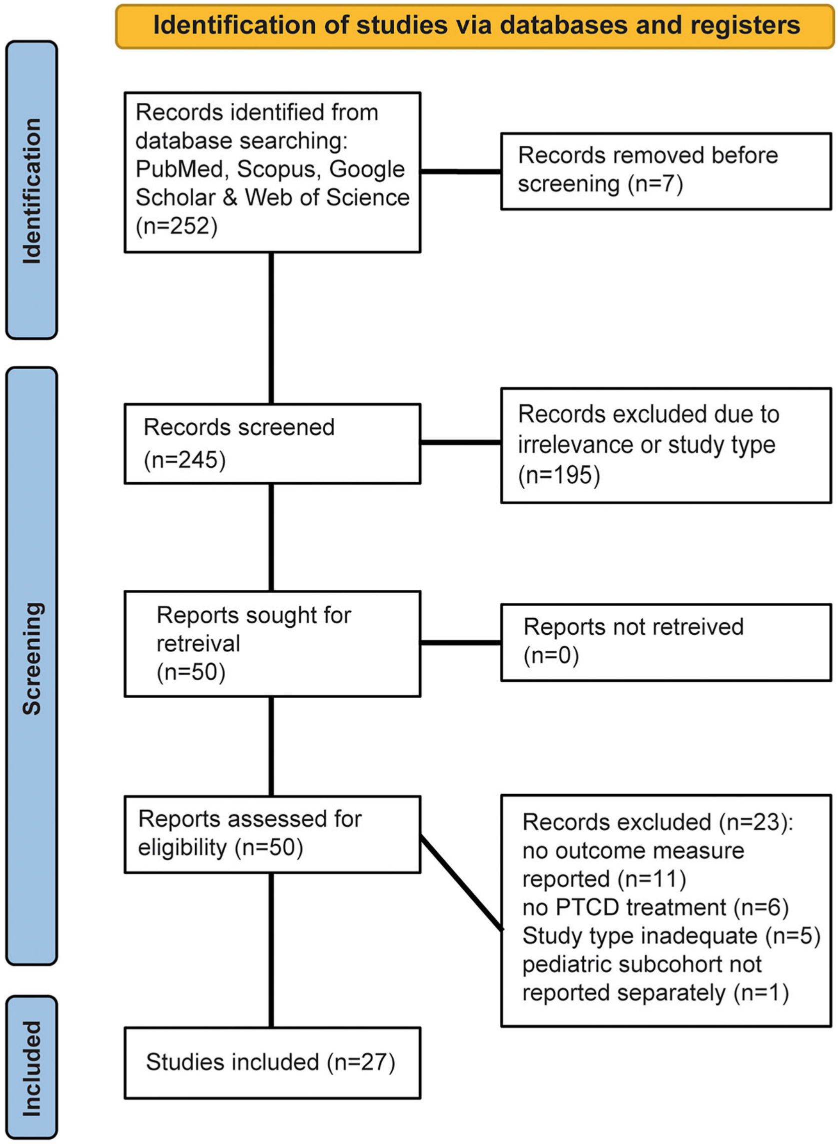


FIGURE 1 Preferred reporting items for systematic reviews and meta-analysis flowchart depicting the screening and selection process of studies included in the systematic review. PTCD, percutaneous transhepatic cholangiography and drainage.

(95% CI: 61.9–86.5, $p = 0.87$) in long drainage duration (Supporting Information S1: Figure 3A,B). Moreover, recurrence rate was not affected which was 17.4% (95% CI: 3.3–37.3) in short versus 20.9% (95% CI: 14.0–28.5, $p = 0.68$) in long drainage duration (Supporting Information S1: Figure 4A,B). Complication rate was not influenced by drainage duration, reaching 8.1% (95% CI: 0.9–19.9) in long and 5.9% (95% CI: 0.0–24.5, $p = 0.99$) in short drainage duration. When analyzed as a continuous variable via meta-regression, days of catheter drainage did not affect resolution rate ($p = 0.28$) or recurrence rate ($p = 0.72$).

We further analyzed whether the time interval between multiple PTCD interventions (i.e., catheter changes or repeated dilations) would influence outcome. Intervals ranged from 6 to 90 days in the individual PTCD protocols. There was no significant correlation between intervention intervals and resolution ($p = 0.20$), recurrence ($p = 0.16$), or complication rate ($p = 0.80$), respectively.

Moreover, we hypothesized that the stricture type (single anastomotic vs. nonanastomotic/multiple) would influence outcome. As the studies did not report the outcomes separately for anastomotic and non-anastomotic strictures, we used the percentage of multiple or nonanastomotic strictures per study as an approximation and analyzed the effect by meta-regression. There was no significant correlation between stricture type and resolution ($p = 0.17$), recurrence ($p = 0.61$), or complication rate ($p = 0.86$). However, due to incomplete reporting a present correlation might have been missed.

3.4 | Surgical revision

Meta-analysis revealed that 20.2% (95% CI: 13.3–28.0) of patients required surgical revision due to BS ($n = 700$ patients) either after failed PTCD or

TABLE 1 Baseline characteristics of the studies included.

Study	Publication year	Study period	Design	Country	Age at LT, year	Age at PTCD, year	Patient number, *n*	Females, %	Drainage duration, days	Resolution, *n*	Recurrence, *n*	Complications, *n*	Surgery, *n*	Re-LT, *n*	Risk of bias
Vingrovich et al.	2024	2011–2020[a]	Observational	Israel	3.6	11	12	53.3	75	8	0	3[c]	3	0	Moderate
Calinescu et al.	2024	1997–2018	Observational	France	1.8	NA	106	58.0	21	81	57	32	40	25	Moderate
Valentino et al.	2022	2011–2016[a]	Observational, multicenter	United States	3.1	NA	51	44.2	101	42	12	40[d]	NA	NA	Moderate
Oggero et al.	2022	2013–2019[b]	Observational	Argentina	3.6	NA	17	58.8	33.5	14	4	NA	2	0	Serious
Yan et al.	2021	1998–2019[a]	Observational	United States	1.9	NA	50	44	287.1	38	9	2[c]	2	5	Moderate
Lee et al.	2021	1989–2019[a]	Observational	United States	0.9	NA	33	48.5	80	16	1	NA	13	5	Moderate
Lin et al.	2020	1994–2017[a]	Observational	Taiwan	1.2	10.8	10	NA	682.6	3	0	NA	2	0	Moderate
Reis et al.	2019	2006–2016[a]	Observational	United States	3.1	NA	31	64.7	NA	19	0	NA	12	NA	Moderate
Sanada et al.	2019	2001–2018[b]	Observational	Japan	1.4	4.4	48	NA	271	35	9	0[c]	4	3	Moderate
Hsiao et al.	2019	2001–2015[a]	Observational	Taiwan	1.3	NA	19	NA	NA	NA	NA	NA	9	7	Serious
Czubkowski et al.	2018	1998–2014[a]	Observational	Poland	6.7	12.4	35	37.1	146	20	NA	9[c]	14	4	Serious
Cardarelli-Leite et al.	2017	2012–2015[b]	Observational	Brazil	0.9	5	7	42.9	174	7	0	NA	0	0	Moderate
Holguin et al.	2017	2001–2013[a]	Observational	Colombia	NA	NA	37	56.5	364	28	4	NA	4	1	Serious
Prajapati et al.	2017	1997–2012[a]	Observational	United States	3.7	NA	36	NA	NA	20	0	NA	2	12	Serious
Imamine et al.	2015	1997–2014[a]	Observational	Japan	NA	5	52	59.6	109.1	43	4	NA	2	2	Moderate
Fonio et al.	2015	1999–2010[a]	Observational	Italy	NA	NA	13	NA	34	8	0	2[c]	3	1	Serious
Uller et al.	2014	2008–2012[b]	Observational	Germany	NA	4	16	50	260	9	1	2[c]	4	NA	Serious
Feier et al.	2014	1995–2012[a]	Observational	Brazil	1.3	NA	43	NA	240	33	9	5[c]	8	5	Serious
Anderson et al.	2010	2000–2007[a]	Observational	United States	5.5	NA	16	NA	270	11	NA	NA	4	1	Serious
Moreira et al.	2010	1993–2008[2]	Observational	Brazil	NA	5.3	35	NA	300	35	12	127[d]	NA	NA	Serious
Brun et al.	2010	1995–2006[b]	Observational	Spain	NA	6.6	10	NA	NA	10	6	NA	3	2	Serious

TABLE 1 (Continued)

Study	Publication year	Study period	Design	Country	Age at LT, year	Age at PTCD, year	Patient number, *n*	Females, %	Drainage duration, days	Resolution, *n*	Recurrence, *n*	Complications, *n*	Surgery, *n*	Re-LT, *n*	Risk of bias
Miraglia et al.	2008	2004–2007[b]	Observational	Italy	3.2	NA	27	NA	NA	20	4	NA	4	1	Serious
Sunku et al.	2006	1997–2003[b]	Observational	United States	1	NA	35	45.7	91	19	7	NA	14	7	Moderate
Lorenz et al.	2005	Until 2004[a]	Observational	United States	4.7	7.3	19	NA	90	11	0	0[c]	6	1	Moderate
Belenky et al.	2004	1997–2001[a]	Observational	Israel	NA	1.6	7	25	45	7	0	1[c]	0	0	Moderate
Schwarzenberg et al.	2002	1997–1999[a]	Observational	United States	NA	NA	6	NA	NA	6	3	0[c]	1	0	Serious
Egawa et al.	2001	1990–1998[a]	Observational	Japan	3.7	NA	34	NA	NA	21	11	NA	18	NA	Serious

Abbreviations: LT, liver transplantation; NA, not available; *n*, number of patients; PTCD, percutaneous transhepatic cholangiography and drainage.

[a]Transplantation era.

[b]PTCD era.

[c]Number of patients with complications.

[d]Total number of complications.

stricture recurrence after PTCD. Meta-regression showed no significant influence of drainage duration ($p = 0.26$), number of interventions ($p = 0.37$), or interval between interventions ($p = 0.90$).

3.5 | Graft and patient survival

Re-transplantation was necessary in 9.9% (95% CI: 5.2–15.5) of patients for any reason during follow-up after PTCD ($n = 635$ patients) and 7.9% (95% CI: 3.1–14.0) of patients died for any reason during follow-up after PTCD ($n = 570$ patients). Reasons were reported to be mostly unrelated to PTCD and included sepsis, acute rejection, graft-versus-host disease, and lymphoproliferative diseases. Meta-regression showed no significant influence of drainage duration ($p = 0.15$, $p = 0.17$) and number of interventions ($p = 0.77$, $p = 0.83$) on graft and patient survival, respectively. Intervals between interventions did not influence graft survival ($p = 0.12$).

4 | DISCUSSION

This meta-analysis gives a comprehensive evaluation of the existing literature on outcomes of PTCD for BS after pLT. However, it also emphasizes the lack of an evidence-based treatment algorithm as randomized controlled trials are lacking.

Our meta-analysis showed an incidence of BS after pLT of 13.1%, aligning with a large meta-analysis in adults by Akamatsu and colleagues, reporting an incidence of 12.8%.[37] The observed variability in incidences among centers might indicate a lack of standardized criteria for diagnosis of BS.

The overall efficacy of PTCD for BS after pLT in this meta-analysis is encouraging, with 78.3% of patients achieving resolution. However, the studies show considerable heterogeneity. Variation in study design, stricture type and severity, treatment protocols, and center experience likely contributed to this heterogeneity. Also, definitions of resolution varied between centers. We aimed to apply the definition of resolution described by Valentino et al. to all studies.[3] This was not possible in all cases, potentially overestimating resolution rates.

In our meta-analysis, 16.0% of patients had BS recurrence. This is slightly higher than Sung et al. with 78.8% of adult patients remaining recurrence-free at 5 years after successful PTCD.[38] The wide range of recurrence rates observed in our study also reflects varying definitions. We aimed to apply our definition to all primary studies. This was not possible in all cases, potentially mistaking insufficiently treated strictures as early recurrences. Additionally, limited follow-up time may result in late recurrences being missed in some studies. However, the included studies had a median

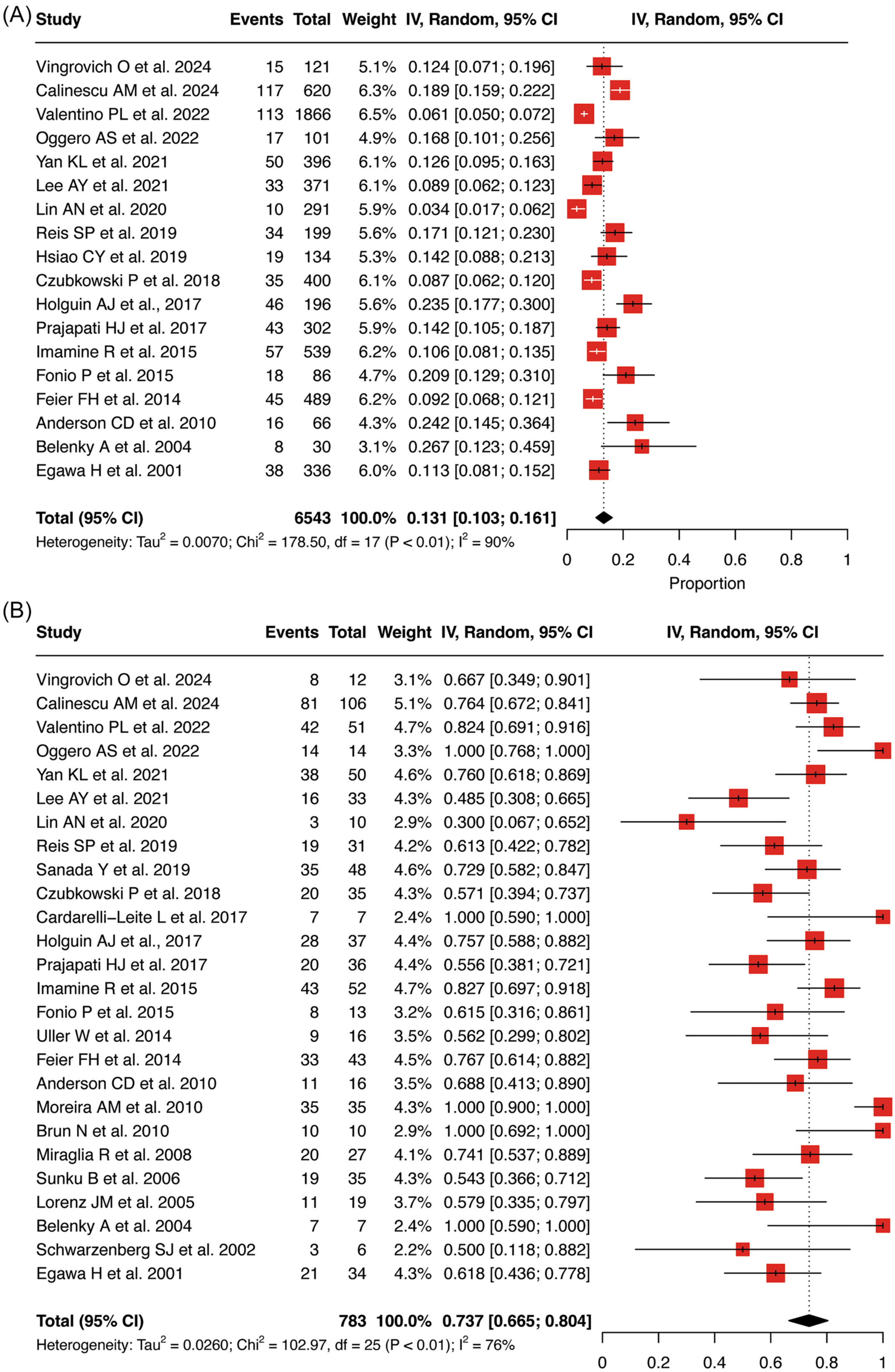


FIGURE 2 (A) Incidence of BS after pediatric liver transplantation. (B) Resolution rate of BS after percutaneous transhepatic cholangiography and drainage. Study details and 95% CI are depicted. Studies are sorted chronologically. BS, biliary strictures, CI, confidence interval.

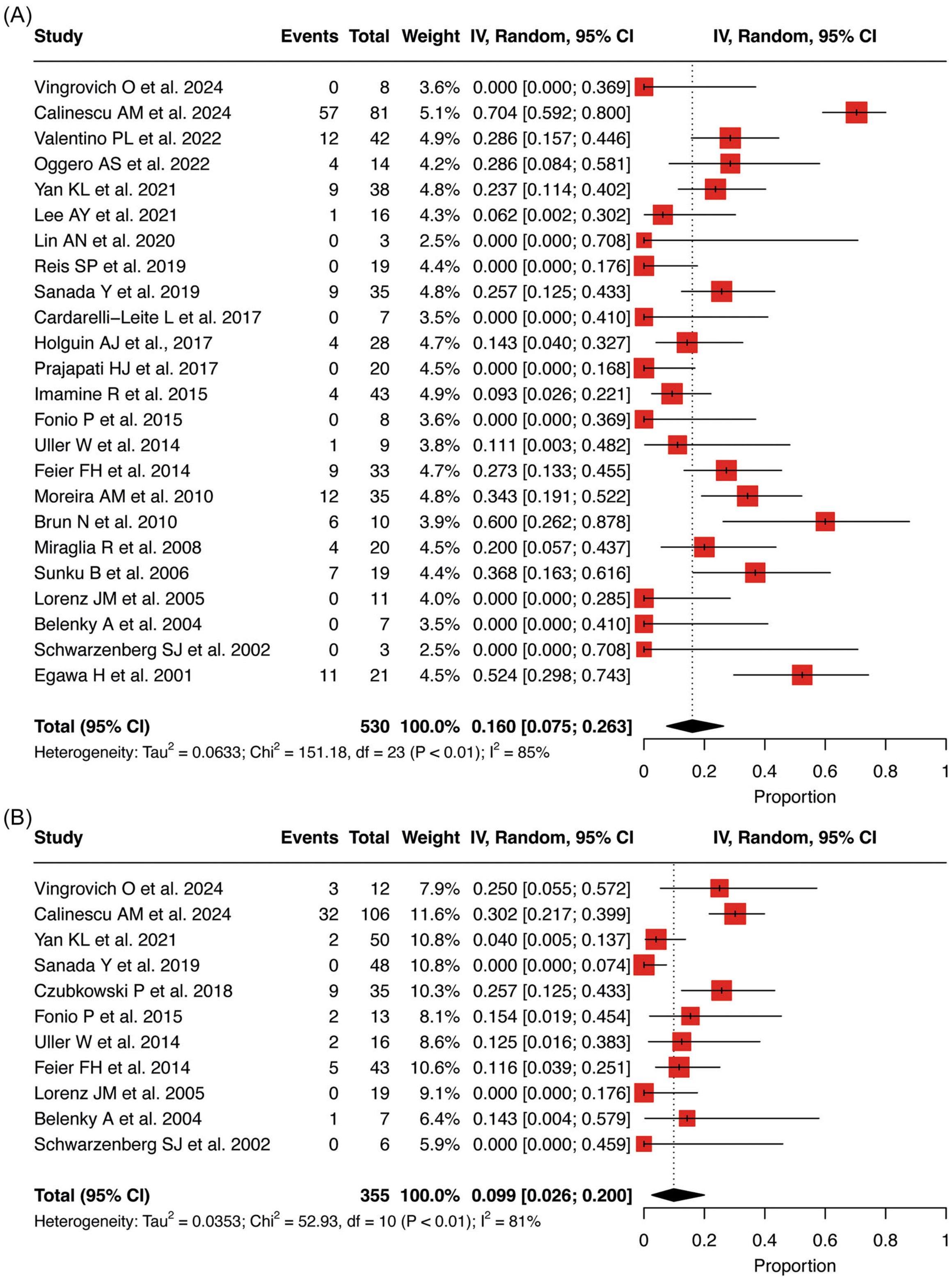


FIGURE 3 (A) Recurrence rate of BS after PTCD. (B) Complication rate of PTCD interventions. Study details and 95% confidence interval are depicted. Studies are sorted chronologically. BS, biliary strictures, CI, confidence interval; PTCD, percutaneous transhepatic cholangiography and drainage.

follow-up time of 48.4 months (IQR: 40.3–100.0). Valentino et al. reported 67% of recurrences occurring in the first year and 81% of recurrences occurring within 2 years from stricture resolution.[3] Thus, we believe the number of missed recurrences to be limited.

Concerning resolution, a transplant era effect can be observed with markedly improved results in patients with LT exclusively performed within the last two decades. However, this was not statistically significant. The re-transplantation rate was lower in patients with LT exclusively performed within the last two decades. This might reflect improvements in timely diagnosis and management of BS.

Various predicting factors for outcome have been proposed, each reflecting the reporting centers' expertise and experiences with their specific management protocol. In our meta-analysis, no predicting factors for resolution and recurrence could be found. Drainage duration did not significantly affect the rates of resolution and recurrence-free resolution. There is though a substantial amount of heterogeneity also within the long and short drainage duration groups. These findings imply a noninferiority of shorter drainage duration versus longer drainage. This carries potential relevance for clinical practice, as long-time drainage over months or years is thought to significantly impact quality of life,[39] especially in the pediatric age group. This is due to indwelling catheters interfering with activities of daily life such as playing or swimming as well as due to repeated time-consuming interventions and hospital-stays. Reducing drainage duration could potentially alleviate the burden of prolonged medical interventions, improving both physical and psychological well-being. However, interpretations must be made carefully. Mostly, decisions on drainage duration are not made a priori according to protocol, but based on clinical considerations, limiting the interpretation of these results. Prospective studies with adequately large sample sizes are essential to confirm or refute this finding and further guide clinical decision-making in this context.

Complications occurred in 9.9% of patients, and these were mainly minor complications. Darius and colleagues reported 8.5% of primarily surgically managed patients having major complications requiring additional surgery in 80% of cases. They reported a mortality rate after surgical reintervention of 3.4%.[39]

Our meta-analysis revealed a 20.2% likelihood of requiring a surgical revision of the biliary anastomosis following the initial PTCD procedure and a 9.9% probability of graft loss necessitating re-transplantation. These rates exceed those reported in prior studies. Valentino et al. reported that 10% of patients managed by PTCD or ERCP eventually required surgical revision, with patient and graft survival at 3 years of 94% and 93%, respectively.[3] In contrast, Darius et al. found that 13.0% of BS primarily managed surgically required a second surgical intervention, while only 2% experienced graft loss and required re-transplantation.[39] However, to our knowledge the mentioned study is the only published literature on complications and morbidity after surgical stricture treatment in pLT, limiting the ability to draw comparisons.

Treatment choices for BS are limited in the pediatric population. While ERCP is the first-line treatment for BS following LT in adults, its application in children is often impractical due to anatomical modifications from Roux-en-Y hepaticojejunostomy or the incompatibility of pediatric body size with available equipment. Surgery is generally agreed to be reserved for recurrent or treatment-resistant strictures.[40,41] Nevertheless, some suggest surgery as primary treatment option, avoiding the reduced quality of life associated with indwelling catheters.[39,42] However, this comes at the cost of slightly higher morbidity and mortality.[39]

The present study has several limitations. All included studies were retrospective, introducing inherent bias. Furthermore, we were unable to differentiate between early and late BS, a factor that might significantly influence treatment success and patient outcomes. Additionally, our meta-analysis could not accurately distinguish between anastomotic and non-anastomotic strictures, despite its importance, as emphasized by Akamatsu et al.[37] Also, technical variants of pLT and anastomosis types were not addressed in this review. While we aimed to extract data on the outcomes of these subgroups, data were insufficiently reported, making a comprehensive analysis unattainable. Furthermore, the study by Valentino et al. might comprise patients from other studies[4,30] included in our meta-analysis, potentially leading to bias.[3]

Future studies that prospectively evaluate these variables will be critical in elucidating the optimal management strategies for pediatric patients experiencing BS posttransplantation. Further research might emphasize the establishment of standardized management protocols concerning drainage duration, intervals between interventions and subsequent treatment decisions. Establishing uniform definitions for critical outcomes—such as stricture resolution, recurrence, and complications—could substantially improve the quality and consistency of reporting.

While this meta-analysis provides valuable insights into the outcomes of PTCD in pLT recipients, the identified limitations highlight the need for further research. Prospective studies with standardized methodologies will enhance understanding and guide clinical decision-making.

5 | CONCLUSION

PTCD is efficient to treat BS after pLT. Drainage time did not impact outcome, implying a non-inferiority of shorter versus longer drainage duration. Randomized trials are necessary to determine the optimal treatment protocol, including the ideal drainage duration and intervals between interventions.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Additional data are made available upon reasonable request.

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