

Percutaneous Treatment of Biliary Complications in Pediatric Patients After Liver Transplantation

Perkutane Therapie biliärer Komplikationen nach pädiatrischer Lebertransplantation

Authors

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Key words

- bile ducts
- bile duct radiography
- percutaneous
- catheters
- cholangitis
- transplantation

Zusammenfassung

Ziel: Evaluation von Effizienz und Sicherheit der perkutanen Therapie biliärer Komplikationen bei Kindern nach Lebertransplantation.

Methoden: Von Juni 2008 bis August 2012 wurden alle perkutanen biliären Interventionen nach pädiatrischer Lebertransplantation (PLT) evaluiert. Hierzu wurde Art der biliären Komplikation, Zeitintervall zwischen PLT und Intervention, Gefäßstatus, interventionelles Vorgehen, technischer und klinischer Erfolg, interventions-bedingte Komplikationen und Überleben analysiert.

Ergebnisse: 23 perkutane transhepatische Cholangiodrainagen (PTCD) wurden bei 16 Kindern wegen insgesamt 18 biliären Komplikationen nach PLT angelegt. Die Drainagen wurden individuell für jedes Kind durch Kürzen und Einbringen von zusätzlichen Löchern modifiziert. Mittels PTCD konnte in 4 Fällen erfolgreich die Zeit bis zur Re-transplantation oder chirurgischen Revision überbrückt werden. In einem Fall konnte eine Insuffizienz der biliodigestiven Anastomose erfolgreich behandelt werden. Eine Langzeitdilata-tion der biliodigestiven Anastomose wegen Stenosierung wurde bei 13 Kindern mittels PTCD durchgeführt, wobei ein Kind eine Rezidivstenosierung während des follow-ups (median 295 Tage) zeigte. Die Bilirubinwerte sanken nach PTCD-Behandlung signifikant. Bei einem Kind kam es zu einer Bakteriämie nach Drainagewechsel.

Zusammenfassung: Die perkutane transhepatische Therapie biliärer Komplikationen nach PLT ist effektiv und sicher.

Kernaussage: Mittels perkutaner transhepatischer Cholangiodrainage können unterschiedliche biliäre Komplikationen nach PLT erfolgreich behandelt werden. Hierbei ist allerdings ein individualisiertes, auf jeden Patienten abgestimmtes Vorgehen, unter Modifikation der Drainagen, nötig.

Abstract

Purpose: Evaluation of the efficiency and safety of the percutaneous treatment of biliary complications in pediatric liver transplant recipients.

Methods: We conducted a retrospective analysis of children who underwent biliary percutaneous interventions after pediatric liver transplantation (PLT) over a 4-year period. Kind of biliary complication, interval between liver transplantation and intervention, status of the vessels, procedural interventional management, technical and clinical success, course of cholestasis, PTBD-related complications and patient survival were analyzed.

Results: 23 percutaneous transhepatic biliary drainages (PTBD) were placed in 16 children due to 18 biliary complications. The drains were customized individually by shortening and cutting additional holes. PTBD placement was performed with technical and clinical success in all children. 4 children received PTBD to bridge the time to re-transplantation and surgical revision. One child received PTBD for successful treatment of anastomotic leakage. Long-term dilation of biliary stenoses was performed in 13 children using PTBD. One of these 13 patients showed recurrent stenosis during a median follow-up of 295 days. Bilirubin values decreased significantly after PTBD placement for biliary stenosis. One patient suffered from bacteremia after PTBD replacement.

Conclusion: PTBD treatment for biliary complications after PLT is effective and safe.

Key points: Various biliary complications after PLT can be successfully treated by PTBD. For this purpose, a highly individualized approach with catheter modification is mandatory.

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Introduction

Biliary leakages occur in up to 9% and biliary strictures in up to 11 % of pediatric liver transplant recipients [1]. Lu et al. recently described an incidence of anastomotic strictures of 4.5 % [2]. These anastomotic strictures are mostly related to scar tissue and negative remodeling at the suture site. Furthermore, anastomotic strictures and particularly non-anastomotic strictures may be induced by an impaired biliary blood supply [2 – 5]. Untreated biliary complications go along with high morbidity, mortality and long-term graft loss [2, 6]. Minimally invasive percutaneous treatment of these complications constitutes a helpful and important alternative to surgical revision since hepaticojejunostomy with Roux-en-Y reconstruction is the most common type of biliary anastomosis in pediatric patients, and thus endoscopy is rarely feasible in these cases [6]. Furthermore, percutaneous transhepatic cholangiography can demonstrate the type, the location, and severity of biliary complications and allows immediate treatment. The aim of this study is to report the single center experience in the treatment of biliary complications after pediatric liver transplantation (PLT) by placement of percutaneous transhepatic biliary catheters.

Patients and methods

Patients

Institutional review board approval was not required by our hospital for publishing a retrospective case series. However, in keeping with the ethical conduct of studies, the principles of the Declaration of Helsinki were followed. Patients were obtained from a prospective clinical database and reviewed for pediatric patients who underwent percutaneous transhepatic cholangiography (PTC) and percutaneous transhepatic biliary drainage (PTBD) catheter placement between June 2008 and August 2012. During this period a total of 16 children suffered from 19 biliary complications after PLT. The study population included 8 girls and 8 boys whose age at the time of the first intervention ranged from 2 months to 16.6 years (median age 4 years). The median body weight was 13.2 kg at the time of first intervention. The children underwent transplantation at different centers. Table 1 summarizes patient age and weight, indication for PLT and type of graft. The clinical characteristics of the study cohort, the type of biliary complication, the interval between PLT and first drain placement and the surgical revisions between PLT and radiological intervention were evaluated. The biliary stenoses were further divided into anastomotic strictures (isolated strictures at the biliary anastomosis site) and non-anastomotic strictures (defined as one or more stenoses of the intrahepatic biliary system apart of the ste-

Table 1 Patient and liver transplantation data including indication for PLT, type of graft (liver segments and donor), time interval between PLT and percutaneous intervention, age and weight at the date of first percutaneous intervention and type of stenosis.

Tab. 1 Patienten- und Lebertransplantationsdaten bestehend aus Indikation für die Lebertransplantation, Transplantattyp (Lebersegmente und Spender), Zeitintervall zwischen PLT und perkutaner Intervention, Alter und Gewicht zum Zeitpunkt der ersten biliären Intervention und Stenosentyp.

patient #	indication for PLT	type of graft: liver segments and donor	interval between PLT and intervention	age	weight	type of stenosis
1	α ₁ -antitrypsin deficiency	I, IV–VIII deceased	1 st interv. 2291 d	16y 7 m	62.1 kg	anastomotic stricture, ITBL
			2 nd interv. 3041 d	18y 8 m	63.0 kg	re-stricture
2	Alagille-syndrome	II – III deceased	1179 d	12y 3 m	27.8 kg	anastomotic stricture
3	biliary atresia	II – III deceased	1106 d	4y11 m	19.3 kg	anastomotic stricture, ITBL
4	biliary atresia	II – III deceased	121 d	1y 1 m	7.5 kg	anastomotic stricture, IBL
	transplant dysfunction (re-PLT)	II – III deceased	49 d	4y 8 m	20.0 kg	anastomotic stricture, IBL
5	Wollcot-Rallison syndrome	II – III deceased	33 d	2y 2 m	9.7 kg	ITBL
6	progressive intrahepatic cholestasis type III	II – III deceased	392 d	12y 8 m	19.6 kg	anastomotic stricture
7	biliary atresia	II – III living	134 d	3y 1 m	13.2 kg	anastomotic stricture, ITBL
8	biliary atresia	II – III deceased	318 d	2y 3 m	12.0 kg	ITBL
9	Alagille-syndrome	II – III deceased	622 d	10y 5 m	18.6 kg	IBL
10	biliary atresia	II – III deceased	77 d	8 m	6.3 kg	IBL
11	liver failure	II – III deceased	43 d	2 m	3.9 kg	anastomotic stricture
12	biliary atresia	II – III deceased	2903 d	11y11 m	36.0 kg	anastomotic stricture
13	mitochondriopathy	II – III part of IV deceased	1 st interv. 41 d	1y 5 m	10.2 kg	anastomotic leakage
			2 nd interv. 151 d	1y 9 m	10.7 kg	anastomotic stricture
14	biliary atresia	II – III living	3615 d	10y 5 m	32.0 kg	anastomotic stricture
15	biliary atresia	II – III living	262 d	1y	8.6 kg	anastomotic stricture S III
			262 d			non-anastomotic bile duct S II (treatment excluded from this study)
16	cystic fibrosis	II – III deceased	925 d	8y 7 m	24.2 kg	anastomotic stricture

PLT: pediatric liver transplantation, 1st interv.: first intervention, 2nd interv.: second intervention, m: month(s), d: days, kg: kilogram, IBL: ischemic biliary lesion, ITBL: ischemic type biliary lesion.
PLT: pädiatrische Lebertransplantation 1st Interv.: erste Intervention, 2nd Interv.: zweite Intervention m: Monat(e), d: Tage, kg: Kilogramm, IBL: ischemic biliary lesion, ITBL: ischemic type biliary lesion.

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nosis site). These non-anastomotic stenoses were subclassified as: (1) ischemic biliary lesions (IBL) defined as strictures, dilations and/or biliary cast of the biliary system and radiologically proven stenosis or thrombosis of the hepatic artery or (2) ischemic-type biliary lesion (ITBL) defined as strictures, dilations and/or biliary cast of the biliary system without evidence of stenosis or thrombosis of the hepatic artery. Patency of the hepatic artery, hepatic vein and the portal vein were assessed based on duplex ultrasound and additional cross-section imaging (magnetic resonance imaging or computed tomography) and digital subtraction angiography if performed. The course of cholestatic laboratory parameters was analyzed.

In addition, procedural interventional management, mean duration of PTBD catheter placement, technical and clinical success, PTCB-related complications, outcome and patient survival were noted.

Percutaneous Biliary Interventional Procedures

Biliary complications were diagnosed clinically and radiologically using ultrasonography, MRI and PTC. Indication for PTC was imaging findings suspicious for biliary leakage or for biliary outflow obstruction combined with cholangitis and elevated serum bilirubin values. Indication for PTBD catheter placement was contrast leakage from the hepaticojejunostomy and significant obstruction of the hepaticojejunostomy and/or strictures of the intrahepatic bile ducts detected by PTC.

Interventional procedures were performed under general anesthesia or monitored anesthesia with spontaneous respiration and additional local anesthesia by investigators with more than 4 years of experience in biliary interventions (WU, NZ, WAW, PH). After application of intravenous antibiotic prophylaxis, PTC was carried out using a CHIBA needle (21G, Boston Scientific, Natick, MA, USA) advanced under ultrasound guidance into a peripheral bile duct. The surface of the needle tip was roughened with a scalpel in order to increase echogenicity and visibility in ultrasound. The biliary tree was catheterized using the Accustick Introducer System (Boston Scientific) over a 0.018-inch Cope wire (Cook, Bjæverskov, Denmark). Angled catheters and glide guidewires were used to pass the strictures. To reduce radiation dose, ultrasound guidance was preferred to fluoroscopy for crossing the stenosis whenever possible. When internal drainage could not be achieved, a 6F external drain was placed to allow biliary decompression and healing of inflammation.

In the first session, customized 8.5F internal-external biliary catheters (Cook) were placed with side holes above and below the stricture or leakage. After two weeks, these drains were exchanged for soft "Münchner" silicone drains (Pflugbeil, Zorneding, Germany). The initial diameter of the drains was adapted to the child's weight (8F in case of a body weight < 20 kilogram; 10F in case of > 20 kg and 12F in case of > 40 kg). Long-term dilatation with "Münchner" drains was performed for at least 4–6 months; diagnostic cholangiogram and drain exchanges were performed every 2–3 months. The drains were removed in the case of no residual flow-reducing stenosis after this time period. In the case of residual stenosis > 30% in diameter after 6 months of dilation, drain placement was continued for 3 months using drains with an increased size by 2F.

Since no biliary drains that are adapted to the needs of pediatric patients are available, it was necessary to customize the catheters available for adults to the individual needs of the children. The parents of the patients were informed accordingly and informed consent was obtained because the use of these customized drains

should be considered an off-label use. To facilitate optimal biliary fluid decompression and drainage, additional side holes were cut proximally into the drains such that the first proximal hole of the drain was always situated inside the peripheral bile duct next to the puncture site. The lengths of the "Münchner" drains were shortened by 7–12 cm according to the individual size of the liver and length of bile ducts.

All catheters remained open to outside drainage during the first 24–72 hours and were closed for internal drainage when the patients were discharged. Drains were flushed with 5–10 ml sodium chloride once to twice a day according to the diameter and bile consistency.

Technical success of the external drainage catheter was defined by collection of biliary fluid. Technical success of treatment of biliary strictures was defined by a prompt passage of contrast medium from the intrahepatic bile duct to the bowel without flow-reducing residual stenosis. The success of interventional radiological treatment of biliary insufficiency was defined by the absence of contrast media leakage at the anastomotic site. Clinical success was defined by resolution of cholangitis.

Follow-up

Ultrasound, laboratory and clinical follow-up were performed at least every 3 months in the first postprocedural year and then every 6 to 12 months. Follow-up was performed until January 2013.

Results



Patients

Five patients had surgical revisions of the hepaticojejunostomy prior to the percutaneous biliary intervention due to anastomotic stenosis (Patient #1, #2 and #6) and due to repeated biliary leakage at the hepaticojejunostomy (Patient #4 and #9). At the time of intervention, one child (Patient #16) presented with a hepatico-hepaticostomy, whereas the other children presented with a hepaticojejunostomy with a Roux-en-Y jejunal loop. Two patients had had two separate bile duct anastomoses to the jejunal loop. All children with stenoses presented with clinical findings of cholangitis and elevated serum bilirubin. Ultrasound and magnetic resonance imaging (MRI) of the liver with MR-cholangiopancreatography (MRCP) were performed in all children for assessment of anatomy and for planning of the most suitable approach.

Percutaneous transhepatic cholangiography, initial PTBD

PTC was performed technically successfully in all patients. The patients suffered from isolated anastomotic strictures (n=8, **Fig. 1, 2**), isolated IBL (n=2), isolated ITBL (n=2, **Fig. 3**), a combination of anastomotic stenosis and IBL (n=2) and a combination of anastomotic stenosis and ITBL (n=3). Hence, 4 patients (Patient #1, #3, #4 – before and after re-PLT – and #7) exhibited strictures of the intrahepatic bile ducts and in addition an accentuated stenosis of the biliary anastomosis. One child showed a leakage of the anastomosis (n=1, Patient #13). Patient #15 suffered from a non-anastomotic bile duct of segment II to the jejunum and an additional anastomotic stricture of segment III. Concerning this patient, we will only focus on the anastomotic stricture in this publication. We excluded the treatment of the non-anastomotic bile duct since we already reported on the successful percutaneous connection of the non-anastomotic segmental duct to the jejunum in this patient [7]. However, the treat-

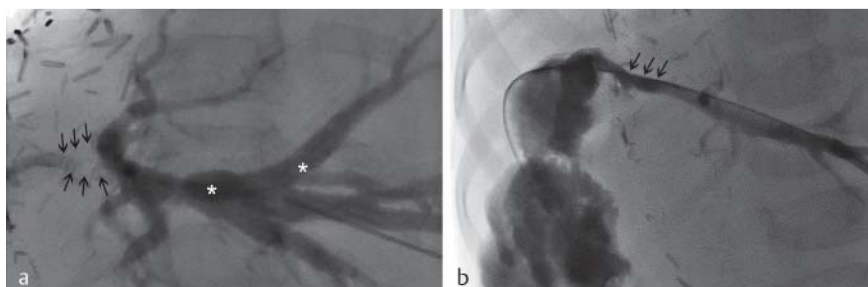


Fig. 1 21-month-old boy (Patient #13) after split-liver transplantation (segments II, III and part of IV) for treatment of mitochondriopathy. **a** Initial percutaneous transhepatic cholangiography depicts a high-grade isolated stenosis of the hepaticojunostomy (arrows) and dilated intrahepatic bile ducts (asterisk). **b** After long-term dilation for 9 months, percutaneous transhepatic cholangiography performed through a sheath shows complete resolution of the stenosis (arrows) and no dilated bile ducts.

Abb. 1 Bei diesem 21 Monate alten Junge (Patient #13) wurde eine Split-lebertransplantation (bestehend aus den Segmenten II, III und Teilen von Segment IV) wegen einer Mitochondriopathie durchgeführt. **a** Die initiale perkutane transhepatische Cholangiografie zeigt die hochgradige, isolierte Stenose der Hepatikojejunostomie (Pfeile) sowie dilatierte intrahepatische Gallengänge (Sterne). **b** Nach 9 Monaten Langzeitdilatation zeigt die über eine eingewechselte Schleuse durchgeführte Cholangiografie eine regelrechte Darstellung der Hepatikojejunostomie ohne Nachweis einer residuellen Stenosierung (Pfeile) sowie nicht dilatierte Gallengänge.

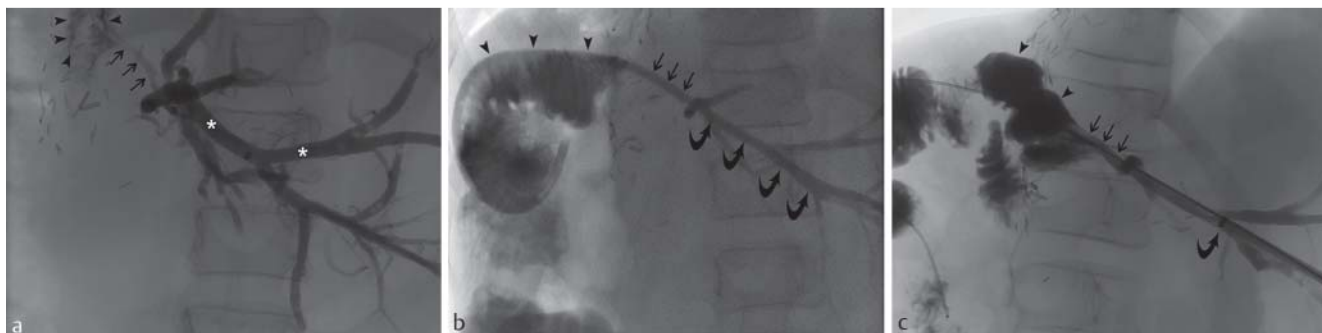


Fig. 2 12-year-old girl (Patient #6) after split-liver transplantation (segments II and III) for treatment of progressive intrahepatic cholestasis type III. **a** Initial percutaneous transhepatic cholangiography detected an isolated stenosis of the hepaticojunostomy (arrows) with a marginal contrast medium flow in the jejunum (arrowheads) and dilated intrahepatic bile ducts (asterisk). **b** The 10F "Münchener" drain was shortened by 7 centimeters and side holes were cut in the section of the drain between the point of peripheral bile duct puncture and the first preexisting hole (curved arrows). The drain bridged the stenosis (arrows) and provided contrast media flow in the jejunum (arrowheads). **c** After 9 months of long-term dilation, cholangiography with contrast medium application through a sheath (curved arrow) showed patent hepaticojunostomy with no residual stenosis (arrows) and prompt contrast media flow in the jejunum (arrowheads).

Abb. 2 Wegen einer progressiven intrahepatischen Cholestase Typ III wurde bei diesem 12-jährigen Mädchen (Patient #6) eine Splitlebertransplantation (bestehen aus den Segmenten II und III) durchgeführt. **a** Die initiale perkutane Cholangiografie detektiert eine isolierte Stenose der Hepatikojejunostomie (Pfeile) mit nur minimalem Kontrastmittelübertritt in das Jejunum (Pfeilspitzen) und dilatierten intrahepatischen Gallengängen (Sterne). **b** Eine 10F Münchner Drainage wurde um ca. 7 cm gekürzt. Zusätzliche Seitlöcher wurden manuell in den zwischen dem Eintritt in das Gallengangssystem und dem ersten vorgefertigten Seitloch befindlichen Abschnitt der Drainage eingebracht (gebogene Pfeile). Die Drainage überbrückt die Stenose (Pfeile) und gewährleistete die Kontrastmittelpassage in das Jejunum (Pfeilspitzen). **c** Nach 9 Monaten Langzeitdilatation zeigte die über eine Schleuse (gebogener Pfeil) angefertigte Cholangiografie keine residuelle Stenosierung der Hepatikojejunostomie (Pfeile) mit einem zügigen Kontrastmittelübertritt in das Jejunum (Pfeilspitzen).

ment of the anastomotic stricture was not described in this case report [7].

A total of 23 initial drain placements were successfully performed in 16 children (Patient #4 –after re-PLT-, #8, #9, #10, #12 and #13 received two catheters, Patient #1 received 3 catheters). In 20 cases internal-external drains were placed, 3 children received only external drains. The time interval between PLT and PTC (combined with first catheter placement) ranged from 33 days to 3041 days (median, 318 days).

• **Table 1** shows the time interval between PLT and radiological intervention and cholangiographic findings (type of stenosis).

Status of the hepatic artery, hepatic vein and the portal vein

Stenoses of more than 50% of the normal vessel diameter were considered significant. No stenoses or occlusion of the hepatic veins was detected. Hepatic artery (HA) stenoses/occlusions were detected in 4 cases resulting in the diagnosis of IBL (Patient #4 before and after re-PLT, Patient #9 and #10). Patient #15 presented with a short stenosis of the HA and isolated anastomotic stenosis of the hepaticojunostomy. Angiography performed shortly after PTC showed multiple collaterals that provided adequate filling of the HA distal to the stenosis in appropriate time and volume. Stenoses of the portal vein (PV) were identified in three cases (Patient #4, #9 and #13) and thrombosis of the PV in three cases (Patient #3, #10 and #12). Except for the patient

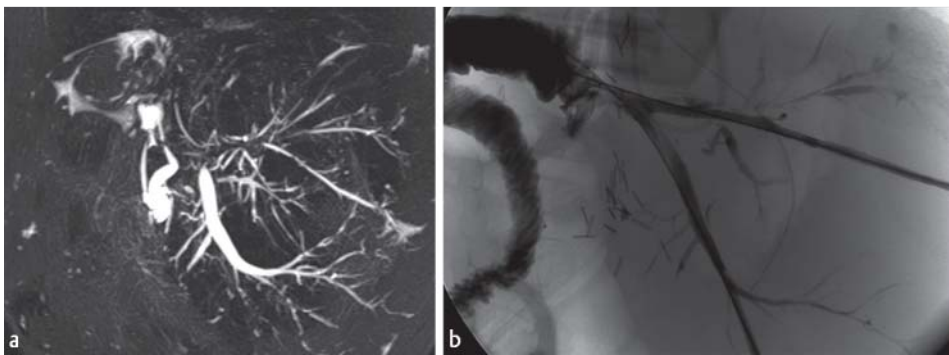


Fig. 3 2-year-old boy (Patient #8) after split-liver transplantation (segments II and III) for the treatment of biliary atresia. **a** Preinterventional magnetic resonance imaging (MRI) of the liver with MR-cholangiopancreatography (MRCP) shows numerous intrahepatic strictures beside dilation of a biliary duct (segment II). **b** 6 months after long-term dilation using 2 drains: Cholangiography after contrast application through two sheaths shows normal caliber of the bile ducts with prompt contrast media flow in the jejunum.

Abb. 3 2-jähriger Junge (Patient #8) nach links lateraler Splitlebertransplantation wegen biliärer Atresie. **a** Die präinterventionell durchgeführte MR-Cholangiopankreatikografie (MRCP) zeigt zahlreiche Strikturen der intrahepatischen Gallengänge sowie eine deutliche Dilatation des Segment II Gallengangs. **b** Die Cholangiografie nach Kontrastmittelapplikation über zwei Schleusen zeigt die intrahepatischen Strikturen nach 6-monatiger Langzeitdilatation deutlich rückläufig, eine Dilatation von Gallengängen lässt sich nicht mehr detektieren. Das Kontrastmittel verteilt sich zügig im Jejunum.

Table 2 Vascular complication data including type of vascular complication, type of treatment and time interval between first percutaneous biliary intervention and vascular treatment.

Tab. 2 Daten zu vaskulären Komplikationen bestehend aus Typ der Komplikation, Therapieart und Zeitintervall zwischen erster perkutaner biliärer Intervention und vaskulärer Therapie.

patient #	type of stenosis	vascular complications	vascular treatment	time interval between vascular treatment and first PTBD placement
1	anastomotic stricture, ITBL	–	–	–
	re-structure	–	–	–
2	anastomotic stricture	–	–	–
3	anastomotic stricture, ITBL	occlusion PV (thrombosis)	mesenterico-intrahepatic shunt mesenterico-renal shunt	11 months prior to PTBD
4	anastomotic stricture, IBL	occlusion HA (thrombosis)	repeated PLT	
	anastomotic stricture, IBL	stenosis HA stenosis PV	balloon and stent-PTA HA balloon and stent-PTA PV	20 days after PTBD 20 days after PTBD
5	ITBL	–	–	–
6	anastomotic stricture	–	–	–
7	anastomotic stricture, ITBL	–	–	–
8	ITBL	–	–	–
9	IBL	stenosis HA stenosis PV	repeated PLT (chronic dysfunction)	
10	IBL	occlusion PV (thrombosis) stenosis HA	balloon-PTA HA balloon-PTA PV	9 days after PTBD same day as PTBD
11	anastomotic stricture	–	–	–
12	anastomotic stricture	occlusion PV (thrombosis)	–	–
13	anastomotic leakage			
	anastomotic stricture	stenosis PV	balloon-PTA PV	5.5 months after PTBD
14	anastomotic stricture	–	–	–
15	anastomotic stricture S III	stenosis HA (multiple collateral vessels)	–	–
	non-anastomosed bile duct S II			
16	anastomotic stricture	–	–	–

IBL: ischemic biliary lesion, ITBL: ischemic type biliary lesion, HA: hepatic artery, PV: portal vein, PLT: pediatric liver transplantation PTBD: percutaneous transhepatic biliary drainage
IBL: ischemic biliary lesion, ITBL: ischemic type biliary lesion, HA: Arteria hepatica, PV: Pfortader, PLT: pädiatrische Lebertransplantation, PTBD: perkutane transhepatische Cholangiodrainage

with isolated PV thrombosis (Patient #12), all vascular complications were successfully treated by interventional radiological or surgical means prior to or after PTBD catheter placement. Vascu-

lar stenoses, performed treatment and the time of treatment are summarized in **Table 2**.

PTBD for bridging (4 patients)

In 4 cases (Patient #3, #4, #5 and #9) successful drainage catheter placement resolved the septic condition and bridged for surgical revisions and re-transplantation (re-PLT: Patient #4 and #9 for chronic dysfunction). Surgical revisions included segmental liver resection (Patient #3 because of multiple intrahepatic strictures and biliomas), and revision of the Roux-en-Y reconstruction as well as lavage (Patient #5 because of intra-abdominal abscess). In three of these cases external catheters were placed since it was not possible to cross the distinct strictures.

PTBD for long-term dilation (13 patients)

Long-term dilation by PTBD was performed in 13 children. At the end of follow-up for this study, long-term dilation was still ongoing in 4 children. In these four patients the long-term dilation showed a significant effect on the extent of the strictures but the minimum duration of long-term dilation (4–6 months) had not been reached (Patient #4 after re-PLT, Patient #14–#16).

Concerning the 9 children with completed long-term dilatation, the median duration of PTBD catheter placement was 260 days (range, 125–289 days). 7 of these children showed no recurrent stenoses during a median follow-up of 295 days (range 38 days to 714 days; **Fig. 1–3**). One patient developed a recurrent isolated anastomotic stricture during follow-up, which was again treated with PTBD until surgical revision (Patient #1). Patient #8 died 4 months after drainage catheter removal due to multi-organ failure but remained symptom-free with respect to biliary stenosis after drain removal.

Bilirubin values, measured one day prior to PTBD and within the first 5 days after drain removal, decreased significantly from 1.8 mg/dl (+/-1.65 mg/dl) to 0.75 mg/dl (+/- 0.83 mg/dl) in these patients ($p=0.008$).

Cholangitis resolved in all 13 patients reflecting the clinical success of PTBD treatment.

PTBD for treatment of biliary insufficiency (one patient)

Leakage of the hepaticojejunostomy was successfully treated using a custom-made transanastomotic catheter (Patient #13; 1st intervention).

Complications

One patient suffered from an episode of bacteremia after exchange of a transhepatic biliary drainage catheter. This was successfully treated with antibiotics (Patient #2). Another patient developed bacteremia and a septic condition prior to planned exchange of the catheter (Patient #13; 2nd intervention). In this child, the PTBD catheter was exchanged 6 weeks after placement. A venous access catheter was also exchanged and after application of antibiotics the septic condition resolved. It remains unclear whether the septic condition was caused by PTBD or by the venous catheter. In one patient (Patient #12), the skin adjacent to the drain showed marginal signs of inflammation at the end of long-term dilation, but this boy remained completely asymptomatic and no therapy was necessary.

Discussion

In the present study, we described our experience and results of treating biliary leakages and strictures after pediatric liver transplantation by percutaneous transhepatic drainage catheter placement.

The indication for performing PTC was based on the synopsis of clinical, laboratory and imaging data. All children in this study underwent ultrasound and MRI before intervention. MRI allows evaluation of the anatomy of bile ducts, anastomosis and transplant, and evaluation of torsion and growth of the graft. Furthermore, MRI is helpful in planning complex interventions like the placement of a biliary catheter in children with two separate hepaticojejunostomies and non-dilated bile ducts.

In the present study diagnostic cholangiogram and catheter placement were carried out successfully in all of the 23 cases using a combination of ultrasound and fluoroscopic guidance. In previous studies, PTC failed in the first attempt in 7% of the liver-transplanted children without US guidance [8]. Other authors report a technical success rate of 92% using fluoroscopy or US guidance during PTC in children [9]. Our results suggest that, beside the importance of MRI for access planning, sonographic needle guidance is mandatory for successful performance of PTC and PTBD. Furthermore, additional color Doppler sonography should be performed intraprocedurally to avoid puncture of vascular structures. Roughening of the tips of the puncture needles for better visibility in ultrasound is easy to perform, simplifies safe puncture and decreases the number of needle passes.

In 4 of the 23 PTBD catheter placements, catheter placement bridged successfully for re-transplantation and surgical revisions. Surgical and histological findings showed that further interventional radiological treatment in these cases would neither have been successful nor indicated. Hence, PTBD catheter placement is helpful to control cholestasis and cholangitis to bridge to carefully planned re-transplantation and surgical treatment.

All external and transanastomotic silicone catheters used in this study were individually customized to the children's needs, because commercially available PTBD catheters are not available in sizes that match the biliary system after PLT. Therefore, it is essential to shorten the drains and to insert additional side holes. However, the use of these drains should be considered as off-label use and parents have to be informed accordingly. In patients with anastomotic leakage, holes should only be presented proximal and distal to the leakage in order to "cover" the leakage site. The available literature concerning dilation therapy of biliary strictures after liver transplantation reports differences in the number of applied balloon dilations, the duration of balloon inflation, and the duration of stent placement [5, 10–14]. Sunku et al. reported a success rate of 34% after balloon dilation and stent placement for 3 months with a median follow-up of 4.5 years in pediatric liver transplant recipients [14]. In another study, the biliary-enteric anastomoses after PLT were not patent 3 months after balloon dilation and catheter placement in 40% of the cases [11]. In these patients surgical revisions, re-transplantation or endobiliary metallic stent placement was eventually performed [11]. Moreira et al. reported the resolution of bilioenteric anastomotic stenosis in 23 of 35 liver-transplanted children (65.7%) after one session of balloon dilation and a mean duration of drainage catheter placement of 10 months [8]. Some authors consider repeated balloon dilation of biliary stenoses to be too traumatic and may result in more focal fibrosis and scarring [5, 15]. To the best of our knowledge, there is no study available dealing only with long-term dilation with silicone catheters after PLT. In our study, balloon dilation was only performed when it was not possible to pass the stricture with a catheter or when after long-term dilatation for at least six months residual strictures >30% in diameter were identified. Technical success of the treatment of stenoses was achieved in all cases ex-

cept one, thus indicating that long-term dilation with silicone catheters is effective and might be preferable to balloon dilatation in pediatric patients. Furthermore, the size of the catheter can be adapted to the child's increasing size.

We did not note complications associated with the long drainage period in our small study population. Only one patient showed bacteremia after exchange of a catheter, and one patient exhibited local inflammation at the skin but remained asymptomatic. The relatively large diameter of the used drains was not related to bleeding complications or fistulas and was considered appropriate for successful dilation therapy. No transient hemobilia, melena, drop in hematocrit, pancreatitis, or bile leak occurred. These complications were reported in studies dealing with balloon dilation [12, 16, 17]. It is reported that ischemic strictures of bile ducts go along with an increased rate of recurrence [18–20]. In the present study there was no increased rate of recurrent strictures in patients with hepatic artery stenosis or thrombosis, which might be a consequence of successful recanalization of the hepatic artery, the relatively short follow-up period and repeated transplantation in 2 cases. On the one hand it has been postulated that the development of collateral vessels can provide appropriate perfusion of the transplant. On the other hand some authors believe that collateral flow is insufficient to prevent biliary ischemia [21–23]. It remains unclear if 1) immediate and successful treatment of hepatic artery stenoses reverses biliary ischemic changes including anastomotic strictures and 2) portal vein stenoses or occlusions cause or boost anastomotic strictures after PLT. Because of the small cohort in our study and the lack of long-term follow-up, it remains unclear if the prompt treatment of hepatic artery and/or portal vein stenoses in children can lead to successful treatment of biliary ischemic changes when combined with long-term placement of biliary drains. However, according to Lu et al. we consider early diagnosis and treatment of vascular stenosis essential to prevent further ischemia injury [2]. There are some studies dealing with the treatment of biliary stenosis in adult patients after liver transplantation. Since the most frequent reconstruction of the biliary system in those patients remains choledochcholedochostomy, a comparison to our series is not reasonable as only one child in our cohort had a choledochcholedochostomy.

Conclusion

Radiological treatment of biliary complications after PLT with customized percutaneous transhepatic biliary drainage catheters is safe and effective. Taking the characteristics concerning the anatomy of the transplant and bile ducts as well as the technical distinctions in pediatric patients into account, percutaneous therapy enables bridging to repeated transplantation and long-term remodeling of biliary strictures in growing children.

Clinical relevance of the study

Percutaneous management of biliary complications in pediatric patients after liver transplantation

- ▶ is safe and effective, if
 - ▶ biliary drains are individually customized to the child's needs
 - ▶ the special anatomy after PLT is kept in mind

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