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ORIGINAL ARTICLE

Endoscopic treatment of biliary complications after duct-to-duct biliary anastomosis in pediatric liver transplantation

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Abstract

Background Studies reporting outcomes of endoscopic treatment methods in children who underwent liver transplantation (LT) is very limited. We present our outcomes, as a high-volume transplant center where endoscopic methods are preferred as the first choice in the treatment of biliary complications in children.

Methods Patients who underwent endoscopic retrograde cholangiopancreatography (ERCP) as the first treatment approach for biliary complications after LT between 2005 and 2017 were included. Clinical data included patient demographics, ERCP indications (stricture or leak), and treatment outcomes, including the need for percutaneous and surgical intervention.

Results ERCP was performed in 49 patients who had a duct-to-duct anastomosis (38 living donor liver transplantation (LDLT), 11 deceased donor liver transplantation (DDLT)). The most common biliary complication was stricture. Our endoscopic success rate was 66.7% (18/27) and 75% (6/8) in LDLT and DDLT patients with stricture ($p > 0.05$), respectively. While our endoscopic success rate was 75% (3/4) in patients with leak alone after LDLT, it was 25% (1/4) in patients with leak and stricture in this group. The endoscopic success rate was 50% in two patients who had leak alone after DDLT.

Conclusions ERCP should be considered as a preferential treatment option for the management of biliary complications in pediatric liver transplant patients with duct-to-duct anastomosis, as in adults.

Keywords Pediatrics · Liver transplantation · Biliary complications · Endoscopic retrograde cholangiopancreatography

Introduction

Liver transplantation (LT) is a life-saving treatment modality in adults and children with acute liver failure and chronic end-stage liver disease [1, 2]. Biliary complications are one of the main causes of morbidity and graft loss in pediatric patients after liver transplantation [3, 4] and include biliary strictures, leaks, and cast formation. The type of graft used is an important determinant of the development and frequency of these complications [5–7] . In a large series of pediatric liver transplant recipients, biliary complication rate varied with graft type: whole liver 17.3%, split 28.5%, reduced 25.3%, and live donor 40.1% [3]. Unlike adults, split- or reduced-size or live donor grafts have been more frequently used instead of whole liver in children. Therefore, biliary complications are more common in children after liver transplantation.

Endoscopic access to the biliary tract is the main factor that determines type of treatment in the management of biliary complications. Surgeons often prefer bilioenteric anastomosis because of the necessity of using small-sized liver grafts in children [8]. The first choice of treatment in bilioenteric anastomosis is percutaneous intervention. Therefore, almost all of the publications about management of biliary complications after pediatric liver transplantation report outcomes of percutaneous and surgical interventions [8, 9].

Endoscopic interventions are a first choice for patients who underwent duct-to-duct anastomosis. In recent years, very

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successful results have been obtained with endoscopic methods in the treatment of biliary complications in adults [10, 11]. This has led to the preference for endoscopic methods that are less invasive instead of percutaneous and surgical interventions in patients with duct-to-duct anastomosis. Currently, the number of studies reporting the outcomes of endoscopic treatment methods in children who underwent liver transplantation is very limited.

Our center is the highest volume liver transplantation center in Turkey (200–300 patients per year undergoing primarily living donor liver transplantation (LDLT) in both adults and children). In this study, we aimed to present our results as a high-volume center where endoscopic methods are preferred as the first choice in the treatment of biliary complications in children.

Patients and methods

We retrospectively reviewed the patient database of the Liver Transplantation Institute of Inonu University. A total of 360 pediatric patients (age < 18 years) who underwent liver transplantation between September 2005 and May 2017 were screened; patients who underwent endoscopic retrograde cholangiopancreatography (ERCP) as the first treatment option for biliary complications were included in the study. The ethics committee of Inonu University Medical Faculty approved the study (2019/4-39).

Clinical data included patient demographics, indications for LT, time to first ERCP after LT, number of ERCP procedures, ERCP indications (stricture or leak), ERCP interventions (endoscopic sphincterotomy, dilatation, stent placement, or stone extraction), and recurrence of biliary problems, complications, and treatment outcomes, including need for percutaneous and surgical interventions. We also investigated the incidence of hepatic artery complications in liver imaging studies (computed tomography CT or magnetic resonance imaging, MRI). Before ERCP, every patient was evaluated by a multidisciplinary team including transplant surgeons, radiologists, and gastroenterologists (adult and pediatric), along with their clinical data and imaging, including MRI or catheter cholangiography. Biliary complications were divided into three main categories and further procedures were planned. These are stricture (anastomotic and/or non-anastomotic), leak (intra-abdominal or intrahepatic), and bile duct-filling defects (stones and/or sludge). Biliary complications were suspected on the basis of clinical symptoms (jaundice, itching, bilious drainage, and cholangitis), deranged liver function tests (bilirubin, transaminases, and/ or gamma-glutamyl transferase levels), or radiologic imaging. Figure 1 shows our procedure algorithm for suspected biliary complications. Biliary stricture was suspected if there were symptoms of cholangitis or elevation of liver function tests. Magnetic resonance cholangiopancreatography (MRCP), computerized tomography (CT), or transhepatic biliary catheter cholangiography was performed to diagnose biliary strictures. If there were findings of biliary stricture, ERCP was preferred as the first choice in patients with duct-to-duct anastomosis. Catheter cholangiography was performed when clinical indications occurred and routinely just prior to catheter removal, at approximately 180 days after LT. During catheter cholangiography, we used diluted contrast reagent (Iohexol, Omnipaque 300™, 647 mg iohexol/ml, GE Healthcare, Oslo, Norway) to confirm the presence of biliary complications. We did not implement ERCP in patients without duct-to-duct anastomosis. Three experienced gastroenterologists (M.A., M.H., and Y.B.) performed ERCP using Olympus duodenoscopes (TJF 160, Olympus Optical Co., Ltd., Tokyo, Japan). Informed written consent was obtained from the legal guardian of the patients. An intravenous prophylactic antibiotic (50 mg/kg iv ampicillin/sulbactam) was administered before all procedures. We performed endoscopic sphincterotomy routinely in every patient during ERCP. A 0.025 or 0.035-in. guidewire (Jagwire, Boston Scientific, Natick, MA, USA) was inserted via catheter into the intrahepatic bile ducts if biliary stricture is detected on contrast cholangiography. Then, we dilated it using a Bougie (7 and 10 French, Wilson-Cook Medical GI Endoscopy, Winston Salem, NC, USA) and/or a balloon catheter (4, 6, or 8 mm, Hurricane RX; Boston Scientific, USA). Then, Amsterdam-type biliary stents (7 and 10 French, 9–16 cm long, Boston Scientific) were placed across the stricture or anastomosis. ERCP and stent revision were performed every 3 months. We aimed to improve the stricture as soon as possible. Therefore, we tried to increase the number and diameter of stents in each session. If the stricture improved during follow-up ERCP (at approximately 18 months), we removed the biliary stents and followed the patient without stents. If stricture persisted or recurred, re-dilatation and re-stenting were performed endoscopically.

In cases where the cholangiogram showed a bile leak, ERCP was preferred as the treatment modality in patients with duct-to-duct anastomosis. If biliary leakage was detected on ERCP, we inserted biliary stents after sphincterotomy to stop the leak. If biliary stones were found on imaging or ERCP, we extracted the stones with a balloon or basket catheter. Ursodeoxycholic acid was used to decrease the viscosity of bile in all patients with stricture and biliary filling defects after procedure.

If ERCP was unsuccessful (failure to pass stricture or persistent biliary complications despite dilatation and stent placement), our multidisciplinary team decided whether percutaneous transhepatic biliary interventions (PTBI) and/or surgical treatments were indicated. After percutaneous drainage with PTBI was shown to be successful, we performed a stent revision with ERCP at a later point. If endoscopic and

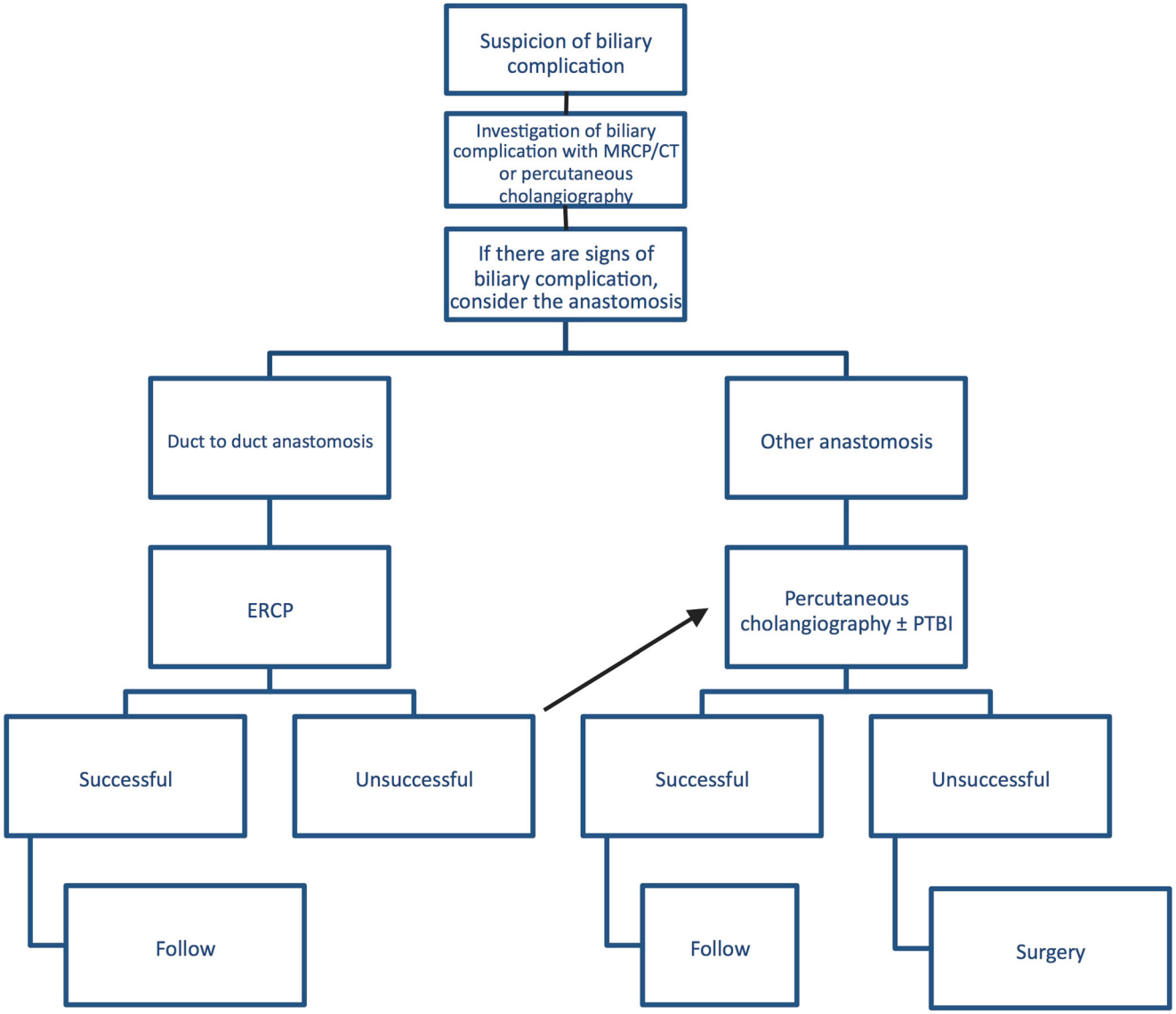

Fig. 1 Procedure algorithm for suspected biliary complications after liver transplantation

percutaneous treatments failed, surgical treatment was offered as a final option. In this study, patients who did not have PTBI or surgery due to biliary complications at any time during follow-up after first ERCP were considered an ERCP success.

Data were statistically analyzed using SPSS version 16.0 (SPSS Inc., Chicago, IL, USA). The Kruskal–Wallis test was used for comparisons, and a p value of less than 0.05 was considered statistically significant.

Results

Of 360 pediatric liver transplant patients, 298 were LDLT (82.7%) and 62 were deceased donor liver transplantation (16.3%) (DDLT). In patients with LDLT, 225 children had duct-to-duct anastomosis (75.5%) and the remaining 73 patients had bilioenteric anastomosis (245%). In cadaveric transplants, 47 children had duct-to-duct anastomosis (75.8%) and 15 children had bilioenteric anastomosis (24.2%). While the total number of patients with duct-to duct anastomosis was 272 (75.5%), the remaining 88 patients had bilioenteric anastomosis (24.5%). ERCP was chosen as the first-choice treatment for biliary complication in 49 (18.0%) of 272 patients with duct-to-duct anastomosis (38 LDLT (77.5%), 11 DDLT (22.5%)).

Table 1 shows the demographic characteristics of the patients. The age of the patients included in the study ranged from 3 to 18 years (36–216 months). The mean ERCP procedure number per patient was 4.1 and 3.7 in the LDLT and DDLT groups, respectively ($p > 0.05$). The mean duration from LT to first ERCP was 11.8 and 15 months in the LDLT and DDLT groups, respectively ($p > 0.05$).

The most common biliary complication was stricture. Stricture frequency was 71.0% and 72.7% in LDLT and DDLT patients, respectively ($p > 0.05$) (Table 2). All strictures

Table 1 Baseline patient demographics

	LDLT ($n = 38$)	DDLT ($n = 11$)	p value
Age at transplant (mean ± SD months)	142.71 ± 56.27	160.0 ± 39.0	NS
36–96 months (4–8 year)	10	1	
97–156 months (9–13 year)	11	5	
157–216 months (14–18 year)	17	5	
Female/male	17 (44.7%)/21 (55.3%)	5 (45.4%)/6(44.6%)	NS
Mean procedure number	4.18 ± 3.3	3.73 ± 3.74	NS
Mean duration between LT and first ERCP (months)	11.8 ± 17.3	15.0 ± 23.1	NS
Etiology	Cryptogenic ($n = 11$; 28.9%) Wilson's disease ($n = 6$; 15.7%) Autoimmune hepatitis ($n = 5$; 13.1%) Mushroom poisoning ($n = 3$; 7.8%) Hepatitis B ($n = 2$; 5.2%) Budd-Chiari syndrome ($n = 2$; 5.2%) Others ($n = 9$; 23.6%)	Wilson's disease ($n = 5$; 45.4%) Budd-Chiari syndrome ($n = 4$; 36.3%) Cryptogenic ($n = 1$; 9.0%) Hepatitis B ($n = 1$; 9.0%)	

LDLT living donor liver transplantation, *DDLT* deceased donor liver transplantation, *NS* non-significant

were anastomotic. Stricture and leak was observed in four patients after LDLT, but not in any patients with DDLT. Biliary leak alone was found in four LDLT (10.5%) and two DDLT (18.1%) patients. Stricture and stone was detected in one patient with LDLT and DDLT. While stone alone was found in two patients with LDLT, none of the DDLT patients had stone alone on ERCP (Table 2).

Table 3 shows how often PTBI is applied according to transplant type and biliary complication type. Our endoscopic success rate was 66.7% (18/27) in LDLT patients, and 75% (6/8) in DDLT patients with stricture ($p > 0.05$). While our endoscopic success rate was 75% (3/4) in patients with leak alone after LDLT, it was 25% (1/4) in patients with leak and stricture in this group. The endoscopic success rate was 50% in two patients with leak alone after DDLT. Two patients with LDLT, who had stone alone, were successfully treated endoscopically. But one LDLT and one DDLT patient with stone and stricture, respectively, could not be treated endoscopically.

In both LDLT and DDLT patients, endoscopic success rates were lower in children under 96 months than in children between 96 and 155 months (60% versus 73.7%, $p > 0.05$; and 0% versus 60%, $p < 0.05$, respectively) (Table 4). In DDLT patients, endoscopic success rates were lower in children between 96 and 155 months than in children older than 155 months (60% versus 80%, $p > 0.05$).

The reasons for endoscopic failure in 14 LDLT patients who underwent PTBI were as follows: severe stricture in 10 patients (71.4%), unsuccessful cannulation in two patients (14.3%), and a clinical condition that did not resolve despite ERCP in two patients (14.3%). In four patients with DDLT who underwent PTBI, failure reasons were clinical conditions that did not resolve despite ERCP in one patient (25%), failure of endoscopic removal of stone in one patient (25%), unsuccessful cannulation in one patient (25%), and severe stricture and leakage association in one patient (25%).

ERCP and PTBI were not successful in only one LDLT patient with stricture. This patient underwent surgical treatment for biliary complications. ERCP combined with PTBI resolved biliary problems in 97.3% (37/38) of patients with LDLT. None of the DDLT patients needed surgical treatment due to biliary complications. The success rate of ERCP and PTBI in this patient group was 100%.

Twenty-five of the 37 LDLT patients whose biliary problems had been resolved after ERCP or PTBI + ERCP continued to be stent-free. The remaining 12 patients were followed up with stenting. The average follow-up period was 18.2 months in this group. Two patients who were followed up and who were stent-free had recurrent stricture. The time to recurrence was 1 month in one patient and 29 months in the other. Both patients underwent re-stenting with ERCP. Six of

Table 2 ERCP findings

	Frequency of biliary complications n (%)					Total
	Leak	Stricture	Stricture + leak	Stone	Stricture + stone	
LDLT	4 (10.5%)	27 (71.0%)	4 (10.5%)	2 (5.2%)	1 (2.6%)	38
DDLT	2 (18.1%)	8 (72.7%)	0	0	1 (9.0%)	11
Total	6 (12.2%)	35 (71.4%)	4 (8.1%)	2 (4.0%)	2 (4.0%)	49

LDLT living donor liver transplantation, *DDLT* deceased donor liver transplantation

Table 3 Percutaneous transhepatic biliary intervention (PTBI) rates according to age, biliary complication, and transplantation type

Transplantation type			Biliary complication					Total *N* (%)
			Leak *n* (%)	Stricture *n* (%)	Stricture + leak *n* (%)	Stone *n* (%)	Stricture + stone *n* (%)	
LDLT	PTBI	Yes	1 (25)	9 (33.3)	3 (75)	0 (0)	1 (100)	14 (36.8)
		No	3 (75)	18 (66.7)	1 (25)	2 (100)	0 (0)	24 (63.2)
		Total	4 (100)	27 (100)	4 (100)	2 (100)	1 (100)	38 (100)
DDLT	PTBI	Yes	1 (50)	2 (25)	0 (0)	0 (0)	1 (100)	4 (36.4)
		No	1 (50)	6 (75)	0 (0)	0 (0)	0 (0)	7 (63.6)
		Total	2 (100)	8 (100)	0 (0)	0 (0)	1 (100)	11 (100)
Total	PTBI	Yes	2 (33.3)	11(31.4)	3 (75)	0 (0)	2 (100)	18 (36.7)
		No	4 (66.7)	24 (68.6)	1 (25)	2 (100)	0 (0)	31 (63.3)
		Total	6(100)	35 (100)	4 (100)	2 (100)	2 (100)	49 (100)

LDLT living donor liver transplantation, *DDLT* deceased donor liver transplantation, *PTBI* percutaneous transhepatic biliary intervention

the 11 DDLT patients whose biliary problems had been resolved after ERCP or PTBI + ERCP continued to be stent-free. Four patients with stents were followed. One patient underwent re-transplantation due to chronic rejection. The average follow-up period was 15.3 months in this group. One patient had stricture recurrence in this group. The time to recurrence was 4 months. This patient was stented again with ERCP.

The most common complications after ERCP were pancreatitis (18.4%, 7/38 in LDLT and 18.1%, 2/11 in DDLT) and bleeding at the sphincterotomy site (7.9%, 3/38 in LDLT only). These complications were treated conservatively. None of the patients needed an additional intervention, including surgery.

Hepatic artery thrombosis was detected in one patient in each group (2.6%, 1/38 in LDLT and 9.1%, 1/11 in DDLT) on liver imaging studies. There was no statistically significant difference between the LDLT and DDLT groups ($p > 0.05$).

Table 4 Percutaneous transhepatic biliary intervention (PTBI) rates according to age and transplantation type

Type of transplantation			PTBI		Total
			Yes	No	
LDLT	Age	36–95 months	4 (40%)	6 (60%)	10
		96–155 months	4 (36.3%)	7 (73.7%)	11
		156–216 months	6 (35.3%)	11 (64.7%)	17
	Total		14	24	38
DDLT	Age	36–95 months	1 (100%)	0 (0%)	1
		96–155 months	2 (40%)	3 (60%)[a]	5
		156–216 months	1 (20%)	4 (80%)	5
	Total		4	7	11

LDLT living donor liver transplantation, *DDLT* deceased donor liver transplantation, *PTBI* percutaneous transhepatic biliary intervention

[a] $p < 0.05$ when compared with 36–95 months

The mortality rate was 10.5% in the LDLT group and 18.1% in the DDLT group ($p > 0.05$).

When we evaluate the overall results of all transplanted children, the success rate of endoscopic treatment was 63.3% (31/49) (Table 3). The success rate of endoscopic treatment was similar in the presence of leakage and stricture alone (66.7% and 68.6%, respectively). The success rate was very high in cases with stone alone (100%), but it was significantly lower when leakage and stone were accompanied by stricture (25% and 0%, respectively).

Discussion

ERCP was performed in 38 LDLT and 11 DDLT patients with duct-to-duct anastomosis who had a biliary complication. Our endoscopic success rates were similar in patients with LDLT and DDLT (24/38 or 63.2% and 7/11 or 63.6%, respectively).

In our cohort of patients who underwent ERCP after LT, the most common biliary complication was stricture (27/38, 71.0% in LDLT and 8/11, 72.7% in DDLT). Our endoscopic success rate was 66.7% (18/27) in LDLT patients and 75% (6/8) in DDLT patients with stricture. Figure 2 shows ERCP dilatation and stenting in a child with stricture after LDLT. Otto et al. reported the results of 48 ERCP in 25 children aged between 62 days and 20 years who experienced biliary problems after abdominal organ (liver, bowel or other) transplantation [12]. In their series, only nine patients had isolated LT (others were combined). They reported that therapeutic interventions were performed in 37 of 48 cases (77%), including sphincterotomy in 19 cases (40%), stent placement in 14 cases (29%), and stone extraction in nine cases (19%) [12]. However, Dechene reported the results of 17 children treated endoscopically for biliary complications after LT (11 DDLT, 6 LDLT). Eleven of them had biliary stricture, and all were successfully treated with ERCP [6]. In a study involving seven

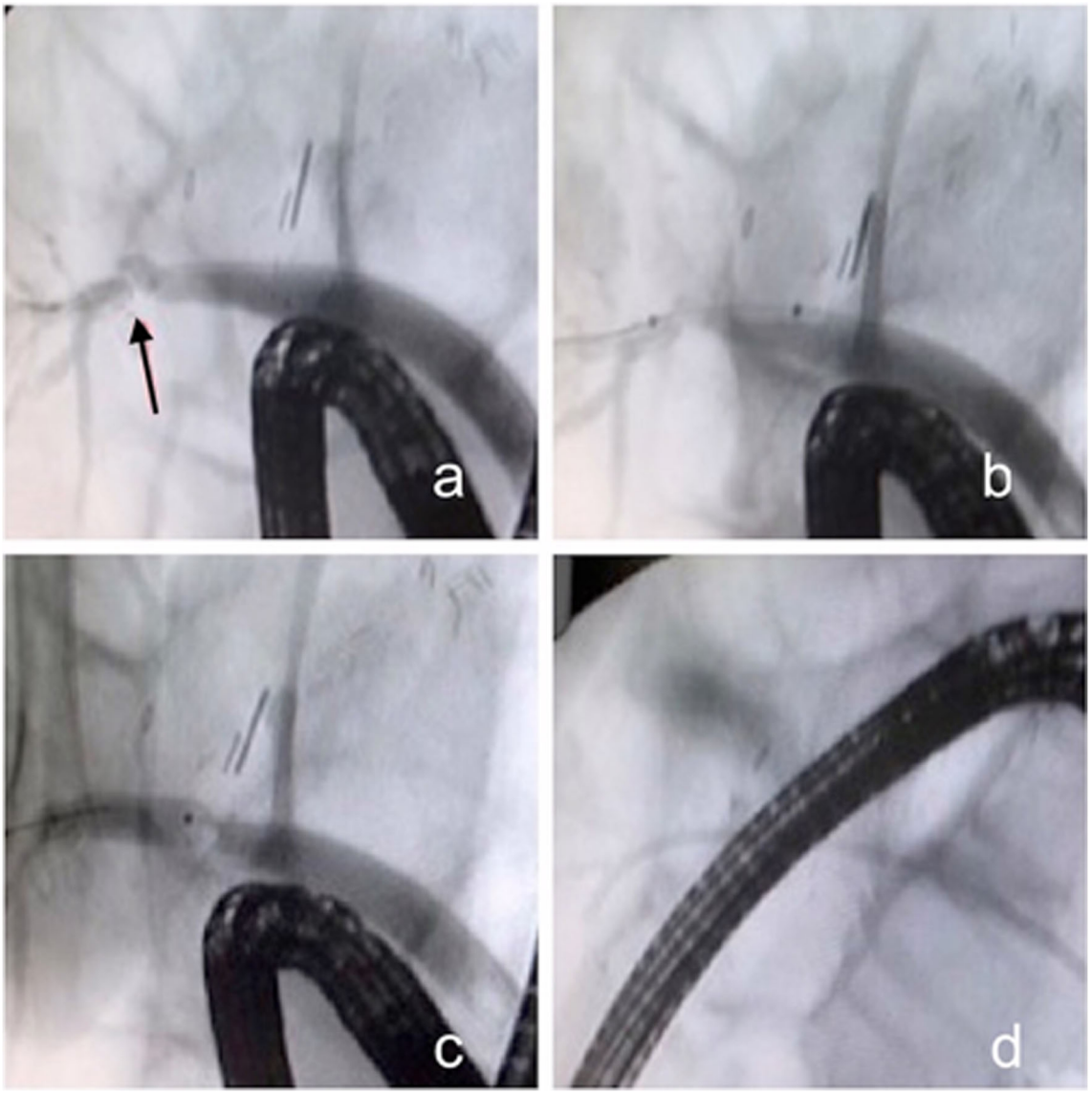

Fig. 2 Biliary stricture (marked by arrow) detected on cholangiography during ERCP in a pediatric patient after living donor liver transplantation (**a**). Advancing biliary dilatation balloon over the guidewire (using radiopaque markers on the balloon) (**b**). Dilatation of stricture by inflation of dilatation balloon with contrast (**c**). A 7-French plastic biliary stenting to the proximal of the stricture, after dilatation (**d**)

pediatric transplant patients, it was reported that biliary stricture was successfully treated endoscopically in four patients [13]. Our endoscopic success rate is lower than these studies. This difference can be attributed to the following reasons: our patient number is higher, and the majority of our patients undergo LDLT, unlike the above studies. It is well known that biliary stricture treatment in LDLT patients is much more difficult than in DDLT patients. The lower success rate for LDLT patients versus DDLT patients can be attributed to small-caliber anastomoses, peripheral locations, and twisted structures, which probably result from anastomotic fibrosis and hypertrophy of the transplanted liver [14]. Indeed, in our study, endoscopic procedures failed because of tight stricture in 10 of 14 LDLT patients. Tight stricture was a rare cause of endoscopic treatment failure in our DDLT patients (only one patient). Unlike pediatric patients, there are more studies reporting successful treatment of biliary strictures with ERCP after LT in adults. In a meta-analysis, an overall ERCP success rate of 57% was reported in the largest patient group with biliary stricture, including 11547 DDLT and 2812 LDLT patients with biliary complications [15]. The endoscopic success rate for biliary stricture in LDLT has been reported to be between 68 and 93% [16, 17]. Our results are similar to these success rates in adults. This similarity suggests that ERCP should be considered as a preferential treatment option for the management of biliary stricture after pediatric liver transplant, as in adults.

In our study, the second most common biliary complication was leak. In LDLT patients, biliary leak alone was found in four patients (10.5%, 4/38). Leak and stricture occurred in

four patients (10.5%, 4/38) in this group. The leak only rate was 18.1% (2/11) in DDLT patients. Leak accompanying stricture was not observed in this group. The prevalence of bile leaks does not differ significantly between DDLT and LDLT. The overall incidence of bile leakage is 2–25% [18]. Leak frequency in LDLT patients was similar to that in DDLT patients in our cohort. Our finding was consistent with previous data on adult patients. While our endoscopic success rate was 75% (3/4) in patients with leak alone after LDLT, it was 25% (1/4) in patients with leak and stricture. Our endoscopic success rate was 50% in two patients with leak alone after DDLT. These similar success rates suggest that endoscopic treatments are effective in patients with leak only, regardless of graft type. However, contrary to leak alone, we observed that the presence of leak and stricture together significantly reduced our endoscopic success rate. Dechene et al. reported that only one patient with leak and stricture was successfully treated endoscopically after LDLT [6]. There are almost no studies on the success of endoscopic treatment in children with leak (leak alone or leak plus stricture) after LT. Table 5 summarizes previous studies of endoscopic treatments for biliary complications after pediatric liver transplantation. Although our patient count is small, our data suggest that the success of endoscopic treatments decreases if there is combined leak and stricture. Further work is needed to reach a definite judgment on this regard.

Filling defects in the biliary system after LT are multifactorial. These include biliary stones, sludge, casts, blood clots, and migrated stents in most cases. Biliary stones constitute the most common etiology. The incidence of biliary stones, sludge, and casts is between 2.5 and 12% [19–21]. In our study, stone was found in three patients (7.8%, 3/38) with LDLT. In one of these cases, stone was accompanied by stricture. Only one patient with DDLT (9.1%, 1/11) had stone and stone accompanied by stricture. Two patients with LDLT, who had stone alone, were successfully treated endoscopically. But one LDLT and one DDLT patient with stone and stricture could not be treated endoscopically. The management of biliary stones in transplant patients is similar to non-transplant conditions. The presence of stricture may complicate the extraction of stones. Although Dechene et al. reported that five pediatric patients with biliary casts were successfully treated endoscopically even they had an additional biliary complication [6]. Eminler et al. reported that biliary stone extraction rates decreased and the total number of sessions required for the extraction of stones increased in the presence of stricture in adults [21]. In pediatric transplant patients, the presence of stricture seems to be an important factor affecting the success of endoscopic treatment of biliary stones and leaks.

Table 5 Previous studies on endoscopic treatment of biliary complications after pediatric liver transplantation

Patient number	Transplantation type (DDLT/LDLT)	Biliary complication type	Success rate (%)	Reference
15[a]	15/0	BS ($n = 15$)	Stent placement in 14 cases	Otto et al. [12]
17	11/6	BS ($n = 11$) Leak ($n = 2$)	100% both	Dechene et al. [6]
7	7/0	BS ($n = 4$)	100% in BS	Karthik et al. [13]
49	11/38	BS ($n = 35$) Leak ($n = 6$)	68.6% in BS 66.7% in leak	Present study

DDLT deceased donor liver transplantation, *LDLT* living donor liver transplantation, *BS* biliary stricture

[a] Nine composite graft recipients and six isolated liver recipients

In our study, we found that endoscopic success rate in both groups (LDLT and DDLT) increased with age (Table 4). We are unable to provide an endoscopic success rate for younger ages because there are no children under 36 months in this study. However, our findings suggest that the endoscopic success rate in pediatric transplant patients increases with age.

In our study, acute pancreatitis developed at similar rates in LDLT and DDLT patients (18.4% versus 18.1%). In LDLT patients, bleeding developed in three patients (7.9%, 3/38) after ERCP. All patients with complications were treated conservatively. The incidence of complications due to ERCP in children has not been well established. In children older than 1 year, complication rates are 3–10% [22, 23]. The most common complication of ERCP in children and adults is acute pancreatitis [24, 25]. The frequency of post-ERCP pancreatitis has been reported as 4.7% in non-transplant pediatric patients [26]. In pediatric transplant patients, Otto et al. reported that frequency of acute pancreatitis was 2.08% [12]. Dechene et al. did not report pancreatitis in their series [6]. Although our acute pancreatitis frequency is higher than that of pediatric transplant and non-transplant patient series, all of our patients were successfully treated with conventional approaches. It has been reported that the frequency of post-ERCP bleeding was 0.6% in non-transplant pediatric patients [26]. Dechene also reported high bleeding rates (17.6%) in transplant patients as in our study (7.9%) [6]. These high rates in transplant patients suggest that transplant patients are more prone to bleeding after ERCP than non-transplant patients.

Our study has several limitations. First, there were no children younger than 36 months in our study. Therefore, data on biliary complications, its management, and outcomes after LT were not presented in this age group. Second, our study is of a retrospective nature. This may have affected data about post-ERCP complications and outcomes.

Biliary reconstruction had a significant impact on the incidence of biliary complications. In a series of 173 pediatric liver transplant patients, the frequency of biliary complications in patients who underwent reconstruction by biliary-

enteric anastomosis was significantly lower than that of duct-to-duct anastomosis (13.3% versus 28.2%). They reported that the rate of biliary complications in patients undergoing duct-to duct anastomosis was six- and twofold higher in whole grafts and partial grafts, respectively [9]. Bilioenteric anastomoses have been widely used in children because of the high prevalence of biliary atresia and technical challenges related to the small size and fragility of the ducts of pediatric recipients [27]. However, duct-to duct anastomosis facilitates postoperative endoscopic access by preserving anatomic continuity. It enables endoscopic treatments with high success rates. Duct-to-duct reconstruction is the standard technique for biliary anastomosis in adult cases. It is more physiologic and reduces the risk of enteric reflux into the biliary tract. The faster anastomotic procedure may be another advantage [28]. In our study, all patients were duct-to-duct anastomosis. This study does not include the results of our patients with bilioenteric anastomosis. However, the advantages mentioned above and our favorable endoscopic treatment results suggest that the choice of duct-to-duct anastomosis in pediatric liver transplant patients is a right decision.

Since bilioenteric anastomoses are common in liver transplantation in children, most studies regarding treatment of biliary complications report the results of percutaneous treatments. Although endoscopic treatments can rarely be applied in bilioenteric anastomosis, it can be applied easily in duct-to-duct anastomosis. When we compare the results of percutaneous therapeutic biliary interventions and endoscopic treatments, we can see high success rates with both treatments [6, 29, 30]. The most important advantage of percutaneous interventions is that it can be applied in infants and bilioenteric anastomoses where endoscopic treatments are difficult. However, percutaneous therapeutic biliary interventions are invasive procedures and may cause complications such as bleeding, fever, bacteremia, and perforation. These procedures frequently need long fluoroscopy times and large radiation doses because transplanted children have small liver volume, the possible absence of intrahepatic biliary dilatation, and the possibility of multiple biliary anastomoses. In addition, other disadvantages of interventional radiology that negatively influence the quality of life, especially in children, are the frequent use of internal-external biliary catheters and the need for repeated treatment sessions under general anesthesia in small children [31]. Endoscopic treatments do not negatively affect the quality of life as much as percutaneous treatments. Endoscopic procedures have less radiation exposure and are less invasive than percutaneous interventions. An experienced team for both procedures is needed. Surgical treatment in the management of biliary complications after transplantation is generally preferred after endoscopic and percutaneous interventions. Darius et al. reported that anastomotic biliary complications in transplanted children were treated very successfully with surgical treatment [31]. In this large series of 60 patients, most of the cases had bilioenteric anastomosis. There is no report about surgical treatments in patients with duct-to-duct anastomosis. Surgical treatment is a very invasive procedure compared to endoscopic procedures. In our study, ERCP combined with PTBI resolved biliary problems in 97.3% (37/38) of patients with LDLT. None of the DDLT patients needed surgical treatment due to biliary complications. The first-line treatment for biliary complications after transplantation in adults is endoscopic interventions. Considering the advantages and disadvantages of all these interventions, it seems more logical to evaluate the endoscopic treatments as first-line treatment in transplanted children if the conditions are appropriate for endoscopic interventions.

In conclusion, ERCP should be considered a preferential treatment option for the management of biliary complications in pediatric liver transplant patients with duct-to-duct anastomosis, as in adults.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

The ethics committee of Inonu University Medical Faculty approved the study (2019/4-39).

Informed consent In our study, informed written consent was obtained from the legal guardian of the patients.

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