Original Article

Comparative study between duct-to-duct anastomosis versus R-Y hepaticojejunostomy in pediatric living donor liver transplantation: A retrospective cohort study

Ahmed Khalil, Amr Abdel Aal, Mostafa Abdo and Mahmoud Talaat

Department of Hepatobiliary and General Surgery, Faculty of Medicine, Ain Shams University, Cairo, Egypt.

ABSTRACT

Background: Biliary complications after pediatric living donor liver transplantation (LDLT) remain a significant cause of morbidity and graft loss. Because of the predominance of biliary atresia and the small size of donor ducts, Roux-en-Y hepaticojejunostomy has been the standard procedure for biliary reconstruction in pediatric LDLT. However, duct-to-duct (D2D) reconstruction is suggested to have less risk of biliary contamination and shorter operative time. In our study, we compare D2D and Roux-en-Y hepaticojejunostomy as regards biliary outcome.

Patients and Methods: A retrospective cohort study was conducted on pediatric LDLTs between July 2015 and December 2022. In all, 107 cases were divided into two groups according to the type of biliary anastomosis: group A included 53 recipients who had stentless D2D biliary anastomosis compared with group B including 54 recipients, who underwent Roux-en-Y hepaticojejunostomy.

Results: The incidence of biliary-related complications was higher in the D2D group reaching 44.4%, double that recorded in the H-J group (22.8%, *P=0.011*). The incidence of biliary leakage alone was significantly higher (61.5%, n=8/13) in the H-J group versus 8.7% (n=2/23) in the D2D group (*P=0.027*). Biliary anastomotic stricture alone represented 39.1% (n=9/23) of the biliary complications in D2D groups and only 23.1% (n=3/13) in the H-J group (*P=0.014*), and it was accompanied by leakage in 26.1% (n=6/23) in the D2D group and 7.7% (n=1/13) in H-J groups and had been proceeded by leakage in a similar number of cases (*P=0.093*). Most of the biliary complications (84.6%, n=11) (*P=0.050*) in the H-J group were diagnosed early (<3 months), while in the D2D group, the incidence was nearly equally distributed between early and late presentations (56.5 vs. 43.5%, respectively) (*P=0.030*). Biliary-related mortality was nearly similar in both groups (8.7 vs. 7.7%) (*P=0.558*).

Conclusion: The D2D anastomosis seems to be a safe and feasible method of biliary reconstruction in pediatric LDLT and harbors multiple advantages over H-J, especially the ability to use Endoscopic retrograde cholangio pancreatography (ERCP) in the management of Biliary Complications (BCs). Our study showed a relatively high rate of postoperative BCs, which was the most among patients who had undergone D2D biliary reconstruction. As these complications can be managed safely and effectively, D2D biliary reconstruction can be the method of choice for pediatric patients with suitable bile ducts for reconstruction and surgeons should master both techniques.

Key Words: Biliary complications, biliary leak, biliary stricture, duct-to-duct reconstruction, pediatric liver transplant, Roux-en-Y hepaticojejunostomy.

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Corresponding Author: Ahmed Khalil, MSc, Department of Hepatobiliary and General Surgery, Faculty of Medicine, Ain Shams University, Cairo, Egypt. **Tel.:** 01095062152, **E-mail:** akhaleelm92@gmail.com

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INTRODUCTION

Liver transplantation is an established curative treatment for pediatric patients with end-stage liver disease or acute liver failure[1]. However, biliary complications remain a significant cause of morbidity and late graft loss[2,3].

The type of graft used is an important determinant of the development and frequency of these complications[4-6]. In a large series of pediatric liver transplant recipients, the 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-size or reduced-size or live donor grafts have been more frequently used instead of the whole liver in children. Therefore, biliary complications are more common in children after liver transplantation with significant morbidity and mortality occurring with an incidence of 10–50%[6–8].

Although transplant-related biliary complications are not associated with decreased patient survival in pediatrics, these complications do cause considerable morbidity, increased length of stay, need for increased operative and nonoperative interventions, and occasionally retransplantation[9].

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Because of the predominance of biliary atresia along with the technical challenges related to the small size and fragility of the recipient's duct in the pediatric population, Roux-en-Y hepaticojejunostomy has been the standard procedure in living donor liver transplants (LDLT). The disadvantages of this technique are a comparatively long operative time and a higher risk of contamination due to the construction of the Roux-en-Y limb[10].

Also, duct-to-duct (D2D) biliary reconstruction is mostly the standard technique in adult liver transplantation. When the D2D technique can be used for LDLT, an extraintestinal anastomosis can be avoided, the continuity is more physiologic than that of Roux-en-Y hepaticojejunostomy, and preservation of the sphincter function of the lower bile duct may reduce the risk of enteric reflux into the biliary tract[10].

Aim:

The aim of this study was to compare the outcomes of D2D versus Roux-en-Y hepaticojejunostomy biliary anastomoses in pediatric liver transplant recipients.

PATIENTS AND METHODS:

Study design

This research was performed at the Department of General Surgery, Ain Shams University Hospitals. Ethical Committee approval and written, informed consent were obtained from all participants.

All patients under the age of 18 years eligible for LDLT, fulfilling the criteria of transplantation according to the center protocol, and approved by the transplantation multidisciplinary committee were included. The type of donor hepatectomy (right lobe without Middle Hepatic Vein (MHV), left lobe, or LLS) was determined according to the recipient's body weight, and graft volume by preoperative computed tomographic volumetry.

During this study, 107 patients who underwent LDLT were divided into two groups according to the type of biliary anastomosis: group A included 53 recipients who had stentless D2D biliary anastomosis compared with group B including 54 recipients who underwent Roux-en-Y hepaticojejunostomy.

Patients with less than 1 year of follow-up or patients who die within less than 3 months posttransplant at the time of data analysis or incomplete data were excluded from this study except those who developed biliary complications.

Patients underwent double-organ transplant (liver and kidney), retransplant, and patients with biliary non-anastomotic (ischemic-type) strictures (manifested as hepatic artery thrombosis, recurrence of primary sclerosing cholangitis or acute or chronic rejection) were also excluded. In addition, selected cases in which a combination of D2D and HJ were performed for multiple donor bile ducts.

The recipients' age, sex, blood type, hepatopathy, preoperative laboratory and imaging test results, diagnosis of hepatocellular carcinoma, pediatric for end-stage liver disease score, Child–Pugh score, BMI, previous biliary tract surgeries, type and weight of graft, date of transplant, and graft-to-recipient weight ratio were abstracted. Intraoperative variables were also recorded.

Postoperative outcome included the following: postoperative duplex reading, morbidity (hepatic artery thrombosis, recurrent portal vein thrombosis), biliary leak or biliary anastomotic stricture (BAS), and the time elapsed from the date of transplantation to the diagnosis of biliary complications were recorded for each patient and mortality.

The primary surgical intention for biliary reconstruction was D2D anastomosis, especially under unfavorable bowel loop conditions, such as marked edema, peritonitis-induced thickening, for example, spontaneous bacterial peritonitis, or shrunken mesentery.

HJ was done in all recipients with biliary atresia, previous HJ, primary sclerosing cholangitis, primary biliary cirrhosis, and any other clinical condition, where D2D anastomosis was not feasible as multiple duct anastomoses, common bile duct dilatation (diameter >1.5 cm), or definite injury of the recipient's bile duct because of the dissection during the recipient's hepatectomy, for example during thrombectomy in case of portal vein thrombosis. In addition, if it was impossible to use the recipient's bile duct when there was no bleeding at its cut end before the anastomosis or it was too short for a direct D2D without tension and if the recipient duct opening was smaller than the graft duct opening.

Statistical analysis

Data were collected, revised, coded, and entered into the Statistical Package for Social Science (IBM SPSS, Chicago, Illinois, USA), version 27. The quantitative data were presented as mean, SDs, and ranges when parametric and median, and interquartile range when data was found nonparametric. Also, qualitative variables were presented as numbers and percentages.

The comparison between groups regarding qualitative data was done using the χ^2 test and/or Fisher's exact test when the expected count in any cell was found to be less than 5.

The comparison between two independent groups with quantitative data and parametric distribution was done using the independent t test while nonparametric distribution was done using the Mann–Whitney test.

The confidence interval was set to 95%, and the margin of error accepted was set to 5%. So, the P value was considered significant as the following:

P value more than 0.05: nonsignificant.

P value less than 0.05: significant.

P value less than 0.01: highly significant.

RESULTS:

During this study, 107 pediatric LDLT, after excluding 33 cases due to different reasons (six cases with RLG, a single case with hepatic artery thrombosis, and 26 cases died from nonbiliary complications before the end of the follow-up period), were divided into two groups according to the type of biliary anastomosis. The D2D group included 53 recipients who had stentless D2D biliary anastomosis compared with the H-J group which included 54 recipients who underwent Roux-en-Y hepaticojejunostomy. All patients completed at least 12 months follow-up.

The demographic data of the two groups are compared in (Table 1). Table 1 shows that sex distribution was comparable in each of the two groups with no statistical difference (*P=0.156*). In contrast, when comparing the age (months) and weight (kg) in both groups it showed a significant difference with *P value* of *0.049* and *0.022*, respectively, with a significant tendency toward lower weights (<10 kg) in the H-J group (*P=0.006*). Other demographic data were not statistically significant.

The main etiology of pediatric liver disease in Egypt is biliary atresia, representing 22.4% of cases in our study (Table 2), and it was the most common cause of LTx in the H-J group (44.4%). The most common cause of LTx in the D2D group was PFIC representing 38.8% in comparison to 9.2% in the H-J group being the third most common cause in this later group (*P=0.001*). Cryptogenic cirrhosis was significantly higher in the D2D when compared with the H-J group (*P=0.022*).

According to operative data (Table 3), segment II–III graft was used in 64.8% (n=35) of cases in the H-J group compared with 47.2% (n=25) in the D2D group. On the contrary, segment II-II-IV was more frequently used in the D2D group (52.8%, n=29) than in the H-J group (35.2%, n=19).

Arterial reconstruction using the LHA, RHA, and having two arterial anastomoses was comparable in both groups (*P>0.05*, NS), unlike CHA that was used significantly higher in the H-J group in 24.1% of cases (n=13) versus three (5.7%) cases (*P=0.007*).

Other operative data were statistically nonsignificant except for the operative time, which was longer in the H-J group (*P=0.030*).

As regards the number of graft ducts (Table 4), it is far more pronounced that the single duct graft was more frequently used in both groups (92.5%, n=49 and 94.4%, n=51), respectively. This was reflected on the method of biliary reconstruction; 94.4% (n=51) of recipients in the H-J group B had a single HJ (*P=0.696*) and the only three (5.7%) recipients who received a two-duct graft had two HJ in the same limb using two separate orifices. While in the D2D group, the 1×1 technique was used in 92.5% (n=49) of recipients (*P=0.308*), the 2×2 technique was used in a single recipient (1.9%) from which a recipient received a graft with two right hepatic ducts anastomosed to the recipients left hepatic duct and right hepatic duct. Ductoplasty was used only in three recipients in the D2D group in the whole study (*P=0.007*, HS).

The incidence of biliary-related complications (Table 5) was higher in the D2D group reaching 44.4% (n=23), double that recorded in the H-J group 22.8% (n=13, *P=0.011*). Patients who developed biliary complications in the D2D group included two cases with leak only, nine cases with BAS, and 12 cases who developed both. However, this distribution was different in the H-J group being eight cases with leak only, three with BAS only, and two with both. In a subanalysis comparing those complications, the incidence of biliary leakage only was significantly higher (61.5%, n=8/13) in the H-J group versus 8.7% (n=2/23) in the D2D group (*P=0.027*). BAS alone represented 39.1% (n=9/23) of the biliary complications in D2D groups and only 23.1% (n=3/13) in the H-J group (*P=0.014*), and it was accompanied by leakage in 26.1% (n=6/23) in the D2D group and 7.7% (n=1/13) in H-J groups and had been proceeded by leakage in a similar number of cases (*P=0.093*). Concerning the timing of diagnosis of biliary complication, most of the biliary complications (84.6%, n=11) (*P=0.050*) in the H-J group was diagnosed early (<3 months), while in the D2D group the incidence was nearly equally distributed between early and late presentations (56.5 vs. 43.5%, respectively) (*P=0.030*). Biliary-related mortality was nearly similar in both groups being 8.7% (n=2/23) in D2D group versus 7.7% (n=1/13) in the H-J group (*P=0.558*).

As regards the D2D group (Table 6), we had one recipient with biliary leakage that was managed conservatively. Nine patients had biloma (biliary collection) in which an ultrasound-guided pigtail was inserted. Another two (8.7%) recipients underwent ERCP to manage bile leakage and two (8.7%) patients needed to be explored for surgical drainage. Concerning BAS, only one patient was managed conservatively as he had only laboratory and radiological findings with no symptoms; 10 (43.5%) patients had PTC and balloon dilatation; 12 (52.2%) patients had ERCP and stenting; and bilioenteric conversion was done in six (26.1%) patients.

In the HJ group (Table 6), we had eight (61.5%) recipients with biloma, in which an ultrasound-guided pigtail was inserted to drain the biliary collection. Surgical exploration and drainage were indicated in only two patients and redo bilioenteric anastomosis was done in one patient. As regards BAS, PTC and balloon dilatation was successful to manage four (30.8%) cases and redo bilioenteric anastomosis was the treatment of choice in a single patient (7.7%).

In a trial to understand the relationship between arterial anastomosis and biliary complications (Table 7), we found that the use of two arteries for arterial reconstruction (two anastomoses) resulted in a higher incidence of biliary complications in the D2D group (21.7%, n=5/23). However, in the H-Jgroup there was no recorded case. Again the use of the LHA for arterial reconstruction was accompanied by a significantly higher rate of biliary complications in the D2D group, 52.2 versus 46.1% in the H-J group.

There was a remarkably higher incidence of biliary complications (Table 7) in patients who received grafts with two ducts in the D2D group who underwent 2×1 ductoplasty (66.7%, two out of three patients). In the H-J group patients receiving grafts with two ducts, the tendency for biliary complication was higher in 2×2 anastomosis (33.3% one out of three patients) compared with no recorded cases in the D2D group (n=0/1; *P=0.315*). Finally, the less than 10 kg weight was not an evident risk factor in our study (*P=0.051*).

Table 1: Comparison between duct-to-duct and H-J groups according to demographics and disease-related data

Baseline characteristics	D2D group (*N*=53)	H-J group (*N*=54)	Test value	*P* value	Significance
Age (months)					
Median (interquartile range)	91.2 (60–120)	66 (23–114)	−1.972‡	0.049	S
Sex					
Range	12–180	9–201			
Female	24 (45.3)	17 (31.5)	2.010*	0.156	NS
Male	29 (54.7)	37 (68.5)			
Weight (kg)					
Median (interquartile range)	22 (16.25–32.5)	18.5 (10.75–25.5)	−2.292‡	0.022	S
Range	7.5–79	6–61			
Weight <10 kg					
n, %	4 (7.5)	12 (22)	7.638	0.006	HS
BMI					
Mean±SD	17.1±3.43	16.26±3.78	1.195•	0.235	NS
Range	11.4–30	10.4–29.7			
ABO compatibility					
Identical	37 (68.5)	33 (61.1)	2.600	0.107	NS
Compatible	16 (31.5)	21 (38.9)	0.663	0.415	NS
Child score					
A	15 (28.3)	10 (18.6)	2.580*	0.108	NS
B	18 (34.0)	24 (44.4)	3.212*	0.073	NS
C	20 (37.7)	20 (37.0)	0.170*	0.680	NS
Pediatric for end-stage liver disease					
Median (interquartile range)	12.85 (3.6–18)	12.35 (7.2–18.35)	−0.413‡	0.680	NS
Range	-7.6–59	0–43			
Previous Kasai	0	22 (40.7)	24.762*	0.000	HS
Donor’s age (years)					
Mean±SD	33.98±7.01	33.04±6.1	0.732•	0.466	NS
Range	24–50	21–48			

Donor's sex					
Female	25 (47.2)	22 (40.7)	0.979*	0.322	NS
Male	28 (52.8)	32 (59.3)			

*χ^2 test.
‡Mann–Whitney test.
•Independent t test.
P value more than 0.05: nonsignificant (NS); *P value* less than 0.05: significant (S); *P value* less than 0.01: highly significant (HS).

Table 2: Comparison between duct-to-duct and H-J groups according to hepatopathy

	D2D group (*N*=53)	H-J group (*N*=54)			
Hepatopathy	*n* (%)	*n* (%)	Test value*	*P* value	Significance
Biliary atresia	0	24 (44.4)	27.902	0.000	HS
PFIC	21 (38.8)	5 (9.2)	11.848	0.001	HS
HCC	5 (9.3)	7 (12.9)	0.125*	0.724	NS
Hepatoblastoma	3 (7.4)	6 (11.1)	0.443	0.506	NS
Tyrosinemia	5 (9.2)	2 (3.7)	2.167	0.141	NS
Cryptogenic cirrhosis	5 (9.2)	1 (1.9)	5.253	0.022	S
Acute fulminant hepatitis	4 (7.4)	2 (3.7)	0.707	0.400	NS
Congenital hepatic fibrosis	3 (5.5)	3 (5.5)	0.000	1.000	NS
Alagille syndrome	2 (3.7)	3 (5.5)	1.040	0.308	NS
Autoimmune hepatitis	2 (3.7)	2 (3.7)	0.343	0.558	NS
Primary hyperoxaluria	1 (1.9)	2 (3.7)	0.000	1.000	NS
Crigler–Najjar syndrome	2 (1.9)	1	1.010	0.315	NS
Familial hypercholesteremia	2 (3.7)	0	1.010	0.315	NS
Primary sclerosing cholangitis	0	1 (1.9)	1.010	0.315	NS
Caroli disease	0	1 (1.9)	1.010	0.315	NS
Caroli syndrome	0	1 (1.9)	1.010	0.315	NS
Cystic fibrosis	1 (1.9)	0	1.010	0.315	NS
Hepatic hemangioendothelioma	1 (1.9)	0	1.010	0.315	NS
GSD type 1	1 (1.9)	0	1.010	0.315	NS

GSD, glycogen storage disease; HCC, hepatocellular carcinoma; PFIC, progressive familial intrahepatic cholestasis.
*χ^2 test.
P value more than 0.05: nonsignificant (NS); *P value* less than 0.05: significant (S); *P value* less than 0.01: highly significant (HS).

Table 3: Comparison between duct-to-duct and H-J groups according to operative data

	D2D group	H-J group			
Operation	*N*=53	*N*=54	Test value	*P* value	Significance
Graft type					
Segment II–III	25 (47.2)	35 (64.8)	3.869*	0.049	S
Segment II–III–IV	28 (52.8)	19 (35.2)	3.869*	0.049	S
Graft weight (g)					
Mean±SD	403.02±105.06	373.96±94.61	1.482•	0.141	NS
Range	205–670	180–575			
Graft-to-recipient weight ratio					
Mean±SD	1.95±0.95	2.33±1.11	−1.902•	0.060	NS
Range	0.7–5.9	0.9–5.7			
Arterial reconstruction					
LHA	29 (54.7)	23 (42.6)	2.600	0.107	NS
RHA	14 (26.4)	12 (22.2)	0.663	0.415	NS

CHA	3 (5.7)	13 (24.1)	7.386	0.007	HS
2 arteries	7 (13.2)	6 (11.1)	0.124*	0.733	NS
Cold ischemia time (min)					
Mean±SD	33.83±17.95	35.75±16.99	−0.561•	0.576	NS
Range	10–100	10−85			
Warm ischemia time (min)					
Mean±SD	42.81±15.6	43.13±15.56	−0.107•	0.915	NS
Range	20–136	25−120			
PV velocity (cm/s)					
Mean±SD	58.04±20.09	53.27±17.65	1.286•	0.201	NS
Range	25–117	25−110			
HA RI					
Mean±SD	0.6±0.08	0.6±0.08	−0.085•	0.932	NS
Range	0.37−0.77	0.45−0.8			
Operative time (min)					
Mean±SD	425.61±92.24	469.92±112.27	−2.199•	0.030	S
Range	300–660	300−900			
Blood loss (ml)					
Median (interquartile range)	300 (200–500)	300 (300–500)	−1.451‡	0.147	NS
Range	150–1050	250–2500			
Hospital stay (days)					
Mean±SD	19.87±7.96	21.10±6.21	−0.879•	0.381	NS
Range	9–55	12–40			
Follow-up (months)					
Mean±SD	49.69±22.22	36.58±17.53	3.342	0.001	HS
Range	9–96	5–80			

CHA, common hepatic artery; HARV, hepatic artery resistive index; LHA, left hepatic artery; PV, portal vein; RHA, right hepatic artery.
*χ^2 test.
‡Mann–Whitney test.
•Independent t test.
P value more than 0.05: nonsignificant (NS); *P value* less than 0.05: significant (S); *P value* less than 0.01: highly significant (HS).

Table 4: Comparison between duct-to-duct and H-J groups according to the number of donor duct and biliary reconstruction

		H-J group	Test value		
		N=53	*N*=54		
	D2D group	*n* (%)	*n* (%)	*P* value	Significance
No. of donor duct					
1	49 (92.5)	51 (94.4)	0.153*	0.696	NS
2	4 (7.5)	3 (5.6)	0.700	0.401	NS
No. of anastomoses					
1	52 (98.1)	51 (94.4)	1.040	0.308	NS
2	1 (1.9)	3 (5.6)	1.030	0.397	NS
Biliary reconstruction					
1×1	49 (92.5)	51 (94.4)	1.040	0.308	NS
2×1 (ductoplasty)	3 (5.6)	0	6.275	0.007	HS
2×2	1 (1.9)	3 (5.6)	1.040	0.308	NS

*χ^2 test.
P value more than 0.05: nonsignificant (NS); *P value* less than 0.05: significant (S); *P value* less than 0.01: highly significant (HS).

Table 5: Comparison between duct-to-duct and HJ groups according to biliary complications

	D2D group *N*=53	H-J group *N*=54			
	n (%)	*n* (%)	Test value	*P* value	Significance
Biliary complications	23/53 (43.4)	13/54 (24.0)	6.500	0.011	S
Leak	2/23 (8.7)	8/13 (61.5)	2.167	0.027	S
BAS	9/23 (39.1)	3/13 (23.1)	6.029	0.014	S
Leak+BAS	6/23 (26.1)	1/13 (7.7)	2.830	0.093	NS
Leak then BAS	6/23 (26.1)	1/13 (7.7)	2.830	0.093	NS
Time of biliary complication (mon)					
<3	13/23 (56.5)	11/13 (84.6)	3.831	0.050	NS
>3	10/23 (43.5)	2/13 (15.4)	5.253	0.030	S
Biliary-related mortality	2/23 (8.7)	1/13 (7.7)	0.343*	0.558	NS

BAS, biliary anastomotic stricture.
*χ^2 test.
P value more than 0.05: nonsignificant (NS); *P value* less than 0.05: significant (S); *P value* less than 0.01: highly significant (HS).

Table 6: Comparison between duct-to-duct and H-J groups regarding intervention for biliary complications

	D2D group	H-J group			
	N=23	*N*=13			
	n (%)	*n* (%)	Test value	*P* value	Significance
Intervention for leakage					
Observation only	1/14 (4.3)	0/10	1.010	0.315	NS
Pigtail	9/14 (39.1)	8/10 (61.5)	0.000	1.000	NS
ERCP	2/14 (8.7)	0/10	2.039	0.153	NS
Exploration and drainage	2/14 (8.7)	2/10 (15.4)	1.333	0.513	NS
Bilioenteric	0/14	1/10 (7.7)	1.010	0.315	NS
Intervention for BAS					
Observation only	1/21 (4.3)	0/4	1.010	0.315	NS
PTC and balloon dilatation	10/21 (43.5)	4/4 (30.8)	4.308	0.038	S
ERCP	12/21 (52.2)	0/4	12.301	0.000	HS
Bilioenteric	6/21 (26.1)	1/4 (7.7)	3.829	0.050	NS

BAS, biliary anastomotic stricture’ ERCP, endoscopic retrograde cholangiopancreatography; PTC, percutaneous transhepatic cholangiography.
*χ^2 test.
P value more than 0.05: nonsignificant (NS); *P value* less than 0.05: significant (S); *P value* less than 0.01: highly significant (HS).

Table 7: Comparison between duct-to-duct and H-J groups as regards biliary complications in relation to other studied parameters

	D2D group *N*=23	H-J group *N*=13			
	n (%)	*n* (%)	Test value*	*P* value	Significance
No. of arterial anastomosis					
LHA	12 (52.2)	6 (46.1)	4.022	0.031	S
RHA	4 (17.4)	5 (38.5)	0.689	0.411	NS
CHA	2 (8.7)	2 (15.4)	1.333	0.513	NS
2 arteries	5 (21.7)	0	5.200	0.020	S
No. of donor duct					
Single duct	21 (91.3)	12 (92.3)	6.499	0.010	S
Two ducts	2 (8.7)	1 (7.7)	0.343*	0.558	NS

Biliary reconstruction					
1×1	21 (91.3)	12 (92.3)	6.499	0.010	S
2×1 (ductoplasty)	2 (8.7)	0	2.039	0.153	NS
2×2	0	1 (7.7)	1.010	0.315	NS
Weight <10 kg	1 (4.3)	4 (30.8)	3.607	0.051	NS

CHA, common hepatic artery; LHA, left hepatic artery; RHA, right hepatic artery.
P value more than 0.05: nonsignificant (NS); *P value* less than 0.05: significant (S); *P value* less than 0.01: highly significant (HS).

DISCUSSION

Posttransplant biliary complications including bile leak and biliary stricture lead to high morbidity and mortality, which is the second most common cause of graft dysfunction[11].

Although Roux-en-Y hepaticojejunostomy (H-J) has been the standard technique in pediatric LTs for years, there is a limited number of reports on the feasibility of D2D anastomosis, and those reports have controversial outcomes[5,6,12–15].

To devise the most suitable biliary reconstruction procedures, we had chosen to eliminate the risk factor of BCs other than the method of biliary reconstruction.

Surgical technique, anatomical variations, duration of the cold ischemia time, quality of arterial supply of the donor, and recipient bile ducts and immunological factors that are considered as the possible causes of BCs[13] were not significant in the statistical analysis of our study group.

In our study including 107 pediatric LDLT, the overall BCs was 33.6%. The prevalence of this complication was significantly lower in patients who have undergone Roux-en-Y hepaticojejunostomy (24%) compared with the D2D anastomosis group (43.4%).

This was higher than that reported in the literature as the overall rate of BCs was documented to be approximately 15% in a large series[16,17]. There are studies reporting rates as low as 6% and as high as 38%[18,19].

A more recent study indicated a 12.7% rate of biliary complication in a group of 298 LDLT pediatrics, 75% of which had undergone D2D anastomosis[7] being 12.6% in Roux-en-Y hepaticojejunostomy versus 20.2% in the D2D anastomosis group. However, this difference was not significant.

In a series of 173 pediatric liver transplant patients, the frequency of biliary complications in patients who underwent reconstruction by bilioenteric anastomosis was significantly lower than that of D2D anastomosis (13.3 vs. 28.2%)[20].

Another finding in our study, the overall rate of biliary leakage was found to be higher in the H-J group reaching 61.5% of the reported biliary-related complications in this group. On comparing D2D to H-J using collected data, D2D was found to be associated with a higher likelihood of BAS rather than H-J reaching 39.1% in the D2D group that if we add to it the BAS proceeded or accompanied by leakage reaching up to 91%.

Similar results were reported in a retrospective study from South Korea by Yi *et al*[34]. on 74 adult patients who underwent LDLT indicated a lower incidence of BCs (11.1%) with H-J than D2D anastomosis (33.3%), and they recommended HJ was associated with improved long-term survival outcomes.

In cases of BAS in D2D biliary reconstruction, conventional endoscopic interventions have become the first-line treatment in our center because they are less invasive and less traumatic compared with surgical and percutaneous interventions[21–26]. However, for biliary reconstruction by H-J, PTCD is the first-line treatment option in pediatric posttransplantation biliary stricture patients[27].

Indeed, in our study, ERCP was done in 14 cases with BCs, including two cases with biliary leakage in whom the patients passed smoothly postintervention. The procedure failed because of tight stricture in two (16.7%) of 12 LDLT patients, which can be attributed to small caliber anastomoses, peripheral locations, and twisted structures, which probably result from anastomotic fibrosis and hypertrophy of the transplanted liver[23]. One of these two patients needed PTC and balloon dilatation, and the other patient underwent unsuccessful PTC and dilatation that was followed by bilioenteric reconstruction. Also, we observed that the presence of a leak followed by stricture significantly reduced our endoscopic success rate.

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 the graft type. However, contrary to leak alone,we observed that the presence of leak and stricture together significantly reduced our endoscopic success rate.

Dechene reported the results of 17 children treated endoscopically for biliary complications after LT (11 DDLT, six LDLT). Eleven of them had biliary stricture, and all were successfully treated with ERCP[5]. In a study involving seven pediatric transplant patients, it was reported that biliary stricture was successfully treated endoscopically in four patients[28]. In another study by Yilmaz in 2019 from Turkey, the endoscopic success rate is lower and he referred this to the higher number of patients, and that the majority of this patients had undergone LDLT[7].

Four of our patients in the H-J group had BAS. While our PTC success rate was 75% (3/4) in patients with BAS after LDLT, it failed in 25% (1/4) who needed redo bilioenteric reconstruction, the first presentation of this patient was BAS alone with no leakage.

When we compare the results of percutaneous therapeutic biliary interventions and endoscopic treatments, we can see high success rates with both treatments[5,29,30].

In our study, ERCP and PTC resolved biliary problems in 77.8% (28/36) of patients with BCs following LDLT. Surgical treatment in the management of biliary complications after transplantation is generally preferred after endoscopic and percutaneous interventions, and it was used to treat leakage after H-J in one patient and seven patients with BAS 6 out of this seven who had D2D biliary reconstruction and all were treated successfully. This was similar to the results reported by Darius *et al*. , who observed that anastomotic biliary complications in transplanted children were treated successfully with surgical treatment[31].

On a trial to understand the risk factor for BCs in pediatric LDLT, we analyzed the arterial reconstruction, number of bile ducts, and the technique of reconstruction and if the weight under 10 kg will have an impact on the BCs or not.

We observed that the two major risk factors were 2×1 duct reconstruction with ductoplast in the D2D and arterial reconstruction. First, we had seven grafts with two bile ducts; three out of four patients in the D2D group had 2×1 biliary reconstruction with ductoplasty. The remaining four underwent 2×2 biliary reconstruction, three with H-J and a single patient with D2D anastomosis. Out of this, more than 66% of patients had undergone ductoplasty.

Ikegami *et al*.[32] reported that ductoplasty is a major cause of BAS because of the tension applied and scarring. In our study, although ductoplasty itself is not an appealing option in our practice, we could find a relationship between ductoplasty and biliary complications.

Children weighing under 10 kg did not seem to be a significant risk factor in our studied group. In 2008, Shirouzu *et al*.[33] compared the outcome of H-J and D2D biliary reconstruction and concluded that the D2D technique in recipients weighing no more than 10 kg produced excellent outcomes with a low incidence of biliary complications.

As regards biliary-related mortality in our study, only one case was recorded in the H-J group and two cases in the D2D group. All received graft with single duct, and they all developed early biliary complications within the hospital stay.

The patient in the H-J group was a boy of 11 years old, who underwent Kasai operation for BA, Child B, and received LLS graft. He suffered from biliary leak that was failed to be controlled with pigtail and PTD, so laparotomy and redo bilioenteric anastomosis were done. Unfortunately, he developed leak again, deteriorated rapidly and died from a septic shock.

The two patients in the D2D group developed both leak and BAS. One of them was a 4-year-old female, GSD, Child A, and received LLS graft. Early postoperative, she developed minor leak which was controlled by pigtail insertion. She improved and was discharged then and developed BAS within 2 months for which PTD was inserted. The condition deteriorates due to the formation of multiple graft abscesses and progresses to septic shock and death. The other child was a 13-year-old female with acute fulminant hepatitis, Child C, received a left lobe graft, and developed a biliary leak shortly postoperatively for which she underwent relaparotomy and evacuation of biloma. As her condition improved, she was discharged 3 months later, she developed BAS. ERCP and PTC were done. Recurrent attacks of severe cholangitis eventually led to the patient's death.

CONCLUSION

D2D anastomosis seems to be a safe and feasible method of biliary reconstruction in pediatric LDLT and harbor multiple advantages over H-J, especially in its the ability to use ERCP in the management of BCs. Our study showed a relatively high rate of postoperative BCs, which was the highest among patients who had undergone D2D biliary reconstruction. As these complications can be managed safely and effectively, D2D biliary reconstruction can be the method of choice for pediatric patients with suitable bile ducts for reconstruction, and surgeons should master both reconstruction techniques and weigh the risks and benefits case by case. In addition, further studies of our treatment strategy and the accumulation of prospective experience are necessary.

LIMITATION

Our study had several limitations. This is a single-center study; therefore, the results may not be generalizable to other transplant centers. Second, our study is retrospective. Third, there are only a few reports on the use of D2D anastomosis among children. Though they show conflicting results in a restricted number of patients, besides these reports compared results from an inhomogeneous type of graft from both living and deceased donors.

CONFLICT OF INTEREST

There are no conflicts of interest.

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