Dual right portal vein graft versus type-I portal vein graft transplant with interpretation according to portal vein type and reconstruction technique

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Received: 21 March 2022
Revised: 16 April 2022
Accepted: 26 April 2022
Published: 04 January 2023

The Egyptian Journal of Surgery 2023, 41:697–707

Introduction
Living-donor liver transplantation (LDLT) has been developed as an alternative procedure for adult and pediatric patients with end-stage liver diseases awaiting deceased-donor liver transplant. Although children and small-sized adults get benefit from left-sided grafts, larger size of right-liver graft makes it preferable in terms of LDLT. However, anatomic variations have higher incidence in right-lobe than left-sided grafts, this leads to surgical difficulties and complications. Anomalous portal vein branching (APVB) that results in dual portal vein (PV) openings is one of the common variations with a reported incidence of 6–22%. Several techniques were innovated to overcome this problem.
Aim
The aim was to compare the outcome of LDLT with right-lobe graft associated with APVB to the right-lobe LDLT with ordinary PV anatomy in both donors and recipients, and to compare between the outcome of different techniques of PV reconstruction in cases of APVB.
Patients and methods
In total, 168 grafts (group B) containing type-I PV were compared with 31 grafts (group A) with APVB as regards recipient outcome after transplantation, interpretation of outcome after each reconstruction technique, and according to PV type that was done.
Results
Portal vein thrombosis (PVT) was significantly higher in group A (9.6%) than group B (2.4%). Group A and group B had 90-day mortality rate as 13 and 11.3%, respectively, cumulative mortality in group A and group B was 22.5 and 18.5%, respectively.
Conclusion
Dual right PV grafts could be accepted with satisfactory results with technical advancement in comparison with our previous experience, PVT is the main cause for mortality in APVB group. Our survival rates are accepted in comparison with international rates.
All techniques for reconstruction could be tailored as case by case, all techniques could bring good outcome in suitable patients by trained hands.

Keywords:
graft, portal, transplant, trifurcated

Egyptian J Surgery 2023, 41:697–707

1110-1121

Introduction

Living-donor liver transplantation (LDLT) has been developed as an alternative procedure for adult and pediatric patients with end-stage liver diseases awaiting deceased-donor liver transplant. Although children and small-sized adults get benefit from left-sided grafts, larger size of right-liver graft makes it preferable in terms of LDLT [1].

However, anatomic variations have higher incidence in right-lobe than left-sided grafts, this leads to surgical obstacles and complications [2,3]. Anomalous portal vein (PV) branching (APVB) that results in dual PV openings is one of the common variations with a reported incidence of 6–22%. Several techniques were innovated to overcome this problem [4,5], another study reported that the incidence of APVB is 10–15% [6].

Reconstruction of these vessels during transplantation can be challenging, and even donors with such APVB have often been disqualified as right-lobe living donors [4,7]. To enable the use of right-lobe liver grafts from donors with APVBs, surgeons have innovated

several reconstruction techniques [8]. There are several disadvantages and obstacles with each technique [8].

Donor risk or recipient complications could happen following single or combined graft vascular or biliary anomaly. Because of their small caliber, proximity to other hilar structures, and abnormal alignment with the native vasculature, reconstruction of these vessels during implantation process can be challenging [9].

The configurations of the PV have been classified by Cheng5 into type-I (the right anterior branch and posterior branch from a short right common neck, normal), type-II (early division of anterior and posterior sectoral branches, trifurcation), type-III (independent posterior sectoral branching from the main trunk), type-IV (anterior sectoral branching from the umbilical portion of the left PV), and unclassified types. In type-III APVB, an extrahepatic location of the anterior right portal branch differentiates it from the type-IV variant [10].

Dynamic computed tomography (CT) or a MRI careful review can discriminate this APVB [9].

Several surgical reconstruction techniques for anastomosis of dual PV branches have been developed as follows: direct dual PV anastomosis, autologous PV Y-graft interposition, U-graft interposition, back-wall plasty, conjoined-unification venoplasty technique followed by crotch-opened autologous Y-graft interposition, Malatya approach using autologous saphenous vein graft, and so on. However, the most suitable technique for dual portal branches in the right-liver graft remains controversial [11].

The preferred reconstruction method for these double PVs consists of Y-shaped graft interposition using the recipient's own PV bifurcation or vein allograft [12].

Since 2001 till 2007, our team operated 148 adult-to-adult LDLT cases. Seven donors only with dual RPV (4.7%) were accepted. Three recipients underwent single-portal anastomosis, and four recipients underwent double-portal anastomoses [13].

This study discusses different techniques for management of APVB with a larger spectrum of patients at our center.

Aim of the work

(1) To compare the outcome of LDLT with right-lobe graft associated with APVB to the right-lobe LDLT with ordinary PV anatomy in both donors and recipients, we aim to interpret the outcome according to PV type and anastomotic techniques.

(2) To compare between different techniques of PV reconstruction in cases of APVB in our recent study to our team previous work, including technical differences, variability, and outcome.

Patients and methods

Patients

This is a single-team retrospective cohort study conducted on 199 cases of LDLT who were operated in Ain Shams University Specialized Hospital (ASUSH) and Wadi EL-Nile Hospital from first of January 2016 to December 31, 2020, the least follow-up period was 1 year, and the maximum follow-up period was 6 years. Ethical approval from Ain Shams University surgical committee was taken.

Patients are divided into two groups of patients, group A was 31 patients who received right-liver grafts with APVB, group B consisted of 168 patients who received grafts with ordinary (type 1) portal anatomy, group A was furtherly subdivided according to type of graft portal anatomy such as type 2 and type 3, and we analyzed data between two major groups, according to PV type and according to the reconstruction technique.

The study excluded cases of APVB who underwent left-lobe transplantation.

Methods

Study procedure

All donors and recipients passed into the following preoperative preparation:

Preoperative workup:

Clinical evaluation and laboratory investigations [14].

Preoperative imaging procedures

Abdominal duplex ultrasonography, spiral CT scan of the abdomen for exclusion of any unrecognized diseases (for both donors and recipients), CT arteriography, and portography and venography to assess arterial and venous anatomy and to classify PV anatomy and to ensure if there is any APVB [15].

Donor operation

After mobilization of the right liver, ligation–division of direct tributaries from liver to inferior vena cava (IVC). We dissected and tapped the right hepatic artery (HA) and PV carefully.

All the vessels feeding the left liver were left intact with minimal dissection. Cholecystectomy and transcystic cholangiography were done to assess biliary tree.

We did hepatic parenchymal transection using a Cavitron ultrasonic surgical aspirator and harmonic scalpel.

We divided the HA and PV ~2–3 mm from the confluence. The grafts were flushed with histidine–tryptophan–ketoglutarate solution on the back table via the PV, and then weighed and preserved in the same solution.

Right PV branches excision

Type-I PV: in total, 168 donors' right PV branches were transected on the principle of donor priority: was excised in the neck with a common opening ~2–3 mm from the confluence while leaving intact donor PV stump.

Type-II PV anomaly: of 14 donors, 12 underwent division of right PV branches with common opening or two separate openings separated by a narrow bridge of tissue. Other two donors underwent division of right PV branches on the principle of donor priority with two separate openings, closely adjacent two separately divided donor right PV branches in two donors were joined as common orifice on the back table.

Type-III PV anomaly: we had 17 donors with type 3 anomalies: donor right PV branches were transected on the principle of donor priority with two separate openings, and each stump was transversely sutured by Heineke–Mikulicz maneuver. One out of 17 had a very narrow bridge and 2 branches were approximated on the back table.

In donors with a type-III PV, we isolated posterior sectorial branch usually before anterior branch. During the recovery of RL grafts from donors with a type-III PV, the right HA is transected first. Two vascular clamps are separately applied to the right anterior and posterior sectoral PV branches. The perpendicular application of vascular clamps from the ventral to dorsal direction appears to prevent donor side PV stenosis after primary closure of 2 PV stumps, with closure on Heineke–Mikulicz technique.

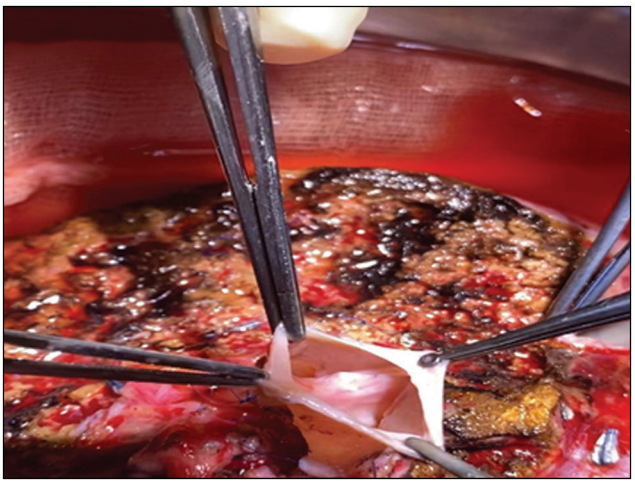
Recipient operation

All LDLT procedures for both donors and recipients were performed according to previously reported methods [13,16].

We did PV reconstruction by one of the upcoming techniques:

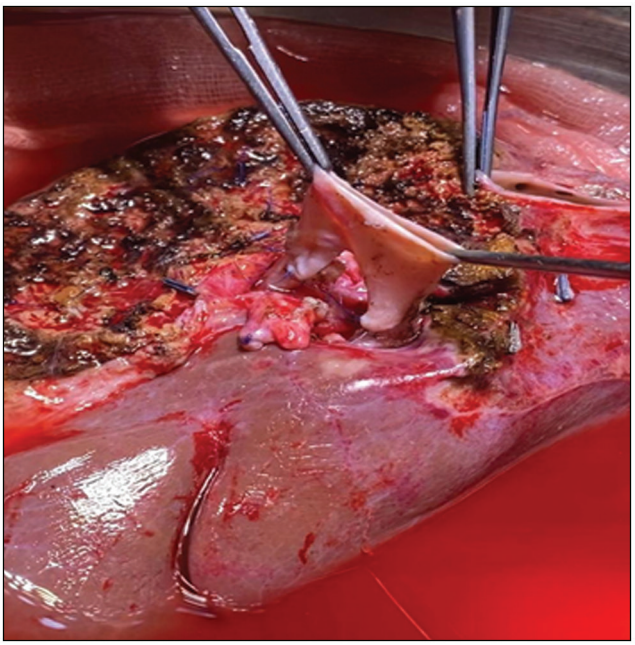
(1) Normal: the donor right PV branches with one opening in 168 cases of type 1 were anastomosed to the recipient's main portal vein trunk (MPV).
(2) Confluence of right anterior and posterior branches of donor's PV was anastomosed to MPV of the recipient, this was done in 12 cases with type-II and a single case with type-III anomaly.
(3) Y-graft interposition: we performed this technique in six patients, both donor anterior and posterior branches of right PV were anastomosed to the recipients' right and left portal branches near the bifurcation of the main PV on the back table, and then we anastomosed the main stump of Y-graft to the recipient's main stump after excision of a redundant part of PV (Figs 1–4).

Figure 1



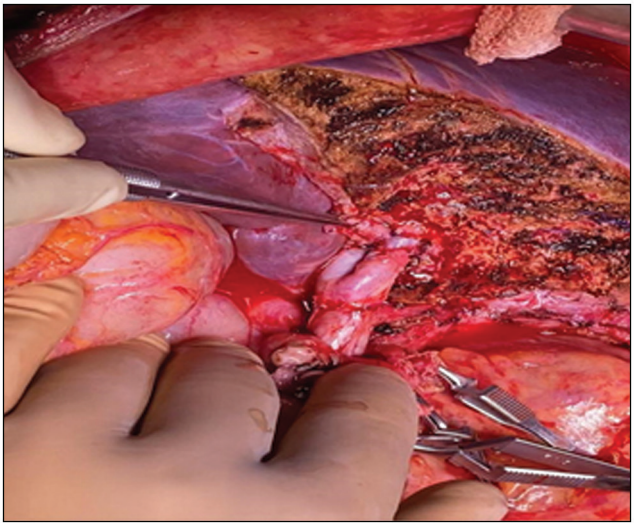
Holding angles of the Y single limb showing the anastomotic axis.

Figure 2



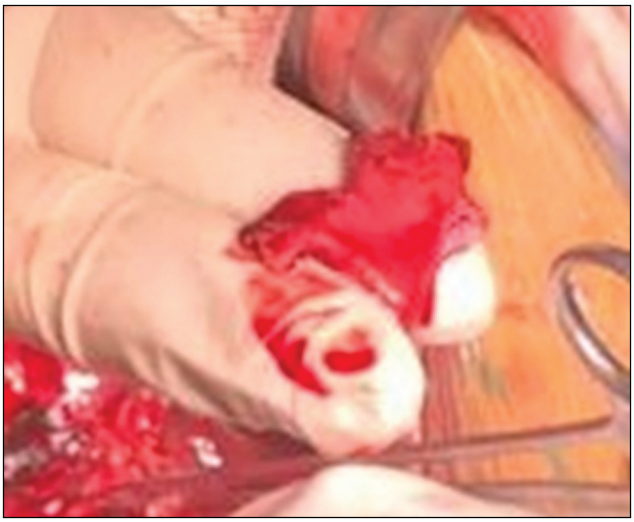
Holding angles of portal orifice after double anastomosis of the graft.

Figure 3



After anastomosis of the interposition graft with recipient main portal vein.

Figure 4



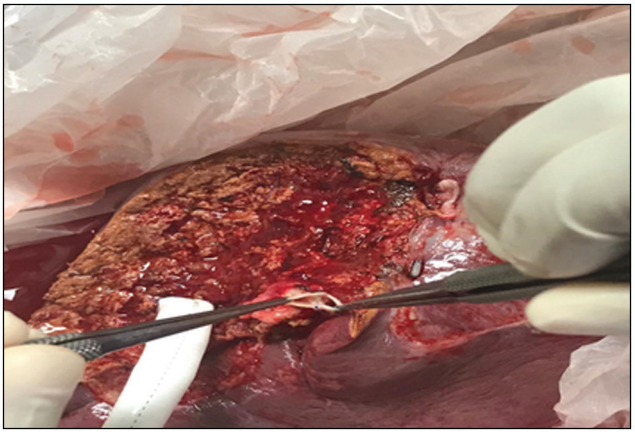
Y-graft after being harvested from recipient side.

(4) Unification: two PV orifices were joined as a common orifice on the back table. The joined common orifice was anastomosed to the recipient main PV, we did this in six recipients (Fig. 5).
(5) Double anastomosis: anterior and posterior branches of grafts' veins of the graft were anastomosed to the right and left PV branches of the recipient in five patients.
(6) Homologous fresh PV graft from the other recipient was done due to PVT in one recipient who primarily underwent unification.

Results

Data were collected, revised, coded, and entered to the Statistical Package for Social Science (IBM SPSS) version 23 (IBM Company, New York, USA). The quantitative data were presented as mean, SD, and ranges when parametric and median, interquartile range when data were found nonparametric. Also, qualitative variables were presented as number and percentages. The comparison between groups regarding qualitative data was done by using χ^2-test and/or Fisher's exact test when the expected count in any cell found was less than 5. While quantitative data and parametric distribution were done by using independent *t*-test, while nonparametric distribution was done by using Mann–Whitney test.

Figure 5



Conjoined-unification technique.

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>0.05: nonsignificant (NS).

P<0.05: significant (S).

P<0.01: highly significant (HS).

Donors

We explanted grafts from 199 donors, 57 females and 142 males, the mean age for donation was 27.40 ± 6.85, type-I PV anatomy was found in 168 grafts, type-II in 14, and type-III in 17 grafts.

The postoperative period passed with no complications related to portal division: bleeding, thrombosis, or stricture.

Donors' stay in the hospital was 6–45 days and ICU stay varied between 2 and 4 days.

Recipients

Demographic recipient data, model of end stage liver disease (MELD) and child scores are shown in Table 1, no statistical difference was detected, except in Child–

Table 1 Preoperative recipient data

	Group A (*N*=31)	Group B (*N*=168)	Test value	*P* value	Significance
Recipient age					
Mean±SD	49.45±9.75	50.87±7.81	–0.892	0.374	NS
Range	15–64	25–67			
Child classifications [*n* (%)]					
Child A	1 (3.2)	12 (7.1)	1.635	0.442	NS
Child B	8 (25.8)	56 (33.3)			
Child C	22 (71.0)	100 (59.5)			
CHILD score					
Mean±SD	10.61±2.30	9.63±1.72	2.781	0.006	HS
Range	6–14	5–14			
MELD score					
Mean±SD	16.42±3.12	15.86±3.86	0.767	0.444	NS
Range	12–27	8–27			
Recipient sex [*n* (%)]					
Female	6 (19.4	26 (15.5)	0.292*	0.589	NS
Male	25 (80.6)	142 (84.5)			
Preoperative PVT [*n* (%)]					
No	25 (80.6)	144 (85.7)	0.525*	0.469	NS
Yes	6 (19.4)	24 (14.3)			

PVT, portal vein thrombosis.

Table 2 Etiology for transplant

Hepatopathy	Total no.=199 [*n* (%)]
ESLD and HCV	105 (52.8)
ESLD, HCV, and HCC	65 (32.7)
Cryptogenic	9 (4.5)
Autoimmune hepatitis	4 (2.0)
ESLD, HCV, and PVT	3 (1.5)
HCV and HCC	2 (1.0)
ESLD and HCC	2 (1.0)
ESLD, 1ry sclerosing cholangitis	1 (0.5)
ESLD, HBV, and HCC	1 (0.5)
ESLD, HCC, and PVT	1 (0.5)
Budchiari syndrome	1 (0.5)
Caroli	1 (0.5)
ESLD and HBV	1 (0.5)
Cryptogenic PVT	1 (0.5)
HCV, HCC, and PVT	1 (0.5)
Sclerosing cholangitis	1 (0.5)

ESLD, end stage liver disease; HBV, hepatitis b virus infection; HCC, hepatocellular carcinoma; HCV, hepatitis C virus infection; PVT, portal vein thrombosis.

Pugh scoring, as the trifurcated portal group had higher child classification.

Preoperative hepatopathy and the association with PV thrombosis are reported in Table 2.

Although group A had APVB, we harvested all grafts with a single HA, while group B had two cases of double right hepatic arteries, which have been anastomosed, but this was statistically nonsignificant, also, there were two cases of left-lobe transplantation with double hepatic arteries, but they had been excluded from this study, the number of bile ducts from grafts according to PV type is also detailed in Table 3. We noticed significant increase of biliary orifices with trifurcation (Fig. 6).

Intraoperative data are detailed in Table 4 regarding number of portal, arterial, and venous anastomoses. Number of duct anastomoses, graft recipient weight ratio, cold ischemia, and warm ischemia time are also mentioned, there was no significant difference between two groups.

Cold ischemia time was significantly longer in patients who underwent interposition graft technique with mean of 106 min, while it was 32–48 min in other techniques.

Table 5 reports that postoperative complication rates were 35.5 and 36.3 in group A and group B, respectively.

PV thrombosis incidence was significantly higher in group A (9.7%), comparably to group B (2.4%).

PVT predisposed to mortality in two patients from group AI, while only one patient in group B died because of this. Other causes of death are also detailed in Table 6.

Mean hospital stay in both groups was 25 and 28, respectively. ICU stay was significantly higher in group I, while its mean was [5,7] days in both groups.

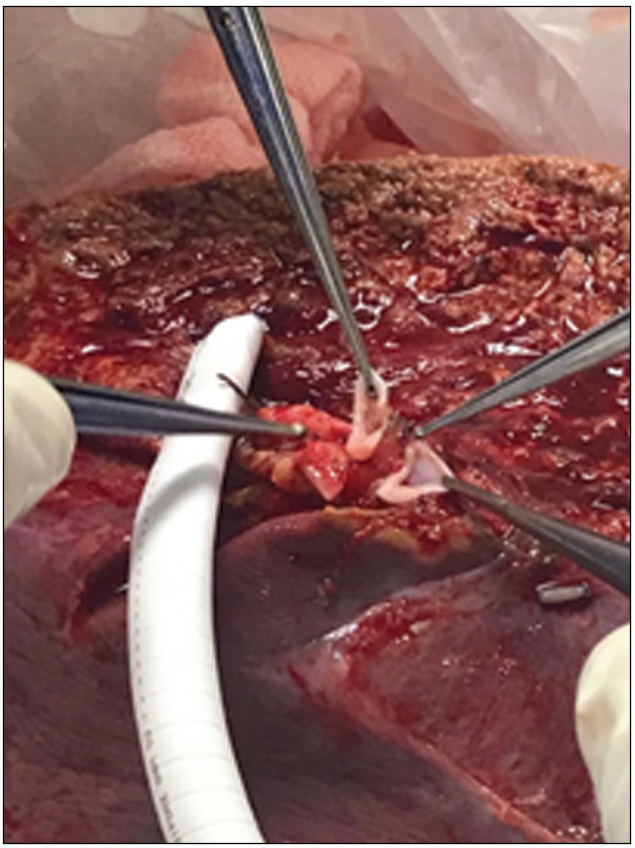
Three patients from group A suffered from PVT postoperatively, unfortunately three patients died, one out of three underwent re-exploration on day 1 post-transplant, we used interposition-Y-graft from the

Table 3 Number of right hepatic arteries and bile ducts according to each portal vein type

	Portal vein anatomical type [*n* (%)]			Test value	*P* value	Significance
	Type-I (*N*=168)	Type-II (*N*=14)	Type-III (*N*=17)			
Number of arterial anastomosis						
I	166 (98.8)	14 (100.0)	17 (100.0)	0.373	0.830	NS
II	2 (1.2)	0	0			
Number of ducts						
I	126 (75.0)	12 (85.7)	10 (58.8)	10.455	0.033	S
II	40 (23.8)	2 (14.3)	5 (29.4)			
III	2 (1.2)	0	2 (11.8)			

S, significance.

Figure 6



Two right portal openings, two right-duct orifices, and synthetic graft for V5.

recipient of another transplant on the same day, she passed the postoperative period smoothly, but she died of sepsis after 37 days, the second patient underwent stenting and was discharged on day 21, he died later on due to sepsis, and the last one died after 8 days, he was unstable to be explored and had graft functional failure.

In group A, PV types, anastomotic techniques, and number of anastomoses were nonsignificant generally for complications as mentioned in Table 7.

Table 8 reports that the most used technique for anastomosis of type-II PV was MPV of the recipient to the anterior and posterior right PV at their branching via single anastomosis with or without unification, we did this in 14 patients, two of them needed unification before the anastomosis.

In type-III APVB, we used all techniques according to the graft pattern of PV after division from donor side, we did six cases of interposition autologous graft and one case of homologous interposition graft due to PVT postunification.

Although being technically demanding, no postoperative PVT occurred after interposition-Y-graft through follow-up period postoperative PVT after each anastomotic technique is detailed in Table 9, PVT occurred once after unification, but the patient was re-explored, and homologous PV graft was used.

Discussion

We studied 199 patients who were transplanted in the last 5 years, our study compared APVB group to the other group with normal PV anatomy since 2016 till 2020, in the group of APVB, we compared each anatomical type regarding used technique and incidence of PVT, and also we evaluated the outcome regarding PVT and mortality after each anastomotic technique.

Donor safety had the priority on PV transection, we had 100% donor survival with no portal-related complications, this was unlike MQ study that had a single case of PVT out of 104 donors due to trial to get one PV orifice in type-II anomaly [9].

APVB incidence was 15.5% (31 donors). Type-II, III donors were 14, 17, respectively, while donors with type-I portal anatomy were 84.5% (168 donors), this goes with Kuriyama and colleagues who transplanted 16.1% cases with APVB. The incidence of APVB was 10% in Yilmaz and colleagues study, ASAN Medical Center's study had 5.5% incidence of portal trifurcation in their study from 2002 to 2007, and our center's previous study documented only seven cases of APVB out of 148 transplants till 2007, this explains increased acceptance rate of APVB grafts may be due to technical advancement and decreases donors' availability [11,13,16,17].

Table 4 Intraoperative data

	Group A (*N*=31)	Group B (*N*=168)	Test value	*P* value	Significance
Preoperative PVT					
No	25 (80.6)	144 (85.7)	0.525*	0.469	NS
Yes	6 (19.4)	24 (14.3)			
Number of arterial anastomosis					
I	31 (100.0)	166 (98.8)	0.373*	0.541	NS
II	0	2 (1.2)			
Right hepatic artery to splenic					
No	31 (100.0)	166 (98.8)	0.373*	0.541	NS
Yes	0	2 (1.2)			
Number of duct anastomosis					
I	22 (71.0)	128 (76.2)	3.678*	0.159	NS
II	7 (22.6)	40 (23.8)			
III	2 (6.5)	2 (1.2)			
Hepaticojejunostomy					
No	30 (96.8)	167 (99.4)	1.820*	0.177	NS
Yes	1 (3.2)	1 (0.6)			
Cold ischemia					
Mean±SD	52.74±33.88	48.71±16.92	1.007•	0.315	NS
Range	30–150	20–90			
Warm ischemia					
Mean±SD	51.13±19.69	47.17±20.03	1.011•	0.313	NS
Range	30–120	20–120			
GRWR					
Mean±SD	1.00±0.17	0.99±0.18	0.174•	0.862	NS
Range	0.77–1.6	0.58–1.7			

GRWR, graft recipient weight ratio; PVT, portal vein thrombosis.
•Independent *t*-test.
P>0.05, nonsignificant.
P<0.05, significant.
P<0.01, highly significant.

Table 5 Postoperative complications in both groups

	Group A (*N*=31)	Group B (*N*=168)	Test value	*P* value	Significance
Not complicated	20 (64.5)	107 (63.7)	0.008*	0.930	NS
Complicated	11 (35.5)	61 (36.3)			
Late biliary	4 (12.9)	26 (15.5)	0.135*	0.713	NS
PVT	3 (9.7)	4 (2.4)	4.105*	0.043	S
Early hepatic artery thrombosis	0	6 (3.6)	1.142*	0.285	NS
Billiary leak	1 (3.2)	5 (3.0)	0.006*	0.940	NS
Graft failure	1 (3.2)	4 (2.4)	0.076*	0.782	NS
Chronic rejection	0	4 (2.4)	0.753*	0.385	NS
Chest infection	0	3 (1.8)	0.562*	0.453	NS
Late hepatic artery stenosis	0	2 (1.2)	0.373*	0.541	NS
Bleeding	0	2 (1.2)	0.373*	0.541	NS
Graft nonfunction	0	2 (1.2)	0.373*	0.541	NS
Stricture	0	1 (0.6)	0.185*	0.667	NS
Biloma	0	1 (0.6)	0.185*	0.667	NS
ARDS	0	1 (0.6)	0.185*	0.667	NS
Hepatic artery stenosis	0	1 (0.6)	0.185*	0.667	NS
Late hepatic artery thrombosis	0	1 (0.6)	0.185*	0.667	NS
Mild rejection	0	1 (0.6)	0.185*	0.667	NS
Small for size	1 (3.2)	0	5.447*	0.020	S
Stroke	1 (3.2)	0	5.447*	0.020	S

ARDS, adult respiratory distress syndrome; PVT, portal vein thrombosis; S, significance.

No associated arterial anomalies were found in our trifurcated grafts, this was unlike Asan Medical Center that reported the incidence of hepatic arterial anatomical variation as 6.7% and 13% in PV types II and III, respectively. There was increased incidence of 2–3 bile-duct orifices in harvested grafts with APVB

Table 6 Mortality and its causes

	Group A (*N*=31)	Group B (*N*=168)	Test value	*P* value	Significance
Mortality					
Alive	24 (77.4)	137 (81.5)	0.289*	0.591	NS
Died	7 (22.6)	31 (18.5)			
30-day mortality	2 (28.6)	12 (38.7)	0.252*	0.615	NS
31–90-day mortality	2 (28.6)	7 (23.3)	0.085*	0.771	NS
90-day mortality	4 (57.1)	19 (61.3)	0.041*	0.840	NS
Late mortality	3 (42.9)	12 (38.7)	0.019*	0.890	NS
Day of mortality					
Median (IQR)	32.5 (17.5–63)	22 (10–40)	–0.771≠	0.441	NS
Range	8–88	1–57			
Cause of death					
Sepsis	1 (16.7)	9 (30.0)	0.443*	0.506	NS
Chest infection	0	4 (13.3)	0.900*	0.343	NS
Graft nonfunction	1 (16.7)	3 (10.0)	0.225*	0.635	NS
Post-ERCP peritonitis	1 (16.7)	2 (6.7)	0.655*	0.418	NS
Biliary complications	0	3 (10.0)	0.655*	0.418	NS
Chronic rejection	0	2 (6.7)	0.424*	0.515	NS
Stroke	1 (16.7)	1 (3.3)	1.694*	0.193	NS
PVT	2 (28.6)	1 (3.3)	4.852*	0.028	S
Acute pancreatitis	0	1 (3.3)	0.206*	0.650	NS
Bleeding	0	1 (3.3)	0.206*	0.650	NS
Late hepatic artery stenosis	0	1 (3.3)	0.206*	0.650	NS
Pulmonary embolism	0	1 (3.3)	0.206*	0.650	NS
Severe gastroenteritis	0	1 (3.3)	0.206*	0.650	NS
Small for size	1 (16.7)	0	5.143*	0.023	S
Myocardial infarction	0	1 (3.3)	0.206*	0.650	NS
7-day syndrome	0	1 (3.3)	0.206*	0.650	NS

ERCP, endoscopic retrograde cholangio pancreatography; IQR, interquartile range; PVT, portal vein thrombosis.
*χ^2-test.
•Independent *t*-test.
≠Mann–Whitney test.
P>0.05, nonsignificant.
P<0.05, significant.
P<0.01, highly significant.

(14%, 41.2% in type-II and type-III, respectively), this was less than Guler and colleagues who had 54% biliary anatomical variations [17,18].

Cold ischemia time ranged from 30 to 50 min, except in cases of interposition graft, it exceeded 100 min, this is explained by recipient side back-table procedure for anastomosis of grafts' portal branches to the resected segment of recipient PV for interposition, this was higher than Saleh *et al*. [19] who had 80 min as a mean for cold ischemia time.

The incidence of PVT after implantation of trifurcated grafts was 9.6%, while in the bifurcated group was 2.4%, our team previous study reported that two out of seven recipients developed PVT (28.5%) in grafts with dual right PVs, this was mostly owing to lower number of accepted grafts with trifurcated PV, additionally, this reflects technical advancement, and decreased disqualification incidence for these groups of donors with time [13].

In our study, PVT occurred once after unification in type-III portal anatomy, double anastomoses (type-III), single anastomosis with the collar of two portals (type-II vein), and the last was in type-III reconstructed by unification. Out of six cases of autologous interposition grafts, a single case of homologous portal grafts had been operated, but PVT did not happen. This agrees with Lee and colleagues study, which reported 100% long-term patency of the grafts in a series of 79 cases of graft interposition, even though there were five cases that needed early stenting because of buckling deformity, this goes against Yilmaz and colleagues who reported 3.3% incidence of PVT after application of MALATYA approach that we did not use, however, they reported 28.5% incidence of PVT with other techniques, this may be explained with technical familiarity with their approach [16,20]

Unification followed by venoplasty was described by Hwang *et al*. [12], which was associated with 6-month patency rate 100%, and this was better than unification

Table 7 Correlation between mortality with complications, portal vein type, number of anastomoses, and anastomotic technique in group A

	Group A		Test value	*P* value	Significance
	Alive (*N*=24)	Died (*N*=7)			
Complication					
Not complicated	20 (83.3)	0	16.439*	0.000	HS
Complicated	4 (16.7)	7 (100.0)			
Late biliary	3 (12.5)	1 (14.3)	0.015*	0.901	NS
PVT	0	3 (42.9)	11.388*	0.001	HS
Biliary leak	1 (4.2)	0	0.301*	0.583	NS
Graft failure	0	1 (14.3)	3.543*	0.060	NS
Small for size	0	1 (14.3)	3.543*	0.060	NS
Stroke, sepsis, and collection	0	1 (14.3)	3.543*	0.060	NS
Portal vein anatomical type					
Type-I	0	0	2.519*	0.112	NS
Type-II	9 (64.3)	5 (35.7)			
Type-III	15 (88.2)	2 (11.8)			
No of portal vein anastomosis					
Single	20 (76.9)	6 (23.1)	0.023*	0.880	NS
Double	4 (80.0)	1 (20.0)			
Anastomotic technique					
MPV to right portal vein of donor	0	0	5.816*	0.213	NS
MPV to anterior right and posterior right portal of donor	9 (69.2)	4 (30.8)			
RT and LT of recipient to anterior and posterior of donor	4 (80.0)	1 (20.0)			
Interposition-inverted y autologous graft	6 (100.0)	0			
Unification anastomosis	5 (83.3)	1 (16.7)			
Unification anastomosis, then interposition-inverted y homologous graft	0	1 (100)			

MPV, main portal vein; PVT, portal vein thrombosis.
*χ^2-test.
P>0.05, nonsignificant.
P<0.05, significant.
P<0.01, highly significant.

Table 8 Correlation between portal vein type with PVT and anastomotic techniques

PVT	Portal vein anatomical type			Test value	*P* value	Significance
	Type-I (*N*=168)	Type-II (*N*=14)	Type-III (*N*=17)			
	4 (2.4)	1 (7.1)	2 (11.8)	4.589*	0.101	NS
Anastomotic technique						
MPV to right portal vein of donor	168 (100.0)	0	0	339.513*	0.000	HS
MPV to anterior right and posterior right portal of donor	0	12 (85.7)	1 (5.9)			
RT and LT of recipient to anterior and posterior of donor	0	0	5 (29.4)			
Interposition-inverted y autologous graft	0	0	6 (35.3)			
Unification anastomosis	0	2 (14.3)	4 (23.5)			
Unification anastomosis, then interposition-inverted y homologous graft	0	0	1 (5.9)			

MPV, main portal vein; PVT, portal vein thrombosis.
*χ^2-test.
P>0.05, nonsignificant.
P<0.05, significant.
P<0.01, highly significant.

alone in our study, which resulted in one case of PVT out of 7.

Regarding group A, our three cases with postoperative PVT unfortunately passed away, one was unstable and died on day 8, one of other two cases underwent stenting and died after 8 months due to biliary complications, and the second died after 38 days due to sepsis. Hwang *et al*. [17] reported only one case of PVT out of 27 anastomosed interposition grafts, the patient was managed by stenting and passed away smoothly after that.

We had four cases of 90-day mortality in the trifurcated group (13%), two of them were discussed before, the other cases died because of small for size

Table 9 Correlation between anastomotic type and PVT

Anastomotic technique	PVT postoperative		Test value	*P* value	Significance
	No (*N*=192)	Yes (*N*=7)			
MPV to right portal vein of donor	164 (97.6)	4 (2.4)	4.105*	0.043	S
MPV to anterior right and posterior right portal of donor	12 (92.3)	1 (7.7)	0.714*	0.398	NS
RT and LT of recipient to anterior and posterior of donor	4 (80.0)	1 (20.0)	4.106*	0.043	S
Interposition-inverted y autologous graft	6 (100.0)	0	0.226*	0.635	NS
Unification anastomosis	6 (100.0)	0	0.226*	0.635	NS
Unification anastomosis, then interposition-inverted y homologous graft	0	1 (100.0)	27.567*	0.000	HS

HS, highly significance; MPV, main portal vein; PVT, portal vein thrombosis; S, significance.
*χ^2-test.
P>0.05, nonsignificant.
P<0.05, significant.
P<0.01, highly significant.

and massive stroke. Group I also had three cases of late mortality, one of them detailed above, the other two cases died due to biliary complications that followed two by post-ERCP peritoniti, the last had intractable graft failure and underwent retransplant and died early postoperative, so total survival was 77.5% in recipients of APVB grafts. Yilmaz and colleagues reported only 15% 1000-day mortality after Malatya approach and 60% after other techniques. Our survival rates were lower than Lee *et al*. [20] who reported that 1-year, 3-year, and 5-year recipient survival rates were 93.6, 88.3, and 85.5%, respectively.

Hwang *et al*. [17] had the overall 1-year, 3-year, and 5-year patient survival rates as 89.8, 82.7, and 82.7%, respectively.

In cases with type-I PV, we had 11.3% mortality till 90 days post-transplant, 18.5% late mortality, this is considered not much lower mortality than group A.

In our study, we discussed mortality rates in each PV type independently from the reconstructive technique. Three recipients of type-II and a single recipient of type-III had 90-day mortality, late mortality occurred in two cases of type-II and one case of type-III portal anatomy.

Except for PVT, hospital stay, ICU stay, and other complications were nonsignificantly different in both groups, and in different PV types operated by different techniques.

Conclusion

Our study is illustrative with original data, we compared the outcome with our previous experience and with the innovative articles for each technique in the literature, we also interpreted results with techniques, PV types, and with the group of ordinary portal anatomy.

Dual right PV grafts could be accepted with satisfactory results with technical advancement compared with our team previous experience, PVT was considered as the main cause for mortality in APVB group. Our survival rates are accepted in comparison with international rates.

All techniques for reconstruction could be tailored as case by case, all techniques could bring good outcome in suitable patients by trained hands, still with more technical development and innovations, we could achieve better outcome.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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