Impact of temporary portocaval shunt during living-donor liver transplant

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Background
Portal vein clamping is needed to facilitate hepatectomy; however, it causes intestinal congestion and damage and hemodynamic instability. Damage become more influenced after reperfusion. It affects both the intestine and the distant organs including the graft. In this study, we evaluated the effect of constructing temporary portocaval shunt (TPCS) during living-donor liver transplant.
Patients and methods
This study was designed as a prospective cohort study, which included 42 cases of living-donor liver transplant performed in the National Liver Institute. The study was conducted from 2018 to 2021. Patients were divided into two groups: group A included 20 patients with TPCS group and group B included 22 patients without TPCS (no-TPCS group).
Results
The procedure of TPCS required about 10.45 min to create, 4.5 min to close, and no major complications were encountered. TPCS was significantly associated with prolonged anhepatic phase (P=0.001). There was decreased requirements of vasopressors (P=0.003) and lower level of lactate on the day of operation (P=0.001), alanine aminotransferase at first week (P=0.027), and lower rate of infection (P=0.047). There was no significant effect on the transfusion of blood products, postoperative gastrointestinal tract function and graft or patient survival.
Conclusion
Based on the results of this study, TPCS is a good choice in cases with difficult hepatectomy, or prolonged anhepatic phase provided no sufficient spontaneous distal portosystemic shunts.

Keywords:
living-donor liver transplant, portocaval, shunts

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Introduction

The technique of liver transplantation has undergone continuous improvement since it was first described by Starzl in 1963. His technique yielded severe hemodynamic instability because of complete cross-clamping of the inferior vena cava (IVC) and a huge reduction of cardiac preload, as well as congestion of the gut due to portal clamping. Therefore, a need was felt for a system that would maintain venous return to the heart and decompress intestinal venous stasis [1].

Belghiti and colleagues modified their technique with the use of a temporary portocaval shunt (TPCS) to preserve portal flow and to maintain splanchnic venous drainage throughout the anhepatic phase. The preservation of both portal and caval blood flows maintained hemodynamic stability and renal perfusion particularly in noncirrhotic patients and patients with fulminant hepatic failure. Moreover, this procedure was of special value in the transplantation of partial livers [2].

Creation of a TPCS during liver transplant improves hemodynamic status, reduces intraoperative blood products transfusion, and preserves renal function during and after the transplant. However, clinical benefits of this technique are more evident in patients with severe portal hypertension [3]. Patients with a TPCS showed a trend toward a shorter operative time. They required less blood product transfusion, and maintained higher mean arterial pressures during portal vein (PV) clamping [4].

Liver transplantation requires the PV to be clamped, causing intestinal congestion, hypoxia in the anhepatic phase, and restoration of blood flow reperfusion, making intestinal ischemia-reperfusion injury inevitable. Oxidative damage is induced by the reactive oxygen species, including the superoxide anion, which play a crucial

role in the pathogenesis of ischemia-reperfusion injury. Bacterial translocation described in liver transplantation is due to portal stasis with intestinal ischemia, diminished clearance of bacteria and endotoxin by the hepatic reticuloendothelial system cells and intestinal ischemia-reperfusion injury. Bacterial translocation and endotoxemia following intestinal injury may play a significant role in postoperative multiorgan dysfunction and systemic inflammatory reaction syndrome. Multiorgan dysfunction and systemic inflammatory reaction syndrome contribute to a high mortality rate [5,6].

On the other hand, Lerut *et al*. [7] declared that liver transplantation without venovenous bypass and also without TPCS is an ideal technique for adult liver grafting. Muscari reported that routine TPCS is not a justified procedure. His study suggests that straightforward orthotopic liver transplantation (OLT) without TPCS for patients with cirrhosis were comparable to a previous work performed on OLT with TPCS as regards perioperative and postoperative hemodynamic parameters, as well as blood component requirements [8].

In 1991, the National Liver Institute, Menoufia University was the first center in Egypt to perform living-donor liver transplantation (LDLT). The transplant program then stopped and started again in April 2003 with the help of a Japanese team from Kyoto University, Japan. Since then, near 400 LDLT operations were performed including pediatric and adult recipients. Few cases of them had TPCS as part of the operation. We designed this study to enlighten the procedure technique, advantages, drawbacks, and impact on the outcome.

Patients and methods

This study was designed as a prospective cohort study including 42 cases of LDLT performed in National Liver Institute. The study was conducted from 2018 to 2022. Patients were divided into two groups: group A included 20 patients with TPCS group and group B included 22 patients without TPCS (no-TPCS group).

Inclusion criteria

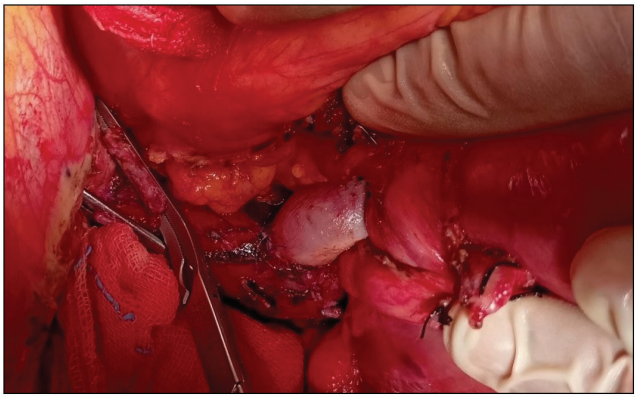
End-stage liver disease patients undergoing elective living-donor liver.

Transplantation, age more than 18 years. Selection criteria for the TPCS group included expected prolonged anhepatic phase and expected difficulty during hepatic mobilization and retrohepatic dissection.

Ethical considerations

Patients were freely given informed consent to participate. Participant's confidentiality and data security are guaranteed. Participants were able to withdraw from the research process at any time.

Figure 1



Intraoperative picture of the constructed temporary portocaval shunt.

Intervention

Creation of shunt by end-to-side anastomosis between the main PV and the anterior aspect of IVC was done using running 5-0 Prolene sutures. Shunt is functioning throughout the anhepatic phase (Fig. 1). After completion of graft outflow anastomosis with hepatic veins, shunt is disconnected at the portal end near IVC so as not to shorten the PV. The portal side is anastomosed with graft PV while the stump is closed later on using running 5/0 polypropylene. In three cases, the stump was not closed but was used to drain the right inferior hepatic vein for venous drainage of segment.

Results

Recipient and graft characteristics

The study population included 42 adult patients who had undergone LDLT in the National Liver Institute. Analysis of patients' demographic data revealed that age ranged from 18 to 61years. The mean age was 46.85 ± 13.30 versus 49.09 ± 10.78. Male to female ratio was 14: 6 versus 15: 7 in TPCS and no-TPCS groups, respectively.

Indications of liver transplant included HCV-related liver cirrhosis, cryptogenic liver cirrhosis, hepatocellular carcinoma, autoimmune hepatitis, primary sclerosing cholangitis, Caroli disease, and Wilson disease. Demographic data and indications of liver transplant are presented in Table 1.

Evaluation of liver disease severity: in the TPCS group Child–Pugh class A was one (5.0%), class B was four (20.0%), class C was 15 (75.0%), while in the no-TPCS group Child–Pugh class A was two (9.1%), class B was

Table 1 Comparison between the two studied groups according to demographic data and indication of transplant

	TPCS (*N*=20) [*n* (%)]	No-TPCS (*N*=22) [*n* (%)]	Test of significance	*P* value
Age (years)				
Mean±SD	46.85 ± 13.30	49.09 ± 10.78	*t*=0.602	0.550
Range	18–61	29–61		
<30 years	2 (10.0)	1 (4.5)	MC	0.963
30–40 years	4 (20.0)	4 (18.2)		
40–50 years	3 (15.0)	4 (18.2)		
>50 years	11 (55.0)	13 (59.1)		
Sex				
Male	14 (70.0)	15 (68.2)	χ^2=0.016	0.899
Female	6 (30.0)	7 (31.8)		
Indications				
HCV-LC	8 (40.0)	11 (50.0)		0.214
Cryptogenic LC	2 (10.0)	3 (13.6)		
Caroli disease	3 (15.0)	0		
HCC on top of LC	6 (30.0)	6 (27.3)		
Wilson disease	1 (5.0)	0		
AIH	0	1 (4.5)		
PSC	0	1 (4.5)		

χ^2, χ^2 test; MC, Monte Carlo test; *t*, Student's *t* test; TPCS, temporary portocaval shunt.

five (22.7%), and class C was 15 (68.2%), *P* value of 1.0. In the TPCS group the model for end-stage liver disease (MELD) score was 16.00 ± 4.72 and in the no-TPCS group the MELD score was 16.23 ± 4.24 (*P*=0.870). Comorbidities occurred among 30% of the TPCS group (*n*=6) while 31.8% (*n*=7) of patients had comorbidities in the no-TPCS group (*P*=0.899).

Preoperative evaluation of PV showed that PV was patent in 18 (90.0%), thrombosed in two (10.0%) in the TPCS group while in the no-TPCS group it was patent in 17 (77.3%), attenuated in three (13.6%), thrombosed in two (9.1%), *P* value of 0.319. Significant spontaneous shunts were detected during the preoperative assessment of three (15.0%) of the TPCS group compared with seven (31.8%) of the no-TPCS group. Degree of disease severity and comorbidities are presented in Table 2.

In the TPCS group, graft type was right lobe in 19 (95.0%) while left lobe was used in one (5.0%). In the no-TPCS group: right lobe was used in 21 (95.5%) and left lobe in one (4.5%). Mean value of graft weight was 788.05 ± 123.49 versus 802.04 ± 101.73. Graft recipient body weight ratio was 0.85 ± 0.12 versus 0.94 ± 0.20 in the TPCS group and the no-TPCS group respectively. Graft characteristics are presented in Table 3.

As shown before, there was no significant difference between both groups as regards recipient's disease severity and needs together with graft characteristics

Course and primary outcome

In all, 20 patients had undergone TPCSs. The procedure results can be described in the following terms: duration for creation ranged from 8 to 16 min and the mean was 10.45 min. Duration of closure ranged from 3 to 7 min and the mean was 4.5 min. No major complications occurred. Minor bleeding was controlled by interrupted stitches.

Indications included expected prolonged anhepatic phase, for example, back table job was indicated in 16 cases. In those patients, shunt was performed after full mobilization of the native liver and division of hepatic veins to complete hepatectomy, while expected difficulty during retrohepatic dissections, for example, extensive collaterals or adhesions, was the cause in four cases. Here shunt was constructed just after division of hepatic artery and common bile duct and before hepatic mobilization.

Secondary outcome

Comparison between the two studied groups regarding operative impact and postoperative outcome, ICU stay, hospital stay, and mortality.

The duration of hepatectomy was 101.00 ± 39.85 in the TPCS group while in the no-TPCS group it was 92.68 ± 17.87 (*P*=0.381), while the duration of anhepatic phase was 211.30 ± 51.06 in the TPCS group while in the no-TPCS group it was 151.36 ± 39.86 (*P*≤0.001). Operative steps and phase durations are presented in Table 4.

Blood product transfusion was as follows: red blood cells units transfusion median (minimum–maximum) was two (1–4) in the TPCS group while in the no-TPCS group it was two (1–4) (*P*=0.863). Plasma units transfusion median (minimum–maximum) was 1 (0–

Table 2 Comparison between the two studied groups according to liver disease severity

Variables	TPCS (*N*=20) [*n* (%)]	No-TPCS (*N*=22) [*n* (%)]	Test of significance	*P* value
Comorbidities				
Yes	6 (30.0)	7 (31.8)	χ^2=0.016	0.899
No	14 (70.0)	15 (68.2)		
Child–Pugh class				
A	1 (5.0)	2 (9.1)	MC	1.0
B	4 (20.0)	5 (22.7)		
C	15 (75.0)	15 (68.2)		
MELD score				
Mean±SD	16.00±4.72	16.23±4.24	*t*=0.164	0.870
Ascites				
Minimal/mild	4 (20.0)	2 (9.1)	MC	0.335
Moderate	9 (45.0)	7 (31.8)		
Marked	7 (35.0)	13 (59.1)		
Spleen span				
Average	3 (15.0)	6 (27.3)	MC	0.604
Moderate	10 (50.0)	11 (50.0)		
Severe	7 (35.0)	5 (22.7)		
Patency of PV				
Patent	18 (90.0)	17 (77.3)	MC	0.319
Attenuated	0	3 (13.6)		
Thrombosed	2 (10.0)	2 (9.1)		
Significant shunts				
Yes	3 (15.0)	7 (31.8)	FET	0.284
No	17 (85.0)	15 (68.2)		
Graft spleen ratio				
Median (minimum–maximum)	0.8 (0.38–3.0)	0.9 (0.24–4.0)	*Z*=2.01	0.055
Splenectomy				
Yes	6 (30.0)	4 (18.2)	FET	0.477
No	14 (70.0)	18 (81.8)		

χ^2, χ^2 test; FET, Fisher's exact test; MC, Monte Carlo test; PV, portal vein; *t*, Student's *t* test; TPCS, temporary portocaval shunt; *Z*, Mann–Whitney test.

Table 3 Comparison between the two studied groups according to graft properties

	TPCS (*N*=20)	No-TPCS (*N*=22)	Test of significance	*P* value
Graft type				
RT lobe	19 (95.0)	21 (95.5)	FET	1.0
LT lobe	1 (5.0)	1 (4.5)		
Graft weight				
Mean±SD	788.05±123.49	802.04±101.73	*t*=0.402	0.690
GRWR				
Mean±SD	0.85±0.12	0.94±0.20	*t*=1.644	0.108

FET, Fisher's exact test; GRWR, graft recipient body weight ratio; *t*, Student's *t* test; TPCS, temporary portocaval shunt.

6) in the TPCS group while in the no-TPCS group it was three (0–4) (*P*=0.132). Platelet units transfusion median (minimum–maximum) was 0 (0–12) in the TPCS group while in the no-TPCS group it was 0 (0–8) (*P*=0.737).

The need for vasopressors and inotropes was as follows: ephedrine total dose (in mg) median (minimum–maximum) was 5.0 (5–25) in the TPCS group, while in the no-TPCS group it was 10 (5–15). Norepinephrine total dose (in μg) median (minimum–maximum) was 3200 (3200–9600) in the TPCS group, while in the no-TPCS group it was 6400 (3200–9600). Epinephrine total dose (in μg) median (minimum–maximum) was 0.0 (0–6000) in the TPCS group while in the no-TPCS group it was 500 (0–2000) (*P*=0.003). The required drugs and transfusion of blood products are presented in Table 5.

Postoperative laboratory assessment showed that bilirubin at postoperative day (POD) 7 was 2.65 mg/dl (1.1–8.1) in the TPCS group while in the no-TPCS group it was 2.1 mg/dl (0.6–9.6) (*P*=0.579). International normalized ratio at POD 7 was 1.2 (1–1.43) in the TPCS group while in the no-TPCS group it was 1.2 (1–1.51) (*P*=0.318). Highest alanine aminotransferase I in the first week was 247.5 U/l (37–1425) in the TPCS group while in the no-TPCS group it was 622.5

Table 4 Comparison between the two studied groups according to operative steps duration

	TPCS (*N*=20)	No-TPCS (*N*=22)	Test of significance	*P* value
Duration of hepatectomy	101.00±39.85	92.68±17.87	*t*=0.887	0.381
Duration of anhepatic phase	211.30±51.06	151.36±39.86	*t*=4.261	≤0.001*
Cold ischemia time median (minimum–maximum)	62.5 (30–221)	55 (20–135)	*Z*=0.785	0.433
Worm ischemia median (minimum–maximum)	58 (25–125)	50 (30–100)	*Z*=1.176	0.240
Art warm ischemia median (minimum–maximum)	147 (0–255)	110 (0–211)	*Z*=1.335	0.182
Total duration (h) (mean±SD)	9.66±2.23	10.44±2.49	*t*=1.06	0.293

t, Student's *t* test; TPCS, temporary portocaval shunt; *Z*, Mann–Whitney test.
*Data is considered statistically significant and if *P* value is less than 0.05.

Table 5 Comparison between the two studied groups according to transfusion of blood products and required dugs

Management	TPCS (*N*=20)	No-TPCS (*N*=22)	Test of significance	*P* value
RBCS transfusion (U)				
Median (minimum–maximum)	2 (1–4)	2 (1–4)	*Z*=0.172	0.863
Plasma transfusion (U)				
Median (minimum–maximum)	1 (0–6)	3 (0–4)	*Z*=1.505	0.132
Platelet transfusion (U)				
Median (minimum–maximum)	0 (0–12)	0 (0–8)	*Z*=0.336	0.737
Ephedrine median (minimum–maximum)	5.0 (5–25)	10 (5–15)	*Z*=1.679	0.093
Norepinephrine total dose Median (minimum–maximum)	3200 (3200–9600)	6400 (3200–9600)	*Z*=2.59	0.003*
Epinephrine median (minimum–maximum)	0.0 (0–6000)	500 (0–2000)	*Z*=2.98	0.003*

RBCS, red blood cells; TPCS, temporary portocaval shunt; *Z*, Mann–Whitney test.
*Data is considered statistically significant and if *P* value is less than 0.05.

Table 6 Comparison between the two studied groups according to graft function indicators in the first week

	TPCS (*N*=20)	No-TPCS (*N*=22)	Test of significance	*P* value
Lactate_day_0 median (minimum–maximum)	35.3 (11.8–72.6)	58.8 (32–95)	*Z*=3.212	0.001*
Bilirubin_day_7 median (minimum–maximum)	2.65 (1.1–8.1)	2.1 (0.6–9.6)	*Z*=0.555	0.579
INR_day_7 median (minimum–maximum)	1.2 (1–1.43)	1.2 (1–1.51)	*Z*=0.998	0.318
Highest ALT median (minimum–maximum)	247.5 (37–1425)	622.5 (49–7374)	*Z*=2.216	0.027*

ALT, alanine aminotransferase; INR, international normalized ratio; TPCS, temporary portocaval shunt; *Z*, Mann–Whitney test.
*Data is considered statistically significant and if *P* value is less than 0.05.

U/l (49–7374) (*P*=0.027). Graft dysfunction occurred in two (10.0%) patients in the TPCS group while in the no-TPCS group it was one (4.5%) (*P*=0.598). Indicators of graft function are presented in Table 6.

Early postoperative complications included the following: gastrointestinal tract (GIT). Complications occurred in one (5.0%) patient in the TPCS group, while in the no-TPCS group it occurred in two (9.1%) patients (*P*=1.0). GIT complications included: melena and upper GIT bleeding. Time required to restore GIT motility was 2 days (2–5) in the TPCS group while in the no-TPCS group it was 2.5 days (2–8) (*P*=0.648). Infections occurred in one (5.0%) of the TPCS group, which as chest infection while in the no-TPCS group infection occurred in seven (31.8%) patients (*P*=0.047). Type of infection included chest infection in two (28.6%), urinary tract infections in three (42.9%), and wound infection in two (28.6%). Postoperative follow-up of PV complications in the TPCS group showed that it was thrombosed in one (5.0%) and attenuated in two (10.0%), while in the no-TPCS group it was thrombosed in 0 (0%), and attenuated in three (13.6%) (*P*=0.820). Neurologic complications occurred in three (15.0%) patients in the TPCS group, while in the no-TPCS group it occurred in two (9.1%) (*P*=0.656). Biliary complications occurred in six (30.0%) patients in the TPCS group, while in the no-TPCS group it occurred in 11 (50.0%) (*P*=0.187). Early postoperative complications are presented in Table 7.

Total hospital stay: in the TPCS group it was 16.13±5.48 while in the no-TPCS group it was 20.84±8.48 (*P*=0.065). ICU stay was 6.56±0.73 in the TPCS group while in the no-TPCS group it was 6.95±1.47 (*P*=0.348). ICU and hospital stay are presented in Table 8.

Mortality: five (25.0%) patients in the TPCS group died in the first 90 days. The causes of death were sepsis secondary to bile leak (*n*=2), graft dysfunction (*n*=2), and chest infection (*n*=1). Compared with six (27.3%) patients in the no-TPCS group. The causes of death were sepsis secondary to bile leak (*n*=3), chest infection (*n*=2), and massive abrupt upper GIT bleeding (*n*=1) (*P*=0.867). There was no significant difference between two groups. Kaplan–Meier overall survival is presented in Table 9. Kaplan–Meier survival curves are graphed in Fig. 2.

Table 7 Complications among temporary portocaval shunt and no temporary portocaval shunt groups

Complications	TPCS (*N*=20) [*n* (%)]	No-TPCS (*N*=22) [*n* (%)]	Test of significance	*P* value
Graft dysfunction				
Yes	2 (10.0)	1 (4.5)	FET	0.598
No	18 (90.0)	21 (95.5)		
Infections				
Yes	1 (5.0)	7 (31.8)	FET	0.047*
No	19 (95.0)	15 (68.2)		
Type of infection				
Chest	1 (100)	2 (28.6)	MC	1.0
UTI	0	3 (42.9)		
Wound	0	2 (28.6)		
GIT complications	1 (5.0)	2 (9.1)	FET	1.0
Day restored GIT median (minimum–maximum)	2 (2–5)	2.5 (2–8)	Z=0.456	0.648
Status of PV (postoperative)				
Patent	17 (85.0)	19 (86.4)	MC	0.820
Attenuated	2 (10.0)	3 (13.6)		
Thrombosed	1 (5.0)	0		
Neurologic complications	3 (15.0)	2 (9.1)	FET	0.656
Biliary complications	6 (30.0)	11 (50.0)	χ^2=1.74	0.187

χ^2, χ^2 test; FET, Fisher's exact; GIT, gastrointestinal tract; MC, Monte Carlo test; PV, portal vein; TPCS, temporary portocaval shunt; UTI, urinary tract infections.
*Data is considered statistically significant and if *P* value is less than 0.05.

Table 8 Outcome among temporary portocaval shunt and no temporary portocaval shunt groups

Outcome	TPCS (*N*=20)	No-TPCS (*N*=22)	Test of significance	*P* value
ICU stay				
Mean±SD	6.56±0.73	6.95±1.47	t=0.952	0.348
Total hospital stay (mean±SD)	16.13±5.48	20.84±8.48	t=1.91	0.065
Mortality				
Died	5 (25.0)	6 (27.3)	χ^2=0.028	0.867
Survived	15 (75.0)	16 (72.7)		

χ^2, χ^2 test; t, Student's t test; TPCS, temporary portocaval shunt.

Table 9 Kaplan–Meier overall survival among temporary portocaval shunt and no temporary portocaval shunt groups

Kaplan–Meier overall survival	Overall survival				
	Mean survival time	SE	95% CI	Log rank test	*P* value
TPCS	73.250	6.823	59.8–86.6	0.001	0.973
No-TPCS	80.318	4.893	70.7–89.9		
Overall survival	76.952	4.238	68.65–85.26		

Log-rank (Mantel-Cox) was used, CI, confidence interval; TPCS, temporary portocaval shunt.

For all the above-mentioned results it was considered significant when *P* value less than or equal to 0.05.

Discussion

The purpose of the TPCS is allowing early portal division to make hepatectomy easier and also prevention of intestinal congestion and reperfusion injury of the intestine that can affect the graft.

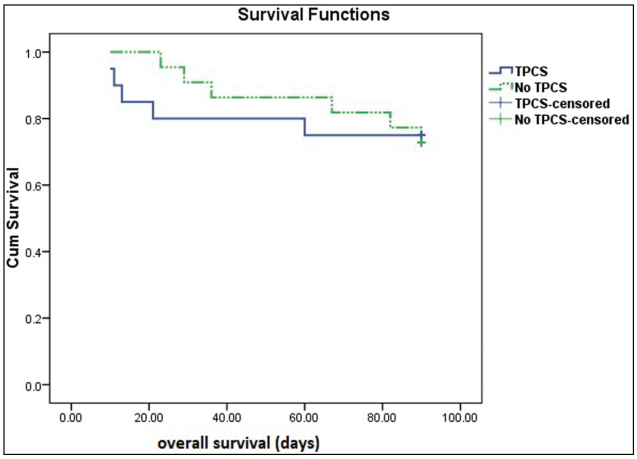
As shown before, there was no significant difference between both groups as regards recipient's disease severity and needs together with graft and patient characteristics were normally distributed.

In this study, PV thrombosis Yerdel grades 1 and 2 was not a contraindication to transplant. Removal of the clot within the PV by eversion is the reference technique. Herein, TPCS allows time to assess the effect of thrombectomy while maintaining continuous flow throughout the PV, thereby avoiding eventual rethrombosis [9].

We did not recognize mere presence of spontaneous shunts to be exclusion criteria for TPCS construction. This view is supported by Faitot who recognized that only patients with large caliber distal shunts (left splenorenal, mesocaval, and mesentericoiliac) showed lower portal pressure increase after clamping and showed a high rate of hemodynamic efficacy [10].

In all, 20 patients had undergone TPCSs. We constructed shunts using the main PV. After graft implantation, shunts were closed using running 5/0

Figure 2



Patient survival Kaplan–Meier curve.

Prolene. This procedure is similar to the one done by Dhar *et al*. [11].

Kawasaki *et al*. [12] described a temporary shunt procedure between the right PV and the inferior vena cava. Left PV was kept perfusing the native liver and then graft. At the end of operation the right PV is disconnected from IVC. Eguchi *et al*. [13] used staplers for its closure and reported good results with a fast, safe, and effective technique.

The total time added to the whole operation, that is the mean time needed for creation and closure of shunts in relation to the mean total duration results in an increase of duration by about 2.5%.

No major complications occurred. Minor bleeding was controlled by interrupted stitches.

Indications included expected prolonged anhepatic phase and expected difficulty during retrohepatic dissection. These were indications for many studies. Kim and Choi [14] used TPCS in the process of LDLT early in patients with a difficult native hepatectomy. It helped decrease transfusion requirements.

These results go parallel with a study by De-Cenarruzabeitia. To him, TPCS neither required more operative time nor shown greater morbidity. It does not affect future graft portal anastomosis. It facilitates hepatic dissection, and reduces the necessity of a rush during hepatic vein anastomosis. It also helps to evaluate the necessity to disconnect the portosystemic shunt [9].

The duration of hepatectomy was slightly longer in the TPCS group. This goes against what previous reports said. Son *et al*. [15] in their study showed that the construction of TPCS significantly shortened the duration of the preanhepatic phase and extended the duration of the anhepatic phase. Use of the TPCS reduced surgery time by more than 1 h due to improved hemostasis from the initial phases of the transplant, this also reduced the need for intraoperative transfusion [16].

In most cases (n=16) of this study, shunts were created at the end of mobilization. Time taken to create the shunt was added. There is a statistically significant longer anhepatic phase duration in the shunt group. The protocol assigned the long duration of anhepatic phase to be an indication of creating TPCS. This result was supported by Rayar *et al*. [17] who found a significant increase in operative time, which could be explained by the additional time required for construction and closure of the TPCS. They found that time waste was accepted compared with the average 6 h of the procedure.

There was no significant difference in blood products transfusion between the two groups. These results go parallel with the study by Muscari *et al*. [8], who concluded that blood component requirements in LT without TPCS were comparable to those of the literature reporting LT with TPCS.

Two studies helped us explain these results. Kim and Choi [14] found that transfusion of blood products and need for catecholamines at early reperfusion phase were significantly lower in TPCS only if recipients are a high-risk group (MELD>20) and De-Cenarruzabeitia and colleagues showed that the use of TPCS reduced blood transfusion requirements, enhanced hemodynamic status, and maintained better renal function during the postoperative period. These observations were more obvious in patients with high preoperative portal flows (>800 ml/min) [9].

Norepinephrine and epinephrine total doses were significantly lower in TPCS (P<0.05). This result is supported by a study of Ghinolfi *et al*. [18], who found that catecholamine requirements to maintain adequate values of blood pressure and heart rates were statistically lower in the TPCS group during the anhepatic phase and reperfusion.

In this study, we adopted Olthoff definition for posttransplant early allograft dysfunction (EAD). Accordingly, only two cases met criteria of EAD. However, highest alanine aminotransferase recording in the first week was significantly lower in the TPCS group; this result is explained by the following.

The wash of metabolites and bacterial products accumulated toxic metabolites from the congested mucosa liver, and systemic circulation may injure the new liver after reperfusion [19] Liver parenchymal injuries related to ischemia reperfusion injury (IRI) could be represented by transaminase levels in the early POD. Despite TPCS improved postoperative liver function only in the early POD and its effect faded progressively, which could explain the similar rate of EAD observed between the two groups because the definition of EAD is based on biological parameters that are collected on POD 7 for the most part. At that time, the potential incidence of other complications (i.e. immunologic, infectious, and vascular complications) may overcome the effect of TPCS.

Lactate level at the same operative day was by far less in the TPCS group (P<0.05). Serum lactic acid has two isomers. D-lactic acid is a metabolite of various bacteria in the intestines. Its serum level increases with destruction of intestinal mucosa barrier [20]. An elevated L-lactate might be a marker of ischemia due to anaerobic glycolysis. In the liver, D-lactate is metabolized too much slower than L-lactate [21]. So despite graft is functioning, lactate is not sufficiently cleared especially if it is of bacterial origin.

GIT complications were similar in both groups. Time required to restore GIT motility was similar. These results were supported by a study which found that prolonged postoperative ileus is mostly due to postoperative narcotics. Another study found MELD score to be the most important factor. Neither has assigned prolonged anhepatic phase to be a statistically significant cause [22,23].

Infections occurred in fewer cases of TPCS group (P<0.5). These results are supported by the fact that bacterial translocation happens through impaired intestinal mucosal barrier [19].

Biliary complications occurred less in patients in the TPCS group despite being not statistically significant. Rayar *et al*. [17] stated similar results which could reflect the reduction of IRI injury in the biliary tree.

ICU stay, total hospital stay, and mortality were similar and there was no significant difference between two groups. Similar results were found by Ghinolfi *et al*. [18] who found that TCPS has only short-term advantage, which may be related to a better intraoperative hemodynamic. TPCS just improves early perioperative outcome.

Data on adult LT in the Unite States showed death associated with cardiovascular complications, cerebrovascular complications, pulmonary complications, and hemorrhage was the most cause of death within the first 21 days. Infections were the most frequent cause of death during the 30–180 days after liver transplantation [24]. This study showed no difference as regards all these causes.

Conclusion

On the basis of the results of this study, TPCS is a good choice in cases with difficult hepatectomy, and prolonged anhepatic phase provided no sufficient spontaneous distal portosystemic shunts.

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Conflicts of interest

There is nothing to declare as regard the conflict of interest disclosure.

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