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ORIGINAL ARTICLE

# The beneficial impact of temporary porto-caval shunt in orthotopic liver transplantation: a single center analysis

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D-model for end-stage liver disease, donor risk index, liver transplantation, model for end-stage liver disease, porto-caval shunt.

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## Summary

The use of temporary porto-caval shunt (TPCS) has been shown to improve hemodynamic stability and renal function in patients undergoing orthotopic liver transplantation (OLT). We evaluated the impact of TPCS in OLT and analyzed the differences according to model for end-stage liver disease (MELD), donor risk index (DRI) and D-MELD. This is a retrospective single-center analysis of 148 consecutive OLT. Fifty-eight OLT were performed using TPCS and 90 without TPCS. Donor and recipient data with pre-OLT, intraoperative and postoperative variables were reviewed. Overall graft survival was 89.9% at 3 months and 81.7% at 1 year. Graft survival at 3 months and 1 year was 93.1% and 79.2%, respectively, in TPCS group versus 85.6% and 82.2%, respectively, in non-TPCS group ($P$ = NS). Intraoperative packed red blood cells requirement was lower in TPCS group ($7.5 \pm 5.8$ vs. $12.2 \pm 14.2$, $P = 0.006$) and non-TPCS group required higher intraoperative total dose of phenylephrine (16% vs. 28%, $P = 0.04$). TPCS group had lower 30-day postoperative mortality (1.7% vs. 10%, $P = 0.04$), no difference was observed at 90 days. Graft survival was lower in patients with high DRI; in this group graft loss was higher at 1 month (25% vs. 4.3%, $P = 0.005$) and 3 months (25% vs. 4.3%, $P = 0.005$) when TPCS was not used. TPCS improves perioperative outcome, this being more evident when high-risk grafts are placed into high-risk patients.

## Introduction

As the first orthotopic liver transplant (OLT) was performed in humans in 1963 [1] its surgical technique has evolved with several improvements and innovations [2]. At the beginning, OLT required the recipient hepatectomy with total resection of the retrohepatic vena cava and cross clamping of both vena cava and portal vein [3], with hemodynamic instability as the main associated problem. Thus, the added refinements were mainly directed to achieve better recipient hemodynamic stability, control of hemostasis and to minimize splanchnic vascular congestion [4]. Venous-venous bypass, first described by Shaw *et al.* [5], achieved hemodynamic stability and decompression of the splanchnic venous system [6], but carried a higher risk of complications such as hypothermia and pulmonary thromboembolism [7,8]. The technique of OLT with retrohepatic preservation (known as piggy-back) [9,10], although not avoiding the congestion of the splanchnic system, quickly gained wide acceptance worldwide and is now commonly used.

Tzakis *et al.* again [11] and then Belghiti *et al.* [12] described the use of a temporary porto-caval shunt (TPCS), and although not widely used [13], this technique is associated with better hemodynamic stability and improved renal function [14,15] as well as decreased transfusion requirements [6,16]. These advantages are particularly evident in acute liver failure [17], where the lack of collateral circulation makes total portal clamping less tolerated and demands fluid overload to maintain an adequate hemodynamic status. Nevertheless, most studies failed to show any improvement in patient or graft

survival or peri- and postoperative complications rates [13,18,19], putting into doubt TPCS long-term benefits.

In 2002, the model for end-stage liver disease (MELD) became the mainstay by which donor allografts are allocated in US [20]. This system has been validated in different populations to predict the severity of liver disease and to accurately estimate the risk of death without OLT [21–23]. Moreover, donor quality impacts OLT outcome and therefore the concept of donor risk index (DRI) recently introduced [24] allows standardization by providing a risk assessment for every potential liver graft compared with the ideal liver graft by using seven donor and graft characteristics associated with increased graft failure rate. Lately, the product of donor age and preoperative MELD, (D-MELD) has appeared to be a simple and highly predictive tool for estimating graft outcomes after OLT by using a cut-off D-MELD score of 1600 [25].

Our program introduced TPCS as an attempt to improve outcomes to the caval preservation technique used programmatically. United Network for Organ Sharing (UNOS) Region 9, where our center belongs, suffers a dramatic shortage of donor livers forcing us to extreme the levels of donor acceptability. In this study, we present our early experience with the use of TPCS and its impact in liver transplant outcomes stratifying the results according to MELD, DRI, and D-MELD.

## Methods

### Patients

Between August 2006 to November 2007, 159 adult OLTs were performed on 151 patients at the Mount Sinai Hospital in New York City (NY, USA). Eight patients undergoing retransplantation and three patients with prior transjugular intrahepatic portosystemic stent shunt placement were excluded from the study. After obtaining institutional review board approval, a retrospective analysis of these 148 patients was performed.

### Surgical technique

The procedure regularly performed at our institution was the cava preservation [9,10]. We initiated the introduction of the TPCS in fulminant hepatitis cases and the subjective impressions were so positive that we decided to extend its use to other diagnosis. There was no established policy for using TPCS and the final decision was made on a case-by-case by the attending surgeon according to the individual preferences of the case. All four surgeons had similar rates of TPCS use, ranging between 34% and 41%. In patients undergoing OLT with TPCS, after dissecting and ligating the hepatic arteries and the biliary structures, the portal vein was dissected from the duodenal level to the bifurcation. The infrahepatic vena cava was exposed enough from the caudate lobe to easily allow the anastomosis. A Satinsky clamp was placed transversally on the vena cava and then the distal end of the portal vein anastomosed in an end-to-side fashion to the infrahepatic vena cava with a 5/0 polypropylene running suture. After restoring flow through TPCS, completion of hepatectomy with retrohepatic cava preservation and selective clamping of the hepatic veins was performed. The donor suprahepatic vena cava was anastomosed to the recipient left and middle hepatic veins adding the anterior cava and, if needed, the medial aspect of the right hepatic vein, in a way in which it does not obstruct the caval flow, by means of an end-to-side 5/0 polypropylene running suture (piggy-back technique). To avoid the collapse of the vena cava, we released its attachments including the left phrenic vein. The infrahepatic vena cava of the graft was left open to allow flushing with Ringer lactate before reperfusion and then closed with a 0 silk tie. TPCS was closed using an EndoGIA vascular stapler and the portal anastomosis was performed by means of an end-to-end 5/0 polypropylene running suture. The graft was reperfused and arterial and biliary anastomoses were subsequently performed. In patients undergoing OLT without TPCS, the surgical steps were the same except that the shunt was not performed. Cell saver was used in all liver transplants, but only after the hepatectomy if the recipient had a hepatocarcinoma.

### Intraoperative anesthetic management

Anesthesia was induced with intravenous thiopental (5 mg/kg), fentanyl (3 μg/kg) and succinylcholine (1 mg/kg). A continuous infusion of norepinephrine was started if systolic arterial blood pressure remained under 80 mmHg despite adequate filling pressure and intraoperative hypotension was treated by means of phenylephrine boluses as needed. Packed red blood cells were administered to maintain hemoglobin blood level above 8 g/dl. Fresh frozen plasma and platelets were administered to treat significant oozing according to intraoperative coagulation parameters and anesthesiologist and surgeon criteria.

### Immunosuppression

All patients were administered the same immunosuppressive regimen based on daclizumab (1 mg/kg on postoperative day 0 and 4), tacrolimus, mycophenolate mofetil and steroids.

### Study design

Patients were divided on two groups based on the use of TPCS technique. Follow-up date was set at 31st December

2008. Donor and recipient demographic data with pre-OLT, intraoperative and postoperative variables were acquired from a prospective institutional database. Three prognostic scores were calculated for every patient:

**1** The Donor Risk Index (DRI) [24] takes into account the donor age, race, cause of death, height, cold ischemia time, regionality of the donor and whether the graft comes from a donation after cardiac death (DCD) or has been split. We considered grafts with DRI under 1.8 and DRI over 1.8 as low risk and high risk, respectively, because in the original article this was the cut-off value providing at least a 75% 1-year graft survival.

**2** The MELD score [23] uses serum bilirubin and creatinine concentrations and international normalized ratio (INR) values to predict survival in end-stage liver disease. We considered patients with MELD scores under and over 24 were low risk and high risk, respectively, because this was our mean value.

**3** The D-MELD score [25] takes into account the MELD score and the donor age, the final value resulting from the product of the previously mentioned parameters. We considered patients with D-MELD under 1600 and over 1600 as low risk and high risk, respectively, because this was the cut-off value used in the original article.

### Statistical analysis

Categorical variables were compared using the chi-square or Fisher's exact test. Continuous variables were expressed as the mean ± SD unless otherwise specified and compared using Student's *t*-test and ANOVA test where applicable. When a normal distribution was not present, continuous variables were expressed as the median and the range and compared using the Mann–Whitney *U*-test. Multivariate analysis considering donor and recipient factors was performed using Cox regression models. Patient actuarial survival analysis was calculated using the Kaplan–Meier method and comparisons were made using the log-rank test. A $P$-value $<0.05$ was considered significant. All statistical analyses were performed using the ''Statistical Package for the Social Sciences'' version 13.0 for Windows (SPSS, Chicago, IL, USA).

## Results

Temporary porto-caval shunt was performed in 58 patients (TPCS group) and 90 patients underwent OLT without TPCS (non-TPCS group). Data of the overall patients in the series are summarized in Table 1. Calculated MELD over 24 accounted for the 49.7% of the patients of the series. DRI over 1.8 accounted for the 48.8% of the patients. Overall graft survival at 3 months and 1 year was 89.9% and 81.7% respectively. Overall patient survival at 3 months and 1 year was 92.6% and 85.1% respectively. Eight patients underwent combined kidney transplant (one in the TPCS group and seven in the non-TPCS).

**Table 1.** Donor and recipient demographic data.

| | |
|---|---|
| Donor characteristics | |
| Age (years) [mean ± SD (range)] | 51.2 ± 20.3 (12–86) |
| DCD [*n* (%)] | 8 (5) |
| Split graft [*n* (%)] | 11 (7.4) |
| DRI [mean ± SD (range)] | 1.78 ± 0.45 (1.048–3.212) |
| Recipients characteristics | |
| Gender (female/male) | 43/105 |
| Age (years) | 55.5 ± 10.3 |
| Patient with ascites [*n* (%)] | 104 (70.3) |
| Indication for OLT [*n* (%)] | |
| HCV | 33 (22.8) |
| HCV + HCC | 32 (21.6) |
| HBV | 7 (4.7) |
| HBV + HCC | 6 (4.1) |
| ETOH | 17 (11.5) |
| ETOH + viral | 13 (8.8) |
| ETOH + HCC | 5 (3.4) |
| Metabolic | 6 (4.1) |
| Acute liver failure | 3 (2) |
| Autoimmune | 3 (2) |
| Cholestatic | 7 (4.7) |
| Others | 16 (10.8) |
| Patients with HCC [*n* (%)] | 50 (33.8) |
| Pre-OLT platelets (×100 000/cc) | 92.8 ± 72.2 |
| UNOS pre-OLT MELD | 29.1 ± 6.9 |
| Calculated pre-OLT MELD | 24 (6–56) |
| Calculated pre-OLT D-MELD | 1108 (72–4088) |

DRI, donor risk index; OLT, orthotopic liver transplantation; MELD, model for end-stage liver disease; HCV, hepatitis C virus; HCC, hepatocellular carcinoma; HBV, hepatitis B virus; ETOH, alcoholic cirrhosis.

### Preoperative variables

There were no differences between the two groups according to donor characteristics except a higher BMI in the TPCS group. Similarly, higher recipient weight was found in the TPCS group (Table 2). There were no differences in the basal creatinine levels (TPCS vs. non-TPCS: 2.09 ± 2.5 mg/dl vs. 1.98 ± 1.56 mg/dl, $P$ = NS).

### Intraoperative variables

There were no differences in surgical time by the use of TPCS. Intraoperative packed red blood cells (PRBC) requirement was lower in the TPCS group, without differences for the other blood products. Patients in the non-TPCS group required a higher total dose of phenylephrine to maintain adequate blood pressure and heart rate values. No differences were noted for the use of epinephrine or norepinephrine (Table 2). Thirty-seven (63%) patients

**Table 2.** Donor and recipient data according to temporary porto-caval shunt group.

| | TPCS group ($n$ = 58) | Non-TPCS group ($n$ = 90) | |
|---|---|---|---|
| Donors characteristics | | | |
| Age, years (range) | 51.3 ± 22.1 | 51.1 ± 19.1 | NS |
| Gender (female/male) | 24/34 | 44/46 | NS |
| BMI (kg/m$^2$) | 30.4 ± 7.2 | 27.1 ± 7.8 | 0.012 |
| DCD [$n$ (%)] | 5 (5.8) | 3 (3.3) | NS |
| Split graft [$n$ (%)] | 4 (6.9) | 7 (7.8) | NS |
| Cold ischemia time (min) | 455 ± 163 | 470 ± 164 | NS |
| DRI | 1.73 ± 0.39 | 1.81 ± 0.48 | NS |
| Recipients characteristics | | | |
| Gender (female/male) | 16/42 | 27/63 | NS |
| Age (years) | 55.5 ± 10.2 | 55.4 ± 10.5 | NS |
| Weight (kg) | 82.7 ± 16.4 | 76.4 ± 19.1 | 0.039 |
| Patient with HCC [$n$ (%)] | 19 (32.7) | 31 (34.4) | NS |
| Patient with ascites [$n$ (%)] | 38 (65.5) | 66 (73.3) | NS |
| Pre-OLT platelets (×100 000/cc) | 95 ± 73 | 91 ± 71 | NS |
| UNOS pre-OLT MELD | 29.7 ± 7.1 | 28.7 ± 6.4 | NS |
| Calculated pre-OLT MELD | 22.1 ± 12.7 | 25.1 ± 11.1 | NS |
| Calculated pre-OLT D-MELD | 1153 ± 917 | 1275 ± 677 | NS |
| Intraoperative variables | | | |
| Mean surgical time (min) (range) | 416 ± 134 (251–1047) | 431 ± 124 (249–840) | NS |
| PRBC transfusion (units) (range) | 7.5 ± 5.8 (0–30) | 12.2 ± 14.2 (0–91) | 0.006 |
| FFP transfusion (units) (range) | 7.9 ± 6.8 (0–38) | 10.4 ± 10.3 (0–75) | NS |
| Platelet transfusion (units) (range) | 2.5 ± 6.4 (0–30) | 3.8 ± 9.8 (0–70) | NS |
| No transfusions (PRBC) (%) | 5 (8) | 7 (7) | NS |
| Phenylephrine boluses [$n$ (%)] | 9 (16) | 25 (28) | 0.04 |
| Total dose (μg) | 106.7 ± 40 | 232 ± 204 | |
| Epinephrine boluses [$n$ (%)] | 19 (33) | 30 (33) | NS |
| Total dose (μg) | 29 ± 34 | 33 ± 52 | |
| Norepinephrine boluses [$n$ (%)] | 18 (31) | 33 (37) | NS |
| Total dose (μg) | 33 ± 34 | 34 ± 46 | |
| Mean blood pressure (mmHg) | 77 ± 9 | 78 ± 10 | NS |
| Mean heart rate (bpm) | 83 ± 15 | 85 ± 15 | NS |
| Postoperative variables | | | |
| Hospital stay (days) [median (range)] | 13 (4–97) | 13 (1–102) | NS |
| Postoperative complications (%) | 15 (26) | 13 (14) | NS |
| Post-OLT bleeding [$n$ (%)] | 5 (9) | 6 (7) | NS |
| Post-OLT biliary complications [$n$ (%)] | 6 (10) | 9 (10) | NS |
| Vascular complications [$n$ (%)] | 3 (5) | 4 (4) | NS |
| Need for reoperation [$n$ (%)] | 10 (6) | 11 (12) | NS |
| PNF [$n$ (%)] | 3 (5.2) | 7 (7.8) | NS |
| Retransplantation [$n$ (%)] | 6 (10.3) | 4 (4) | NS |
| 30 days mortality (%) | 1.7 | 10 | 0.04 |
| 90 days mortality (%) | 3.4 | 10 | NS |

DRI, donor risk index; OLT, orthotopic liver transplantation; TPCS, temporary porto-caval shunt; NS, nonsignificant.

in the TPCS group required at least one pressor during the procedure and 14 patients required two pressors. In the non-TPCS group 56 (62%) patients required at least one pressor, 25 patients required two pressors and nine patients more than two pressors.

### Postoperative variables

There were no differences regarding hospital stay. Global postoperative complications only showed a trend toward an increased incidence in the TPCS group (26% vs. 14%, $P = 0.06$). Vascular complications included three hepatic artery stenoses in the non-TPCS and two in the TPCS group and one hepatic artery thrombosis for each group. Biliary complications included six cases in the non-TPCS group (five stenoses, one leak) and nine cases in the TPCS group (five stenoses, three leaks, and one necrosis). Analyzing pre- and postoperative creatinine clearance data on day 1, 3, 7 and 30 (after excluding the patients who received a combined liver–kidney transplant) we found

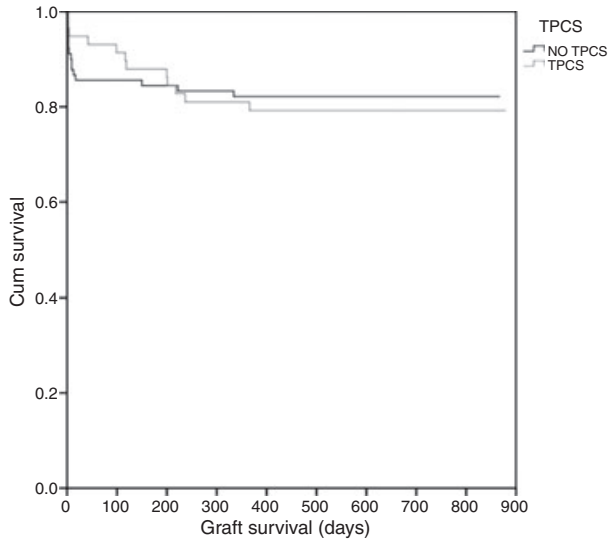


**Figure 1** Graft survival according to temporary porto-caval shunt groups.

higher clearance on postoperative day 3 in the TPCS group (70.0 ± 39.4 vs. 92.5 ± 64.1, $P = 0.019$). When analyzing pre and post-transplant liver function tests (aspartate aminotransferase (AST), alanine aminotransferase, prothrombin time (PT), total and direct bilirubin) only nonsignificant trends were found in day 7 for lower AST values in TPCS group (54.3 ± 52.6 IU/dl vs. 73.8 ± 70.6 IU/dl, $P = 0.073$) and in day 7 for lower PT values in TPCS group (16.2 ± 2.8 s vs. 15.4 ± 1.8 s, $P = 0.070$).

### Patient and graft survival

Temporary porto-caval shunt group had lower 30 days postoperative mortality compared with non-TPCS group (1.7% vs. 10%, $P = 0.04$) but without differences at 90-day mortality (Table 2). Graft survival at 3-month and 1-year was 93.1% and 79.2% in the TPCS group versus 85.6% and 82.2% in non-TPCS group respectively ($P$ = NS) (Fig. 1). Patient survival at 3 months and 1 year was 96.6% and 80.9%, respectively, in TPCS group versus 90% and 87.8% in the non-TPCS group respectively($P$ = NS). Causes and timing of retransplantation, graft loss and patient death are summarized in Tables 3 and 4. There were no differences when comparing graft survival stratified by low and high MELD values. Patients with a DRI over 1.8 had lower graft survival compared with patients with DRI under 1.8 (survival at 3 months and 1 year was 82.5% and 71.3% vs. 95.5% and 89.3%, respectively, $P = 0.008$). Patients with a D-MELD over 1600 had lower graft survival compared with patients with D-MELD under 1600 (3-month and 1-year graft survival: 82.1% and 69.2% vs. 93.1% and 86.2% respectively, $P = 0.02$). When comparing patients with and without TPCS and stratified by low and high MELD, no differences in graft survival were found between the four groups. When stratifying patients with and without TPCS by low and high DRI, we found that the group with low DRI and no TPCS had better graft survival than those with high DRI and no TPCS ($P = 0.022$), but no difference was found in TPCS patients when stratified by DRI (Fig. 2). Graft loss in patients with high DRI was higher

**Table 3.** Causes and timing of graft loss and patient death.

| TPCS group | | | | Non-TPCS group | | | |
|---|---|---|---|---|---|---|---|
| Graft loss | | Patient death | | Graft loss | | Patient death | |
| Cause | Days | Cause | Days | Cause | Days | Cause | Days |
| PNF | 2 | PNF | 5 | PNF | 1 | PNF | 1 |
| PNF | 2 | Sepsis | 40 | PNF | 1 | PNF | 1 |
| PNF | 3 | Sepsis | 98 | PNF | 2 | PNF | 2 |
| Sepsis | 40 | Sepsis | 116 | PNF | 2 | PNF | 7 |
| HAT | 61 | Sepsis | 118 | PNF | 2 | Sepsis | 8 |
| Sepsis | 98 | Met. HCC | 200 | PNF | 3 | Sepsis | 12 |
| Sepsis | 116 | HCV recur. | 217 | PNF | 7 | Sepsis | 16 |
| Sepsis | 118 | Rejection | 236 | Sepsis | 8 | HAT | 28 |
| Met. HCC | 200 | Sepsis | 314 | Sepsis | 12 | Duodenal perfor. | 30 |
| Rejection | 200 | Sepsis | 325 | Sepsis | 16 | Sepsis | 149 |
| HCV recur. | 217 | Sepsis | 365 | HAT | 28 | Met. HCC | 221 |
| Sepsis | 314 | | | Duodenal perfor. | 30 | Rejection | 297 |
| Sepsis | 365 | | | Sepsis | 149 | | |
| | | | | Met. HCC | 221 | | |
| | | | | Rejection | 297 | | |
| | | | | Rejection | 333 | | |

TPCS, temporary porto-caval shunt; HAT, hepatic artery thrombosis; Met. HCC, metastatic hepatocellular carcinoma.

**Table 4.** Causes and timing of retransplantation.

| TPCS group | | Non-TPCS group | |
|---|---|---|---|
| Cause | Days after OLT | Cause | Days after OLT |
| PNF | 2 | PNF | 2 |
| PNF | 2 | PNF | 2 |
| PNF | 3 | PNF | 2 |
| Hepatic artery thrombosis | 61 | Chronic rejection | 333 |
| Chronic rejection | 199 | | |
| Chronic rejection | 595 | | |

OLT, orthotopic liver transplantation; TPCS, temporary porto-caval shunt.

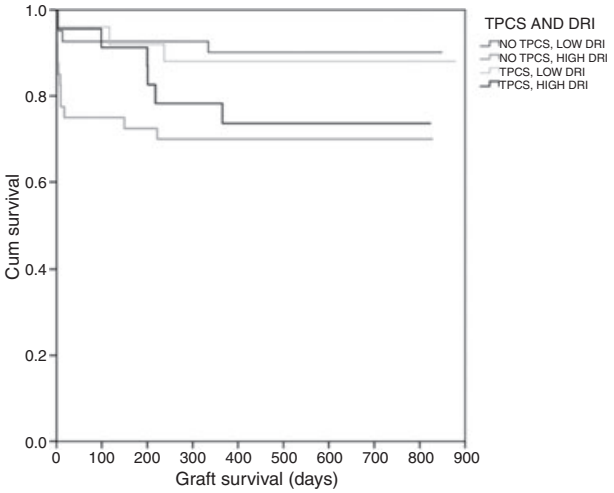


**Figure 2** Graft survival according to temporary porto-caval shunt and donor risk index groups.

at 1 month (25% vs. 4.3%, $P = 0.005$) and at 3 months (25% vs. 4.3%, $P = 0.005$) when TPCS was not used. Similarly, when stratifying patients with and without TPCS by D-MELD, we found the group with low D-MELD and no TPCS had a trend to a better graft survival than those with high D-MELD and no TPCS (10% vs. 25.9%, $P = 0.06$), but no difference was found in TPCS patients when compared using D-MELD (Fig. 3). In patients with high D-MELD, the graft loss was significantly higher at 1 month (25.9% vs. 0%, $P = 0.008$) and at 3 months (25.9% vs. 0%, $P = 0.021$) when TPCS was not used. When performing multivariate survival analysis considering donor factors (DRI), intraoperative data (use of TPCS) and recipient factors (weight, age, preoperative platelets MELD score) only DRI (HR: 3.53, 95% CI: 1.49–8.33, $P = 0.004$) had influence in graft survival.

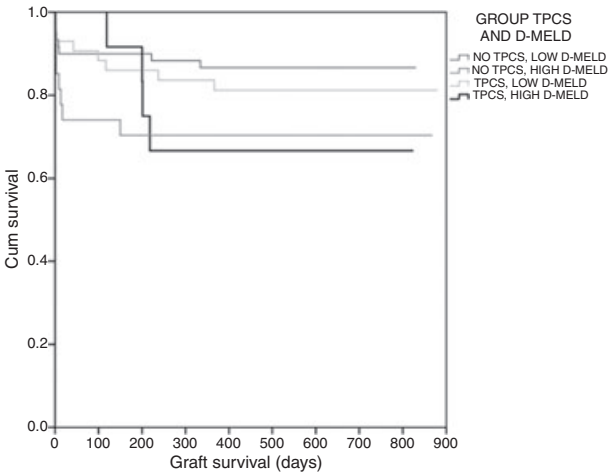


**Figure 3** Graft survival according to temporary porto-caval shunt and D-model for end-stage liver disease (D-MELD) groups.

## Discussion

The severe cadaveric liver donor shortage affecting certain regions has stimulated the use of alternatives, like living donation, imported organs from other regions or extreme the acceptability criteria of local donors. In many instances, we are faced with situations in which a rather high-risk donor is used with a prolonged ischemia time, accentuating its risk for graft failure.

Surgical technique has evolved with several improvements and innovations since the first OLT. The use of the cava preservation technique maintains venous return reducing the need of large fluid volume infusion or pressors during the dissection and the anhepatic phase. This technique does not resolve the deleterious effect of portal flow interruption during the hepatectomy. Portal vein clamping during OLT leads to several hemodynamic consequences, with decreased venous return and cardiac output. At the same time, the increased pressure in the splanchnic system reflects on the microcirculation with increased permeability of the membranes, interstitial edema, endothelial damages and consequent production of pro-inflammatory cytokines. At declamping, the release of all these factors in the systemic circulation might lead to central and peripheral vasodilatation, with severe hypotension and possible organ damage [25]. A theoretical solution to these possible problems is using a TPCS during OLT as it would improve venous return, patient's hemodynamic stability and would avoid all the effects derived from increased splanchnic pressure [6]. However, most of the experiences reported in the literature have failed to conclusively demonstrate the efficacy and the benefit of the TPCS [16,26,27].

Surgical time is not affected by the creation of the TPCS. Our impression is that the time spent performing TPCS is regained with an easier hepatectomy with a fully devascularized organ and shorter final hemostasis. Reducing portal pressure and devascularizing the liver produced a reduced intraoperative PRBC requirement in the TPCS group. An additional advantage is to allow the trainees to work in a more controlled and relaxed environment by performing the retrohepatic dissection with a devascularized liver and without splanchnic collateral vessels congestion [26].

Temporary porto-caval shunt has been associated with better hemodynamic stability and improved renal function [14,15] as well as reducing the reperfusion syndrome [28]. In our study, we found that phenylephrine requirements to maintain adequate values of blood pressure and heart rates were statistically higher in the non-TPCS group during the anhepatic phase and reperfusion. We also found that creatinine clearance was better in the immediate postoperative period (postoperative day 3) in the TPCS group, although this advantage was already lost 7 days after the procedure. Most studies failed to show improvement in perioperative and postoperative complication rates [13,18,19]. We were only able to find a trend toward an increased incidence of postoperative complications in the TPCS group, without differences in the specific complications groups.

One of the most important differences in our series is the improvement in 30-day graft and patient survival in the TPCS group, although this advantage was lost at 3 months after OLT. We hypothesize that this short-term advantage might be related to a better intraoperative hemodynamic stability generated by the TPCS.

Most studies have not stratified their donor or recipient variability that could benefit most from TPCS. Belghiti *et al.* [12] reported that TPCS was able to maintain the portal and caval flow and avoid the drop in venous return in patients with acute liver failure where the consequences of the portal vein clamping are more severe. The role of TPCS is unclear in cirrhotic patients, where anatomical shunts already provide a decompression of the splanchnic system. Muscari *et al.* [13] reported that the use of TPCS was not justified in these patients and Lerut *et al.* [18] sustained that TPCS can always be avoided.

Nevertheless, Figueras *et al.* [6] showed that clinical benefits of this technique are evident in patients with a baseline portal flow of 1000 ml/min or greater and in those with severe portal hypertension and porto-caval gradient of 16 mmHg or greater. In our study, we were not able to find outcome differences depending on the recipient's status based on MELD score suggesting that other variables can play a role in TPCS benefits other than only the recipient status.

At the present time, no study has analyzed the effect of the donor quality and the matching donor recipient in the outcome of patients undergoing OLT with or without TPCS. When analyzing graft survival by DRI and D-MELD, we found that they both had great influence in the graft survival by themselves. If we consider D-MELD and DRI survival stratified by the use or not of TPCS, a protective effect of TPCS on graft survival was evident in high-risk groups, i.e. in patients with a high DRI or a high D-MELD. A possible explanation would be that graft quality, more than recipient clinical status, is sensitive to the use of TPCS. High-risk grafts are extremely sensitive to hemodynamic instability and reaching reperfusion with excess fluid volume or pressors have deleterious effects. Graft loss in the short term was higher when TPCS was not used in high DRI patients or high D-MELD, although long-term survival was not improved in these groups of patients. All these data seem to support the concept that TPCS could maximize the results of using marginal grafts by means of optimizing intraoperative management.

Although the degree of ischemia reperfusion injury correlates with long-term outcome, especially in the HCV population [29], our long-term results were not affected by the TPCS procedure but by the quality of the graft and the matching of donor/recipient.

This study is not a randomized trial and several definitive biases i.e., lack of policy regarding the use of TPCS except the surgeon patient-based personal decision, limit the conclusions. However, we believe that despite the possible confounding (inherently derived from the study design) the results found in our study should encourage the design of randomized clinical trials to better clarify the perioperative effect of TPCS on high-risk donors and recipients.

In conclusion, a technical modification in the liver transplantation, using TPCS accompanying caval preservation, seems to improve short-term outcome to high-risk organs in times in which severe donor liver shortage forces its utilization.

## Authorship

DG: designed the study, performed the study, and wrote the article; JM: analyzed the data; GR-L: designed the study, performed the study; MS and KI: performed the study; DB: collected the data; CS: collected the data, analyzed the data; MS: performed the study, designed the study; TS: designed the study; HS: performed the study; JDRM: designed the study, performed the study, and wrote the article.

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