Impact of Temporary Portocaval Shunting and Initial Arterial Reperfusion in Orthotopic Liver Transplantation

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The use of a temporary portocaval shunt (TPCS) as well as the order of reperfusion (initial arterial reperfusion [IAR] versus initial portal reperfusion) in orthotopic liver transplantation (OLT) is controversial and, therefore, still under debate. The aim of this study was to evaluate outcome for the 4 possible combinations (temporary portocaval shunt with initial arterial reperfusion [A+S+], temporary portocaval shunt with initial portal reperfusion, no temporary portocaval shunt with initial arterial reperfusion, and no temporary portocaval shunt with initial portal reperfusion) in a center-based cohort study, including liver transplantations (LTs) from both donation after brain death and donation after circulatory death (DCD) donors. The primary outcome was the perioperative transfusion of red blood cells (RBCs), and the secondary outcomes were operative time and patient and graft survival. Between January 2005 and May 2017, all first OLTs performed in our institution were included in the 4 groups mentioned. With IAR and TPCS, a significantly lower perioperative transfusion of RBCs was seen ($P < 0.001$) as well as a higher number of recipients without any transfusion of RBCs ($P < 0.001$). A multivariate analysis showed laboratory Model for End-Stage Liver Disease (MELD) score ($P < 0.001$) and IAR ($P = 0.01$) to be independent determinants of the transfusion of RBCs. When comparing all groups, no statistical difference was seen in operative time or in 1-year patient and graft survival rates despite more LTs with a liver from a DCD donor in the A+S+ group ($P = 0.005$). In conclusion, next to a lower laboratory MELD score, the use of IAR leads to a significantly lower need for perioperative blood transfusion. There was no significant interaction between IAR and TPCS. Furthermore, the use of a TPCS and/or IAR does not lead to increased operative time and is therefore a reasonable alternative surgical strategy.

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During orthotopic liver transplantation (OLT), clamping and sectioning of the portal vein (PV) from the native liver induces splanchnic venous congestion, intestinal edema, bacterial translocation, and accumulation of noxious elements.[1,2] The use of a temporary portocaval shunt (TPCS) may prevent these complications by alleviating gut edema, reducing bleeding with reduction of portal venous pressure, and improving hemodynamic stability.[3]

After the introduction of TPCSs in 1993 by Tzakis et al.,[4] the evidence of its benefit has been controversial. Several retrospective studies have shown better intraoperative hemodynamic parameters, a decrease in the incidence of reperfusion syndrome,[5,6] and better graft survival[7] by using a TPCS. However, other studies[3,8] showed no effect of a TPCS on intraoperative transfusion of red blood cells (RBCs). Therefore, potential advantages of the TPCS remain questionable, and its use is still debated.[9-11]

Several older, small, prospective studies that were nonrandomized, randomized, and retrospective

Abbreviations: A+S+, temporary portocaval shunt with initial arterial reperfusion; A+S−, no temporary portocaval shunt with initial arterial reperfusion; A−S+, temporary portocaval shunt with initial portal reperfusion; A−S−, no temporary portocaval shunt with initial portal reperfusion; ALT, alanine aminotransferase; AST, aspartate aminotransferase; BAR, balance of risk; BMI, body mass index; CIT, cold ischemia time; DBD, donation after brain death; DCD, donation after circulatory death; DRM, donor–recipient model; ET-DRI, Eurotransplant donor risk index; FFP, fresh frozen plasma; GGT, gamma-glutamyltransferase; IAR, initial arterial reperfusion; INR, international normalized ratio; LT, liver transplantation; MELD, Model for End-Stage Liver Disease; NR, not reported; OLT, orthotopic liver transplantation; PTT, partial thromboplastin time; PV, portal

investigated initial arterial reperfusion (IAR)[12-17] and showed controversial results on outcomes after liver transplantation (LT). Thus, the ideal sequence of reperfusion is an issue that is still debated. The increased demand for LT has led to the increased use of extended criteria donor livers, specifically from donation after circulatory death (DCD) donors.[18-20] In contrast to LT with donation after brain death (DBD) organs, DCD LT is known to have an increased risk for posttransplantation complications, especially early allograft dysfunction, acute kidney injury, and nonanastomotic biliary strictures.[21] Little is known about the effect of a TPCS or IAR in DCD LT.

The aim of this study was to evaluate perioperative blood loss, hepatic injury, operative time, and outcomes for LT with or without TPCS and/or IAR in a retrospective center-based cohort study including both DBD and DCD LTs. This study has received approval by the institutional review committee.

Patients and Methods

PATIENTS

Between January 2005 and May 2017, all LTs at the Leiden University Medical Center, Leiden, the Netherlands, were included in this study. Recipients who received a domino, split, or auxiliary LT or a retransplantation were excluded. Clinical information was obtained from a prospectively collected database. Covariates included donor demographics, recipient demographics, pretransplant information, intraoperative data, and postoperative outcomes.

Laboratory Model for End-Stage Liver Disease (MELD) scores were included in the recipient analysis. If necessary, the original patient notes were reviewed for missing information. The Eurotransplant donor risk index (ET-DRI), simplified recipient risk index (sRRI), combined donor-recipient model (DRM), and balance of risk (BAR) scores were calculated as described previously.[22-24] The peak value of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) during the first 7 days after transplantation was used as a marker of ischemia/reperfusion injury.[25]

DEFINITION OF PERIOPERATIVE BLOOD LOSS

Mild blood loss requiring transfusion may often be ongoing after surgery. Therefore, perioperative blood loss was defined as the need for transfusion of RBCs during the first 24 hours after the start of surgery. Moreover, Cell Saver (LivaNova, London, UK) volume and fresh frozen plasma (FFP) transfusion were also noted.

OPERATIVE TECHNIQUES OF RECIPIENT SURGERY

Briefly, the standard incision and exposure was followed by the dissection of the hepatoduodenal ligament and by liver mobilization. Since May 2010, a change in center protocol was incorporated, which consisted of the use of a TPCS prior to mobilization and removal of the native liver. The TPCS consisted of an end-to-side anastomosis of the PV to the inferior vena cava at the level of the renal veins. After insertion of the liver graft, a side-to-side caval anastomosis was performed. Shortly after the introduction of a TPCS, IAR was introduced. In the historic control group, the portal anastomosis was directly followed by portal reperfusion of the liver. Thereafter, arterial anastomosis and reperfusion followed. Since the change in protocol, the arterial anastomosis has been directly followed by arterial reperfusion of the liver. Hereafter, portal anastomosis and reperfusion followed. Just before portal reconstruction, the TPCS was divided using a vascular endo GIA stapling device (Medtronic, Minneapolis, MN), after which a standard end-to-end portal anastomosis was performed. Finally, biliary reconstruction was performed, preferably with a duct-to-duct anastomosis.

vein; RBC, red blood cell; SD, standard deviation; SE, standard error; sRRI, simplified recipient risk index; TPCS, temporary portocaval shunt; WIT, warm ischemia time.

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Correction Statement: Correction added on October 11, 2019 after first online publication: In Fig. 1, the x-axis was set incorrectly as A-S+, A+S-, A-S+, A+S+. It has been updated to read: A-S-, A+S-, A-S+, A+S+. We apologize to the author and to our readers for this error.

STATISTICAL ANALYSIS

Continuous variables were presented as mean and standard deviation (SD), or median (range) and SD, whereas categorical variables were presented as n (%). Categorical variables were compared with the Pearson's chi-square test. Characteristics of the donor, transplantation, and recipient were analyzed using 1-way analysis of variance. Perioperative blood loss and peak value of AST and ALT were analyzed by using the Kruskal-Wallis test. Patient and graft survival rates, noncensored for death, were analyzed by Kaplan-Meier estimation with a log-rank test for differences.

MULTIVARIATE ANALYSIS

To analyze the influence of covariates on blood loss, a multivariate logistic regression was performed using donor, transplantation, and recipient covariates that were most likely to influence blood loss. A possible interaction between TPCS and IAR was also examined in a secondary model. The level of significance was set at 0.05. Statistical analyses were performed using SPSS, version 25.0 for Windows (SPSS Inc., Chicago, IL).

Results

In total, 365 patients received a LT between January 2005 and May 2017. There were 60 recipients who were excluded due to receiving either a domino LT (n = 3), split-liver transplantation (n = 2), auxiliary LT (n = 11), or retransplantation (n = 44). The use of a TPCS and the order of reperfusion could not be traced in 2 patients, who were therefore excluded from further analysis. Of the 303 recipients included in the study, 156 (51%) received no temporary portocaval shunt with initial portal reperfusion (A–S–); 15 (5%) received no temporary portocaval shunt with initial arterial reperfusion (A+S–); 41 (14%) received temporary portocaval shunt with initial portal reperfusion (A–S+); and 91 (30%) received temporary portocaval shunt with initial arterial reperfusion (A+S+).

TABLE 1. Donor, Transplantation, and Recipient Characteristics

	A–S– (n = 156)	A+S– (n = 15)	A–S+ (n = 41)	A+S+ (n = 91)	*P* Value
Donor age, years	48 ± 15	46 ± 20	46 ± 15	45 ± 16	0.56
Recipient age, years	54 ± 10	48 ± 15	52 ± 14	55 ± 10	0.10
Recipient BMI, kg/m^2	27 ± 5	26 ± 4	25 ± 4	26 ± 4	0.36
Medical history, %					0.16
Metabolic disease	4	0	7	4	
Acute liver disease	5	0	10	9	
Cholestatic liver disease	11	40	17	13	
Alcoholic liver disease	19	13	5	18	
Malignancy	32	20	46	36	
Hepatitis B	2	0	2	2	
Hepatitis C	4	0	0	4	
Other cirrhosis	15	7	7	9	
Other/unknown	8	20	6	6	
DCD liver grafts, %	33	27	32	54	**0.005**
Portal hypertension, %	25	43	44	35	0.10
ET-DRI	1.81 ± 0.3	1.73 ± 0.4	1.70 ± 0.3	1.83 ± 0.3	0.18
sRRI	1.96 ± 0.6	1.80 ± 0.4	1.94 ± 0.7	2.08 ± 0.7	0.26
DRM	1.40 ± 0.1	1.35 ± 0.1	1.38 ± 0.1	1.42 ± 0.1	0.11
BAR score	5.983 ± 4.2	5.60 ± 4.1	7.02 ± 5.3	6.38 ± 4.7	0.42
Laboratory MELD	15 ± 8	15 ± 9	16 ± 11	16 ± 9	0.75
CIT, minutes	566 ± 124	552 ± 168	522 ± 108	540 ± 127	0.18
WIT, minutes	34 ± 8	42 ± 11	38 ± 14	39 ± 12	**<0.001**
Operative time, minutes	338 ± 82	355 ± 99	358 ± 93	322 ± 90	0.12

NOTE: Data are presented as mean ± SD. Bolded values are significant.

DONOR, TRANSPLANT, AND RECIPIENT CHARACTERISTICS

Tables 1-4 show the basic donor, transplantation, and recipient characteristics of all groups. The A+S+ group consisted of a significantly higher percentage of DCD LTs compared with the other groups (33% in the A–S– group versus 27% in the A+S– group versus 32% in the A–S+ group versus 54% in the A+S+ group; $P = 0.005$). The warm ischemia time was significantly shorter in the A–S– group compared with the other groups (34 ± 8 minutes in the A–S– group versus 42 ± 11 minutes in the A+S– group versus 38 ± 14 minutes in the A–S+ group versus 39 ± 12 minutes in the A+S+ group; $P < 0.001$). Other donor, transplantation, and recipient characteristics did not significantly differ among the groups. Also, the mean operative time did not significantly differ among the groups ($P = 0.12$).

TABLE 2. Post Hoc Analysis for WIT and DCD LTs

	P Value	
Operation Technique	WIT	DCD
A–S–		
A+S–	**0.005**	0.78
A–S+	**0.02**	0.17
A+S+	**<0.001**	**0.002**
A+S–		
A–S–	**0.005**	0.78
A–S+	0.24	0.79
A+S+	0.31	**0.009**
A–S+		
A–S–	**0.02**	0.17
A+S–	0.24	0.79
A+S+	0.71	**0.03**
A+S+		
A–S–	**<0.001**	**0.002**
A+S–	0.31	**0.009**
A–S+	0.71	**0.03**

NOTE: Bolded values are significant.

BLOOD LOSS

Tables 3 and 4 show the hematological and coagulation parameters of all groups preoperatively and the number of packed RBCs, FFP, and Cell Saver fluid (mL) transfused during the first 24 hours from incision. The partial thromboplastin time (PTT) in the A–S– group was significantly shorter compared with the other groups ($P = 0.04$). Other preoperative hematological and coagulation parameters did not differ between both groups. The median number of packed RBCs transfused in the A–S– group was 6 ± 7 units (range, 0-33 units) versus 2 ± 6 units (range, 0-19 units) in the A+S– group, 5 ± 6 units (range, 0-30 units) in the A–S+ group, and 2 ± 5 units (range, 0-23 units) in the A+S+ group ($P < 0.001$; Fig. 1). When analyzing outcomes based on TPCS status alone, the use of a TPCS showed a significantly lower median number of transfused RBCs compared with the group who did not receive a TPCS (3 versus 6 units; $P < 0.001$).

Of the recipients in the A+S+ group, 31% did not receive any RBCs perioperatively, versus 28% in the A–S+ group, 27% in the A+S– group, and 8% in the A–S– group ($P < 0.001$). The mean amount of FFP transfused as well as the mean volume of Cell Saver transfused did not differ among the groups.

TABLE 3. Hematological, Coagulation, and Transfusion Parameters Before, During, and After Surgery

	A–S– (n = 156)	A+S– (n = 15)	A–S+ (n = 41)	A+S+ (n = 91)	*P* Value
INR before surgery	1.35 ± 0.41	1.39 ± 0.48	1.51 ± 0.60	1.40 ± 0.44	0.25
Platelet count before surgery, 10^9/L	110 ± 80	164 ± 118	123 ± 98	119 ± 82	0.12
PTT before surgery, seconds	18 ± 7	20 ± 7	21 ± 9	20 ± 7	**0.04**
Fibrinogen before surgery, g/L	2.9 ± 1.4	3.5 ± 1.5	3.7 ± 5.6	2.8 ± 1.4	0.15
FFP, units	9 ± 9	7 ± 9	10 ± 9	8 ± 9	0.45
Packed RBCs, units	6 ± 7	2 ± 6	5 ± 6	2 ± 5	**<0.001**
Cell Saver, mL*	1072 ± 1158	918 ± 1006	887 ± 949	1418 ± 1231	0.11
No packed RBCs used, %	8	27	28	31	**<0.001**

NOTE: Data are presented as mean or median ± SD. Bolded values are significant.
*Cell Saver values were missing for 99 recipients.

TABLE 4. Post Hoc Analysis for Packed Cells Transfused

Operation Technique	*P* Value
A–S–	
A+S–	0.06
A–S+	0.66
A+S+	**<0.001**
A+S–	
A–S–	0.06
A–S+	0.14
A+S+	0.98
A–S+	
A–S–	0.66
A+S–	0.14
A+S+	**0.01**
A+S+	
A–S–	**<0.001**
A+S–	0.98
A–S+	**0.01**

NOTE: Bolded values are significant.

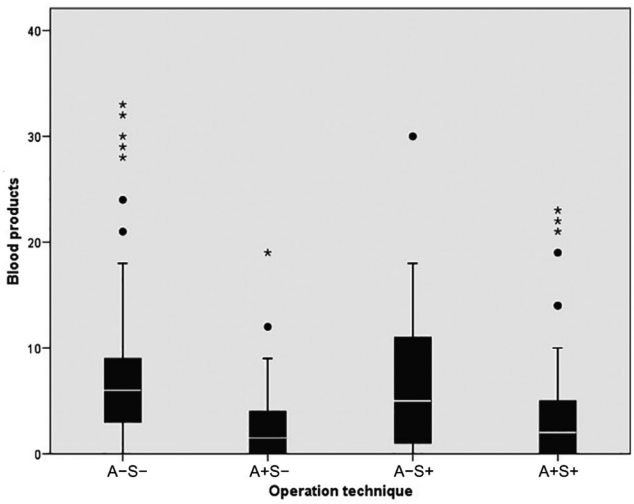

FIG. 1. Boxplot showing the distribution of RBCs transfused perioperatively among the 4 groups. • = outliers, * = extreme outliers.

POSTTRANSPLANTATION PEAK OF AST AND ALT

Table 5 shows the median peak of AST and ALT during the first 7 days after transplantation. The median peak of AST and ALT for all groups did not significantly differ (AST, $P = 0.89$; ALT, $P = 0.92$).

When analyzing only DCD LT, the median peak of AST and ALT also did not significantly differ for all groups (AST, $P = 0.13$; ALT, $P = 0.31$). Also, when performing a Kaplan-Meier analysis with log-rank testing on biliary complications, no significant difference was seen among all groups ($P = 0.57$) even though the A+S+ group consisted of significantly more DCD LTs ($P = 0.005$).

POSTOPERATIVE COMPLICATIONS

When comparing postoperative complications, no statistical difference was seen in Clavien-Dindo complications that were of a grade ≥3 ($P = 0.85$; Table 6).

PATIENT AND GRAFT SURVIVAL

Figure 2 shows the 1-year patient survival. No significant difference was found when comparing all of the groups. Figure 3 shows the 1-year graft survival noncensored for death. No significant difference was found in 1-year patient survival or in 1-year graft survival noncensored for death.

MULTIVARIATE ANALYSIS

When performing multivariate logistic regression of all covariates included, the laboratory MELD score ($P < 0.001$) and IAR ($P = 0.01$) were identified as individual determinants for increased transfusion of RBCs. Interestingly, TPCS did not show a significant difference ($P = 0.78$). Furthermore, IAR and TPCS did not show a significant statistical interaction ($P = 0.54$; Table 7). All other potential determinants did not show a significant difference.

Discussion

This cohort study demonstrates that LT with IAR and TPCS was associated with less perioperative transfusion of RBCs. Furthermore, multivariate analysis showed that laboratory MELD and IAR were individual determinants on the number of RBCs transfused.

To our knowledge, this study is the first to use multivariate analysis to determine individual determinants of perioperative transfusion of RBCs in LT. When performing univariate analysis, a significant beneficial effect of IAR and TPCS on transfusion of RBCs during LT was shown ($P < 0.001$). However, multivariate analysis showed only laboratory MELD and IAR to be individual determinants of perioperative

TABLE 5. Peak of AST and ALT During the First 7 Days After Transplantation for the Whole Population as Well as for DCD LT Separately

	A–S– (n = 156)	A+S– (n = 15)	A–S+ (n = 41)	A+S+ (n = 91)	*P* Value
AST, U/L	1218 ± 2832	1332 ± 1556	1096 ± 2974	1126 ± 2573	0.89
ALT, U/L	775 ± 1863	742 ± 1285	688 ± 1804	777 ± 1713	0.92
DCD LT					
AST, U/L	2199 ± 4017	3833 ± 1900	1161 ± 4663	1309 ± 2893	0.13
ALT, U/L	1525 ± 2326	2011 ± 2000	947 ± 2877	925 ± 1814	0.31

NOTE: Data are given as median ± SD.

TABLE 6. Clavien-Dindo Complications Grade ≥3

	A–S– (n = 156)	A+S– (n = 15)	A–S+ (n = 41)	A+S+ (n = 91)	*P* Value
Clavien-Dindo classification grade					
3a	18 (12)	2 (13)	4 (10)	10 (11)	
3b	27 (17)	3 (20)	5 (12)	18 (20)	
4a	8 (5)	0 (0)	4 (10)	8 (9)	
4b	7 (4)	0 (0)	1 (2)	1 (1)	
5	5 (3)	1 (7)	1 (2)	3 (3)	
Total	65 (42)	6 (40)	15 (37)	40 (44)	0.85

NOTE: Data are given as n (%).

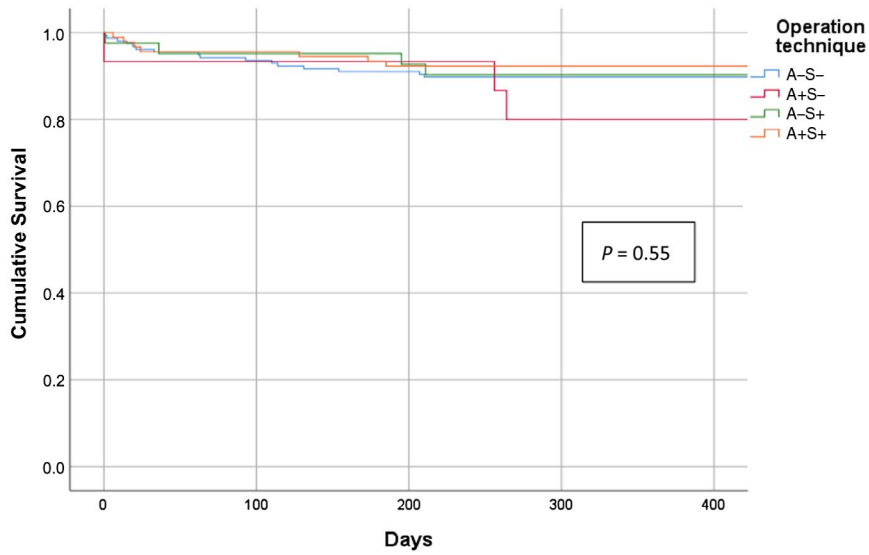

FIG. 2. The 1-year patient survival curve.

transfusion of RBCs, whereas the interaction between IAR and TPCS was low ($P = 0.54$). The beneficial effect of a TPCS, by using univariate analysis, has been described before (Table 8).[7,26-28] These studies do not describe the order of reperfusion used during transplantation, although we assume that portal reperfusion was first. A meta-analysis performed by Pratschke et al. showed a significant beneficial effect of a TPCS on operative blood loss, but the I^2 values indicated substantial heterogeneity among the studies ($P < 0.05$), which could bring a potential bias to the results.[29]

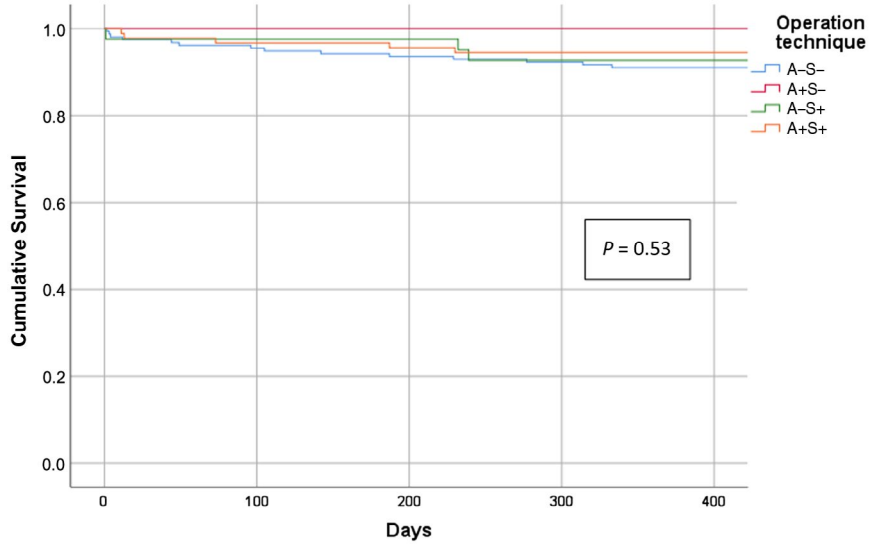

FIG. 3. The 1-year graft survival curve noncensored for death.

TABLE 7. Multivariate Analysis on Perioperative Transfusion of RBCs

	B	SE	*P* Value
TPCS (n = 303)	–0.001	0.15	0.78
IAR (n = 303)	–0.386	0.15	**0.01**
Donor sex (n = 303)	0.136	0.11	0.20
Recipient sex (n = 303)	0.026	0.12	0.85
Recipient diagnosis (n = 303)	0.006	0.03	0.45
Donor liver type, DBD/DCD (n = 303)	0.057	0.12	0.82
Organ-perfusing support before transplant (n = 303)	–0.487	0.24	0.10
Platelets before operation, 10^9/L (n = 301)	0.0	0.001	0.83
Fibrinogen before operation, g/L (n = 299)	–0.038	0.02	0.13
Recipient age, years (n = 303)	0.001	0.005	0.61
Recipient BMI, kg/m^2 (n = 303)	0.0	0.012	0.92
Donor age, years (n = 303)	–0.003	0.004	0.52
Laboratory MELD (n = 303)	0.034	0.007	**<0.001**
Donor last GGT, U/L (n = 300)	0.001	0.001	0.33
Hepatic vein pressure gradient, mm Hg (n = 256)	0.0	0.006	0.89
TPCS * IAR			0.54

NOTE: Bolded values are significant. R^2 = 0.224 (adjusted R^2 = 0.127).
*Statistical interaction.

Multivariate analysis showed IAR to be an individual determinant on perioperative blood loss in LT. A possible explanation for this could be that the hepatic artery accounts for less total liver perfusion. Therefore, IAR may lead to a more controlled reperfusion and less blood loss.

This study also demonstrates that the use of a TPCS and the order of reperfusion used in LT do not have a significant influence on 1-year patient survival nor on 1-year graft survival. In general, DCD LT is associated with more complications and inferior outcomes compared with DBD LT.[23,30] Even though the A+S+ group consisted of significantly more DCD LTs, we did not see a significant difference in patient and graft survival rates among the groups. Because the complication rate is higher with DCD LT compared with DBD LT, this may indicate a beneficial effect of both the use of IAR and TPCS. This is a very interesting finding that needs further research, especially because >40% of LTs in the Netherlands are with a DCD liver.

The operative time between the patients with or without TPCS was almost identical. Creating a TPCS takes some extra time, but clearly these extra minutes are saved during the rest of the procedure. A possible explanation could be that the TPCS causes less venous congestion and resolves portal hypertension. This may make liver mobilization easier with less risk of blood loss, and because the liver hilum is fully transected, this may facilitate access to the dissection plane between the liver and the caval vein. Therefore, less time may be needed for hemostasis and explantation of the native liver. Furthermore, a better hemodynamic

TABLE 8. Characteristics of Studies Included in the Meta-Analysis by Pratschke et al.[29] as Well as a Recent Study by Rayar et al.[28] Showing TPCS Versus No TPCS

References	Country	Study Design	Number of Patients (Interventional/ Control)	Transplantation Type (Intervention/Control)	Graft Type	RBC Transfusion	FFP Transfusion	Biochemical Markers	Operation Time (Duration)	Patient Survival	Graft Survival
Hesse et al.[27]	Belgium	Retrospective case-control study	16/49	Laterolateral cavocavostomy with/without TPCS	NR	↓	=	AST NR ALT NR	=	NR	NR
Figueras et al.[3]	Spain	Randomized controlled trial	40/40	OLT (piggyback technique) with/without TPCS	NR	=	=	AST NR ALT NR	=	NR	NR
de Cenarruzabeitia et al.[26]	Spain	Retrospective case-control study	356/45	OLT (piggyback technique) with/without TPCS	NR	↓	NR	AST NR ALT NR	=	NR	NR
Arzu et al.[5]	Italy	Retrospective case-control study	89/97	OLT (cavocavostomy end-to-side anastomosis) with/ without TPCS	Cadaveric	=	=	ALT NR ALT NR	↓	NR	NR
Ghinolfi et al.[7]	Spain	Retrospective case-control study	58/90	OLT (piggyback technique) with/without TPCS	NR	↓	=	AST = ALT =	=	=	=
Pratschke et al.[8]	Germany	Retrospective case-control study	274/174	OLT (piggyback technique) with/without TPCS	DBD	=	↑	AST = ALT ↓	NR	NR	↑
Rayar et al.[28]	France	Retrospective case-control study	343/343	OLT (laterolateral cavocavostomy with/without TPCS)	DBD	↓	↓	AST = ALT =	↑	NR	↑

NOTE: Content is partially adopted from the meta-analysis by Pratschke et al.[29] (↑) = significant more, (↓) = significant less, (=) = no significant difference.

status during surgery due to less venous congestion may result in a more controlled situation. Since the introduction of the new protocol with IAR and TPCS, a significant increase in the number of recipients who did not receive any perioperative transfusion of RBCs was seen. This is in concordance with Figueras et al.,[3] who showed less decrease in cardiac output in the TPCS group ($P = 0.05$) as well as a greater diuretic output during the anhepatic phase ($P = 0.005$).

This study has some potential limitations. First, the nonrandomized character could bring a potential bias. Most controls were from the oldest cohort. However, some of the controls were from the most recent cohort, when the use of a TPCS and choice of reperfusion technique were according to the surgeon's preference. With the introduction of a new operative protocol, a selection bias is possible because the technique was new for some surgeons, and therefore, some preferred to use the previous surgical technique with initial portal reperfusion and no TPCS. Also, because of the retrospective character of the study, it is possible that other small changes in protocol have occurred during the study period, even though to our knowledge this is not the case. The major changes in protocol were the use of a TPCS and IAR. All relevant factors were included in the multivariate analysis to correct for these.

In conclusion, next to a lower laboratory MELD score, the use of IAR leads to significantly less perioperative blood transfusion. There was no significant interaction between IAR and TPCS. Furthermore, the use of a TPCS and/or IAR does not lead to increased operative time and is therefore a reasonable alternative surgical strategy.

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