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CAVOPORTAL HEMITRANSPOSITION IN LIVER TRANSPLANTATION: TOWARDS A MORE SAFE AND EFFICIENT TECHNIQUE

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ABREVIATIONS used in the text:

CC-LT	Cavo-caval liver transplantation
CPHTr,	Cavoportal hemitransposition
IVC,	Inferior vena cava
LT,	Liver transplantation
PV,	Portal vein
SplVT,	Splanchnic vein thrombosis

KEY-WORDS: liver transplantation; multi-visceral transplantation; surgical technique; portal vein thrombosis; splanchnic vein thrombosis; vena cava preservation.

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ABSTRACT

Extended splanchnic venous thrombosis represents a challenge for the liver transplant surgeon. In the absence of large venous tributaries, the cavo-portal hemitransposition (CPHTr) and the

combined liver-intestinal or multi-visceral transplantation are the only technical solutions. Due to the reported high morbidity and mortality rates (it is used infrequently and lacks standardization), the former technique has (almost) been abandoned by the transplant community. A newly designed technique of CPHTr based on the combination of inferior vena cava sparing hepatectomy, large latero-lateral cavo-caval and end-to-side cavo-portal anastomoses, separated only by a double vascular stapler line is presented. This technique allows the splanchnic blood completely to be diverted towards the allograft and to eliminate low flow IVC areas, possibly leading to complications.

Conclusion: The here proposed modified CPHTr technique offers a valuable alternative to much more complex and invasive intestinal transplantation procedures.

INTRODUCTION

Splanchnic venous thrombosis (SplVT), a part of the natural evolution of chronic liver diseases, is frequently encountered in liver transplantation (LT) (1,2). In order to perform a successful LT, preoperative imaging of the acquired splanchnic venous and/or portosystemic anatomy, timing of donor and recipient surgeries aiming at keeping cold and warm ischemia times to a minimum and deciding on the method of portal vein (PV) reconstruction *before* starting the allograft implantation are essential (3). The applied technical modification of the transplant procedure depends on the extent of the thrombus, the quality of the venous vessel wall, and the final intra-operative evaluation. Eversion thrombectomy and the jump graft technique, connecting donor PV and superior mesenteric or left renal veins, are frequently used to address the problem. Both techniques allow a safe procedure in most recipients, even in case of extended porto-splenic-mesenteric venous thrombosis (3,4). If impossible to achieve, large and patent splanchnic tributaries such as choledochal, hepatoduodenal, left gastric, gastro-epiploic and ileocolonic varices, identified at pre- or intra-operative venography, have all occasionally been reported to be adequate venous inflow allograft vessels (5). PV arterialization, considered as a last resort, has been abandoned because of the compromised (both early and long-term), outcome related to bleeding, acute and secondary PVT, graft fibrosis (due to modified hepatic microcirculation), right-sided heart decompensation and portal hypertension (due to ‘‘over-arterialization’’) (6). If none of those mentioned above options are applicable, only two solutions remain, namely the cavoportal hemitransposition (CPHTr) and the, much more invasive, combined liver-intestinal or multi-visceral transplantation (7,8). Although designed very early in the technical development of LT by Starzl, CPHTr technique has (almost) been abandoned by the surgical transplant community due to the very high reported morbidity and mortality rates. As a corollary, reported experience in the literature is scarce and standardization of the technique lacking (9-13) (**Table 1**).

CPHTr represents an exceptional technique to overcome an extensive splanchnic venous thrombosis. The inflow from the inferior vena cava (IVC) is used to perfuse the PV of the allograft. CPHTr was first developed in animal models for the treatment of some metabolic

diseases. The first human series were performed by Starzl et al. and Riddell et al. for glycogen storage disease (9,14). In 1998, Tzakis et al. reported an initial LT-series of nine cases of CPHTr, which was later extended to 23 patients (11,12). To date, less than 100 cases have been reported worldwide (15).

CPHTr is reported either as an end-to-end or as an end-to-side anastomosis between IVC and PV. The end-to-side anastomosis has been merely carried out in case of the considerable incongruence of PV and IVC diameters. Both connections eventually require the use of an interposition graft to avoid vessel shortness or stretching resulting in stenosis or thrombosis. In the end-to-end technique, the infra-hepatic donor IVC is ligated; in the end-to-side anastomosis, the infra-hepatic IVC is banded, ligated or even transected above the anastomosis to direct all systemic venous blood flow to the allograft. Information about the long-term outcome of CPHTr is almost nonexistent; only a small number of reported cases have a follow-up over five years (15).

The procedure carries high mortality (up to 35%) and morbidity related to anastomotic problems, congestion of the IVC, and insufficient decompression of the splanchnic venous compartment (**Table 2**). These conditions lead to thrombotic events, ascites (90%), mild-to-severe edema of lower torso and limbs, mild (usually) transient, renal dysfunction, and multi-organ failure. Hemodialysis has been reported in 14% of patients and, early or delayed, variceal bleeding in 21% of patients. The majority of gastrointestinal bleeds have been controlled with interventional endoscopy (variceal ligation), radiology (splenic artery embolization) and surgery (splenectomy, sometimes completed with gastric devascularization) (12). Anastomotic thrombosis or stenosis, reported in 18% of patients, has been treated by endovascular stenting (15).

All the hereto-reported CPHTr techniques have several shortcomings explaining the high reported morbidity and mortality of this procedure. IVC resecting LT procedure in the presence of extended SplVT may lead to significant blood losses due to the presence of large retroperitoneal venous collaterals; such event can be counteracted by the IVC sparing hepatectomy technique. Banding, ligation or section of the intrahepatic (donor or recipient) IVC all create a ‘low flow’ area in the distal IVC segment, a condition that may lead to the formation of thrombi and pulmonary emboli. This risk of thrombus formation in the preserved, but partially excluded, recipient IVC is further

raised in the case of the classical piggy-back allograft implantation. Review of the literature reveals three cases of pulmonary embolism, all of them occurring after end-to-side cavoportal anastomosis. This complication is very probably underreported, taking into account the short follow-up of most published case reports and series (15).

To reduce the complication of this procedure, the authors designed a modified CPHTr technique, based on the combination of IVC sparing hepatectomy, end-to-side IVC-PV anastomosis, and IVC stapling (16).

SURGICAL TECHNIQUE

The modified CPHTr technique consists of three simple steps. After an IVC sparing hepatectomy, the allograft is implanted using a large, six-cm-long, latero-lateral cavo-caval anastomosis under partial clamping of the recipient IVC using a specially designed IVC clamp (Lerut-Satinsky clamp®, Ulrich, St-Gallen, CH) (**Fig.1A**). This clamp is a Satinsky clamp of which both the vertical tip and the horizontal part have been prolonged to allow a safer lateral clamping of the IVC and a more comfortable suturing of donor and recipient IVCs. The portal revascularisation is done using an end-to-side cavo-portal anastomosis, which is at a distance of 2 cm beneath the inferior angle of the caval anastomosis and largely above the renal veins (**Fig.1B and C**). This distance corresponds to the breath of a double-rowed, vascular stapler (United States Surgical Corporation, Norwalk, Connecticut, USA). Lastly, the recipient IVC is transversally stapled, thereby accurately separating both caval anastomoses; the IVC is thus not transected (**Fig.1D**). Both venous anastomoses are arranged in such a way that 'diverted splanchnic blood' is wholly directed towards the allograft and that low flow IVC areas are virtually eliminated. This straightforward procedure can be done within 30 minutes without the use of venovenous bypass. Biliary reconstruction was by a Roux-Y hepaticojejunostomy in all cases, and all patients received postoperative anticoagulation as well as regular upper endoscopic checks. Due to possible early and late postoperative complications, splenectomy is not considered during the liver transplant procedure.

RESULTS

This technique was successfully applied in four adults; three of them had a follow-up over ten

years. In all here described cases the decision to go for CPTr was made pre-operatively after confirmation of the presence of a pronounced venous, abdominal, collateral network at imaging. Patient 1, a 43-year-old male, was transplanted because of a decompensated secondary biliary cirrhosis eight years after a multimodal treatment (including neo-adjuvant radio-chemotherapy and curative right extended hepatectomy) of a perihilar cholangiocellular cancer. The extremely difficult hepatectomy was responsible for a very long cold ischemia (21 hours), major benign cholestasis, and complex recovery. He died two months post-LT due to CMV pneumonia and candida-sepsis in the presence of normal allograft vascularization.

Patient 2, a 56-year-old female, was transplanted because of chronic Budd-Chiari syndrome of unknown origin. She, unfortunately, developed a stricture of the cavo-portal anastomosis eight months post-LT arising from a technical problem (too much vessel traction in the absence of an adequate vessel graft). After insertion of an endovascular stent, her evolution was uneventful as testified by her intense activity as a long-distance hobby-walker. Seven years post-LT, the endovascular stent thrombosed and a hilar cavernoma developed. A splenectomy and gastric devascularization were performed because of the occurrence of repetitive gastrointestinal bleedings. Three weeks later a reintervention was necessary for hemorrhagic shock due to an arterial erosion in the Roux-Y loop. She recovered very well, but several endovascular radiologic procedures, including thrombolysis of both the stent and an intraportal thrombosis, and endoscopic variceal ligations were necessary to cope with the consequences of the anastomotic stenosis and stent occlusion. During the following six years, her quality of life remained good despite several of these interventions. Thirteen years post-LT she died of a combined hemorrhagic (spontaneous retroperitoneal bleeding) and E.Coli sepsis-induced multi-organ failure. Retrospectively, one may state that her very long-term evolution was finally compromised by the original technical issues during her LT.

Patient 3, a 36-years old, Portuguese female, was transplanted because of a familial amyloid polyneuropathy. Eight months post-LT, she presented with a severe upper gastrointestinal bleeding caused by a ruptured esophageal varix. Splenectomy and gastric devascularization were successfully performed. Eighteen months post-LT a redo of the stenosed hepaticojejunostomy was

done without problems. She is doing very well 13 years post-LT. An angio-scan, done ten years after LT, showed a patent cavo-portal anastomosis and a standard intra-hepatic venous system.

Patient 4, a 42-years old Romanian male, was transplanted because of a decompensated viral C cirrhosis responsible for repetitive esophageal variceal bleedings despite a previous Sugiura procedure (azygo-portal disconnection and splenectomy). Eighteen years post-LT he is entirely asymptomatic, and angio-CT shows a typical vascularization pattern in the presence of a patent cavo-portal anastomosis (**Fig.2 and 3**).

CONCLUSION

Diffuse splanchnic vein thrombosis may compromise the outcome of liver transplantation. A modified and simplified technique of cavoportal hemitransposition is described. Attention to technical details may improve short- as well as long-term results of this almost 'forgotten' procedure. The presented technique offers a valuable alternative to the much more invasive liver-intestinal or multi-visceral transplantation and therefore needs to be considered seriously in patients presenting with an extended splanchnic venous thrombosis.

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TABLES

Table 1. Reported cases of CPHT with the different reconstruction techniques adopted.

Name First Author	Year	Country	N	IVC Replacement/ Preservation	IVC-PV anastomosis	PB (LL/Cuff)	IVC Interruption/ Narrowing
Weeks SM	2000	United States	1	Preservation=1	E-E=1	PB (NA) =1	Interruption (ligation) =1
Varma CR	2000	United States	1	Preservation=1	E-E=1	PB (NA) =1	Interruption (stapler) =1
Olausson M	2001	Sweden	6	Preservation=6	E-E=6	PB (NA) =6	Interruption=6
Santaniello W	2001	Italy	1	Preservation=1	S-E=1	PB (NA) =1	Narrowing=1
Bakthavatsalam R	2001	United States	1	Replacement=1	E-E=1	No PB=1	Interruption=1
Urbani L	2002	Italy	6	Replacement=6	E-E=5 S-E=1	No PB=6	Interruption=5 Narrowing=1
Gerunda GE	2002	Italy	2	Preservation=1 Replacement=1	S-E=1 E-E=1	PB (Cuff)=1 No PB=1	Interruption=1 NA=1
Shrotri M	2003	United Kingdom	1	Preservation=1	E-E=1	PB (Cuff) =1	Interruption=1
Kumar N	2003	United Kingdom	1	Replacement=1	E-E=1	No PB=1	NA=1
Verran D	2004	Australia	1	Preservation=1	E-E=1	PB (Cuff) =1	NA=1
Bertelli R	2005	Italy	1	NA=1	NA=1	NA=1	NA=1
Wang C	2005	China	1	Replacement=1	E-E=1	No PB=1	Interruption=1
Ozden I	2006	Turkey	1	Preservation=1	E-E=1	PB (Cuff) =1	Interruption=1
Lipshutz GS	2006	United States	7	Replacement=7	E-E=6 S-E=1	No PB=7	Interruption=6 No=1
Egawa H	2006	Japan	1	Preservation (LDLT) =1	E-E=1	PB (Cuff) =1	Interruption=1
Lladó L	2007	Spain	1	NA=1	NA=1	NA=1	NA=1
Selvaggi G	2007	United States	23	NA=23	E-E=15	NA=23	Interruption=23

					S-E=8		
Li FG	2008	China	1	NA=1	E-E=1	NA=1	Interruption=1
Yan ML	2008	China	3	NA=3	NA=3	NA=3	NA=3
Pan C	2009	China	1	NA=1	NA=1	NA=1	NA=1
Tao YF	2009	China	2	NA=2	NA=2	NA=2	NA=2
Gao PJ	2009	China	2	NA=2	NA=2	NA=2	NA=2
Campsen J	2010	United States	1	Preservation=1	E-E=1	PB (NA) =1	Interruption=1
Suarez Artacho G	2010	Spain	4	NA=4	NA=4	NA=4	NA=4
Ravaioli M	2011	Italy	6	NA=6	NA=6	NA=6	NA=6
Shi Z	2011	China	1	Preservation (LDLT) =1	S-E=1	PB (Cuff) =1	Interruption=1
Bhangui P	2011	France	3	Preservation=2 Replacement=1	S-E=3	PB=2 No PB=1	Narrowing=3
Lai Q	2012	Belgium	8	Preservation=3 Replacement=5	S-E=6 E-E=2	PB (LL)=3 No PB=5	Interruption=8
Chmurowicz T	2013	Poland	1	Preservation =1	E-E=1	PB (LL) =1	Interruption & Narrowing=1
Rodríguez-Castro K	2013	Italy	1	Preservation =1	E-E=1	PB (LL) =1	Interruption =1
Srivastava M	2015	India	1	Preservation (LDLT) =1	E-E=1	PB (Cuff) =1	Interruption & Narrowing=1
Kobe A	2016	Switzerland	1	NA=1	E-E=1	NA=1	Interruption=1
Total			**N=92**	**Preservation=24** **Replacement=23** **NA=45**	**E-E=50** **S-E=22** **NA=20**	**PB=24** **No PB=23** **NA=45**	**Interruption=63** **Narrowing=5** **NA=24**

Abbreviations: IVC, inferior vena cava; PV, portal vein; LL, PB, piggyback; latero-lateral; E-E, end-to-end; NA, not available; S-E, side-to-end.

Table 2. Reported cases of CPHT with the different complications and mortality events reported.

Name First Author	Year	Country	N	Post-LT				
				Embolism	Variceal bleeding	Cavo-portal thrombosis	Severe renal failure	Mortality
Weeks SM	2000	United States	1	1*	0	0	0	0
Varma CR	2000	United States	1	0	0	0	0	0
Olausson M	2001	Sweden	6	0	1	2	2	1
Santaniello W	2001	Italy	1	0	1	0	1	0
Bakthavatsalam R	2001	United States	1	0	0	0	0	0
Urbani L	2002	Italy	6	0	1	1	1	1
Gerunda GE	2002	Italy	2	0	2	0	2	1
Shrotri M	2003	United Kingdom	1	1*	0	0	0	0
Kumar N	2003	United Kingdom	1	0	0	0	0	0
Verran D	2004	Australia	1	0	0	0	0	0
Bertelli R	2005	Italy	1	0	1	0	0	0
Wang C	2005	China	1	0	0	0	0	0
Ozden I	2006	Turkey	1	0	0	0	0	0
Lipshutz GS	2006	United States	7	0	0	0	0	2
Egawa H	2006	Japan	1	0	0	0	1	1
Lladó L	2007	Spain	1	0	0	0	0	1
Selvaggi G	2007	United States	23	2	7	6	3	13
Li FG	2008	China	1	0	0	1	0	0
Yan ML	2008	China	3	0	1	0	0	1
Pan C	2009	China	1	0	0	0	0	1
Tao YF	2009	China	2	0	0	1	0	0
Gao PJ	2009	China	2	0	1	0	0	2
Campsen J	2010	United States	1	0	0	0	0	0

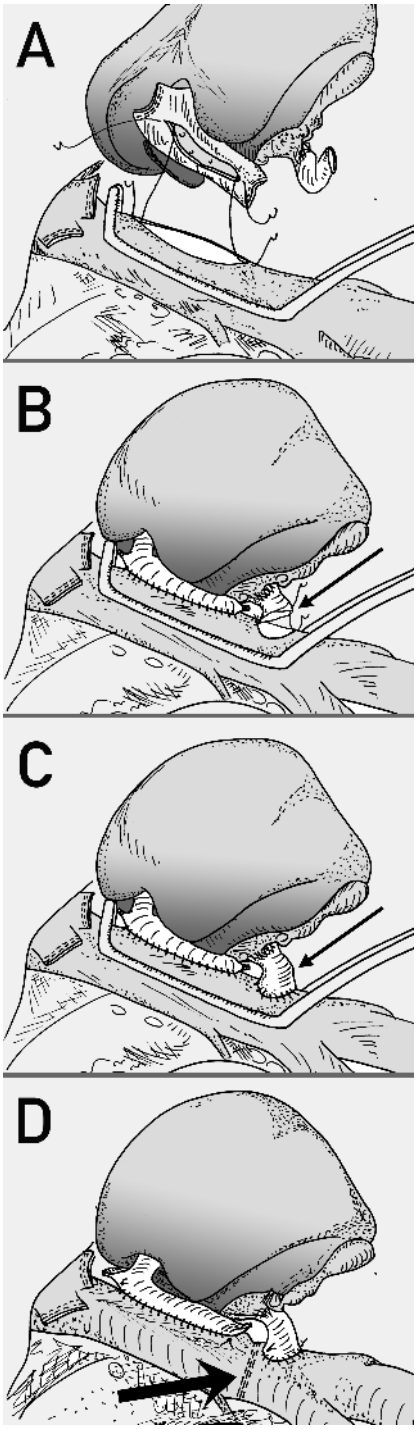
Suarez Artacho G	2010	Spain	4	0	0	0	0	2
Ravaioli M	2011	Italy	6	0	0	0	0	1
Shi Z	2011	China	1	0	0	0	0	0
Bhangui P	2011	France	3	0	1	1	0	1
Lai Q	2012	Belgium	8	0	3	4	2	5
Chmurowicz T	2013	Poland	1	0	0	0	0	0
Rodríguez-Castro K	2013	Italy	1	0	0	0	0	0
Srivastava M	2015	India	1	0	0	0	0	0
Kobe A	2016	Switzerland	1	0	0	0	1	0
Total number (%)			92 (100.0)	4 (4.3)	19 (20.7)	16 (17.4)	13 (14.1)	33 (35.9)
*Saddle embolism of the portal vein.								

LEGEND OF FIGURES

Figure 1. The four different steps of the modified cavoportal hemitransposition in liver transplantation: A) latero-lateral cavo-caval continuous anastomosis; B and C) porto-caval end-to-side anastomosis (arrow); and D) transversal stapling of the vena cava (large arrow).

Figure 2. A and B) Angio-CT scan shows a patent cavoportal transposition 18 years following liver transplantation. C and D) Both the retro-hepatic and infra-hepatic IVCs are patent over their whole length. Both are separated by a stapler line (dotted arrows) exactly located in between the latero-lateral cavo-caval and cavo-portal anastomoses. Panels A and E both reveal the persistence of the portal cavernoma (*) and the very pronounced para-caval and peri-vertebral (**) venous collateralization, highlighting the advantage of the IVC sparing hepatectomy technique when applying this technique.

Figure 3. Doppler ultrasound examination revealing normal portal flow patterns in both portal (C) and hepatic (D) veins.



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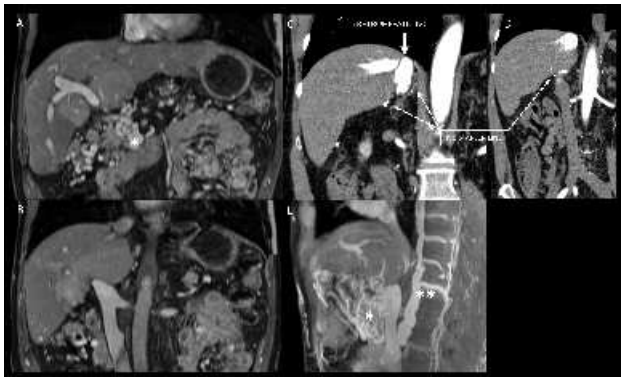

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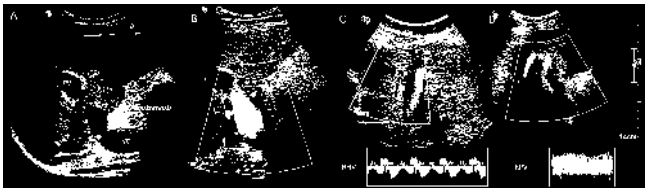

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