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Cavocaval liver transplantation without venovenous bypass and without temporary portocaval shunting: the ideal technique for adult liver grafting?

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Abstract The influence of the implantation technique on the outcome was studied prospectively in a series of 116 consecutive adult patients undergoing primary liver transplantation during the period January 1991–June 1994. Thirty-eight patients (32.8 %; group 1) underwent classical orthotopic liver transplantation (OLT) with replacement of the recipient's inferior vena cava (R-IVC) and with veno-venous bypass (VVB). Thirty-nine patients (33.6 %) had a piggy-back OLT with preservation of the R-IVC (group 2); bypass was used in 17 of them (43.6 %) because of poor hemodynamic tolerance of R-IVC occlusion. Thirty-nine patients (33.6 %) had OLT without VVB and with side-to-side cavocaval anastomosis (group 3). The three techniques were performed irrespective of the anatomical situation and of the status of the recipient at the time of transplantation. The following parameters were assessed in all patients: implantation time, blood product use, morbidity (e.g., hemorrhagic, thoracic, gastrointestinal, neurological, and renal complications), and outcome. Thirty-one patients underwent detailed intraoperative hemodynamic assessment. The early (< 3 months) post-transplant mortality of 10.3 % (12/116 patients) was unrelated to the implantation technique. Group 3 had a significantly shorter mean implantation time, a reduced need for intraoperative blood products, and a lower rate of reoperation due to intra-abdominal bleeding. After excluding two immediate perioperative deaths and eight patients requiring early retransplantation because of primary nonfunction, the frequency of immediate extubation was significantly higher in group 3. Detailed hemodynamic assessment did not show a difference between 6 group 1 patients and 17 group 3 patients, indicating that partial lateral clamping of the IVC fullfills the function of venous bypass. Similar results were obtained in 6 group 2 patients who did not have IVC occlusion. Cavocaval OLT has become our preferred method of liver implantation. It allows the transplantation to be performed without VVB, regardless of the anatomical situation and of the condition of the patient at the time of transplantation. Moreover, it avoids all of the potential complications and costs of VVB.

Key words Liver transplantation, cavocaval technique · Cavocaval technique, liver transplantation · Venovenous bypass, liver transplantation

Introduction

Since its introduction into clinical practice in 1963 by Starzl, the technique of liver grafting has been progressively refined [28]. The classical orthotopic liver transplant procedure (CL-OLT) implies recipient hepatectomy including the retrohepatic part of the recipient's inferior vena cava (R-IVC), whilst extracorporeal venovenous bypass (VVB) is used in order to overcome (potential) hemodynamic instability and to avoid renal and splanchnic venous congestion when occluding the R-IVC.

In 1968, Calne and Williams described a technical modification in which preservation of the R-IVC was complete [5]. This technique, known as piggyback OLT (PB-OLT), was further developed in pediatric OLT, but has only gained acceptance in adult OLT during the last few years, and in most instances VVB was still used [18, 25, 29, 31, 32]. The combination of OLT with a side-to-side cavocaval anastomosis under partial clamping of the R-IVC (CC-OLT) allows OLT to be performed without using VVB [2, 4, 7].

The aim of this prospective study was to assess the feasibility of primary CC-OLT, without VVB and without preservation of portal flow during the anhepatic phase, in a group of 116 consecutive adults. The choice of implantation technique was independent of the intraoperative anatomical conditions and of the condition of the patient at the time of OLT. Various parameters, such as implantation time, intraoperative blood product usage, and hemodynamic profile, were then compared between the patient groups in which the CC-OLT, CL-OLT, and PB-OLT techniques were used.

Materials and methods

Between January 1991 and July 1994, 116 consecutive adult patients underwent primary OLT. Eleven patients (9.4 %) needed one and one patient (0.8 %) two early (< 3 months) retransplantations (re-OLT). Re-OLT was necessary because of primary nonfunction (PNF; $n = 8$), acute rejection ($n = 3$), and hepatic artery thrombosis ($n = 1$) that occurred after a duodenal ulcer bleed. Four patients (3.4 %) had delayed (> 3 months) re-OLT because of chronic rejection ($n = 1$) and diffuse intrahepatic biliary strictures ($n = 3$).

All patients had standardized immunosuppression and anti-infectious prophylaxis, including selective bowel decontamination. Induction immunosuppression consisted of cyclosporin A, azathioprine, and low-dose methylprednisolone; steroids were withdrawn from the 3rd postoperative month onwards.

All patients were anesthesized in a similar way. General anesthesia was maintained with isoflurane and pancuronium. Analgesia was provided with a continuous infusion of sufentanil. None of the patients had perioperative aprotinin administration. VVB was used if there was a decrease in mean arterial pressure of more than 50 % or a decreased cardiac index (> 50 %) during the occlusion test.

Three liver implantation techniques were used. Thirty-eight patients (32.8 %) had a classical OLT (CL-OLT), with removal of the R-IVC and use of VVB (group 1). Thirty-nine patients (33.6 %) had PB-OLT with preservation of the R-IVC (group 2); VVB was used in 17 patients (43.6 %) who became hemodynamically unstable during IVC occlusion. Thirty-nine patients (33.6 %) had OLT with side-to-side cavocaval anastomosis (CC-OLT; group 3). In all cases, the R-IVC was partially clamped in order to perform the single caval anastomosis. Patency of the R-IVC was verified in each case. None of these patients needed VVB. Right split liver and reduced size allografts were used in seven and two patients, respectively.

All transplantations were performed by three experienced liver transplant staff surgeons (JL, JdVdG, JBO). The surgical technique was chosen at random preoperatively by the surgeon on duty, regardless of the condition of the recipient at the time of transplantation and regardless of the anatomical situation. Each surgeon performed all three techniques. These were distributed evenly during the study period and the chosen technique could be performed in all cases.

The preoperative data on the three groups of patients are displayed in Table 1. Patient groups were matched for age, gender, chronic and fulminant liver disease, emergency transplants, pretransplant upper abdominal surgery, splanchnic vein complications (e.g., thrombosis or phlebitis), and renal insufficiency. Two patients from group 2 and four from group 3 had severe impairment of renal function (creatinine clearance < 20 ml/min per 1.73 m^2) due to biopsy-proven glomerulonephritis ($n = 5$) and amyloidosis ($n = 1$); they all had *isolated* OLT without VVB. Seven patients in groups 2 and 3 had pretransplant transjugular intrahepatic portosystemic shunt placement (TIPSS).

Surgical technique

The classical OLT technique follows the guidelines described by Starzl. All patients with normal portal veins have axilloportofemoral VVB [28]. In the case of portal vein thrombosis, an axillofemoral bypass is used. In PB-OLT and CC-OLT, transection of the bile duct and hepatic artery and skeletonization of the portal vein (PV) to the level of the pancreatoduodenal vein allow the liver parenchyma to be freed completely from the retrohepatic IVC without interruption of the PV flow. The right liver lobe is reflected to the left in order to expose the right and anterior sides of the R-IVC. The division of the IVC ligament is, as described by Makuuchi et al. the key element in the dissection of the R-IVC, especially when the prominent part of the caudate lobe encircles the R-IVC [22]. All smaller hepatic veins draining the caudate lobe and right accessory vein(s) are selectively ligated from below upwards. In this way, the suprahepatic veins are approached. The right hepatic vein (RHV) is encircled and transected using an endovascular stapler (Autosuture United States Surgical, Norwalk, Conn., USA). Precise stapler application allows safe and tight transection of the HV without narrowing the R-IVC [19, 20]. This vascular closure avoids bleeding from the parenchymal side when (extensively) mobilizing the liver. The transection of the RHV allows the liver to be reflected from the R-IVC and aids in the safe isolation of the middle (MHV) and left (LHV) hepatic veins. Before completion of the recipient hepatectomy, hemostasis of the retroperitoneal bare areas is performed. After clamping the PV, autotransfusion is achieved by compressing the liver parenchyma. Finally, the MHV and LHV are clamped or transected with the stapler (Fig. 1). The allograft can be reimplanted immediately following liver removal.

In PB-LT, the orifices of the LHV and MHV are joined. If donor and recipient weights are matched, the suprahepatic caval cuff usually fits the ostium of these two veins. If not, the anasto-

Table 1 Preoperative data on 116 consecutive liver transplant recipients

	CL-OLT (Group 1)	PB-OLT (Group 2)	CC-OLT (Group 3)	*P*
Number of patients	38 (32.7 %)	39 (33.6 %)	39 (33.6 %)	NS
Age (years)	46.8 ± 11.6	45.8 ± 12.3	49.4 ± 13.9	NS
Gender (M/F)	23/15	22/17	23/16	NS
Cirrhotic liver disease	32 (84.3 %)	33 (84.6 %)	31 (79.5 %)	NS
*Child-Pugh A	10	5	1	< 0.01[b]
*Child-Pugh B	10	14	11	NS
*Child-Pugh C	12	14	19	< 0.05[b]
Fulminant hepatic failure	6 (15.7 %)	3 (7.7 %)	5 (12.8 %)	NS
Metabolic disease	–	3 (7.7 %)	3[a] (7.7 %)	NS
Emergency transplantation	10 (26.3 %)	6 (15.4 %)	11 (28.2 %)	NS
Previous upper abdominal surgery	13 (34.2 %)	5 (12.8 %)	9 (23.1 %)	NS
Modified portal vein	5 (13.2 %)	3 (7.7 %)	8 (20.5 %)	NS
Organic renal insufficiency (creatinine clearance ≤ 20 ml/min per 1.73 m^2)	–	2 (5.1 %)	4 (10.3 %)	NS
Pre-OLT TIPSS	–	7 (17.9 %)	7 (17.9 %)	< 0.05[c]

[a] Including two patients with familial Portugese amyloidosis
[b] Group 3 vs group 1;
[c] Groups 3 and 2 vs group 1

motic orifice is widened by incising the caval vein in an upward and right direction, thus leaving the stapled RHV intact [15] (Fig. 2). If such is the case, it may be necessary to crossclamp the IVC completely. In PB-OLT, VVB is used only when total IVC clamping is poorly tolerated. The lower IVC cuff of the graft is shortened up to the level of the first major vein draining segment I and oversewn with a running polypropylene 4–0 suture (Prolene, Ethicon, Somerville, N.J., USA).

In CC-OLT, the upper cava cuff is shortened flush to the hepatic veins. Both ends of the IVC are closed with running sutures of polypropylene 4–0. A 6-cm long cavotomy, made on the posterior side of the donor IVC, encompasses the orifices of the major hepatic veins in order to obtain optimal venous allograft drainage and to allow later transjugular biopsy or TIPSS placement [16]. The donor liver is implanted using one large anastomosis between the anterior wall of the R-IVC and the posterior wall of the donor IVC using partial clamping of the R-IVC (Fig. 3). The R-IVC is not encircled or clamped at the level of the diaphragm, and bare areas are not sutured. The anastomosis is performed from the left side using two running sutures of prolene 4–0. During the cavocavostomy, the liver is flushed with cold albumin solution. Next, PV anastomosis is done in standard fashion.

The lateral cava clamp is opened when performing the anterior part of the PV anastomosis. This allows retrograde (sanguinous) flushing of the allograft and complete restoration of caval venous return to the heart before completion of the PV anastomosis. With this technique, the liver can be reperfused within 30 min. The implantation procedure is ended as usual with arterial and biliary reconstructions. All venous anastomoses are done using the intraluminal technique.

In the case of retransplantation, the IVC cuff(s) of the previous allograft are maintained in CL-OLT, PB-OLT, and CC-OLT. In CC-OLT, the failed graft can always be removed very easily without interfering with the IVC flow [19].

Intraoperative hemodynamic assessment

Intraoperative hemodynamic changes were studied in 6 CL-OLT patients (with VVB; group 1), in 6 PB-OLT patients without IVC occlusion and VVB use (group 2), and in 17 CC-OLT patients (without VVB; group 3). Hemodynamic monitoring was also performed in two patients with PB-OLT without VVB, but with total IVC clamping. The parameters studied were blood pressure, pulmonary artery pressure, cardiac index (CI) using a thermodilution technique (Baxter-Edwards, Irvine, Calif., USA), oxygen delivery (DO_2) calculated as the product of CI and arterial oxygen content (ml/dl), and oxygen consumption (VO_2) determined by indirect calorimetry (Deltatrac-Metabolic Monitor, Datex, Helsinki, Finland). All parameters were measured 120 (T1) and 60 (T2) min before hepatectomy, after 30 min of the anhepatic phase (T3), and 30 (T4) and 90 (T5) min after graft reperfusion.

The postoperative course was evaluated for all patients with respect to the implantation technique. Early and late post-transplant morbidity and mortality were defined following the European Liver Transplant Registry as events occurring within or after the first 3 post-transplant months. Primary graft nonfunction was defined as any graft dysfunction necessitating early retransplantation. This decision was based on the presence of encephalopathy and of insufficient synthetic function (measured by prothrombin and factor V level). Ischemic allograft damage was also measured by the peak level of alanine aminotransferase (ALT) during the first 3 post-OLT days.

The effect of different techniques on thoracic complications was evaluated on the basis of the time to extubation (immediate or within 24 h), the incidence of right pleural effusion, and the requirement for drainage during the 1st week. Extubation criteria were based on clinical and blood gases analysis parameters and were as follows: an adequate level of consciousness, respiratory rate < 30 x/min on a T piece, $paO_2 > 60$ mm with less than 3 l of oxygen, $paCO_2 < 40$ mmHg, and absence of metabolic acidosis. Thoracic events occurring later on were not considered because pleural and abdominal fluid overload are then frequently the consequence

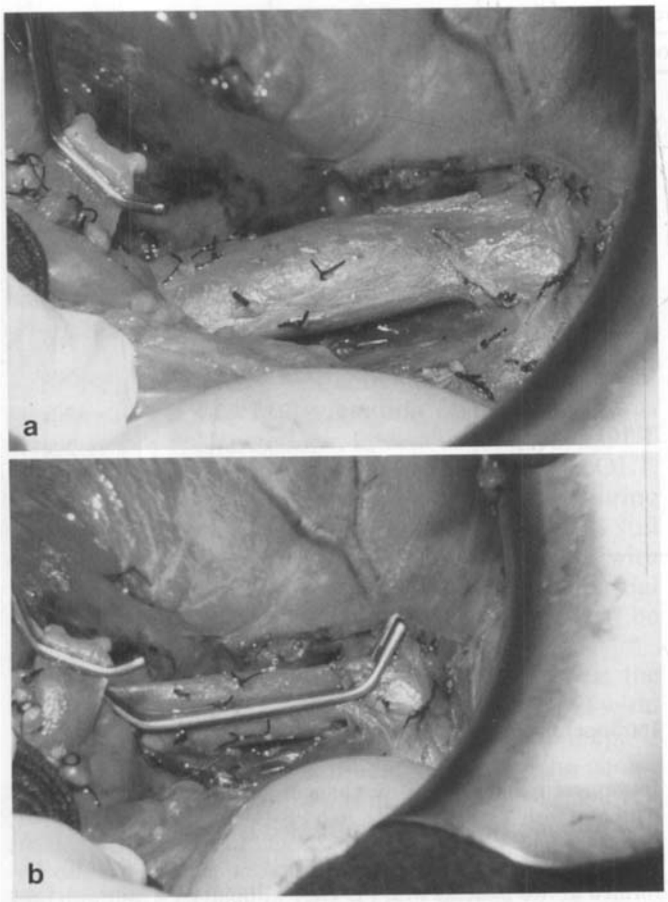


Fig. 1 **a** Intraoperative view of R-IVC preservation after total hepatectomy. One can see the longitudinal and horizontal stapler suture lines of right, middle, and left hepatic veins. There is no encirclement of R-IVC; a porto-caval shunt is not constructed. **b** The R-IVC is clamped partially and laterally in order to prepare allograft implantation

of rejection. Two patients died of hemodynamic failure in the absence of bleeding, and eight patients needed early re-OLT because of PNF; they were excluded from the analysis of thoracic complications. During the 1st week, at least three chest X rays were taken, followed by a weekly X-ray during the 1st month, and then as indicated during follow-up.

The effect of the techniques on bleeding was evaluated by taking into account the amount of intraoperative blood products used and the incidence of reoperations for bleeding. Immediate postoperative blood product use was not considered because persistent bleeding invariably resulted in surgical re-exploration.

All patients had daily Doppler ultrasound (D-US) during the first 5 postoperative days; afterwards, D-US was performed twice weekly during the 1st month and at 3, 6, and 12 months. Special attention was given to the donor IVC and graft outflow at the level of the hepatic veins. Evidence of hepatic vein outflow obstruction was looked for in liver biopsies (performed in all but one patient in the series). All survivors were followed for a minimum of 12 months or until death.

Statistical evaluation

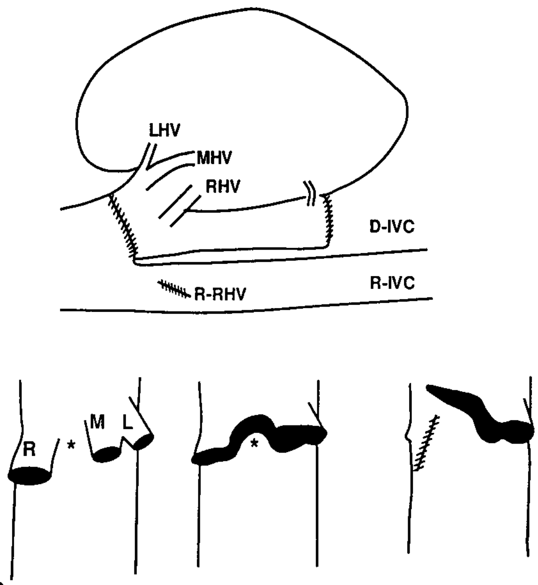
All results are expressed as mean ± standard deviation. Statistical analysis was done using the X^2 test; the exact test was used when appropriate. A two-way analysis of variance for repeated measures was used to compare hemodynamic parameters at different operating times, followed by a Newman-Keuls test. A P level below 0.05 was considered significant.

Results

One-year actual survival rates in groups 1, 2 and 3 were 63.2% (24/38 patients), 94.9% (37/39 patients) and 74.4% (29/39 patients), respectively. Eleven (9.5%) and fifteen (12.9%) patients died during the early and late posttransplant periods, respectively. Mortality was unrelated to the surgical technique (Table 2). Graft dysfunction due to ischemic ($n = 5$) and immunological ($n = 3$) damage were the main causes of early mortality (8/11 patients). One CL-OLT patient died immediately after an uneventful procedure of myocardial infarction; one CC-OLT patient died just after transplantation because of hemodynamic failure of unknown etiology. Late mortality was dominated by recurrent viral or malignant diseases (9/13 patients).

Intraoperative data are shown in Table 3. Twenty-six PB-OLT patients had total IVC clamping; 17 of them (65.4%) needed VVB because of poor tolerance of IVC occlusion. Thirteen patients had partial IVC clamping; in nine of them, the suprahepatic donor IVC cuff was anastomosed to the joined orifices of left and median hepatic veins. None of the CC-OLT patients needed VVB. PB-OLT and CC-OLT implantation methods significantly reduced allograft implantation time (warm ischemia time). At reperfusion, there were two cardiac arrests in the PB-OLT group due to hyperkalemia. One CC-OLT patient went into cardiac arrest; he eventually needed re-OLT because of PNF due to 80% steatosis. The need for intraoperative blood products was significantly reduced with the PB-OLT and CC-OLT implantation techniques. Blood pressure (BP), cardiac index (CI), oxygen consumption (VO_2), and oxygen delivery (DO_2) were similar in all three groups at all measured time points. CI and BP at T3 were significantly lower than at all other operating times. CI at T1 and T2 was lower than at T4 and T5 ($P < 0.05$). DO_2 and VO_2 at T3 were significantly lower than at all other times ($P < 0.01$; Fig. 4). In the two patients with PB-OLT without VVB and with total IVC clamping, CI, DO_2, and VO_2 during the anhepatic phase were 1.6 ± 0.2 l/min per m^2, 247 ± 50 ml/min per m^2, and 79 ± 3 ml/min per m^2, respectively.

Postoperative data are shown in Table 4. The number of relaparotomies for abdominal bleeding was significantly fewer with the PB-OLT and CC-OLT implantation techniques. In group 3, there was only one reopera-



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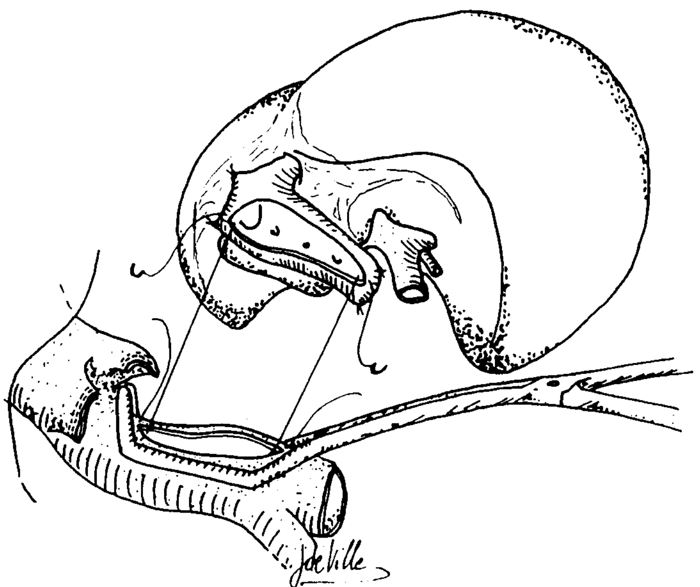

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Fig. 2 Piggyback implantation showing anastomosis between suprahepatic IVC and recipient IVC. The cuff of the LHV and MHV is widened horizontally by incising R-IVC above the stapled RHV

Fig. 3 Piggyback implantation with laterolateral cavocavostomy

tion for bleeding due to hemorrhage from the section margin of a reduced size liver graft. Peak ALT during the first 3 post-transplant days did not differ significantly between the three groups. PNF occurred in eight patients, leading to re-OLT; none had a technical cause revealed at allograft hepatectomy.

Twenty-one of 36 group 3 patients (58.3 %) were extubated on the operating table or immediately on arrival at the intensive care unit; immediate extubation was possible only in two (2/33, 6 %) and five (5/37, 13.5 %) patients in groups 1 and 2 ($P < 0.001$ for group 3 vs groups 1 and 2). Thirty-two group 3 patients (88.8 %) and 28 group 2 patients (75.4 %) were extubated within 24 h, whereas only 13 group 1 patients (39.4 %) were ($P < 0.01$ for group 3 vs group 1; $P < 0.05$ for group 3 vs group 2 and group 2 vs group 1)

Of these, one group 3 patient and one group 1 patient each needed to be reintubated because of graft-versus-host disease (on day 20) and severe septic shock of unknown origin (on day 5), respectively. Right pleural effusion and the need for drainage were lowered, although not significantly, in group 3 patients. The incidence of pleural effusion corresponded in all cases to the presence of a right diaphragmatic elevation.

Five of 38 (one perioperative death excluded) group 3 patients (13.2 %) needed hemodialysis. Renal insufficiency was related to PNF, hyperacute rejection, sepsis, perioperative bleeding, and graft-versus-host disease following mismatched (O to B) liver grafting. In the three surviving patients, kidney function returned to normal. None of the CL-OLT and PB-OLT patients needed hemodialysis, including those patients (two from group 2 and four from group 3) who had pre-OLT renal insufficiency despite having isolated OLT without VVB.

Two of 38 CC-OLT patients (5.2 %) presented ileus postoperatively for 5 and 7 days. Intramural intestinal bleeding was not encountered in the 17 PB-OLT and 39 CC-OLT patients in whom VVB was not used, not even in patients with acute liver failure. Central neurological complications were equally distributed among the three patient groups. One group 1 patient died of cerebral bleeding caused by intracranial pressure monitoring. One group 2 patient had a difficult recovery because of centropontine myelinolysis that developed following a hemorrhagic CL-OLT, and one group 3 patient, with fulminant hepatitis B, was reoperated for bleeding of the cut margin of a reduced size liver; the ensuing renal insufficiency and hemodialysis caused irreversible brain edema.

Six of 55 patients (10.9 %) grafted with VVB had complications related to its use; these were: delayed healing of bypass access sites ($n = 3$), left brachial neuropraxia ($n = 1$), intraoperative air embolism ($n = 1$), and thrombosis of axillary and femoral veins ($n = 1$).

Table 2 Early (< 3 months) and late mortality (> 3 months) after liver transplantation

	Early mortality	Late mortality
CL-OLT ($n = 38$)	Cerebral bleeding due to primary nonfunctioning graft Hepatic artery thrombosis with sepsis (split-liver graft) Allograft trauma and steatosis with graft dysfunction Acute rejection and sepsis Recurrent hepatocellular cancer ($n = 5$, 13.2 %)	Recurrent hepatocellular cancer ($n = 3$) Recurrent hepatitis B viral infection ($n = 3$) hepatitis C viral infection Cardiopulmonary decompensation Chronic rejection ($n = 9$, 23.7 %)
PB-OLT ($n = 39$)	Steatosis with severe graft dysfunction, complicated by iatrogenic pulmonary bleeding ($n = 1$, 2.6 %)	Hepatic lymphoproliferative disease ($n = 1$, 2.6 %)
CC-OLT ($n = 39$)	Hemodynamic failure of unknown origin Graft-versus-host disease with aspergillosis and cerebral bleeding Multiorgan failure related to acute rejection (100 % positive crossmatch) Myocardial infarction related to nonfunctioning split-liver graft Cerebral edema following bleeding of section margin of reduced size liver ($n = 5$, 12.8 %)	Recurrent hepatitis B viral infection Recurrent angiosarcoma Donor-derived tuberculosis Chronic rejection and sepsis ($n = 2$) ($n = 5$, 12.8 %)

Table 3 Intraoperative data on 116 consecutive liver transplant recipients

	Group 1 ($n = 38$)	Group 2 ($n = 39$)	Group 3 ($n = 39$)	P
Technical variant				
Split	3 (7.9 %)	1 (2.6 %)	3 (7.7 %)	NS
Reduced size liver			2 (5.1 %)	NS
Venovenous bypass use	38 (100 %)	17 (43.6 %)	0 (0 %)	–
Ischemia time (min)				
Cold	755.2 ± 261.6	706.9 ± 172.2	769.9 ± 195.3	NS
Warm mean	66.7 ± 21.2	50.4 ± 13.6	45.7 ± 12.3	< 0.01[b] < 0.01[c]
Cardiac arrest at reperfusion	0	2	1[a]	NS
Intraoperative blood product use (ml)				
Mean	8418 ± 7728.4	3889.1 ± 5688.1	1522.8 ± 1878.9	< 0.01[b]
Blood loss < 3 l	9/38 (23.7 %)	25/39 (64.1 %)	31/39 (79.5 %)	< 0.05[c] < 0.001[d]

[a] Steatosis > 80 %
[b] Groups 3 and 2 vs group 1
[c] Group 2 vs group 1
[d] Group 3 vs group 1

At D-US examination, one PB-OLT patient (2.6 %) had a partial thrombosis of the lower part of the donor IVC without interfering with venous outflow. Two PB-OLT patients (5.2 %) had a minor stenosis at the anastomosis between the suprahepatic donor IVC and the hepatic venous cuff. Two CC-OLT patients (5.2 %) had temporary compression of the R-IVC due to the large volume of the allograft. Neither D-US nor liver biopsy showed any hepatic vein outflow obstructions in any patient.

Discussion

The liver transplant procedure has evolved during the last decade to become a routine surgical procedure [28]. In the original technique, the retrohepatic vena cava was removed with the diseased liver; VVB was used routinely in order to overcome the systemic and splanchnic hemodynamic changes caused by the interruption of portal and caval flows. Early morbidity and mortality following LT were mainly due to perioperative bleeding related to removal of the retrohepatic IVC with the diseased liver [6, 16]. Several complications (air or clot embolism, hypothermia, neurological damage, wound infection or dehiscence, infected vascular suture lines) are directly related to VVB use [6, 12, 13, 28].

Liver grafting in the presence of pre-existing IVC abnormalities, such as complete extrahepatic location or absence, has shown that PB-OLT is feasible without compromising graft survival [17, 28]. The concept of

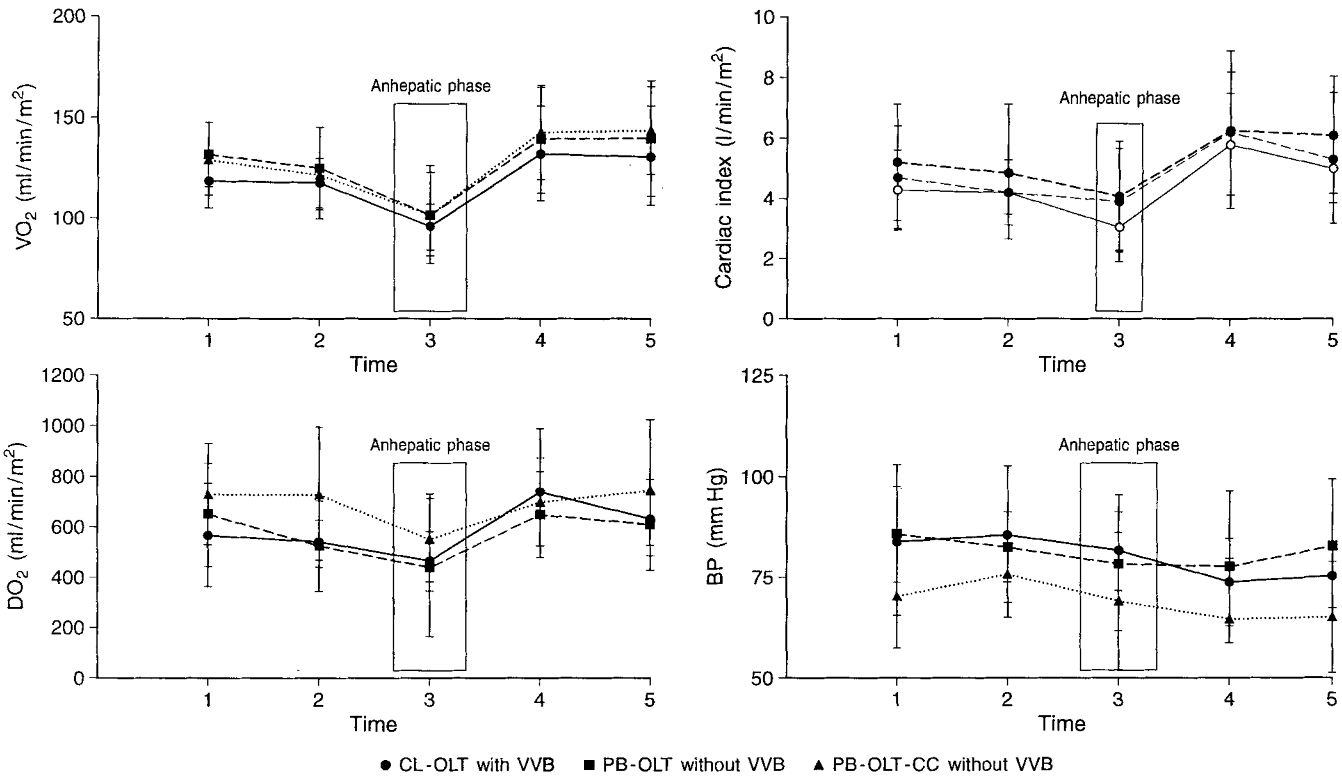

Fig. 4 Intraoperative measurement of blood pressure, cardiac index, oxygen consumption (VO_2) and delivery (DO_2) in CL-OLT patients with VVB ($n = 6$), in PB-OLT patients without VVB and without IVC occlusion ($n = 6$), and in CC-OLT patients ($n = 17$)

preserving the recipient's IVC was then successfully applied when implanting reduced size allografts into children [3, 24] and when performing total hepatectomy as a temporary approach to acute hepatic or graft failure [26]. All descriptions of PB-OLT methods have one common feature, namely, careful disconnection of the recipient's liver and retrohepatic IVC [4, 7, 9, 18, 25, 29, 32]. This dissection explains the significant reduction in the blood product requirement and in reoperation for abdominal bleeding, as bleeding from the adrenal gland, adrenal vein, and para- and retrocaval areas is avoided. The systematic use of VVB, which accounts for an estimated 500–1000 ml of blood and the much higher blood loss in the case of splanchnic venous thrombosis, have been contributing factors to the higher intraoperative blood product use in classical OLT.

In our series, one could argue that the reduced blood product use with the PB techniques could be attributed to the significantly higher incidence in groups 2 and 3 of patients with TIPSS. We have, however, shown in a previous study of 23 TIPSS and 36 non-TIPSS matched, cirrhotic patients (included in these series), that TIPSS does not reduce the need for intraoperative blood product administration [21]. Following TIPSS placement or revision, hepatectomy with R-IVC preservation is frequently more difficult, due to inflammatory changes in the hepatic and caval veins. PB-OLT and CC-OLT implantation significantly shortens the warm ischemia time, as only two (portal and caval) venous anastomoses have to be performed before graft revascularization.

Although more experience with the classical OLT procedure progressively leads to implantation techniques without the systematic use of VVB [10, 29, 30, 34), we feel the safest way to do OLT without using VVB is to preserve the R-IVC and to do the implantation under partial (lateral) R-IVC clamping [2]. This technique can be used in all recipients, irrespective of anatomical findings and the status of the recipient (e.g., acute or chronic liver failure) at the time of LT. Partial IVC clamping, which is not always possible in PB-OLT, and postponement of portal venous flow interruption until the complete separation of the liver from the IVC make the use of VVB and the creation of a temporary portocaval shunt unnecessary [33]. The final transection of the left and middle hepatic veins and of the portal vein of the diseased liver can be followed by immediate graft implantation. All of the time spent performing the tedious R-IVC dissection is largely regained afterwards, when implanting the graft in a dry, operative field.

Hemodynamic measurements confirm that CC-OLT without VVB is similar to CL-OLT with VVB [10]. In

Table 4 Postoperative data on 116 consecutive liver transplant recipients

	Group 1 (n = 38)	Group 2 (n = 39)	Group 3 (n = 39)	P
Relaparotomy for bleeding	14/37[a] (37.8 %)	4/39 (10.3 %)	1/38[a] (2.6 %)	<0.01[h]
Mean peak ALT (Ul/l; days 0–3)	1510.2 ± 1287	3147.1 ± 4210.2	1557.3 ± 1697.3	NS
Primary nonfunction	4 (10.5 %)	2 (5.1 %)	2 (5.1 %)	NS
Early re-OLT (< 3 months)[f]	5[b] (13.2 %)	3[c] (7.7 %)	4[bb] (10.3 %)	NS
Late re-OLT (> 3 months)	1[d] (2.6 %)	1[d] (2.5 %)	2[d, e] (5.1 %)	NS
Extubation immediate (< 24 h)	2.33 (6 %) 13/33 (39.4 %)	5/37 (13.5 %) 28/37 (75.7 %)	21/36 (58.3 %) 32/36 (88.8 %)	< 0.001[i] < 0.01[j] < 0.05[k]
Pleural effusion[g] < 1 week	14/33 (42.4 %)	13/37 (35.1 %)	9/35 (25 %)	NS
Thoracocentesis[g] < 1 week	8/33 (24.2 %)	5/37 (13.5 %)	4/35 (11.1 %)	NS
Early mortality (< 3 months)	5/38 (13.2 %)	1/39 (2.6 %)	5/39 (12.8 %)	NS
Late mortality (> 3 months)	9/38 (23.7 %)	1/39 (2.6 %)	5/39 (12.8 %)	NS

[a] Immediate perioperative death, unrelated to bleeding, excluded
[b] Acute allograft rejection (n = 3)
[c] Hepatic artery thrombosis (n = 1)
[d] Intrahepatic biliary stricture (n = 3)
[e] Chronic rejection (n = 1)
[f] Eight patients had primary nonfunction. (Group 1 = 4; group 2 = 2; group 3 = 2)
[g] PNF patients and immediate perioperative deaths excluded
[h] Groups 3 and 2 vs group 1
[i] Group 3 vs groups 1 and 2
[j] Group 3 vs group 1
[k] Group 3 vs group 2 and group 2 vs group 1

CL-OLT and PB-OLT with total IVC occlusion, VVB remains necessary only in select patients who show major intolerance to total IVC occlusion [10, 34].

CC-OLT has several other advantages, not only in relation to CL-OLT, but also to PB-OLT. Pulmonary and thoracic complications are frequent after OLT [1, 6, 14]. The absence of retrocaval dissection and of caval encirclement, together with lateral and partial clamping of the IVC, may explain the significant reduction in artificial ventilation time in CC-OLT. The correct application of the technique makes suturing of the bare areas and high clamping of the suprahepatic IVC superfluous. Phrenic nerve crush lesions, which have been proven to be responsible for a higher incidence of prolonged intubation, pleural effusion, atelectasis, and even pneumonia, are avoided [11, 23, 28]. The method is also safe from nephrological, neurological, and gastrointestinal points of view, even in patients without portal hypertension (e.g., metabolic disease or acute liver failure) and with chronic renal insufficiency.

Partial clamping of the IVC preserves systemic venous flow with free outflow of the renal veins during the anhepatic phase [8]. This reduces the need for increased fluid administration during this phase, a factor that has been proven to substantially reduce the need for prolonged ventilatory assistance [27].

The CC-OLT technique greatly facilitates early, as well as delayed, retransplantation [20]. Preservation of the previous anastomosis allows the failed allograft to be removed without narrowing the R-IVC and, thus, without interfering at all with caval flow, a feature of importance in critically ill patients. For this reason, we prefer real side-to-side instead of end-to-side cavocavostomy [7]. The CC-OLT technique is also advisable in the case of delayed re-OLT following previous classical liver grafting [20]. Here, the plane between the previous donor IVC and the allograft may indeed be the most accessible (and least hemorrhagic) to the surgeon. The graft is implanted by joining laterolaterally the previous donor IVC and the new donor IVC. CC-OLT is also advantageous when implanting the right part of a split liver, especially when reconstruction of the suprahepatic IVC cuff is difficult because of the excision of a caval patch, encompassing LHV, for the left liver graft [19]. Finally, this method represents another means of reducing the costs of liver transplantation, a factor that will become more and more decisive in the future care of transplant recipients. Indeed, VVB becomes unnecessary, and complications directly related to its use are eliminated.

We believe that CC-OLT should become a routine part of the armamentarium of the liver transplant surgeon, not only because it has the advantages of PB-OLT (shortening of implantation time and reduction in blood product use) but also because it eliminates the use of VVB with its inherent complications and because it reduces artificial ventilation time. All of these advantages are based on anatomical surgery in which the R-IVC and diseased liver are completely disconnected and on partial lateral IVC clamping during the anhepatic phase, avoiding diaphragmatic injury and allowing maintenance of caval flow.

As a consequence of the results obtained, we have, since July 1994, applied CC-OLT, without the use of VVB, to all adult recipients without exception.

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