ORIGINAL ARTICLE

Initial piggyback technique facilitates late liver retransplantation – a retrospective monocentric study

Sophie Laroche[1], Charlotte Maulat[1], Yuki Kitano[1,2], Nicolas Golse[1,3], Daniel Azoulay[1], Antonio Sa Cunha[1,4], Eric Vibert[1,3], René Adam[1,4], Daniel Cherqui[1,3] & Marc Antoine Allard[1,4]

1 AP-HP Hôpital Paul Brousse, Centre Hépato-Biliaire, Université Paris Saclay, Villejuif, France
2 Department of Gastroenterological Surgery, Graduate School of Medical Sciences, Kumamoto University, Kumamoto, Japan
3 Unité INSERM 1193, Villejuif, France
4 Équipe Chronothérapie, Cancers et Transplantation, Université Paris Saclay, Villejuif, France

Correspondence
Marc Antoine Allard MD, PhD, Centre Hépatobiliaire, Hôpital Paul Brousse, 14 av Paul Vaillant Couturier, 94800 Villejuif, France.
Tel.: +33145596436
fax: +33145593857;
e-mail: marcantoine.allard@aphp.fr

SUMMARY

Optimal management of inferior vena cava (IVC) is crucial to ensure safety in late liver retransplantation (ReLT). The aim of this study was to evaluate different surgical strategies with regard to IVC in late ReLT. All consecutive late ReLT (≥90 days from the previous transplant) from 2013 to 2018 in a single center was reviewed (n = 66). Of them, 46 (69.7%) were performed without venovenous bypass (VVB) including 29 with caval preservation (CP) and 17 with caval replacement (CR). The remaining 20 cases (30.3%) required the use of VVB. Among ReLT without VVB, CP was associated with a lower number of packed red blood cells (median 4 vs. 7; P = 0.016) and a lower incidence of post-transplant acute kidney injury (6.9% vs. 47.1%; P = 0.003). The feasibility of CP was 95% (14/15) in patients with previous 3-vein piggyback caval anastomosis versus 48.3% (15/31) after other techniques (P = 0.003). Indirect signs of portal hypertension (PHT) before retransplantation were predictive of VVB requirement. Early and long-term outcomes were similar across the three groups (CP without VVB, CR without VVB, and VVB). Preserving the IVC in late ReLT is associated with better postoperative renal function and is facilitated by a previous 3-vein piggyback. Routine CR is not justified in late ReLT.

Transplant International 2021; 34: 835–843

Key words
caval preservation, caval replacement, liver retransplantation, piggyback

Received: 17 November 2020; Revision requested: 4 January 2021; Accepted: 26 February 2021;
Published online: 18 March 2021

Introduction

Late liver retransplantation (ReLT) is the only treatment of irreversible graft failure occurring several months after the first transplant. Severe adhesions close to major vascular structures and modified anatomical landmarks make this procedure technically demanding, with a risk of massive bleeding during dissection [1]. So far, no consensual technique for elective ReLT has been validated. Appropriate management of inferior vena cava (IVC) is essential to ensure safe removal of the graft and optimal outflow of the new graft. Graft explantation can be done either with IVC *en bloc* resection or with IVC preservation, according to local conditions and surgeon preference. The use of venovenous bypass (VVB), started at the beginning of the intervention, can be helpful in presence of vascularized adhesions resulting from severe portal hypertension (PHT).

doi:10.1111/tri.13857

Numerous studies have shown that caval preservation (CP) in primary LT offers better hemodynamical tolerance, lower blood transfusion requirement, and shorter hospital stay when compared with caval replacement (CR) [2–8]. In contrast, the technical management of the IVC during late ReLT has not been studied specifically [9–11]. This study aimed at evaluating our surgical strategy with regard to outflow reconstruction during late ReLT with special reference to CP or CR during the initial LT.

Patients and methods

Patient cohort and study design

All consecutive patients who underwent ReLT at Paul Brousse Hospital (Villejuif, France) from April 2013 to July 2018 were identified from our prospectively maintained database. Of them, all late ReLT defined as a liver retransplantation occurring 90 days or more after the previous LT was included. Technical aspects, intraoperative data of the transplantation, and outcomes were reviewed retrospectively. Last CT scan available before retransplantation was reviewed to assess spleen diameter, portal vein patency, ascites and the presence of spontaneous portosystemic shunts. The purpose and design of this project were discussed and approved during our weekly research meeting.

Primary liver transplantation technique

Briefly, total hepatectomy with CP is our standard technique for primary transplantation. The two main techniques for caval implantation were side to side cavocaval anastomosis [12] and, more recently, the 3-vein piggyback anastomosis (PB) [13]. In the latter, the upper end of the graft IVC is anastomosed to a wide cavotomy that includes the orifice of the three main hepatic veins with division on the caval septum between them. CR was indicated in the case of inferior vena cava (IVC) encirclement by segment 1, very large graft or native liver, or tumor located in the vicinity of the IVC.

Retransplantation technique—total hepatectomy

Our policy is to attempt CP when technically feasible. Preoperative plan was based on the operative report from the initial transplant and study of IVC and segment 1 anatomy on a preoperative CT scan, but the final assessment was made intraoperatively.

Surgical situation was evaluated very early according to difficulties in penetrating the abdominal cavity and severity and vascularity of adhesions from previous surgery.

Three scenarios occurred.

1. Cases with reasonably dissectable adhesions and previous CP.

Hepatic artery and bile duct were divided at the upper part of the hepatic pedicle. Portal continuity was maintained as long as possible. No temporary portocaval shunt was made in the specific context of ReLT. After complete liver mobilization, the stump of the graft retrohepatic IVC was identified and progressively freed from its adhesions with native vena cava. The previous caval anastomosis was then taped. The portal vein was clamped and divided, followed by partial caval clamping. The clamp was placed in order to preserve sufficient caval flow, maintaining hemodynamic stability. The previous IVC anastomosis was then divided. We tried as much as possible to preserve a cuff of the previous graft IVC that includes the previous caval anastomosis. In the case of a previous "side to side" implantation, the caval clamp was placed vertically while it was placed transversally in case of a previous "3-vein piggyback" implantation. The new caval anastomosis was made just above the previous caval anastomosis, using a cuff of the first graft IVC. The main steps of this technique are shown in Fig. 1.

2. Cases with reasonably dissectable adhesions and previous CR.

In such cases, CP was rarely attempted. Hilar dissection was performed as described above. The portal flow was also maintained during dissection to avoid splanchnic congestion. The liver was mobilized, and the retrohepatic IVC was freed from the diaphragm until it was possible to clamp it below and above the liver. An IVC clamping test was made before removing the liver. In rare cases of hemodynamical intolerance, a VVB was used at this stage.

3. Cases with major bleeding.

In cases with major vascularized adhesions resulting in major bleeding impacting progression, we used venovenous bypass to alleviate portal hypertension (PHT) and facilitate pedicle dissection and liver mobilization. Access to the portal system was made through the inferior mesenteric vein in a remote area from the previous dissection site and adhesions. An additional midline incision was sometimes necessary to avoid the previously dissected area and facilitate cannulation of the portal system. When VVB was used, CR was done in order to achieve fast removal of the graft. In rare extreme cases, pericardiotomy and intrapericardial control of the IVC were required.

Transplant International 2021; 34: 835–843

Retransplantation technique—graft implantation

After completion of caval anastomosis, the portal anastomosis was completed by using the available portal vein. In most cases, the previous portal anastomosis was not dissected again, and the new anastomosis was generally made downstream the first one. The site of implantation for the artery was decided on a case-by-case basis. For biliary reconstruction, repeat duct to duct anastomosis was used when feasible. In such cases, care was taken to remove the entire bile duct of the previous graft and reach the well-vascularized native bile duct. However, in many cases, hepatico-jejunostomy was required due to difficulty in obtaining adequate native bile duct.

Postoperative management

Daily ultrasound was performed in the intensive care unit until transfer to the ward. A postoperative CT scan on day 7 was performed to check vascular anastomosis. Immunosuppression modalities were similar to those used after primary LT, including tacrolimus, mycophenolate sodium, and oral steroids. Patients with renal insufficiency received basiliximab induction therapy followed by the same regimen.

Statistical analysis

We analyzed retransplantation with VVB separately because of its impact on IVC management. Categorical variables were compared by using Chi-square or Fisher test, as appropriate. Continuous variables were expressed as median (range) and compared with non-parametric Mann–Whitney test. Survival curves were plotted by using the Kaplan–Meier method and compared with the log-rank test. Calculations were done with R 3.6.1 software using *compareGroups* and *ggplot2* packages.

Results

Study population

Of the 108 ReLT performed, over the study period, there were 66 late ReLT in 63 patients (three patients had 2 ReLT over the study period). The flow chart is given in Fig. 2. All grafts were recovered from deceased brain donors. Only one ReLT was done with a split liver.

Of the 46 (69.7%) ReLT without VVB, preservation of IVC could be achieved in 29 ReLT (63%) whereas CR was needed in the remaining 17 (37%) ReLT. A VVB was used in 20 (30.3%) of ReLT, leading to CR in 19 of them.

CR versus CP among retransplantations without VVB

As shown in Table 1, recipient and donor characteristics were similar in both groups. In transplants without VVB, CP was possible in 63% and was more often achieved when vena cava had been preserved during previous transplantation. The chance for repeating CP was higher after previous CP compared with previous CR (77.9% (20 of 26) vs. 45% (9 of 20); $P = 0.034$). The feasibilty of IVC preservation was even higher when previous caval anastomosis was a 3-vein piggyback [93.3% (14 of 15) vs. 48.3% (15 of 31) after other types of caval anastomosis; $P = 0.003$].

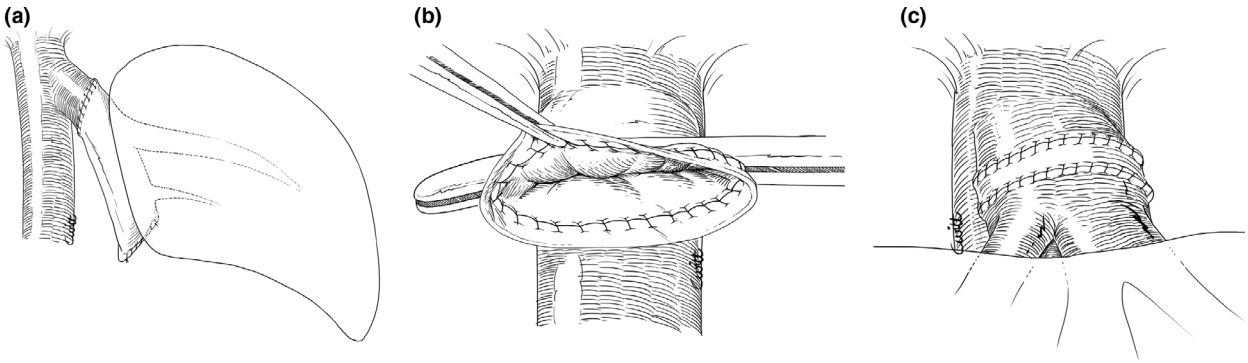

Figure 1 Schematic view of caval preservation in a recipient with a previous piggyback anastomosis. (a) The stump of the graft retrohepatic is identified. The plane between native IVC and graft IVC is then reopen. The graft is brought forward (Portal vein can be divided to make it easier) and a Satinsky clamp is placed below the previous caval anastomosis, either transversally or vertically. (b) IVC is divided above the previous caval anastomosis and the former graft is removed. (c) The new caval anastomosis is completed by using a cuff of the previous graft IVC. IVC, inferior vena cava.

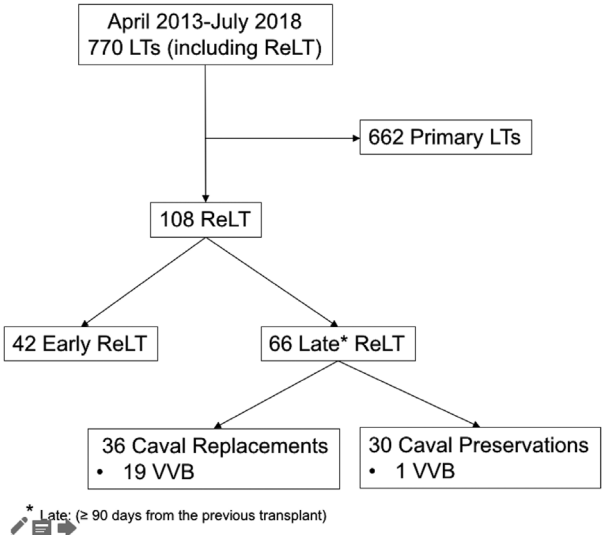

Figure 2 Flow chart of the study population. VVB, venovenous bypass.

The amount of transfusion was significantly lower in the CP group. (The median number of packed red blood cell: 4 after CP vs. 7 after CR; $P = 0.016$). CP was also associated with a shorter duration of the procedure. There were no cases of outflow obstruction (neither intraoperative nor after transplant) following CP.

Acute kidney injury (≥stage I) defined according to the KDIGO (Kidney Disease Improving Global Outcomes) classification [14] occurred less often after CP compared with CR (6.9% vs. 47.1%; $P = 0.003$).

ReLT with VVB

Venovenous bypass was used in 20 (30.3%) ReLT and was indicated to alleviate PHT and facilitate dissection of vascularized adhesions in 18 ReLT. In the two remaining ReLT, VVB was required for hemodynamic reason. CR was finally used in all but one cases.

The comparisons according to the use of VVB are shown in Table 2. Briefly, VVB was required in sicker patients compared to ReLT without VVB (higher MELD score, higher proportion of patients hospitalized at the time of ReLT, higher level of pretransplant serum creatinine). Indirect signs of PHT (defined by the association of a spleen diameter >12 cm and platelets <100 G/l) were observed in 55% of procedures with VVB vs. 23.9% of retransplant without VVB; $P = 0.029$). The time interval from previous transplantation was also longer.

The type of previous caval anastomosis did not differ between the two groups. VVB was associated with longer cold ischemia time, higher number of packed RBC, and longer duration of surgery.

Table 3 shows the proportions of retransplantations which required VVB according to the number of factors associated with VVB. The observed probability for VVB was nil in absence of any factors and of 100% in presence of the three risk factors: (MELD score ≥14; Interval time from last LT ≥60 months and indirect signs of PHT).

Long-term outcomes

Overall, the 90-day mortality after ReLT was 4.5% ($n = 3$). One-year patient survival rate was 92% (CI 85–99%). After a median follow-up of 43 months, median survival from the time of ReLT was not reached. The 3-year patient survival rates of the study population (63 patients) was 87%.

There were no significant differences neither in 90-day mortality nor in overall survival after ReLT according to the three groups (CP without VVB, CR without VVB, and VVB), as shown by Fig. 3. One-year overall survival rates after retransplantation were 84%, 100%, 89% after VVB, CR without VVB and CP without VVB, respectively ($P = 0.44$; Fig. 3).

Discussion

Late ReLT remains a technical challenge. Dense adhesions worsened by PHT and modified anatomical landmarks make the removal of the previous graft technically demanding and at risk of major bleeding. IVC preservation or replacement is both available options during primary transplantation and depends mainly on surgeon and team preferences. By contrast, the management of the IVC during late RLT is usually dictated by the circumstances and has been less studied in the literature [15,16]. In the current study, we analyzed the technical aspects of IVC reconstruction during late RLT.

In this retrospective series of 66 late ReLT, we found that CP preservation during the initial transplantation may facilitate retransplantation by allowing repeat preservation of the native IVC and avoiding of complete caval occlusion during graft implantation. Although previous CP appears to make repeat CP easier, our main finding was that initial 3-vein piggyback implantation was more favorable than side to side cavocavostomy with a 93% rate of repeat CP and piggyback in the former. In such cases, once the liver has been mobilized, the plane between the native and graft IVCs can be found and followed up to the level of the previous caval anastomosis. At that stage, partial IVC clamping

Table 1. Comparisons according to CR or CP in procedures who did not require VVB.

Variables	CR *n* = 17	CP *n* = 29	*P*
Recipient data			
Age, years	49.0 (23–68)	48.0 (13–69)	0.30
Sex (male)	8 (47.1)	17 (58.6)	0.65
Body weight, kg	69.0 (28–97)	58.0 (34–99)	0.34
BMI, kg/m^2	22.4 (9.7–32.8)	19.8 (12.7–36.4)	0.39
Status at retransplantation			
Home	11 (64.7)	19 (65.5)	>0.999
In hospital	6 (35.3)	10 (34.5)	
Intensive care unit	0 (0)	0 (0)	
MELD score	12.5 (6.0–31.9)	11.0 (6.0–32.8)	0.60
Preoperative creatinin, mmol/l	78.0 (51–126)	83.0 (46–204)	0.89
Indication for ReLT			
Cholangitis	1 (5.9)	5 (17.2)	0.75
Regenerative nodular hyperplasia	2 (11.8)	1 (3.5)	
Disease recurrence	6 (35.3)	9 (31.0)	
Rejection	4 (23.5)	9 (31.0)	
Arterial complications	1 (5.9)	2 (6.9)	
Other	3 (17.6)	3 (10.3)	
Portal hypertension			
Platelets, G/l	127 (29–534)	129 (32–458)	0.82
Ascites	6 (37.5)	10 (35.7)	>0.999
Shunt*	6 (35.3)	12 (41.4)	0.92
Portal vein thrombosis	3 (17.6)	1 (3.5)	0.13
Spleen diameter, cm	4.0 (1.0–17.0)	7.0 (1–18)	0.11
Portal hypertension†	4 (23.5)	7 (24.1)	>0.99
Previous LT			
Time from last LT, months	95.0 (7–187)	53.0 (3–300)	0.15
Type of caval anastomosis			
3-vein piggyback	1 (5.9)	14 (48.3)	0.008
Side to side	5 (29.4)	6 (20.7)	
Caval replacement	11 (64.7)	9 (31.0)	
Full graft	15 (93.8)	16 (64.0)	0.06
Post-transplant reoperation	1 (5.9)	3 (13.0)	>0.99
Explanted liver, g	1100 (895–1800)	1415 (394–1730)	0.40
ReLT			
Donor age, years	51.0 (29–78)	56.0 (17–88)	0.54
Donor sex (male)	10 (58.8)	14 (48.3)	0.70
Donor BMI, kg/m^2	24.2 (17.7–36.5)	23.2 (17.1–33.5)	0.48
Predonation cardiac arrest	6 (37.5)	10 (35.7)	>0.99
Donor quality index [25]	1.7 (1.0–2.3)	1.4 (1.0–2.5)	0.49
Intraoperative data of ReLT			
Cold ischemia time, min	472 (243–611)	428 (263–675)	0.85
Graft weight, g	1475 (1100–1835)	1235 (630–2060)	0.13
Graft to body weight ratio	2.4 (1.9–5.5)	2.4 (1.1–3.8)	0.37
Number of packed RBC	7 (3–34)	4 (0–13)	0.016
Total vascular exclusion, min	46 (34–66)	NA	
Duration of surgery, min	515 (387–739)	425 (290–690)	0.018
Outcomes			
Serum creatinin at POD1, µmol/l	86 (63–282)	74 (54–216)	0.18
Serum creatinin at POD3, µmol/l	78 (52–373)	62 (39–201)	0.06
Serum creatinin at POD5, µmol/l	75 (55–494)	69.5 (47–178)	0.06
Serum creatinin at POD7, µmol/l	75 (58–463)	62 (46–177)	0.034
Serum creatinin at POD12, µmol/l	92 (51–286)	66 (44–109)	0.06
AKI ≥ stage II (KDIGO)	4 (23.5)	1 (3.45)	0.06

Table 1. Continued.

Variables	CR *n* = 17	CP *n* = 29	*P*
AKI ≥ stage I (KDIGO)	8 (47.1)	2 (6.9)	0.003
ICU stay, days	5.0 (2–46)	5.0 (1–19)	0.90
Post-ICU hospital stay, days	17.0 (0–57)	13.0 (0–29)	0.06
Dindo-Clavien grade ≥ III	4 (23.5)	9 (32.1)	0.73
90-day mortality	0 (0.0)	1 (3.45)	>0.99

AKI, acute kidney injury; KDIGO, kidney disease improving global outcome classification; MELD, model for end-stage liver disease; NA, not applicable; POD, postoperative day; RBC, red blood cell; VVB, venovenous bypass.

Data are given as median (range) or *n* (%).

*Shunt was defined as the presence of a portosystemic shunt >8 mm.

†PHT was Defined by Platelets <100 G/l and spleen diameter >12 cm.

can be reapplied and the new graft implanted in the same fashion, often just proximal the previous caval anastomosis.

The first mention of retransplantation by using a rim of suprahepatic vein from the first graft without removing native IVC was made by Tzakis *et al.* [15]. Later, Belghiti *et al.* [16] reported 16 ReLT with caval flow preservation, among which 10 patients had CP during the previous transplantation. In 2003, Lerut *et al.* [10] observed that IVC could be preserved in 17 (89.5%) of 19 ReLT. In a study including 1067 LT, 86% of the 136 retransplantations (including late and early ReLT) have been achieved with a piggyback technique [5]. Since ReLT was not the focus of these studies, neither timing of ReLT nor the local conditions were described, which precludes a straightforward comparison with our results.

However, initial caval implantation did not predict the difficulty of adhesiolysis before reaching the IVC. Indeed, we found that VVB was required in 27.3% (18/66) of procedures to decrease PHT and limit blood loss related to the dissection of vascularized adhesions. Interestingly, VVB was not used in primary transplants during this period. The technical complexity of ReLT requiring VVB was much higher compared to ReLT without VVB, as reflected by higher amount of transfusion, longer duration of surgery, and a 90-day mortality rate of 10%. Indirect signs of PHT and long interval from last transplantation were associated with higher chance of VVB, thus being helpful predictors of VVB requirement. An alternative to VVB for cases of adhesions associated with PHT is to use a passive portosaphenous shunt as recently reported in retransplantation cases [17]. In cases of extremely difficult dissection and "impossible" abdominal access through the previous transplantation incision, we have occasionally used a remote undissected midline incision to access the portal system, usually through the inferior mesenteric vein, for portal decompression. Once the portal system has been decompressed by VVB, the transplant incision can be accessed in a safer fashion. Since total IVC clamping is no more an issue with VVB, our strategy was to perform CR for faster graft removal in such cases.

The relationship between IVC management and post-transplant renal function needs to be underlined. All transplanted patients are expected to have a certain degree chronic renal insufficiency due to long-term immunosuppressive therapies, which is usually worsened by retransplantation. In that respect, CP and partial caval clamping yield a protective effect on renal function, as shown by a much lower risk of AKI following ReLT with CP compared to CR without VVB. Although the technique did not affect the need for postoperative renal replacement therapy, the lower proportion of transient renal failure after CP should be emphasized at the light of a registry-based study, which showed that postoperative acute renal failure is an independent predictive factor of chronic renal failure after transplantation of a nonrenal organ [18].

Interestingly, one-year overall survival was higher than that reported in the previous series of retransplantations, including late retransplantations [19–21]. In addition, outcomes reported here were not different according the technique of caval anastomosis. This may reflect the recent period of the study where surgical outcomes have improved significantly but possibly also our policy to tailor the technique according to the intraoperative findings of each patient.

Transplant International 2021; 34: 835–843

Table 2. Comparisons according to the use of VVB.

Variables	No VVB *n* = 46	VVB *n* = 20	*P*
Recipient data			
Age, years	48.0 (13–69)	46.5 (17–74)	0.82
Sex (male)	25 (54.3)	11 (55.0)	>0.99
Body weight, kg	60.0 (28–99)	69.5 (45–87)	0.55
BMI, kg/m^2	21.3 (9.7–36.4)	23.2 (16.3–30.5)	0.35
Status at retransplantation			
Home	30 (65.2)	10 (50.0)	0.035
In hospital	16 (34.8)	7 (35.0)	
Intensive care unit	0 (0.0)	3 (15.0)	
MELD score	11.8 (6.0–32.8)	19.2 (6.6–40.0)	0.012
MELD score ≥14	19 (41.3)	15 (75.0)	0.024
Preoperative creatinin, mmol/l	79.5 (46.0–204)	97.5 (38.0–320)	0.036
Indication for ReLT			
Cholangitis	6 (13.0)	1 (5.00)	0.24
Regenerative nodular hyperplasia	3 (6.5)	2 (10.0)	
Disease recurrence	15 (32.6)	5 (25.0)	
Rejection	13 (28.3)	8 (40.0)	
Arterial complications	3 (6.52)	4 (20.0)	
Other	6 (13.0)	0 (0.00)	
Portal hypertension			
Platelets, G/l	128 (29–534)	91 (22–248)	0.14
Ascites	16 (36.4)	8 (42.1)	0.88
Shunt*	18 (39.1)	7 (35.0)	0.97
Portal vein thrombosis	4 (8.7)	1 (5.0)	>0.99
Spleen diameter, cm	6.0 (1.0–18.0)	7.5 (1.0–15.0)	0.56
Portal hypertension[†]	11 (23.9)	11 (55.0)	0.029
Previous LT			
Time from last LT, months	60 (3–300)	124 (8–360)	0.002
Interval time from last LT ≥ 60 months	23(50)	18 (90)	0.005
Type of caval anastomosis			
Other (left lobe living donation)	0 (0.0)	1 (5.0)	0.24
3-vein piggyback	15 (32.6)	3 (15.0)	
Side to side	11 (23.9)	5 (25.0)	
Caval replacement	20 (43.5)	11 (55.0)	
Full graft	31 (75.6)	9 (56.2)	0.20
Post-transplant reoperation	4 (11.1)	3 (23.1)	0.36
Explanted graft, g	1248 (394–1800)	1228 (995–1470)	0.94
Donor data			
Donor age, years	55.5 (17.0–88.0)	59.5 (17.0–83.0)	0.47
Donor sex (male)	24 (52.2)	8 (40.0)	0.52
Donor BMI, kg/m^2	23.7 (17.1–36.5)	25.3 (17.3–35.6)	0.16
Predonation cardiac arrest	16 (36.4)	8 (42.1)	0.88
Donor quality index [25]	1.57 (1.0–2.5)	1.72 (1.0–2.3)	0.99
Intraoperative data of ReLT			
Cold ischemia time, min	456 (243–675)	535 (349–826)	0.010
Graft weight, g	1415 (630–2060)	1332 (915–2000)	0.86
Graft to body weight ratio	2.4 (1.1–5.5)	2.1 (1.3–3.5)	0.261
Number of packed RBC	4 (0–34)	11 (1–64)	<0.001
Caval replacement	17 (37)	19 (95)	<0.001
Duration of VVB, min	NA	178 (91–398)	
Duration of surgery, min	449 (290–739)	587 (330–810)	0.004
Outcomes			
Serum creatinin at POD1, µmol/l	82 (54–282)	114 (49–254)	0.032
Serum creatinin at POD3, µmol/l	70 (39–373)	127 (35–265)	0.001

Table 2. Continued.

Variables	No VVB *n* = 46	VVB *n* = 20	*P*
Serum creatinin at POD5, µmol/l	70 (47–494)	80 (32–267)	0.19
Serum creatinin at POD7, µmol/l	68 (46–463)	115 (31–201)	0.010
Serum creatinin at POD12, µmol/l	70 (44–286)	94.5 (39–163)	0.06
AKI ≥ stage II (KDIGO)	5 (10.9)	2 (10.0)	>0.999
AKI ≥ stage I (KDIGO)	10 (21.7)	8 (40.0)	0.22
ICU stay, days	5 (1–46)	8 (2–65)	0.001
Post-ICU hospital stay, days	14.5 (0–57)	17 (0–41)	0.53
Dindo-Clavien grade ≥ III	13 (28.9)	8 (42.1)	0.46
90-day mortality	1 (2.2)	2 (10.0)	0.22

AKI, acute kidney injury; KDIGO, kidney disease improving global outcome classification; MELD, model for end-stage liver disease; NA, not applicable; POD, postoperative day; RBC, red blood cell; VVB, venovenous bypass.

Data are given as median (range) or *n* (%).

*Shunt was defined as the presence of a portosystemic shunt >8 mm.

†PHT was Defined by Platelets <100 G/l and spleen diameter >12 cm.

Table 3. Number of cases requiring venovenous bypass according to the number of risk factors.

	No factor	1 factor	2 factors	3 factors
No. cases with VVB/no. cases without VVB, %	0/10 (0%)	4/23 (17.4%)	8/25 (32%)	8/8 (100%)

VVB, venovenous bypass.

3 factors were associated with VVB: indirect signs of portal hypertension; meld score ≥14 and interval time from last LT ≥60 months. Cutoff values for MELD score and interval time from last LT were chosen after identifying the optimal cutoff value with receiver operating characteristics curves.

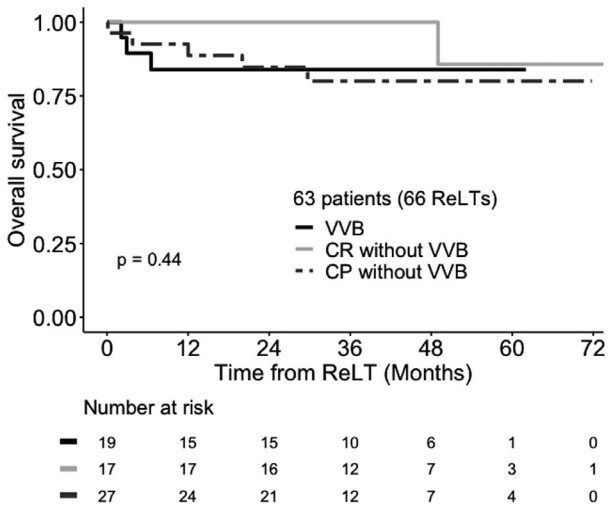

Figure 3 Kaplan–Meier overall survival according to IVC management (*n* = 63 patients). CP, caval preservation; CR, caval replacement; IVC, inferior vena cava; VVB, venovenous bypass.

In the literature, both CR and CP offer good outcomes, and it has been suggested that surgeons should prefer the technique that they know best [22].

Our opinion is that both techniques should be mastered because this offers the possibility to tailor the strategy according to each patient specificities. Although CP yields some advantages, preserving IVC should not be an objective by all means because a compromised outflow resulting from an inappropriate technique may lead to dramatic consequences [23,24]. CR remains an excellent option in very large graft, caval encirclement by segment 1, or any other technical difficulties.

This study has limitations including the limited number of cases and the retrospective design. However, the specific context of late RLT where the surgeon needs to adapt to each individual case makes any comparative study of CP versus CR unpractical. The single-center nature of this study explains the limited number of cases but has the advantage of homogeneity.

In conclusion, CP is feasible in most of ReLT and is facilitated by a previous 3-vein piggyback anastomosis. Our results suggest that CP limits the risk of renal dysfunction after retransplantation and should be promoted whenever technically possible. Routine CR is not justified in late ReLT.

Authorship

SL, MAA and DC: designed the study. SL, YK, CM and MAA: performed the research. SL, MAA and DC: wrote the manuscript. DA, EV, RA, ASC and NG: contributed important reagent.

Funding

The authors have declared no funding.

Conflicts of interest

The authors have declared no conflicts of interest.

Acknowledgements

We thank Claire Witt-Deguillaume for her technical drawings.

REFERENCES

1. Yoo PS, Umman V, Rodriguez-Davalos MI, Emre SH. Retransplantation of the liver: review of current literature for decision making and technical considerations. *Transpl Proc* 2013; **45**: 854.
2. Cherqui D, Lauzet JY, Rotman N, *et al*. Orthotopic liver transplantation with preservation of the caval and portal flows. Technique and results in 62 cases. *Transplantation* 1994; **58**: 793.
3. Hosein Shokouh-Amiri M, Osama Gaber A, Bagous WA, *et al*. Choice of surgical technique influences perioperative outcomes in liver transplantation. *Ann Surg* 2000; **231**: 814.
4. Reddy KS, Johnston TD, Putnam LA, Isley M, Ranjan D. Piggyback technique and selective use of veno-venous bypass in adult orthotopic liver transplantation. *Clin Transplant* 2000; **14**(4 Pt 2): 370.
5. Nishida S, Nakamura N, Vaidya A, *et al*. Piggyback technique in adult orthotopic liver transplantation: an analysis of 1067 liver transplants at a single center. *HPB* 2006; **8**: 182.
6. Sakai T, Matsusaki T, Marsh JW, Hilmi IA, Planinsic RM. Comparison of surgical methods in liver transplantation: retrohepatic caval resection with venovenous bypass (VVB) versus piggyback (PB) with VVB versus PB without VVB: impact of piggyback without venovenous bypass on liver transplant outcomes. *Transpl Int* 2010; **23**: 1247.
7. Levi DM, Pararas N, Tzakis AG, *et al*. Liver transplantation with preservation of the inferior vena cava: lessons learned through 2,000 cases. *J Am Coll Surg* 2012; **214**: 691.
8. Chan T, DeGirolamo K, Chartier-Plante S, Buczkowski AK. Comparison of three caval reconstruction techniques in orthotopic liver transplantation: a retrospective review. *Am J Surg* 2017; **213**: 943.
9. Belghiti J, Panis Y, Sauvanet A, Gayet B, Fékété F. A new technique of side to side caval anastomosis during orthotopic hepatic transplantation without inferior vena caval occlusion. *Surg Gynecol Obstet* 1992; **175**: 270.
10. Lerut J, Ciccarelli O, Roggen F, *et al*. Cavocaval adult liver transplantation and retransplantation without venovenous bypass and without portocaval shunting: a prospective feasibility study in adult liver transplantation. *Transplantation* 2003; **75**: 1740.
11. Mosimann F, Gillet M. Retransplantation of the liver after side-to-side caval anastomosis. *Transpl Int* 1995; **8**: 157.
12. Bismuth H, Castaing D, Sherlock DJ. Liver transplantation by "face-à-face" venacavaplasty. *Surgery* 1992; **111**: 151.
13. Tayar C, Kluger MD, Laurent A, Cherqui D. Optimizing outflow in piggyback liver transplantation without caval occlusion: the three-vein technique. *Liver Transpl* 2011; **17**: 88.
14. Khwaja A. KDIGO clinical practice guidelines for acute kidney injury. *Nephron* 2012; **120**: c179.
15. Tzakis A, Todo S, Starzl TE. Orthotopic liver transplantation with preservation of the inferior vena cava. *Ann Surg* 1989; **210**: 649.
16. Belghiti J. Feasibility and limits of caval-flow preservation during liver transplantation. *Liver Transpl* 2001; **7**: 983.
17. Addeo P, Schaaf C, Lebas B, *et al*. Three-vein piggyback technique and temporary portosaphenous shunt for liver retransplantation following caval replacement. *Liver Transpl* 2020; **26**: 1195.
18. Ojo AO, Leichtman AB, Merion RM. Chronic renal failure after transplantation of a nonrenal organ. *N Engl J Med* 2003; **10**(349): 931–940.
19. Maggi U, Andorno E, Rossi G, *et al*. Liver retransplantation in adults: the largest multicenter Italian study. Gregson A, éditeur. *PLoS One* 2012; **7**: e46643.
20. Martí J, Charco R, Ferrer J, *et al*. Optimization of liver grafts in liver retransplantation: a European single-center experience. *Surgery* 2008; **144**: 762.
21. Marudanayagam R, Shanmugam V, Sandhu B, *et al*. Liver retransplantation in adults: a single-centre, 25-year experience. *HPB* 2010; **12**: 217.
22. Beal EW. Caval reconstruction techniques in orthotopic liver transplantation. *World J Surg Proced* 2015; **5**: 41.
23. Cescon M, Grazi GL, Varotti G, *et al*. Venous outflow reconstructions with the piggyback technique in liver transplantation: a single-center experience of 431 cases. *Transpl Int* 2005; **18**: 318.
24. Navarro F, Le Moine MC, Fabre JM, *et al*. Specific vascular complications of orthotopic liver transplantation with preservation of the retrohepatic vena cava: review of 1361 cases. *Transplantation* 1999; **68**: 646.
25. Winter A, Féray C, Audureau E, *et al*. A donor quality index for liver transplantation: development, internal and external validation. *Sci Rep* 2018; **8**: 15109.