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ORIGINAL ARTICLE

Venous outflow reconstructions with the piggyback technique in liver transplantation: a single-center experience of 431 cases

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Summary

The ideal method of venous outflow reconstruction with the piggyback technique (PB) in orthotopic liver transplantation (OLT) is not well-established. The complications related to PB in 431 primary OLTs were analyzed comparing the orifices used for the anastomosis (cuff of the recipient left and middle hepatic veins [LM], LM with a >1 cm cavoplasty [LM+], or also including the right hepatic vein [LMR]). Treatment strategies and outcome were also evaluated. Twenty patients (4.6%) experienced complications: 13 of 120 (10.8%) with LM, four of 225 (1.8%) with LM+, and three of 86 (3.5%) with LMR (LM versus LM+: $P < 0.0001$; LM versus LMR: $P =$ NS; LM+ versus LMR = NS). Balloon dilation was successful in 10 of 13 cases in which it was attempted (77%). Eight patients required retransplantation (40%). Three patients (0.7%) died from causes linked to stenosis. Five-year survival of patients with and without complications was 75% and 79%, respectively ($P =$NS); 5-year graft survival was 50% and 76%, respectively ($P = 0.001$). The stump formed by the recipient left and middle hepatic veins with a transversal incision >1 cm of the caval wall constantly provides an adequate width for the caval anastomosis with the PB.

Introduction

Orthotopic liver transplantation (OLT) with vena cava preservation (VCP) has gained widespread acceptance because of the better intraoperative hemodynamic profiles at least theoretically achievable compared with the conventional technique [1–8]. Nowadays, the feasibility of VCP exceeds 90% in centers that strongly promote it even in cases of complicated hepatectomy [9].

Since the first report of VCP by Calne [10] and the first clinical series of OLT with the piggyback (PB) technique by Tzakis *et al.* [1], several different methods of performing venous anastomosis have been described, representing effective innovations and variants which have become the routine approach in the institutions that initially proposed them [11–16].

Because of the unnatural location of the graft in front of the recipient vena cava, the PB technique should provide a sufficient width of the anastomotic orifice, which is sometimes hampered by a mismatching between the patient's soma and the graft size, or by a risk of kinking of the donor liver after implantation. Complications related to the venous anastomosis include bleeding, stricture or kinking, the latter two events possibly leading to acute or early Budd-Chiari syndrome, or chronic outflow obstruction, with different clinical presentations.

The largest and most recent series of OLTs performed with the VCP suggest that the best performing techniques are the cavo-caval side-to-side anastomosis, and the PB using the stumps of the three major hepatic veins [17,18].

As supporters of the VCP compared with the conventional technique [5,19], we retrospectively reviewed our

experience of orthotopic whole liver transplantation with the PB technique, with a focus on the results obtained with the different techniques utilized over time and in an attempt to devise the ideal method of performing caval anastomosis.

Methods

From March 1992 to January 2003, of a total of 658 first orthotopic whole liver transplantations 431 (65.5%) were performed with the PB technique at our institution, including 25 OLTs (3.8%) in an emergency setting. The results of 20 cases have already been reported in a randomized study comparing the PB with the conventional technique [5]. The proportion of OLTs carried out with the PB technique has progressively increased over time, reaching more than 90% of all procedures in the last few years (Fig. 1).

The patient population included 300 men (69.6%) and 131 women (30.4%), with a median age of 53 years (range: 12–65).

The leading indication for OLT was postnecrotic cirrhosis (251 patients, 58.2%), followed by hepatocellular carcinoma (73 patients, 16.9%), alcoholic cirrhosis (36 patients, 8.4%), fulminant hepatic failure (24 patients, 5.6%), cholestatic diseases (23 patients, 5.3%), and other diseases (24 patients, 5.6%). Three hundred and seventeen patients (73.5%) were in status 3 or 2B and 114 (26.5%) in status 2A or 1 according to the old and new united network for organ sharing (UNOS) classification, respectively. Twenty-five patients (5.8%) were operated on in an emergency setting (Table 1).

The technique for the caval anastomosis was employed according to the one previously described by Tzakis *et al.* [1]. More in detail, three different techniques were used that were not randomly assigned, but depended on the specific anatomical situations and on the evaluation of the anastomotic orifices by each surgeon. After suturing of the recipient right hepatic vein (RHV), the donor IVC was anastomosed in an end-to-end fashion with the stump formed by the recipient left (LHV) and middle (MHV) hepatic veins, with interruption of the intervening

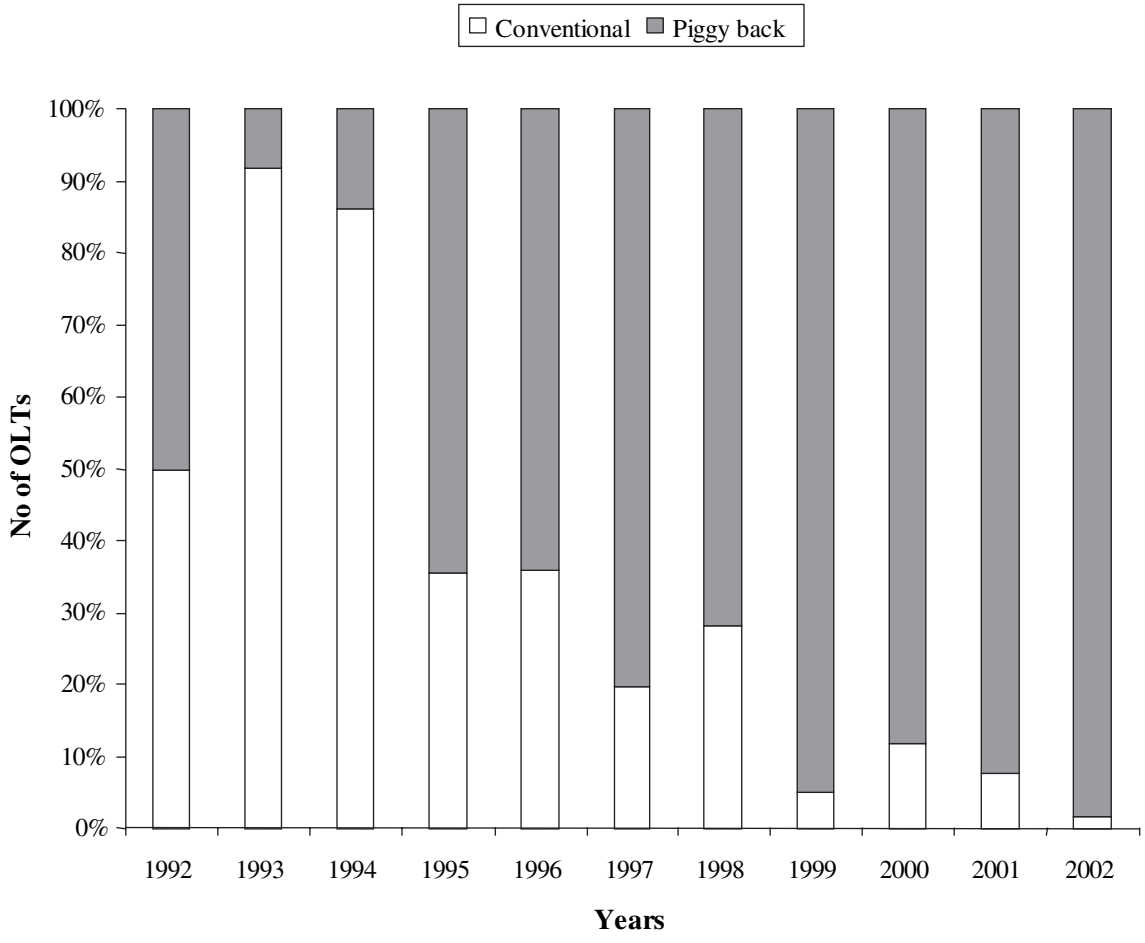

Figure 1 Modification of the use of piggyback and conventional technique in our institution over the years.

Table 1. Preoperative, intraoperative and postoperative profiles of 431 patients undergoing orthotopic liver transplantation (OLT) with the piggyback (PB) technique.

Age (years)	50 ± 10 (12–65)
Sex (male/female)	300 (69.6%)/131 (30.4%)
Condition (elective/urgent)	406 (94.2%)/25 (5.8%)
Gravity	
Status 1, 2* – status 3, 2b†	317 (73,5%)
Status 3, 4* – status 2a, 1†	114 (26,5%)
Indication for OLT	
Postnecrotic cirrhosis	251 (58.2%)
HCC on cirrhosis	73 (16.9%)
Alcoholic cirrhosis	36 (8.4%)
Fulminant hepatic failure	24 (5.6%)
Cholestatic diseases	23 (5.3%)
Other	24 (5.6%)
Operation time (min)	467 ± 95 (250–940)
Total ischemia time (min)	500 ± 127 (245–1024)
I.o. PRBC transfusions (ml)	2776 ± 2815 (0-29 200)
I.o. FFP transfusion (ml)	2623 ± 1727 (0-12 900)
ICU stay (days)	5 ± 7 (1–76)
Hospital stay (days)	20 ± 13 (6–105)

*UNOS scores according to the old classification.
†UNOS scores according to the newer classification.
PBRC, packed red blood cells; FFP, fresh frozen plasma; ICU, intensive care unit; I.o., intraoperative.

septum. The LHV and MHV, without cavoplasty or with an incision of less than 1 cm of the adjacent caval wall (LM), were used in 120 patients (27.8%). In 225 cases (52.2%), the LHV and MHV orifice was enlarged transversally in order to include a tract of more than 1 cm of the anterior caval wall (LM+). Finally, in 86 cases (20%) the venous stump also included the right hepatic vein (LMR), with incision of the caval wall between the RHV and MHV (Fig. 2). The cavo-cavostomy technique was never employed.

In general, when the LM+ and LMR were performed, there was a more accurate dissection of the IVC from the diaphragm and a wider area of the caval wall was included in the transversal clamping. A clamping test was always performed after diaphragm dissection and before proceeding with the anastomosis in order to check the clamp placement ensuring the largest bite and the least reduction of the caval flow at one time. There were no cases of significant caval flow alteration, and no patient transplanted with the PB technique required the use of a venovenous bypass because of intolerance to transversal clamping. It is not the intention of this study to provide a detailed report of the changes of hemodynamic parameters (i.e. arterial and pulmonary pressures, and urine output) during caval anastomosis.

The choice between the LM+ and the LMR was basically dictated by the distance and the alignment between the common channel of the LHV and MHV, and the RHV, and by the patient's tolerance to partial clamping of the vena cava. The inclusion of the venous stump of the RHV was considered unfeasible when its orifice was very far from the LHV and MHV, and/or when it had a significant impact on hemodynamic parameters.

Surgeons performing LM+ used LMR only in sporadic cases (perfect alignment of the three veins), these isolated procedures being randomly distributed throughout the study period. Surgeons performing LM generally moved to LM+ or LMR in more recent years because of the high incidence of complications emerging from the use of LM.

In order to investigate the influence of the mismatch between the graft and the recipient size, the difference between donor and recipient standard liver volume [20] was calculated in patients with outflow complications.

Intra- and postoperative variables were evaluated and charts reviewed for the purpose of this study, with special reference to complications directly correlated to the caval anastomosis and to the three different techniques used. Complications were divided into immediate (intraoperative or within the first p.o. day), early (from the second p.o. day to the first p.o. month) and late (occurring thereafter). Anastomotic stricture or kinking was revealed intraoperatively by sudden graft congestion (acute Budd-Chiari syndrome) and absence of a phasic waveform at the US Doppler examination of major hepatic veins.

Postoperatively, outflow complications were first suspected by the presence of one or more of the following clinical signs, after exclusion of other possible causes: (i) ascites; (ii) tissutal edema at the level of the abdomen and/or lower limbs (these conditions being unresponsive to diuretics); (iii) cholestasis with subsequent progressive liver failure; and (iv) renal dysfuction. All patients received hepatic US Doppler evaluation at least twice in the first postoperative week, and whenever required by clinical and biochemical parameters. The absence or reduction of the typical phasic waveform at the US Doppler examination of the major hepatic veins supported the diagnosis of an outflow obstacle. All but immediate cases of stenosis or torsion seen with Doppler and/or suspected from symptoms were confirmed by percutaneous transjugular cavography. The pressure gradients between the recipient vena cava above and below the anastomosis, and between the suprahepatic vena cava and each of the three major hepatic veins were measured. In the presence of an elevated gradient, balloon catheters of adequate diameter were advanced across the stenosis, inflated and maintained at this level for few minutes. If a reduction of the gradient and a normalization of symptoms were obtained, no further manoeuvres were performed. If the symptoms persisted, a second dilation was attempted or another treatment was adopted. There was no attempt at a third

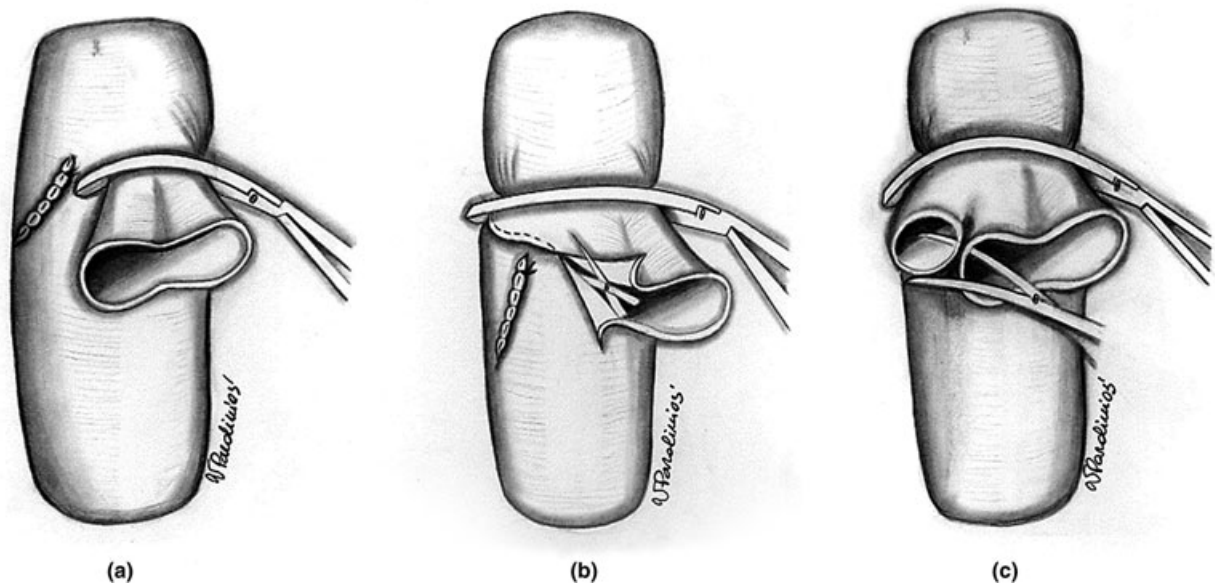

Figure 2 Scheme of the stumps of the recipient's major hepatic veins used for the piggyback anastomosis. (a) Left and middle hepatic veins with a <1 cm opening of the adjacent caval wall (LM). (b) Left and middle hepatic veins with a >1 cm opening of the caval wall (LM+). (c) Left, middle and right hepatic vein (LMR).

dilation and stents were never used. Especially in the initial period of the study, in some patient the interventional approach was not undertaken even in the event of a high pressure gradient, preferring surgical repair or retransplantation (reOLT). The technique of balloon dilatation (BD) did not change throughout our experience [21], and did not differ from the experience of other groups [22].

Finally, the change in the various treatment options over time and the long-term survival were analyzed.

Results were expressed as mean ± SD. Differences between groups were evaluated with the χ^2-test or the Fisher's exact test. Actuarial survivals were computed with the Kaplan–Meier method, and the differences between groups were compared by the log-rank test.

Results

Median follow-up was 34.5 months (range: 0–125.5); 356 patients (82.6%) were alive and 75 (17.4%) were dead at the end of the study.

Mean operation time and total ischemia time were 7 h, 47 min and 8 h, 20 min, respectively. Mean amount of packed red blood cells and fresh frozen plasma transfusions were 2776 and 2623 ml, respectively. Postoperative mean intensive care unit stay and hospital stay were 5.6 and 20.5 days, respectively (Table 1).

Complications related to caval anastomosis occurred in 20 patients (4.6%) (Table 2). They were divided as follows according to the type of anastomosis: 13 of 120 patients (10.8%) operated on with LM, four of 225 patients (1.8%) operated on with LM+, and three of 86 patients (3.5%) operated on with LMR. This resulted in a statistically significant difference between LM and LM+ ($P < 0.0001$), but not between LM and LMR ($P = 0.065$) or between LM+ and LMR ($P = 0.4$).

There were 15 cases of anastomotic stricture (3.5%), four cases of thrombosis (0.9%) and one of kinking (0.2%). As for the timing of complications, they became evident during OLT in two patients (0.4%), in one case following an attempt to suture a severe lesion of the donor vena cava. Early complications occurred in 12 patients (2.8%) and late complications in six (1.4%). In two cases only, the identification of the outflow complication was made more than 2 months after OLT, these patients also having severe hepatitis C recurrence as a coexisting cause of graft failure.

The difference between donor and recipient standard liver volume seemed to have no impact on occurrence of complications, and a discrepancy of more than 100 ml^3 was observed only in eight patients (five with LM, three with LMR and one with LM+).

Regarding the venous outflow complications in the four patients with LM+, they were retrospectively attributable to an insufficient (although >1 cm) opening on the right of the common channel (LHV + MHV) in two cases, to a size mismatch in one case and to an

Table 2. Complications related to caval anastomosis.

N	Complication	Type of anastomosis	Timing	dSLV – rSLV (ml^3)	Treatment	Status	Survival
1	Thrombosis	LM	i.o.	−155	ReOLT	D	42 days
2	Thrombosis	LM+	30 days	75	ReOLT	D	44 days
3	Stenosis	LM	29 days	50	BD	A	65 months
4	Stenosis	LM	14 days	52	CCA	A	60 months
5	Stenosis	LM	226 days	−58	ReOLT	A	57 months
6	Stenosis	LM	62 days	51	BD	A	50 months
7	Stenosis	LM	11 days	−180	BD	A	45 months
8	Stenosis	LM	15 days	285	BD	D*	28 days
9	Stenosis	LM	5 days	113	BD → ReOLT	A	44 months
10	Thrombosis	LM+	10 days	5	ReOLT	A	38 months
11	Thrombosis	LM	i.o.	−257	ReOLT	A	35 months
12	Stenosis	LM	25 days	94	ReOLT	A	35 months
13	Kinking	LM	125 days	−25	BD → CCA → ReOLT	D	11 months
14	Stenosis	LM	63 days	54	BD	A	33 months
15	Stenosis	LM+	50 days	74	BD	A	33 months
16	Stenosis	LM	30 days	38	BD	A	29 months
17	Stenosis	LMR	57 days	−125	BD	A	24 months
18	Stenosis	LMR	19 days	118	BD	A	18 months
19	Stenosis	LMR	16 days	39	BD	A	16 months
20	Stenosis	LM+	20 days	175	BD → CCA	D*	4 months

LM, anastomosis with the stump of the recipient left and middle hepatic veins; LM+, anastomosis with the stump of the recipient left and middle hepatic veins, with a transversal extension along the caval wall >1 cm; LMR, anastomosis with the stump of the recipient left, middle and right hepatic veins; i.o., intraoperative; dSLV – rSLV, difference between donor and recipient standard liver volume; ReOLT, retransplantation; BD, angiographic balloon dilation; CCA, redo cavo-caval anastomosis; A, alive; D, dead; D*, death unrelated to outflow complications.

accidental inclusion of the posterior caval wall in the running anterior suture of the caval anastomosis in one case.

Treatment of complications

All four cases of thrombosis required early reOLT (3–30 days after the first transplant) without performing other treatments; two patients died soon after reOLT and two are still alive and well. ReOLT was also offered as first-line treatment to two patients with anastomotic stricture 25 and 226 days after OLT, respectively. In the first case, the patient presented with deterioration of hepatic function and BD was not performed because a new graft became available immediately after detection of the outflow problem. In the latter case, the concomitant indication for reOLT was a severe hepatitis C reinfection. Both these patients are alive and well.

The remaining cases were initially managed with either BD during cavography (13 patients, 65%) or a second procedure consisting of an end-to-side cavo-caval anastomosis (CCA) between the distal stump of the donor vena cava and the recipient vena cava [23] (one patient, 5%). This latter procedure was successful and the patient is still in good conditions.

All patients treated with BD had an elevated pressure gradient between the suprahepatic inferior vena cava or the right atrium, and at least one of the major hepatic veins. In four cases, there was also a narrowing of the lumen of the recipient inferior vena cava at the anastomotic site. As described previously, BD was applied across the surgical suture and along the proximal tract of the hepatic vein(s) with abnormal pressure, and into the vena cava in the event of residual reduction of its size.

The BD definitely restored a normal flow in 10 cases (77%), in eight patients after one session (62%) and in two patients after two sessions (15%). Only one patient in this group died from causes unrelated to outflow complication. In one case, one session of BD proved only partially successful and the patient was retransplanted, achieving long-term survival. In another patient with progressive liver insufficiency initially ascribed to hepatitis C recurrence, anastomotic kinking was demonstrated late and treated with one session of BD, which was ineffective. CCA was then attempted, but the patient eventually required reOLT and died soon after. The third patient had a partial benefit from one session of BD and a total recovery after CCA, but she subsequently died from causes independent of venous complications.

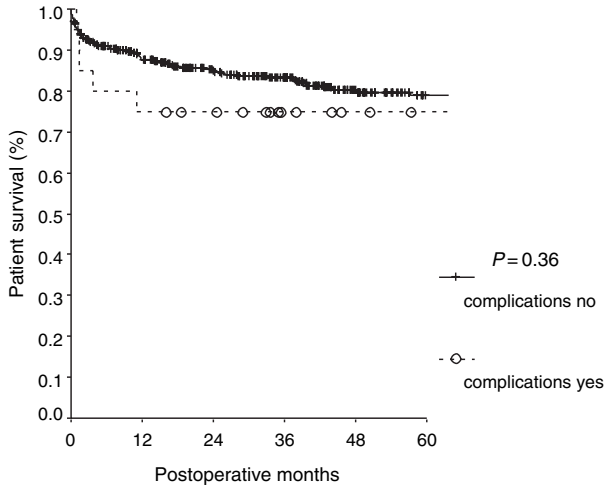

Figure 3 Actuarial survival of patients with and without venous complications related to the piggyback anastomosis.

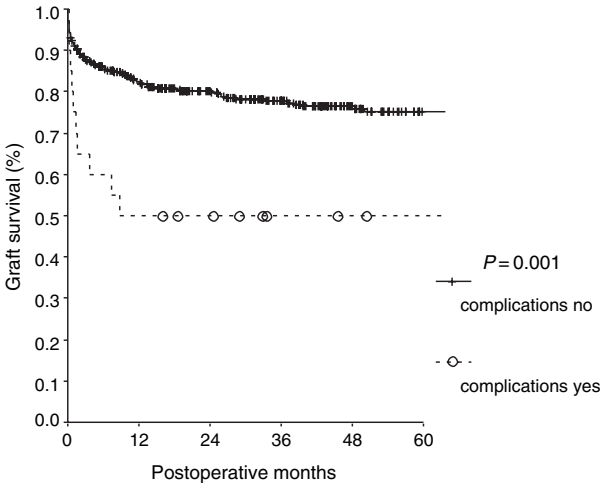

Figure 4 Actuarial graft survival in patients with and without venous complications related to the piggyback anastomosis.

Concerning the four complications in patients in whom LM+ was performed, reOLT was required in two cases, being effective only in one, and BD and CCA in one case each, with complete resolution of the anastomotic narrowing.

Mortality and retransplantation rates – long-term survival

Overall, three of 431 patients (0.7%) died from causes linked to PB complications (15% of all patients with venous outflow alterations). Eight patients (1.8% of the entire series, 40% of those with venous complications) required reOLT as first-, second- or third-line treatment. ReOLT was ultimately performed in eight of 13 (61.5%) patients with venous complications before March 2000, and in 0 of seven (0%) patients with venous complications after March 2000 ($P = 0.015$). Only one patient with LM+ (0.4%) died because of multiorgan failure following reOLT for venous obstruction, while reOLT was needed to definitively obviate outflow alterations in two cases in this group (0.9%).

As a result, 3- and 5-year patient survival in the group with PB complications was comparable with that of patients who did not experience such complications (75% and 75% vs. 83% and 79%, respectively; $P = 0.36$), but graft survival was significantly lower (50% and 50% vs. 78% and 76%, respectively; $P = 0.001$) (Figs 3 and 4).

Discussion

Since the establishment of the superiority of the PB compared with the conventional technique in our institution as regards perioperative parameters [5], we have been routinely attempting VCP in OLT, nowadays succeeding in more than 90% of cases [19]. In spite of its advantages, however, the PB technique does not restore a perfectly physiological situation, and the risk of creating an obstacle to the venous outlet is higher, remaining the only drawback compared with the use of the classic caval reconstruction. This led us to retrospectively assess the effectiveness of the PB technique in our entire series of OLTs.

The analysis of the results achieved with the three types of anastomosis showed that the creation of an orifice formed by the LHV and MHV without cavoplasty led to a markedly increased risk of venous outflow alterations. Conversely, this complication occurred in only 1.8% of cases in which the venous cuff was extended to include a portion of the caval wall longer than 1 cm. Unlike other Centers where the anastomosis with the three major hepatic veins proved to be the best option [16], this technique was used only in a minority of our patients, making it difficult to draw definite conclusions on its effectiveness. We have no experience with side-to-side or end-to-side CCA. Finally, our experience shows that the complication rate remained almost constant over time and was not influenced by a learning curve.

To date there is no unanimous agreement on the best technique to be used for the caval anastomosis.

A large, multi-institutional French study showed that the rate of complications was significantly higher in patients where the PB technique instead of side-to-side CCA was performed in OLTs with VCP [18]. The value of the latter technique was firstly shown and then confirmed, with some variations, by Belghiti *et al.* [12], which also demonstrated the better hemodynamic conditions

achievable with this type of anastomosis [24]. On the contrary, another recent multi-centric study from Spain reported the excellent results (3.8% of complications) obtained with the PB technique, especially when performed by using the three veins on the recipient site [17]. However, this report does not specify whether the use of two veins included any extension along the caval wall. Again, a further recent study showed that the orifice fashioned by including the LHV and MHV with a longitudinal cavotomy did not offer significant advantages compared with the two veins alone [25].

The results obtained with LM+ are similar to the best reported in the largest studies [17,18], whereas some advantages can be devised compared with other techniques. In our opinion, the possibility of widening the anastomotic orifice while maintaining a good flow into the IVC in spite of its transversal clamping makes this technique faster and less demanding than others, but equally efficacious for OLT. The use of the three veins, as already reported [16], implies a more extensive dissection of the diaphragm and a more pronounced obstacle to the caval flow, which might have compromised the hemodynamic stability of some of our patients. In such instances, a venovenous bypass should be performed, although this prolongs the procedure or increases the operative risk. Moreover, while LM+ provides an optimal alignment of the anastomotic orifice, this is not always the case with LMR, because of the frequent location on different planes of the common channel of LHV and MHV, and RHV. Consequently, LMR necessitates an even more careful detachment of the diaphragm from the vena cava, whose imperfect accomplishment might have been responsible for the three complications which occurred with this technique in our series.

Despite a global rate of complications comparable with that reported by others, their type, timing and treatment are somewhat different in our series. The already mentioned multi-center French study [18] showed an incidence of complications related to venous anastomosis of 4.1%, with a correlated mortality of 18%, on a total of 1361 OLTs performed with this technique. However, some 89% of complications were immediate (within the first operative day) and more than 60% consisted of bleeding from the anastomotic site, making immediate surgical management the only treatment option. Moreover, early and late events, which are the most frequent in our experience, were apparently absent in that study. An incidence of 2% of acute outflow obstruction requiring revision of the anastomosis and leading to 80% of graft failure was recently reported in a large single-center experience [9]. Similarly, in the multi-institutional series of Parrilla *et al.* [17], most complications were intraoperative, consisting of mislocation or twisting, and were treated mainly by techniques of graft derotation. In the same study, almost all cases of early complications (acute Budd-Chiari syndromes) required reOLT.

In our experience, there was only one case of severe bleeding whose repair caused the anastomotic stricture, whereas the graft congestion became evident intraoperatively only in two patients, thus limiting the possibilities of immediate surgical treatment, such as a second anastomosis [23] or the creation of a neo-bed to avoid a possible misplacement of the graft [17]. The first solution was adopted as a rescue treatment after OLT in three cases, while the only patient with kinking could not benefit from the derotation of the graft, this complications being diagnosed late in the postoperative course.

Most complications were detected in the early postoperative period probably because the outflow block was less severe than that reported by others, being unapparent during surgery. We had a high incidence of retransplantation (40%), leading to a significantly lower graft survival in the group of patients suffering from obstructive complications. In the report by Parrilla *et al.* [17], however, the need for reOLT was even higher (80%).

We underwent a learning curve in the management of outflow complications. In the initial phase of our experience, we were not confident with the interventional radiology approach and reOLT was often chosen as first-line treatment. More recently, the majority of patients were treated with BD. The pressure gradient at the level of the caval anastomosis was permanently eliminated in nearly 80% of cases treated with this technique, which is now our primary tool in the attempt to correct anastomotic problems.

In the case of outflow complications, our decision process is now the following: (i) intraoperative liver congestion or Budd-Chiari syndrome are immediately treated by graft derotation or CCA, leaving reOLT as the ultimate choice in the event of failure. (ii) Postoperative suspicion of stenosis/torsion/kinking has to be confirmed by cavography and managed with BD, in two sessions if only a partial improvement of pressure gradients and symptoms is achieved through the first one. (iii) Failure of BD or angiographic evidence of torsion/kinking are managed with CCA or graft derotation. (iv) ReOLT is reserved for cases of severe and apparently irreversible graft dysfunction and failure of all of the above treatments.

In conclusion, our study shows that: (i) the caval anastomosis can be effectively performed with a routine utilization of the stump formed by the recipient LHV and MHV, with a transversal incision of more than 1 cm of the adjacent caval wall, while the single orifice formed by the LHV and MHV does not provide an adequate width and should therefore be proscribed; (ii) nowadays most

cases of anastomotic narrowing diagnosed postoperatively can be effectively managed with angiographic BD.

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