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RAPID COMMUNICATION

Intraoperative stent placement for the treatment of acute portal vein complications in pediatric living donor liver transplantation

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Abstract

Purpose

Pediatric living donor liver transplantation (LDLT) in low weight recipients remains one of the most complex surgical procedures, with portal vein (PV) complications occurring in up to 19% of cases. When decreased PV flow is diagnosed intra- or perioperatively, intraoperative stent placement is a good substitute for surgical adjustment. Still, at the present moment, little is known about the technical feasibility, safety, efficacy, and long-term outcome of intraoperative stenting in LDLT.

Methods

Between 2006 and 2017, seven pediatric recipients underwent PV stent placement during the transplant or in the immediate post-operative setting. Preoperative, operative, and post-operative parameters were documented retrospectively.

Results

In total, nine stents were placed in seven patients. Procedures were technically successful in all patients. During the mean imaging follow-up period of 1313 days, none of the patients showed PV abnormality and PV stent remained patent throughout the post-transplant course. There were no deaths or graft loses during the follow-up period.

Conclusions

Intraoperative stenting through the inferior mesenteric vein approach offers both a high feasibility and satisfactory results, with the potential for excellent long-term primary patency despite continued growth in children.

Keywords Portal vein stenosis · Pediatric LDLT · Stent

Introduction

Pediatric living donor liver transplantation (LDLT) in low weight recipients remains one of the most complex surgical procedures. The technical difficulties associated with the almost unavoidable donor–recipient size discrepancy have prompted multiple approaches to overcome the challenges of graft reduction, complex vascular reconstructions, and intricate abdominal closures. The complexity of the surgery contributes to the increased risk for portal vein (PV) complications in the pediatric population. Small PV size, the use of partial grafts, displacement of liver graft, and the use of venous conduits to connect the PV of the donor with the recipient have all been associated with PV stenosis, occlusion, and thrombosis. This is especially prevalent in patients with biliary atresia (BA), who have periportal inflammation and fibrosis from recurrent cholangitis that are additionally young and small at the time of transplantation. In these cases, surgical reconstruction can be technically demanding owing to the hypoplastic and sclerotic PV [1, 2].

So far, the result of stent placement in PV is encouraging, mainly because it can sustain long time period of vessel patency. However, the scientific evidence regarding the use of PV stent in transplantation is still scarce and continues to be based almost exclusively on experience in patients in whom PV steno-occlusive disease is diagnosed long after the transplant and, therefore, is approached percutaneously.

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Intraoperative stent placement, on the other hand, is preferred when low PV flow is detected either during the transplant or in the immediate post-transplantation period. Still, at the present moment, little is known about its technical feasibility, safety, efficacy, and long-term outcome of intraoperative stenting in LDLT. In the current series, we outline our experience in pediatric LDLT recipients in whom PV stents were placed either during the transplant or the immediate (< 24 h) post-transplant period. We propose this technique as an effective alternative to address the complex problem of PV steno-occlusive disease in pediatric LDLT.

Materials & methods

Patient population

Between June 2006 and June 2017, 660 consecutive liver transplants were performed at the Hospital Italiano de Buenos Aires. One hundred and seventy-three involved pediatric (< 18 years old) recipients, of which 64 (36.9%) included living donors. Seven of these patients (10.9%) underwent PV stent placement during the transplant or in the immediate (< 24 h) post-operative period.

According to the Argentinean law, living donors should be genetically related until second line blood (grandparents, father, mother, brother, or uncles) and foreign patients can only be transplanted using living-related donors because they cannot be listed for cadaveric transplants.

Techniques for intraoperative PV stenting via the IMV

All procedures are performed under general anesthesia. The authors' techniques of donor and recipient surgery in pediatric LDLT have been described previously for both left lateral segment [3] and hyper-reduced left lateral segment liver grafts, tailoring the volume and shape of the graft to the specific intraoperative dimensions [4]. The portal vein anastomosis is fashioned with running 7-0 polypropylene sutures, as close as possible to the confluence of the recipient's splenic and mesenteric veins. Growth factor is routinely used in these patients. In order to compensate the PV mismatch, the anastomosis is occasionally performed as close as possible to the confluence of the superior mesenteric vein and the splenic vein. In addition, a small venotomy on the anterior and posterior face of the PV can be done to widen the anastomosis. One patient presented a small portal vein thrombosis at the time of transplantation that occluded less than half of the lumen without compromising the superior mesenteric vein. In this patient, eversion thromboendovenectomy and minimal resection of damaged vein were done before performing the porto-portal anastomosis. In cases that require venous conduits, these are taken from our institutional tissue bank and sutured under the same technique described for PV anastomosis without conduits. In patients with significant portal hypertension who presented PV collaterals on exploration, collateral vessels are ligated surgically including the coronary vein to increase portal flow. The decision to re-do the PV anastomosis in the presence of decreased or absent flow remains at the discretion of the surgeon. This case-by-case decision is mostly based on the appearance of the anastomosis as well as the findings in the intraoperative portal venogram. Portal vein re-anastomosis is preferred in patients in whom this alternative appears technically feasible, and there is a visible imperfection in the disposition of the anastomosis. If the stent placement is performed during the LDLT, the procedure occurs in a regular OR under portable C-arm (BV300, Philips, Amsterdam, the Netherlands) fluoroscopic guidance. In cases in which the stent is placed after the transplant, patients are taken to a hybrid OR prepared with a rotational angiography equipment (Artis Zeego, Siemens, Forchheim, Germany).

After laparotomy, the inferior mesenteric vein (IMV) is isolated and then punctured with a Jelco 18-gauge teflonized catheter (Fig. 1) (Smith Medical International, Pemberton, UK). With a Seldinger technique, the angiocatheter is exchanged for a 5-F sheath over a 0.035-in. angulated hydrophilic guidewire (Terumo, Tokyo, Japan). Next, direct portal venography is performed to assess the portal anatomy and detect alterations such as stenosis, torsion of the portal vein, or spontaneous portosystemic shunts. The hydrophilic guide and a 5-F cobra catheter (Cook, Bloomington, IN) are used to advance the intrahepatic portal vein through the surgical portal vein anastomosis. At this point, a bolus of 1000 units of heparin is administered directly into the portal vein.

The choice of stent and its subsequent placement is made on the basis of the diameter and length of the donor's proximal portal vein. Three types of metal self-expanding MRI compatible stent are used: Wallstent (Boston Scientific, Galway, Ireland), Zilver Stent (Cook), and Precise Pro (RX, OH, USA). The stents are used according to the available stock in our institution. These are intentionally oversized approximately 1–2 mm to reduce the risk of migration. When necessary, angioplasty is performed with a 10–12-mm balloon (Ultrathin diamond or Synergy; Boston Scientific, Watertown, MA) before or after stent placement. The balloon is insufflated during 30 s once or twice as decided by the angiographist. Following stent placement, direct portal venography is repeated to evaluate the improvement of portal inflow and changes in the portosystemic shunt. Finally, the puncture site is closed using a simple closure with 8-0 to 10-0 prolene.

Patients with PV stents receive enoxaparin—0.5 mg/kg every 12 h—to reach a antiXa of 0,2 a 0.4 UI as well as oral antiplatelets (aspirin 3 to 5 mg/kg every 24 h) for 3–6 months following the procedure. However, patients who have coagulopathy are given oral anti-platelets when their coagulation function had normalized.

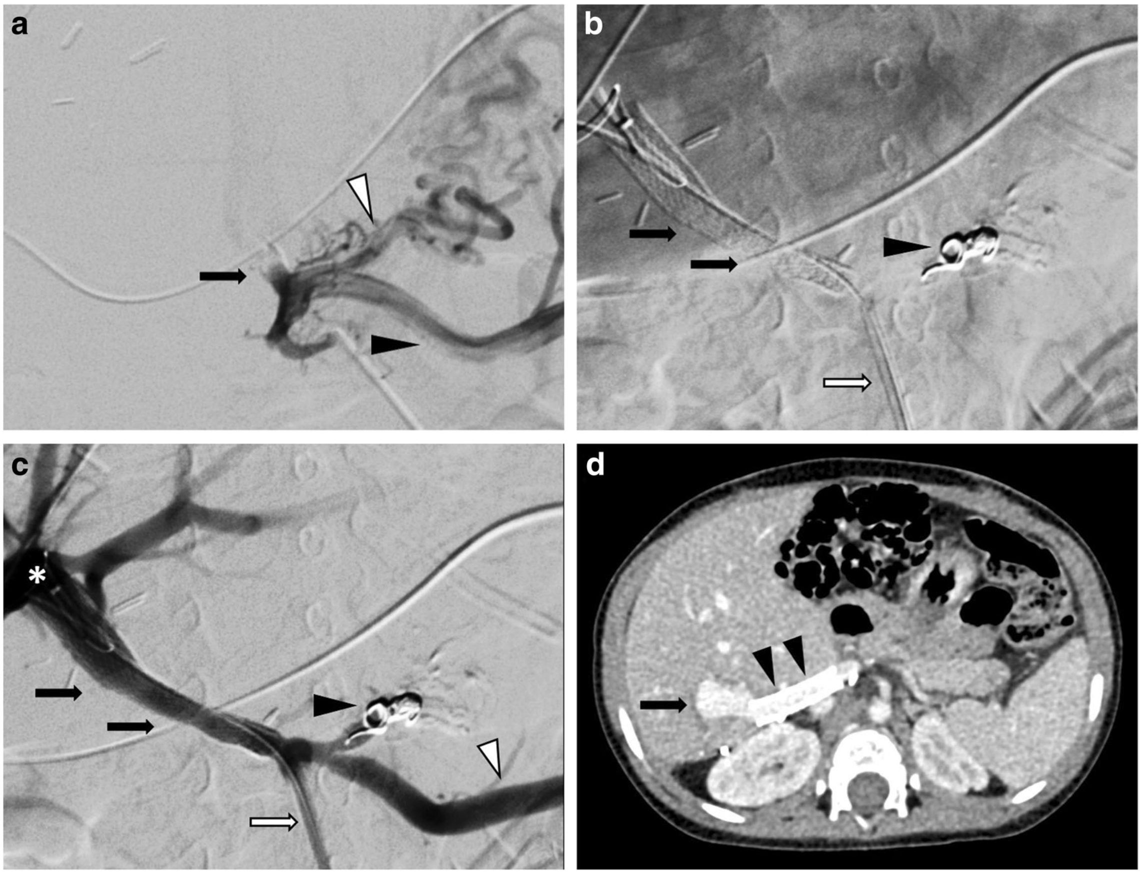

Fig. 1 Intraoperative portal vein stent placement from a 15-month-old male with portal steal flow syndrome after living donor liver transplantation. **a** Initial portal venography demonstrates absence of contrast in the portal vein (black arrow), as the flow takes an hepatofugal direction towards the splenic (black arrowhead) and coronary veins (white arrowhead). **b** With the intention of lowering the resistance in the portal system and increasing the portal flow, a portal vein stent (black arrows) is placed through the inferior mesenteric vein (white arrow) and the coronary vein is embolized with coils (black arrowhead). **c** Venography following procedure through the inferior mesenteric vein (white arrow) shows a markedly improved appearance, with the portal vein stent (black arrows) correctly placed, absence of contrast in the coronary vein (black arrowhead), and proper flow to the portal system (white asterisk) with some contrast enhancement of the splenic vein (white arrowhead). **d** Computed tomography angiography ordered a year after the procedure shows the stent correctly placed in the portal vein (black arrowheads) with a contrast-enhanced Rex recess (black arrow) confirming its patency

Follow-up

The following parameters were documented retrospectively: technical success and complications, clinical success, and the patency of the PV inflow. We defined technical success as successful stent placement in the intended location of the PV with subsequently normal PV inflow. We defined clinical success as subsequent improvement of liver function after LDLT and absence of the clinical manifestations related to portal hypertension. We defined major complications as those necessitating an increased level of care, an additional surgical or interventional manipulation, adverse sequelae, or death.

Patency of the PV inflow was evaluated by means of Doppler ultrasound (DUS) and computed tomography angiography (CTA). Doppler US was routinely performed every 12 h for the first week after LDLT, and weekly thereafter until the patient was discharged, then 1, 3, 6, and 12 months after discharge. A CTA was required in case of abnormal DUS results, and a direct portogram was carried out if necessary.

Results

Patient characteristics

Demographic data of all patients is resumed in Table 1. The primary indication for LDLT was BA in all the patients included. Mean age was 16.7 months (range, 6–26) and all children weighed < 13 kg (9.119 kg; range, 7.2–12.5), with a mean graft–recipient weight ratio of 4.05% (range, 2.8–4.9). Donors were the mother in three cases, the father in two, and an aunt in one case. Pretransplant DUS demonstrated hepatopetal flow in four and hepatofugal flow in three patients. One patient had partial PV occlusion visualized on preoperative CTA.

Table 1 Demographic data of all patients

Case	Year	Age (months)	Sex	BW (kg)	Height (cm)	Primary disease	GRWR (%)	Pretransplant CTA PV size (mm)	Pretransplant DUS PV flow	Portal hypertension
1	2006	6	F	7.7	65	BA	4.2	5	HP	Mild
2	2011	23	F	12.5	81	BA	3.7	4.7	HF	Moderate
3	2015	18	M	8.9	73	BA	2.8	4.2	HP	Moderate
4	2016	18	F	7.9	73	BA	3.9	4	HP	Mild
5	2016	26	F	11.6	79	BA	4.4	5.4	HF	Severe
6	2016	15	M	7.2	67	BA	4.5	4.3	HF	Mild
7	2017	11	M	8.1	70	BA	4.9	4.1	HF	Severe

BA biliary atresia, *CTA* computed tomography angiography, *DUS* Doppler ultrasound, *GRWR* graft–recipient weight ratio, *HF* hepatofugal, *HP* hepatopetal, *M:F* male:female, *PV* portal vein

Technical details and outcomes of intraoperative PV stenting are shown in Table 2. Mean age was 16.7 months (range, 6–26), and all children weighed < 13 kg (9.119 kg; range, 7.2–12.5). Mean ischemia and surgery time were 90 min (range, 60–240) and 378 min (range, 249–480), respectively. In four patients included, PV was reconstructed using a venous conduit due to donor-recipient PV mismatch. In total, nine stents were placed in seven patients. In four cases, stents were placed during the LDLT procedure, while three patients had the stent placed during the first 24 h after the transplant. Five cases developed PV thrombosis after the anastomosis and required thrombectomy together with the placement of the PV stent. All thrombosis found in the series would correspond to a grade II of Yerdel's classification (50 to 100% of portal vein occlusion with no or minimal obstruction of the superior mesenteric vein). Two patients required two stents due to the length of the lesion. They were placed coaxially through the inferior mesenteric vein. One of these patients had both stents placed in the PV during the same procedure. On the other, a stent was placed during LDLT, but post-operative DUS showed absence of portal flow. The patient was taken to the hybrid OR and a second stent was placed with no procedural complications. Portal vein stent placement was technically successful in all patients. Interestingly, no difference was noticed among the different stents used in terms of procedural technical aspects or in final (short- and long-term) outcomes.

Mean hospital stay was 39 days (range, 15–93) after LDLT and stent placement with appropriate liver function and stent clinical success. During the mean imaging follow-up period of 1313 days (range 399–4255 days), none of the patients showed PV abnormality and PV stent remained patent throughout the post-transplant course. There were no deaths or graft loses during the follow-up period.

Table 2 Operative characteristics of pediatric recipients with intraoperative PV stenting

Case	Donor	Graft type	IT (min)	ST (min)	Venous conduit	IO PVF	Setting (h)	PVT*	Stent size (mm)	Re-anastomosis	Outcome	PRC	HS (days)	FU, days (months)	Status
1	Mother	HR	85	360	No	Decreased	IO	No	6 × 40	No	Successful	No	34	4255 (141)	Patent
2	Father	LLS	240	420	Yes	Absent	IO	No	8 × 40	Yes	Successful	No	93	1544 (51.4)	Patent
3	Mother	HR	110	480	Yes	Normal	PO (6)	Yes	6 × 40	No	Successful	No	29	1163 (38.7)	Patent
4	Father	HR	75	310	No	Normal	PO (20)	Yes	6 × 40	No	Successful	No	37	549 (18.3)	Patent
5	Mother	LLS	90	480	Yes	Decreased	IO (6)	Yes	6 × 40, 7 × 30	Yes	Second stent needed	No	25	500 (16.7)	Patent
6	Mother	HR	80	249	No	Normal	PO (16)	Yes	7 × 30	No	Successful†	No	15	781 (26)	Patent
7	Aunt	HR	60	350	Yes	Absent	IO (6)	Yes	6 × 40, 8 × 30	Yes	Successful	No	29	399 (13.3)	Patent

FU follow-up, *HR* hyper-reduced, *HS* hospital stay, *IT* ischemia time, *IO* intraoperative, *LLS* left lateral segment, *PO* post-operative, *PRC* procedure-related complications, *PV* portal vein, *PVF* portal vein flow, *PVT* portal vein thrombosis, *ST* surgery time

*Thrombus found during portal venography after portal vein anastomosis

†Left gastric vein embolization

Discussion

The shortage of deceased donor liver grafts led to the use of LDLT. Patients who undergo LDLT have a higher risk of PV complications than those who undergo deceased donor LT [5]. Small PV size, the use of partial grafts, displacement of liver graft, and the use of venous conduits to connect the PV of the donor with the recipient have all been associated with PV stenosis, occlusion and thrombosis. In children, LDLT is particularly challenging, with PV complications occurring in up to 19% of cases [6]. A number of surgical strategies have been implemented to avoid PV complication in the pediatric recipient population including the use of branch patch anastomosis at the bifurcation of the right and left branches of the recipient PV, doing anastomosis at the recipient confluence of the superior mesenteric and splenic veins, the use of an interposing vein graft (for children in whom insufficient length was observed between the graft PV and recipient PV), and the use of portoplasties (for patients with sclerotic or stenotic PV) [7]. However, none of these strategies completely eliminates the risk of early PV complications. Early management of PV abnormalities is essential to obtain morbidity, mortality, and graft loss rates comparable to that of the general population of pediatric liver recipients. However, current experience with pediatric PV stenting is mostly focused on PV abnormalities diagnosed long after the transplant, when the percutaneous approach is feasible. When decreased PV flow is diagnosed intra- or perioperatively, on the other hand, intraoperative stent placement is a good substitute for surgical adjustment. This is especially useful in patients with BA, as the presence of a hypoplastic and sclerotic PV prevents an effective surgical reconstruction [5, 8, 9]. In these patients, when insufficient portal flow is detected by DUS after reperfusion, on-table direct portogram can be made to assess the cause of insufficient PV flow and do stent placement if necessary [10]. The present study is the largest series of intraoperative stent placement in LDLT using the IMV approach. We propose this technique as an effective alternative to prevent the frequent and complex problem of PV steno-occlusive disease in pediatric LDLT.

The long-term patency of PV stents has been previously investigated in the population of liver recipients. Reported stent patency was of 60–100% during 1–2-year follow-up periods [11]. To date, few studies have focused on longer term outcomes with stent treatment for the PV occlusion after pediatric LT showing excellent patency rates [12]. Regarding intraoperative PV stents in pediatric recipients, the experience is limited to only few cases reported. Kim et al. reported a series of 36 patients who underwent intraoperative PV stent placement with a technical success and long-term vessel patency rates of 97.7% and 94.3%, respectively [6]. Among the 36 patients analyzed, only two recipients were children but no description of the graft used or underlying condition of these cases are included in the study. LDLT in children differ from adult LT in two fundamental issues: technical difficulties are greater (due to the smaller size of the vessels and the almost unavoidable donor–recipient size discrepancy) and children are subjected to a continuous growth after the transplant. Both considerations make the results reported in adults difficult to transpose to the pediatric population, both in terms of technical feasibility and long-term patency. More recently, Chen et al. reported a series of 15 LDLT recipients in whom intraoperative PV stents were placed retrogradely through a P4 stump on the cut surface of the living donor graft [5]. Authors reported that all stents were successfully placed and maintained primary patency throughout a mean follow-up of 27.7 months. Even though stents does not grow with the child, and may eventually result in a “fixed stenosis,” authors did not required stent placement during follow-up. In our institution, the approach through the IMV is used. Stenting via the IMV allows an antegrade access to the PV from a straight path and, therefore, prevents the struggle caused by angulation that can potentially damage delicate structures or a recently made anastomosis. Advocates of the P4 stump route may argue that the IMV approach requires a more extensive vascular dissection. In the presence of extensive collaterals and coagulopathy, bleeding is a potential problem. However, such complication did not occur in any patient of our cohort. Our results are identical to those reported by Chen et al., suggesting that PV can be safely and successfully approached using either via, with the same potential for excellent long-term primary patency. Authors consider, however, the IMV approach to be more convenient as it is not influenced by anatomical variances in the portal vasculature and can be used in patients with different ages and types of graft.

Limitations of the current study include those inherent to a retrospective case series. Small patient numbers preclude more rigorous study designs at single institutions. However, the homogeneity of the patients included and lack of variation in technique over the prolonged time course of the study makes results more generalisable to future patients, though technological advances are likely to improve outcomes. Good long-term patency and clinical outcomes are achievable with judicious surveillance following.

In conclusion, the intraoperative stenting through the IMV approach may offer both a high feasibility and satisfactory results, with the potential for excellent long-term primary patency despite continued growth in children. However, final conclusions should be cautious, as larger studies are still needed to confirm these statements. A proper collaboration between surgeons and radiologists may avoid the need for complicated revision surgery, portosystemic shunting, or retransplantation.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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