Case Report

Hitched-Vein Monosegment (HVM) Technique for Liver Transplantation of Very Small Pediatric Recipients (<5 Kg): Report of Four Cases and Surgical Technique

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Abstract

Background: Liver reduction techniques have been standardized to allow partial liver grafts in pediatric liver transplantation. Although the most commonly used partial liver graft in children is the left lateral segment from an adult liver, patients weighing 5 kg or less cannot benefit from these grafts without further reduction. We aim to describe a novel surgical technique of reduction and implantation that provides a graft of compatible size for any very small recipient.

Methods: We collected the cases conducted under the "hitched-vein" monosegment technique between December 2021 and June 2022.

Results: Four patients were transplanted using this technique. Three received a single graft and the last patient required retransplantation. All donors were younger than 33 years and weighed less than 65 kg. One graft was obtained from a living donor and the other four came from brain-dead donors. All surgical procedures were uneventful perioperatively. Three out of four patients are alive with adequate graft function and a mean follow-up time of 2,5 years.

Conclusion: The HVM technique allowed us to overcome the mismatch between graft and recipient and safely implant a monosegment graft. It might be used for any size discrepancy, reducing waiting times and avoiding clinical deterioration.

Keywords: Pediatric Liver Transplantation; Neonatal Liver Transplantation; Very Small Recipients; Liver Graft Reduction; Monosegment Grafts

Abbreviations

CIT: Cold Ischemia Time; DBD: Donor after Brain Death; HVM: Hitched-Vein Monosegment; INR: International Normalized Ratio; LLS: Left Lateral Segment; PICU: Pediatric Intensive Care Unit; VSR: Very Small Recipients

Introduction

Liver reduction techniques have been standardised to allow partial liver grafts to be used in pediatric liver transplantation. The most common partial liver graft used for children is the Left Lateral Segment (LLS) (Couinaud's liver segments 2 and 3). It can be used in a donor/recipient weight ratio of 10 to 1 (for example, an adult donor of 70 Kg can generally provide a LLS for a 7 kg child). LLS grafts (either from cadaveric or living donors) have provided excellent outcomes for most children [1]. However, there is a group of Very Small Recipients (VSR) (equal to or less than 5 kg) who cannot be transplanted with the LLS of an adult and must wait for a LLS from a scarce pediatric donor or receive a monosegment graft. For these children, various hyper-reduction techniques have been developed [2-6]. The success of monosegment liver transplantation requires a refined surgical technique and has only been reported by experienced surgeons in higher-volume centers. Furthermore, the implantation of the monosegment graft is challenging and often requires temporarily closing the abdomen with synthetic mesh, as the graft is usually

still big for the recipient. Therefore, liver transplantation in the VSR is prone to more post-transplant complications. Here, we describe a novel surgical reduction and implantation technique that provides a size-matched graft for any VSR requiring liver transplantation.

Patients and Methods

Surgical Considerations of the "Hitched-Vein" Monosegment (HVM) Technique

The limiting factor for liver graft hyper-reduction is the anatomy of the left lateral segment. After the diseased native liver is removed, it leaves the native inferior vena cava with an anterior orifice for the left hepatic vein anastomosis (to secure good venous graft outflow) and the recipient portal vein for anastomosis (venous graft inflow) (Fig. 1). The distance between these structures, the Venous Inflow and Venous Outflow (VI-VO), can be measured in centimetres (X). After the split or reduction of an adult liver graft to produce a LLS, the distance VI-VO (from the left portal vein to the left hepatic vein) is usually double the length (2X) of the VI-VO of the VSR (Fig. 1). This mismatch renders the LLS too big for implantation without jeopardising forward flow in the portal vein, thus the need for 'hyper´-reduction. Many techniques have been described to divide the liver parenchyma during reduction/splitting (e.g. mosquito clamp crushing, CUSA or Harmonic scalpel). An alternative used in our center is a sharp division of the liver with a knife and suture of the main vascular structures in the cut surface, followed by applying a haemostatic agent (Veriset™) to prevent bleeding on reperfusion. In our experience, this technique is successful and less time-consuming than others. Before reducing the LLS to a monosegment, the anatomy of the segment II and III hepatic veins and the point at which they join to form the left hepatic vein is established. With a probe positioned into the segment II vein, the parenchyma can be divided with a superior straight cut (Fig. 2) to reduce the LLS to a monosegment (segment III). If segment III is still too big, a further reduction can be made parallel to the falciform ligament (Fig. 2). Finally, it is essential to make an oblique cut on the parenchyma to make sure that the segment III hepatic vein is the main venous outflow for the monosegment (Fig. 2). Depending on the size and the shape of the LLS, another inferior cut can also be performed. After this hyper-reduction, the VI-VO of the grafts matches the VI-VO size of the VSR (X) (Fig. 3).

Once a size-matched graft has been achieved, there is the issue of graft implantation using the standard piggyback triangulation technique, which can be challenging for a graft to be reduced in this way. The "hitched-vein" technique complements this monosegment reduction. A donor iliac vein is prepared and a triangular opening is made on its anterior surface, matching the diameter of the segment III hepatic vein of the graft. An end-to-side venous anastomosis is performed between the segment III hepatic vein and the donor iliac vein using the standard triangulation technique (Fig. 4) on the back table at 4ºC. Performing this anastomosis in this way is easier and safer (Fig. 5).

The recipient's native liver is removed en bloc with the cava and a caval-replacement technique is utilised for implantation (Fig. 6) [7]. The HVM graft is anastomosed first with the supra-hepatic vena cava and then the posterior wall of the infra-hepatic vena cava. Next, the graft is flushed and the anterior wall is completed. Finally, the donor's left portal vein is anastomosed in standard fashion (Fig. 6). Before reperfusion, the haemostatic agent Veriset™ is attached to all the cut surfaces with normal saline to avoid parenchymal bleeding (Fig. 7).
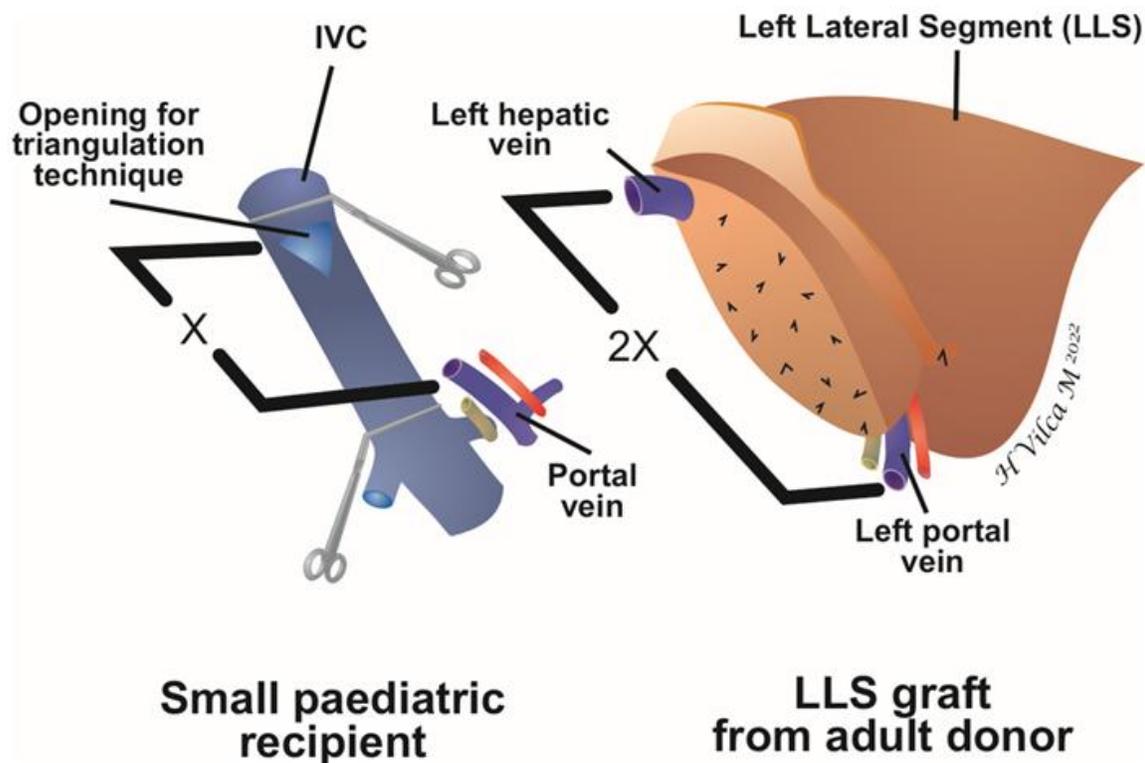
Figure 1: Relationship between vascular structures relevant to graft implantation of the small pediatric recipient and the reduced adult donor Left Lateral Segment (LLS) graft. IVC= Inferior Vena Cava; X= Distance between the vein inflow (VI) and vein outflow (VO); LLS= Left lateral segment.
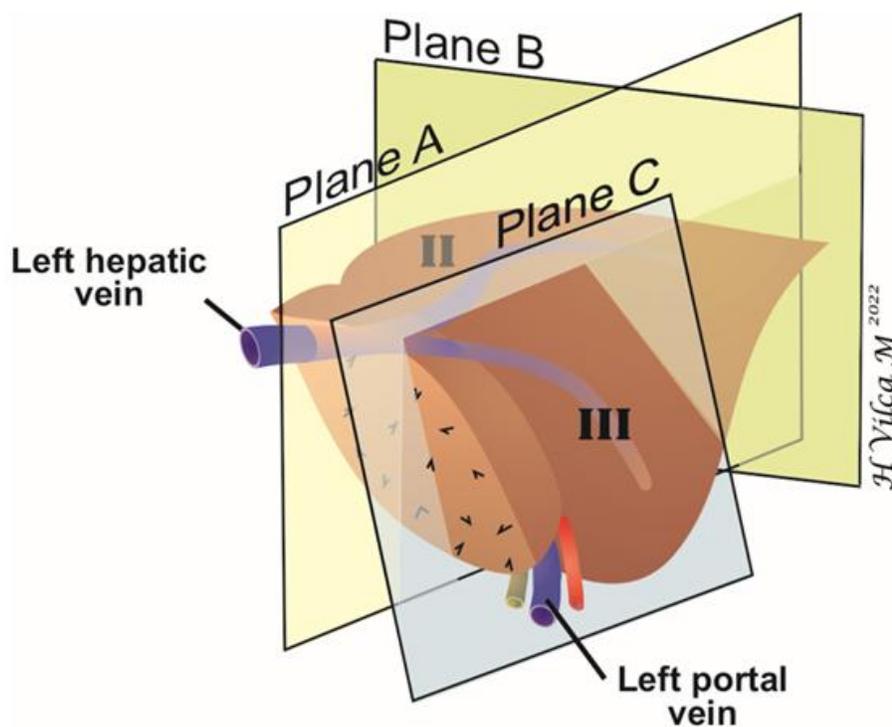

Figure 2: Sharp cutting planes to reduce the LLS into a Segment III monosegment.
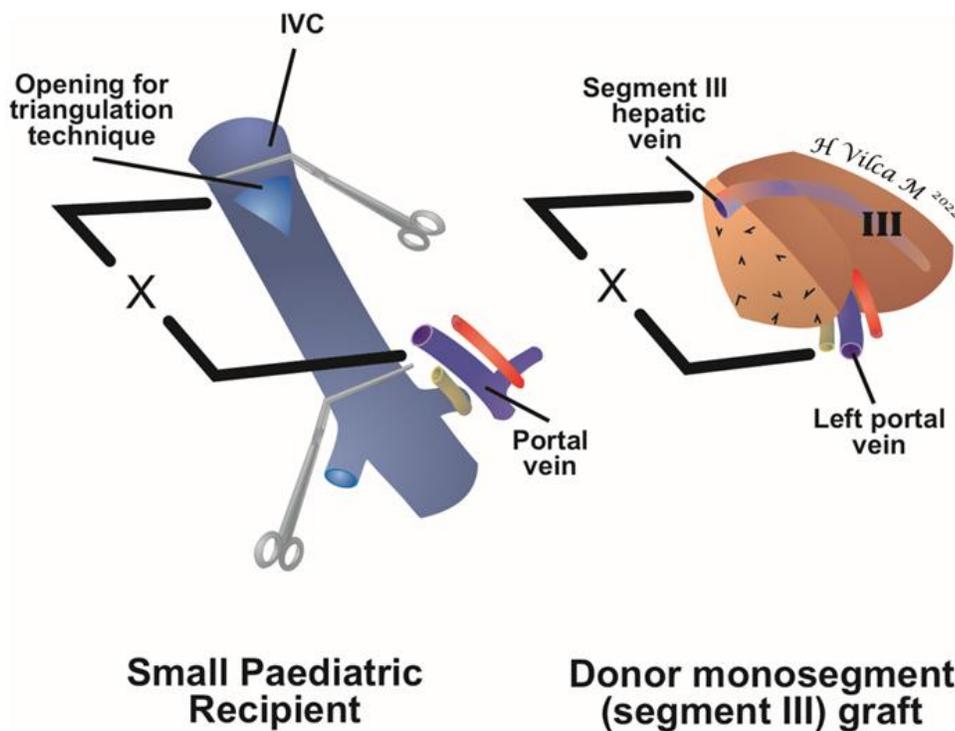
Figure 3: Relationship between vascular structures relevant to graft implantation of the small pediatric recipient and the reduced donor monosegment (segment III) graft. IVC= Inferior Vena Cava; X= Distance between the Vein Inflow (VI) and Vein Outflow (VO).
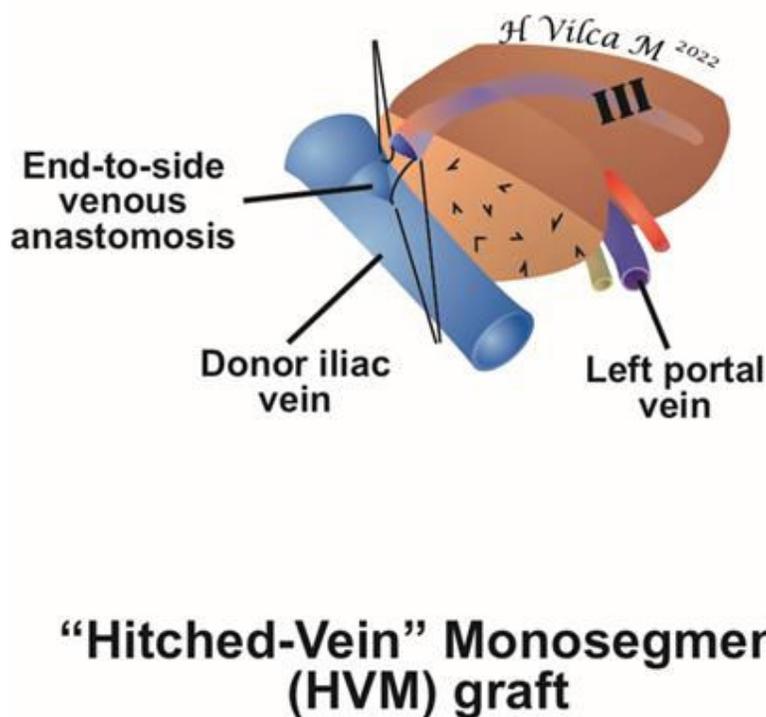

Figure 4: Preparation on the side bench of the "Hitched-Vein" Monosegment (HVM) graft using a donor iliac vein and anastomosing (end-to-side) the segment III hepatic vein and the anterior wall of the iliac vein.
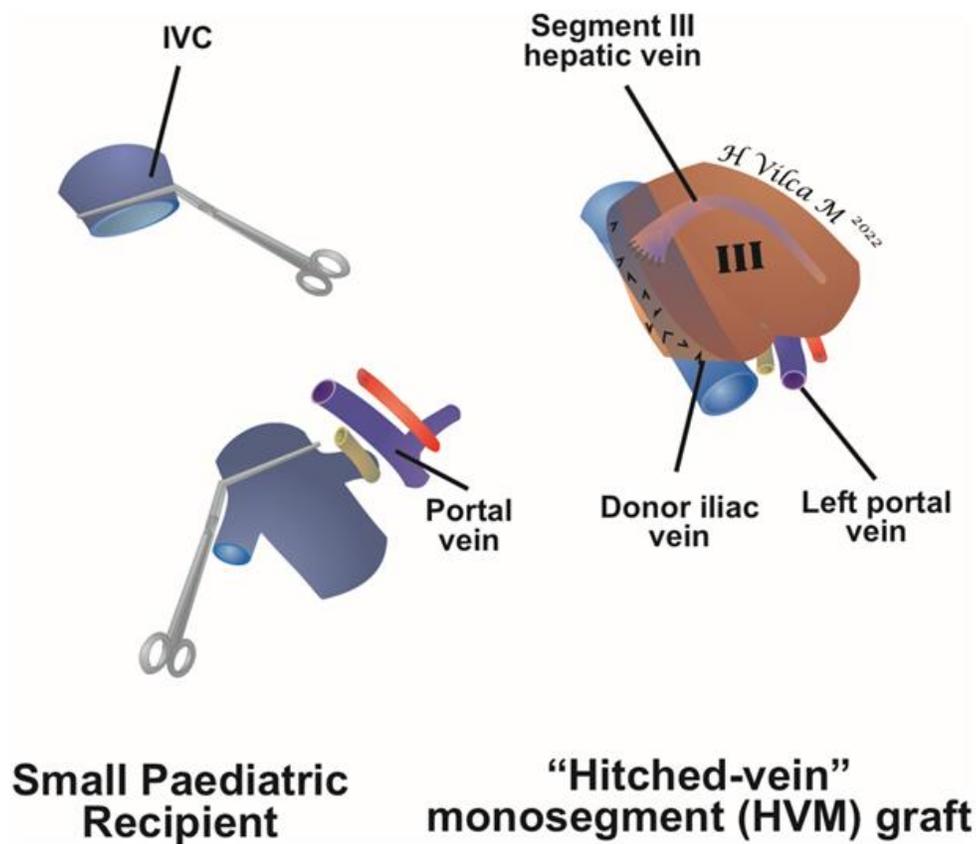
Figure 5: Relationship between vascular structures relevant to graft implantation in the small pediatric recipient and the "Hitched-Vein" Monosegment (HVM) graft. IVC= Inferior Vena Cava; HVM="Hitched-Vein" Monosegment.
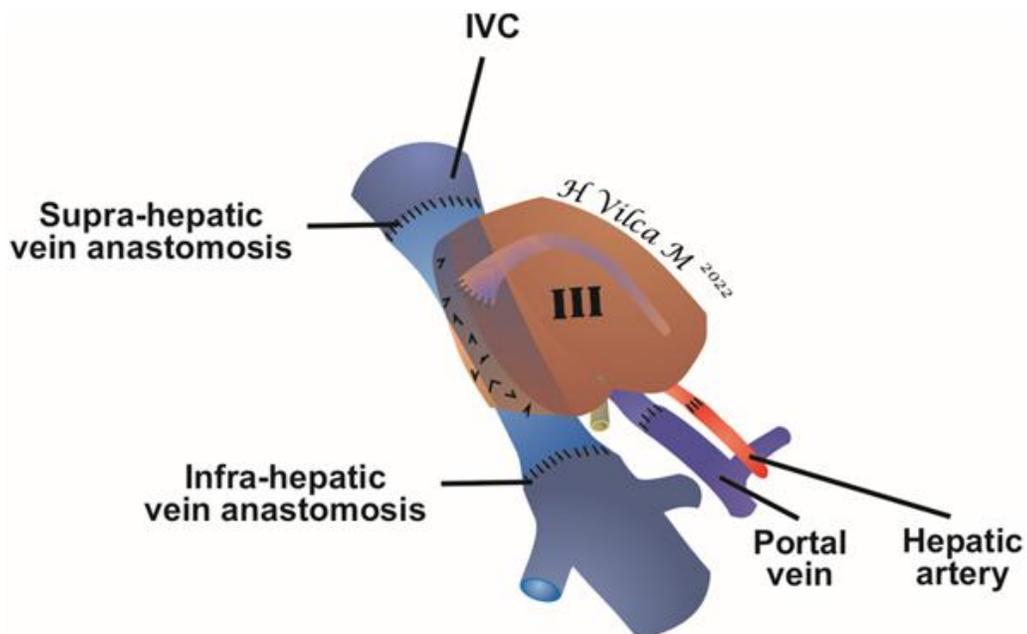
Figure 6: Liver transplantation in very small recipients using the "Hitched-Vein" Monosegment (HVM) technique. IVC= Inferior Vena Cava.
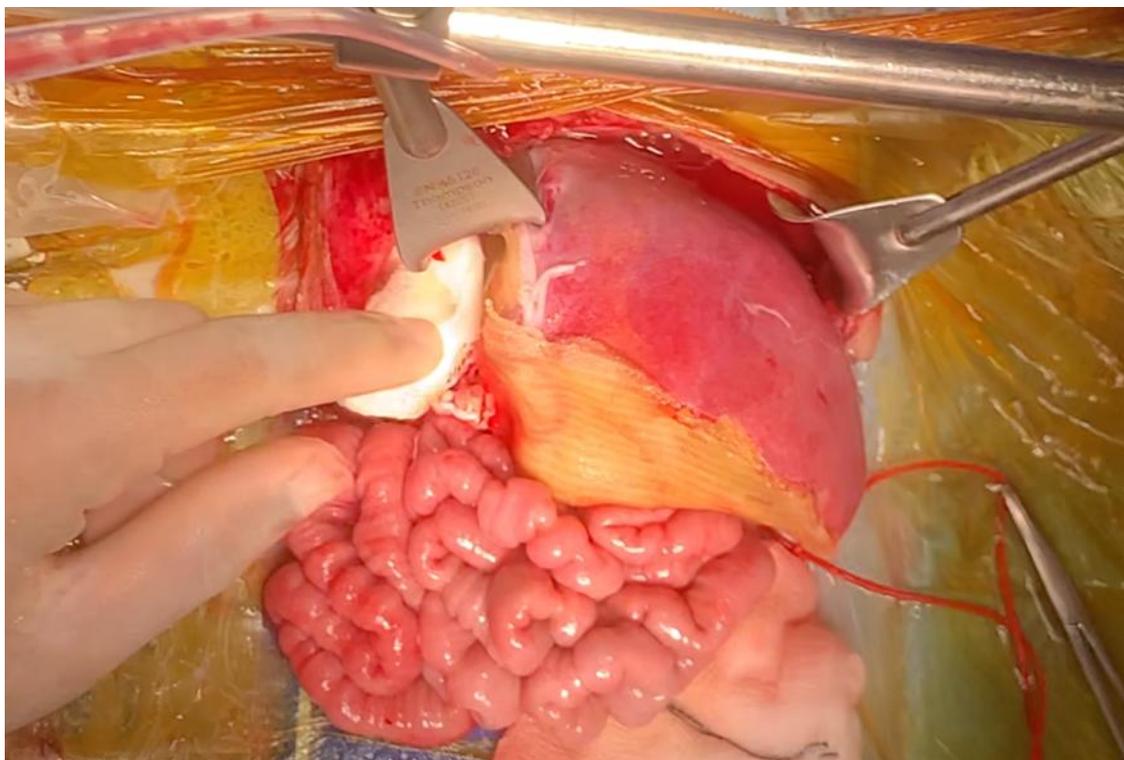
Figure 7: HVM graft reperfused and showing the application of Veriset™ haemostatic agent over the cut surfaces.

Case Report

Report of Our Series

Four patients were transplanted using the "Hitched-Vein" Monosegment (HVM) technique between December 2021 and June 2022. Three received a single graft and the last patient required retransplantation due to primary graft failure. All liver donors were younger than 33 years (mean = 18) and weighed less than 65 kg (mean = 48.5). One graft was obtained from a living donor and the other four came from Brain-Dead Donors (DBD). The donor and recipient characteristics are summarized in Table 1. The primary procedure took a median of 8.75 hours (8.7-10.9) with a Cold Ischaemia Time (CIT) of 12.1 hours (10.5-15.2) (Table 1). In all cases, graft bench surgery was performed simultaneously with the recipient hepatectomy. No intraoperative incidents were experienced. Immediate closure of the abdomen was performed in one case. In the other three primary transplants, the abdomen was closed with a silastic mesh (Table 1). Primary abdominal closure was performed using donor rectus muscle fascia in the retransplant. Postoperatively, prophylactic anticoagulation with heparin 50 U/kg was started when the International Normalized Ratio (INR) was <1.5. The median time to abdominal closure was 21 days (0-65) and the mean Pediatric Intensive Care Unit (PICU) stay was 33.5 days (10-115).

Surgery

All surgical procedures were uneventful perioperatively. Postoperatively, PICU management was challenging due to the complexity of these neonates. Graft function and postoperative complications are shown in Table 2. Three out of four patients are alive with adequate graft function and a mean follow-up time of 2,5 years [4-10]. During the early postoperative period, the first patient bled from one of the cut surfaces, requiring washout and hemostasis control. The second recipient had a change in liver function on postoperative day 11 and the ultrasound showed hepatic artery thrombosis. Further surgery re-established hepatic arterial flow using an iliac conduit. Prophylactic anticoagulation with heparin 50 U/kg was restarted and no further complications were noted. The postoperative course of the third patient was uneventful. Our last patient (the smallest of the series, 1.7 kg) underwent an uneventful transplant with a prolonged cold ischemia time (15 h), developed Primary Non-Function (PNF) and was relisted (on day 2) for retransplantation. A pediatric liver (whole graft weight = 604 g) was available 3 days later and she was retransplanted using the HVM technique (monosegment weight = 82 g). The postoperative course was complicated by hemodynamic and respiratory dysfunction related to neonatal problems. The patient underwent multiple laparotomies for bleeding and bowel perforations at different levels of the small intestine (presumably of ischemic origin) and died on day 37 post-retransplant with multi-organ failure but with normal liver graft histopathology.

Patient	#1	#2	#3	#4	#4
Clinical condition	Haemochromatosis	Haemochromatosis	Haemochromatosis	Haemochromatosis	PNF
Age at listing (days)	25	8	21	9	48
Retransplant	No	No	No	No	Yes
Age at transplant (days)	47	40	72	45	49
Weight at transplant (kg)	3.8	2.5	3.4	1.7	2.2
Donor age (years)	33	25	15	11	6
Donor weight (kg)	60.5	65	45	47	25
Type of graft	LDLT Segment 3	DBD Segment 3	DBD Segment 3	DBD Segment 3	DBD Segment 3
Whole liver weight (g)	Not available (LDLT)	1687	Not available	939	604
LLS weight (g)	174	340	170	Not available	Not available
Graft weight (g)	Not available	129	127	147	82
Cold ischaemia time	Not available	10 h 28 min	12 h 32 min	15 h 9 min	11 h 43 min
Surgical time	Not available	8 h 50 min	8 h 42 min	10 h 55 min	8 h 40 min
Abdominal closure	Direct full closure	Rectus fascia transplant	Rectus fascia transplant	Silastic mesh	Rectus fascia transplant

Table 1: Donor and recipient characteristics.

Patient	#1	#2	#3	#4	#4
Graft number	Primary	Primary	Primary	Primary	Retransplant
Peak of AST after transplant UI/L	755	5843	816	2690	1097
Peak of bilirubin after transplant	51	121	86	55	115
Graft disfunction	No	No	No	PNF	No
Vascular complications	No	HAT	No	No	No
GI complications	No	No	No	No	Hepaticojejunostomy dehiscence Multiple ischaemic small bowel perforations
Other complications	Bleeding Sepsis	Diaphragmatic paralysis	No	No	Bleeding Haemothorax Sepsis
Alive	Yes	Yes	Yes	No	

Table 2: Surgical complications and outcome after transplant.

Discussion

Neonatal liver disease is characterized by a rapidly progressive course and a poor prognosis. The clinical and surgical management of these frail patients is challenging. Furthermore, the lack of size-matched donor organs results in longer waiting times for transplant, particularly for very small children (<5 kg). Using grafts that are too large for the recipient results in compression of the graft, ischemia and abdominal compartment syndrome, leading to graft failure and patient death [8-11]. Partial liver grafts have increased the potential donor pool and contributed significantly to the decrease in the mortality rate on the pediatric waiting list. However, even an LLS may be too large for these neonatal patients. Therefore, liver transplantation using a monosegment (either segment II or III) is a valuable option for these very small children. The division of the LLS can be performed *in-situ* from a living donor or on the back table from a cadaveric liver (split liver). Houssin, et al., were the first to describe the use of a reduced LLS graft from a cadaveric donor in 1992 [12]. They reported using segment III of the LLS to enable abdominal closure. However, this second reduction was performed after graft implantation and the resection was complicated by difficult hemostasis. In 1999, our group described 6 cases of monosegment liver grafts using segment III from cadaveric donors [5]. This set a precedent for the increased safety of using segment III in favor of segment II grafts, with a lower rate of vascular and biliary complications and provided an approach for the future use of living donors as monosegment grafts. The use of monosegment grafts is now considered routine elective liver transplantation in children <5 kg, especially using segment III from a living donor [2-6,13-20]. Monosegmentectomy appears to be as safe as standard left lateral segmentectomy in living donor grafts without increasing the rate of complications in the donor [2-4,7,8,10,11,14,18-22]. Sharp dissection for liver reduction techniques and reliable hemostatic agents (such as Veriset™) that control cut surface bleeding after graft reperfusion have been shown to be safe and effective in our split liver experience and have extended their use to more radical reduction techniques. Depending on the size of the donor, even the transplanted monosegment may be too large for the size and can make graft placement technically tricky, leading to postoperative complications. With very young children, the challenge lies not only in the size but also in the thickness of the graft and the implantation technique. Implantation is performed using the "piggy back" technique, preserving the native inferior vena cava and anastomosing the graft left hepatic vein to the common orifice of the recipient hepatic veins. However, the surgical challenge increases when a proportionally larger monosegment is anastomosed to a fragile neonatal vena cava. The use of a donor iliac vein to replace the vena cava and use of the "triangulation" technique for graft implantation is routine [23,24]. However, this can be technically challenging in VSR. The "hitched vein" monosegment technique allows for safe implantation of the graft hepatic vein to the tailored neo-cava on the back bench under favorable conditions with excellent access. Using these monosegments does not always allow for abdominal wall closure and a synthetic mesh may be required. Most patients undergo secondary closure at a later stage [7-9]. Kasahara, et al., described a further modification to reduce the thickness of the monosegment which allowed for primary abdominal closure and reduced the potential for compartment syndrome [25]. The delay in abdominal closure is not a major concern, but to ensure sufficient vascular inflow and tissue oxygenation the graft-to-recipient body weight ratio should be less than 4%, to reduce the vascular complication rate and the likelihood of graft dysfunction.

Conclusion

The HVM technique allowed us to overcome the VI-VO mismatch between graft and recipient and safely implant a monosegment graft into a VSR. This novel technique might be used for any size discrepancy between graft and VSRs, further reducing waiting times and avoiding clinical deterioration while waiting for a suitable pediatric donor. An adult cadaveric or living donor can provide a suitable LLS for hyper-reduction to a monosegment with safe implantation. The immediate outcome is satisfactory and the long-term outcomes are being assessed.

Conflict of Interests

The authors declare that they have no conflicts of interest.

Author Contributions

All authors participated in the design and review of this article; HVM and AB jointly wrote the manuscript.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author, Miss Alba Bueno, upon reasonable request.

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