



Original Research

Heterotopic Reversed Position Technique in Pediatric Liver Transplantation

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Abstract

Objectives: Many challenges persist, especially when transplanting large grafts into small pediatric patients in liver transplantation (LT). In this study, we will discuss the details of the "heterotopic reversed position technique" in LT, which is applied to prevent complications and allows primary closure of the abdomen in the initial surgery without causing an increase in intra-abdominal pressure.

Methods: From March 2002 to December 2021, our institution performed 3121 LT of these 691 (22.1%) were pediatric LT. We present the outcomes of 11 pediatric patients who underwent LT using this method.

Results: In the postoperative phase, none of the 11 cases had vascular complications. Five of the cases were alive for an average of 9.2 years. The causes of mortality in the three cases were due to persistent hepatic encephalopathy after surgery in one case, another due to hemodynamic instability in the early postoperative period, and the third due to graft-versus-host disease that manifested two months after surgery.

Conclusion: The reversed positioning technique offers a promising solution to the challenges of pediatric liver transplant, especially in cases of acute fulminant liver failure.

Keywords: Pediatric living donor liver transplantation, heterotopic reversed position, large for size syndrome

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The evolution of liver transplantation (LT), especially in the pediatric population, has been marked by significant milestones and innovations. With the increasing demand for organs, attention was shifted towards living donor liver transplantation (LDLT). The first LDLT was performed in the late 1980s, and over the years, surgical techniques were refined, making LDLT a valuable procedure for pediatric patients, especially in regions with limited organ donation from deceased donors.^[1,2]

Despite these advances, challenges persist, especially when transplanting large grafts into small pediatric patients. Technical difficulties, such as increased intra-abdominal pressure and challenges in abdominal closure, have been significant concerns.^[3] Primary closure of the abdomen may lead to elevated intra-abdominal pressure. This can result in inflow or outflow obstructions in the implanted graft, an extended need for mechanical ventilation due to increased intrathoracic pressure, the development of abdominal compartment syndrome, associated renal

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failure, graft loss, infection, and wound dehiscence.^[4, 5] To address these challenges, innovative techniques, such as the use of monosegment or reduced-size grafts, have been introduced.^[6] However, even if vascular complications are partially prevented by reducing the volume of the graft with these techniques, the challenges to closing the abdomen remain unchanged, since the anterior-posterior diameter of the graft remains the same and there is no effect on the vascular anastomosis difficulties, since the distance between the hepatic vein and the portal vein of the graft remains unchanged (Fig. 1).

In this study, we will discuss the details of the "heterotopic reversed position technique" in liver transplantation, which is applied to prevent the complications and allows primary closure of the abdomen in the initial surgery without causing an increase in intra-abdominal pressure and present the outcomes of 11 pediatric patients who underwent LT using this method.

Methods

This is a retrospective analysis of prospectively collected data, and no patient can be identifiable through the manuscript, the consent form was not obtained from the patients. We reviewed the medical records of pediatric patients who underwent heterotopic liver transplantation between March 2002 and December 2021.

Patients aged 0-18 years diagnosed with end-stage liver disease and who underwent heterotopic liver transplantation were included. Exclusion criteria included patients with incomplete medical records, those who were older than 18 years of age, and those who underwent orthotopic liver transplantation.

All statistical analyzes were performed using the Statistical

Package for Social Sciences software version 24 (IBM SPSS Statistics for Windows/Mac, Armonk, NY: IBM Corp.). Continuous variables were presented as mean±standard deviation or median (min-max, range) and categorical variables were presented as numbers and percentage.

Surgical Technique

Donor selection criteria are described elsewhere.^[7] All potential living donors were evaluated, including CT angiography for graft size, future remnant liver size of the donor, and evaluation of vascular anatomy. Informed consent was obtained from all donors.

The technique prerequisites are as follows:

- Graft-to-Recipient Weight Ratio (GRWR) >4%
- The anterior-posterior diameter of the graft is 1.5 times the diameter of the recipient's abdominal cavity.
- The distance from the portal vein (PV) to the hepatic vein (HV) of the graft is double that of the recipient.
- A graft that curving under the diaphragm due to an extended left lateral liver segment was seen as a relative contraindication.

For living donors, we used a reverse T incision followed by a left lateral segmentectomy. Full-sized grafts from deceased donors were split and prepared for transplantation upon arrival at our center. Since the order of anastomosis could change due to graft rotation, we meticulously examined the topographic placement of the hilar structures (Fig. 2) Additionally, we used a saphenous vein graft as a circumferential fence for the left hepatic vein of the grafts. After rotating the left lateral segment graft 180° in the sagittal plane, it was placed on the right side of the inferior vena cava (IVC) similar to the right lobe LDLT (Figure 3a,b). The subsequent anastomosis was performed between the left hepatic vein

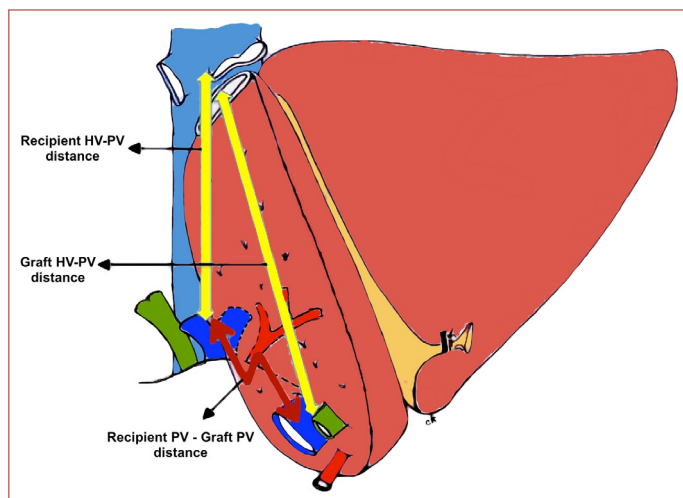


Figure 1. Difference distance between the hepatic vein and the portal vein of the graft and recipient.

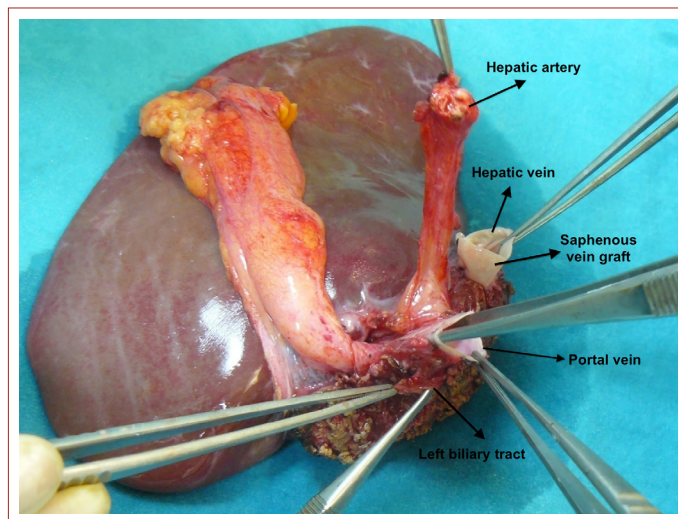


Figure 2. Topographic placement of the hilar structures.

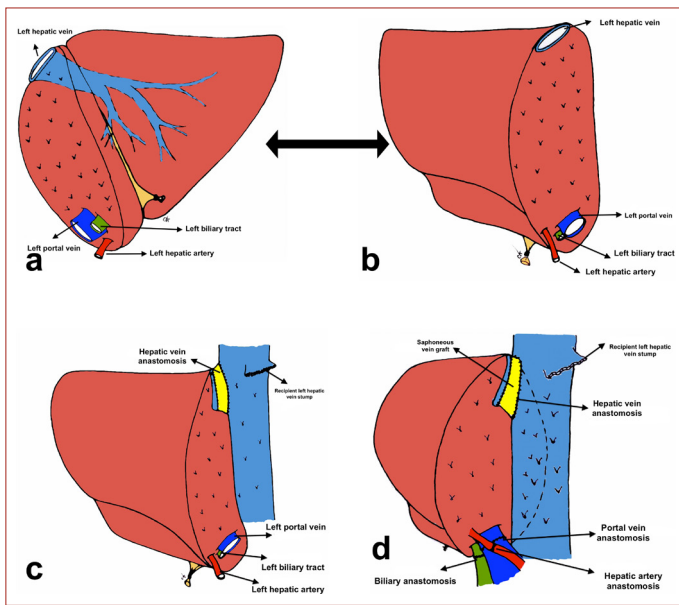


Figure 3. (a) Normal position of segment 2-3 graft, (b) Position after rotating the left lateral segment graft 180° in the sagittal plane, (c) It is placed on the right side of the inferior vena cava (IVC) similar to the right lobe LDLT. The subsequent anastomosis is performed between the left hepatic vein of the graft and the orifice of the recipient's right hepatic vein, (d) Subsequently, anastomoses of the bile duct, portal vein, and hepatic artery were performed in sequence.

of the graft and the orifice of the recipient's right hepatic vein (Fig. 3c). Subsequently, anastomoses of the bile duct, portal vein, and hepatic artery were performed in sequence (Fig. 3d). Rotation of the graft repositioned the bile duct posterior to the portal vein, necessitating a modification in the sequence of anastomosis (Fig. 4a, b).

Results

From March 6, 2002 to December 31, 2021, our institution performed 3121 LT of these 691 (22.1%) were pediatric LT. Eleven of these pediatric patients underwent the heterotopic reversed position technique for LT.

The median age at the time of transplantation of this subgroup was 31 months (range: 12-64 months), with an average weight of 13.5 kg (range: 9-20 kg). There were six males and five females. Indications for LT included fulminant liver failure (9 patients), cholestatic liver disease (1 patient), and chronic rejection (1 patient). Six received left lateral segment grafts from living donors, four from deceased donors. And a 16-year-old patient underwent retransplantation using a left lobe graft from a deceased donor (segment 2-3-4) graft. The heterotopic reversed position technique was used due to significant adhesions in the region corresponding to the left lobe of the liver in this patient. Demographic and intraoperative data are summarized in Table 1. The average GRWR for the ten pediatric patients, exclud-

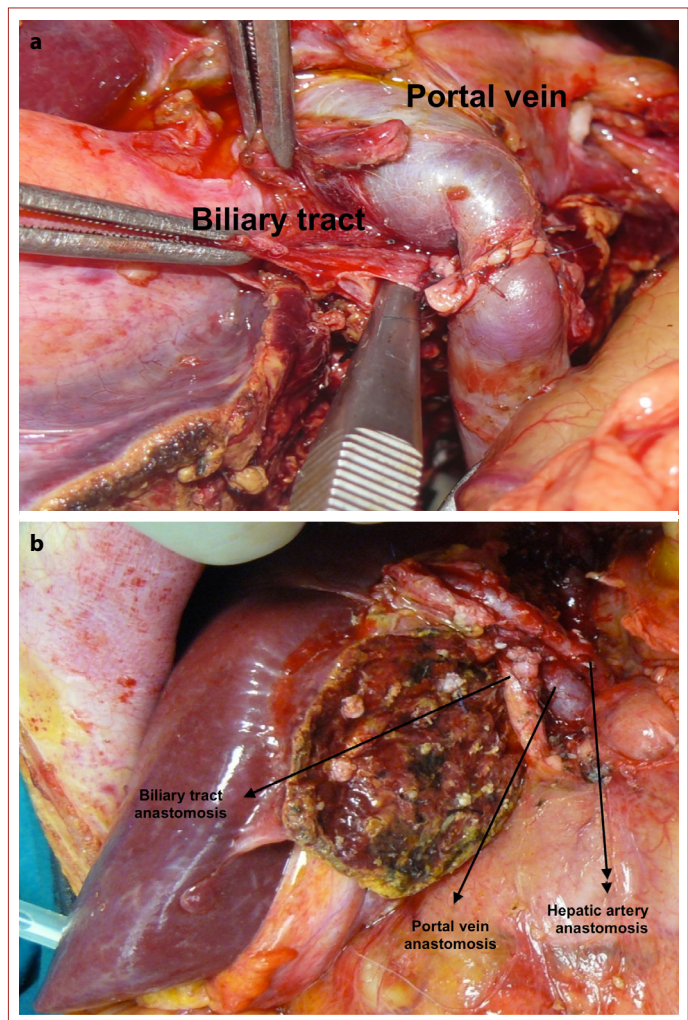


Figure 4. (a) Rotation of the graft repositioned the bile duct posterior to the portal vein, necessitating a modification in the sequence of anastomosis. (b) Appearance of hilar structures after completion of anastomose.

ing the retransplantation case, ranged from 1.5 to 3.4. The anterior-posterior diameter of the grafts averaged 8.3 cm, contrasting with the 4.3 cm anterior-posterior diameter of the orthotopically transplantable abdominal cavity. The distance between the portal vein (PV) and the hepatic vein (HV) in the grafts was 8.2 cm on average, while the corresponding distance in the recipients was 3.7 cm on average. Nine out of the ten cases had fulminant liver failure in which the liver is normal in size and ascites is usually absent.

In the postoperative phase, none of the 11 cases had vascular complications (Fig. 5a, b). Five of the cases were alive for an average of 9.2 years. The biliary stricture that occurred in two of them was treated with percutaneous biliary interventions (Fig. 6a, b, c). The causes of mortality in the three cases were due to persistent hepatic encephalopathy after surgery in one case, another due to hemodynamic instability in the early postoperative phase, and the third due to

Table 1. Demographic and intraoperative data

Case	Age (months)	Indication	Donor	Graft (segment)	Patient Weight (kg)	Graft weight (gr)	GRWR (%)	Total bilirubin (mg/dL)	Child / PELD
1	22	HAV	Mother	2-3	13	236	1.8	3	B / 8
2	34	HAV	Mother	2-3	10	250	2.3	25	B / 34
3	25	HAV	Mother	2-3	12	240	2.0	18	C / 27
4	23	HAV	Uncle	2-3	12	269	2.2	14	B / 24
5	39	HAV	Father	2-3	18	275	1.5	24	C / 59
6	48	HAV	Mother	2-3	16	270	1.6	24	C / 48
7	37	HAV	Deceased	2-3	11	370	3.3	25	C / 18
8	64	HAV	Deceased	2-3	20	450	2.2	16	C / 25
9	28	Biliary atresia	Deceased	2-3	10	345	3.4	4	B / 10
10	12	HAV	Deceased	2-3	9	270	3.0	16	B / 30
11	192	Chronic rejection	Deceased	2-3-4	50	550	1.1	35	C / 19 *

*The MELD score was calculated because the patient was over 12 years old. GRWR: Graft-to-recipient weight ratio; PELD: Pediatric end-stage liver disease; MELD: Model for end-stage liver disease; HAV: Hepatitis A virus.

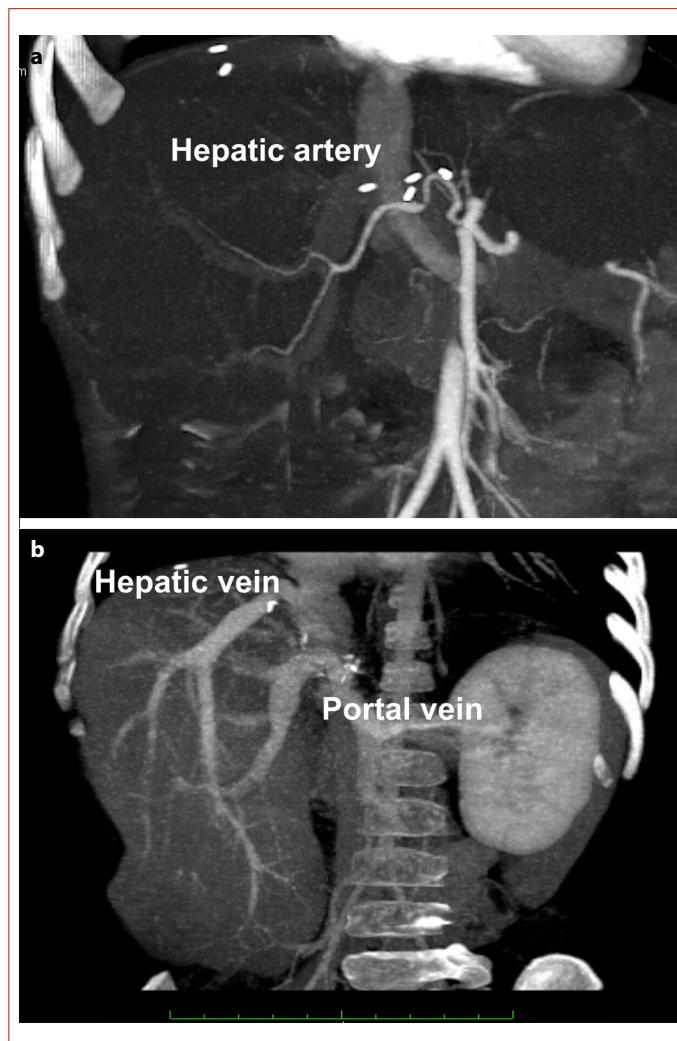


Figure 5. Radiological image of postoperative (a) hepatic artery, (b) portal vein and hepatic vein anastomoses.

graft-versus-host disease that manifested two months after surgery. The eleventh patient, the retransplantation case, died due to peritonitis resulting from postoperative duodenal ulcer perforation.

Discussion

Pediatric liver transplantation presents unique challenges, especially when there is a mismatch in age and body mass index (BMI) between the donor and the recipient. Ideally, if there is a perfect match, complications related to the size of the graft and the difficulties of anastomosis are minimized. However, in many pediatric cases, as observed in our study, transplantation involves a segment 2-3 from a living or deceased donor. If the anterior-posterior diameter of the graft exceeds that of the pediatric patient's abdominal cavity, it will invariably impede primary abdomen closure during orthotopic transplantation. Since the anterior-posterior diameter of the graft remains the same, the use of reduced-size or monosegment grafts cannot solve this problem. Using the reversed position technique, the anterior-posterior diameter of the segment 2-3 graft, regardless of its size, remains considerably smaller than that of the right hypochondrium. Consequently, within the context of this technique, the size of the anterior-posterior diameter of the segment 2-3 graft does not hinder the primary closure of the abdominal cavity. The orthotopic position is always preferred for graft placement if it is technically feasible and allows primary abdominal closure. However, this is not possible in many cases. Therefore, the heterotopic reversed position technique was preferred in these cases.

In pediatric patients presenting with acute fulminant insufficiency, while the segment 2-3 grafts are not large enough



Figure 6. (a) The biliary stricture that occurred in two of the patients (b) was treated with percutaneous biliary interventions and (c) dilatation, external catheter, and stenting.

to induce the large-for-size syndrome, their orthotopic implantation remains notably challenging. Children with fulminant liver failure do not exhibit the manifestations typically associated with chronic liver disease. Conditions such as ascites or liver enlargement, which are prevalent in chronic liver failure, lead to expansion of the right hypochondrium and epigastric space.^[8-11] Consequently, in pediatric cases of fulminant liver insufficiency, where the abdominal cavity has not had the opportunity to adapt or expand, orthotopic transplantation of segment 2-3 graft becomes a formidable challenge. In this case, rotating the segment 2-3 graft 180° in the sagittal plane and transplanting it heterotopically to the right hypochondrium allows the graft to fit into the abdominal cavity and the anterior wall of the abdomen to be closed primarily.

Another concern is the misalignment between the graft's hilar structures and those of the pediatric recipient. Specifically, the distance between the hepatic vein and the hilar structures of the segment 2-3 graft substantially exceeds the distance between the recipient's hepatic vein orifice and the hilar structures. Undertaking anastomosis of the portal vein and hepatic artery without tailored adjustments can result in pronounced kinking of these vascular structures, predisposing them to thrombotic events. Current best practices advocate for the recipient's portal vein to align with the coroner vein and the hepatic artery to align with the common hepatic artery level for optimal anastomotic outcomes.^[12, 13] However, the inherent shortness of the pediatric recipient's vascular structures complicates this process. Even with meticulous alignment, the risk of vascular kinking and subsequent thrombosis remains palpable. Once the segment 2-3 graft is situated in the right hypochondrium, the elongated nature of the recipient's portal vein transitions from a perceived disad-

vantage to a beneficial attribute. As evidenced in our series, the extended portal vein maintains its physiological alignment. Similarly, the graft's hepatic artery's length in this technique ensures that the anastomosis remains relaxed, mitigating undue tension. It is worth noting that, in certain instances, the hilar vascular and ductal anastomoses within this technique may experience tension. To counteract this, supportive devices, such as expanders or balloons, which elevate the graft anteriorly and alleviate tension in the hilar structures, can be strategically positioned posterior to the graft.^[14]

A meticulous examination of the graft's hilar structures is imperative, especially when considering a 180° sagittal plane rotation for heterotopic transplantation. In the standard transplantation procedure, the recipient's hilar structures follow a sequence from anterior to posterior: bile duct, hepatic artery, and portal vein. However, with the reversed position technique, this sequence for the graft's hilar structures is altered to portal vein, hepatic artery, and bile duct. Consequently, the anastomotic sequence shifts to prioritizing the bile duct, followed by the hepatic artery, and culminating with the portal vein. This specific sequence has been previously discussed in the context of dual lobe LT cases.^[15, 16] Yet, it is crucial to note that this sequence is not universally applicable. Based on our observations, initiating with the portal vein anastomosis often does not compromise subsequent anastomoses of the bile duct and hepatic artery. Hence, it is imperative for an experienced transplant surgeon to meticulously evaluate the topographical arrangement of the hilar structures during the back-table preparations to determine the optimal anastomotic sequence.

Some segment 2-3 grafts are seen to extend more to the left and upwards than usual. In this case, when the graft is

rotated 180° in the sagittal plane and positioned to the right and the corner of the right diaphragm with the abdominal side wall of the parietal peritoneum, the long lateral edge of the graft and the liver parenchyma corresponding to the left triangular ligament will bend. Such placement may cause graft dysfunction in the postoperative period. Therefore, excessive extension of the segment 2-3 graft to the left may be considered a relative contraindication for this technique. Balci et al. suggested heterotopic implantation of reduced size monosegment or left lateral segment grafts.^[17] The author suggested that the right lateral part of the graft can be resected in accordance with the preoperative right hypochondrium volume of the recipient.

In conclusion, the reversed position technique offers a promising solution to the challenges of pediatric liver transplantation, especially in cases of acute fulminant liver failure. However, further studies are needed to assess its long-term outcomes and establish its broader applicability.

Disclosures

Ethics Committee Approval: İnönü University Scientific Research And Publication Ethics Committee Health Sciences Non-invasive Clinical Research Ethics Committee 2023/4969-20-09-2023.

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Conflict of Interest: None declared.

Authorship Contributions: Concept – S.Y.; Design – V.E., S.Y.; Supervision – V.E., C.K.; Materials – V.E., F.I.V.; Data collection &/ or processing – V.E.; Analysis and/or interpretation – V.E., S.Y.; Literature search – V.E., S.Y.; Writing – V.E., S.Y.; Critical review – V.E., F.I.V., C.K., S.Y.

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