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Complex vascular reconstructions in living donor liver transplantation

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Abstract We describe here the indications for and our experience with complex vascular reconstructions in living donor liver transplantation. From December 1999 to June 2002, 59 patients underwent liver transplantation, 51 receiving the right lobe, and 8 the left lateral lobe, as a graft from a living donor. The indication for interpositional grafts on the arterial side (6/59, 10%) were stenoses of the celiac trunk and after resection of the hepatic artery for oncological reasons in adults. In children, arterial interpositional grafts were performed in situations of long distances between the donor and recipient artery, or in cases of inflow release from the aorta in patients with small hepatic arteries. On the portal-venous side, one interpositional graft was performed after an oncological resection. Once the portal vein was partially arterialized because of insufficient inflow. We used veins from the recipient, and native or cryopreserved arterial homografts for these grafts. All patients were treated during the first 6 months after transplantation with aspirine only. During the follow-up we did not observe vascular complications. If required, vascular interpositional grafts in the arterial and portal-venous position can be performed without adding postoperative complications.

Keywords Living donor · Liver transplantation · Graft interposition · Artery · Portal vein

Introduction

Twelve years after the first publication of successful living donor liver transplantation, this approach has gained widespread acceptance as one way of expanding the donor organ pool [1, 14, 18]. Both donor and recipient operation are technically demanding. To date, the results of living donor transplantation still do not fully equal those obtained with full-size liver transplantation. Hepatic arteries, veins, portal vein and bile ducts are of smaller diameter and shorter in length than those of full-sized liver grafts and present a variety of anatomical variants [3, 9, 10]. As to the bile duct drainage, in children, typically biliodigestive anastomoses are performed, whereas in adult recipients a duct-to-duct anastomosis is usually preferred nowadays [1, 10]. Accessory dorsal and middle hepatic vein segments often have to be reconstructed in left or right lobe transplants in order to prevent segmental congestion [4, 8]. A conduit interposition of the portal vein or a hepatic artery reconstruction is omitted whenever possible, due to the increased risk of thrombosis [12]. The indications for vascular interpositions of the portal vein and hepatic artery reconstruction in living donor transplantation involve situations of morphologically inappropriate recipient segments with low inflow, anatomic variants, pathologically modified peripheral vessels (e.g. cavernous portal vein transformation, celiac artery stenosis

etc.) and oncological reasons (resection of the hepatoduodenal ligament).

Here we describe the indications for and our experience with complex vascular reconstruction in adult and pediatric recipients of living donor liver segments.

Patients and methods

From December 1999 to June 2002, 59 patients underwent liver transplantation, 51 receiving the right lobe and 8 the left lateral lobe, segments II and III, as a graft from a living donor. The median age of the recipients of the right lobes was 57 years (10–70), and that of the recipients of the left lobes was 9 months (3–25). Indications for transplantation are shown in Table 1. Actual patient and graft survival for the right lobes are 82% (42/51) and 76% (38/51) respectively. Five adult patients who had received a right lobe underwent retransplantation. 3 to 28 months later, 7 of the 8 patients who received a left lateral graft are alive after transplantation. One child died 4 months after undergoing transplantation, due to acute gastrointestinal bleeding.

Table 1 Indications for transplantation of patients undergoing living donor liver transplantation in Berlin ($n=59$)

Graft	Indication	No. of patients
Right lobes	Alcohol cirrhosis	11
	HCV cirrhosis	7
	HBV cirrhosis	5
	PSC	5
	PBC	1
	Autoimmune hepatits	2
	Budd-Chiari-Syndrome	1
	Kryptogenic cirrhosis	1
	Polycystic degeneration	1
	Neuroendocrine tumor	1
	Klatskin tumor	2
	HCC in cirrhosis	13
	α1-antitrypsin deficiency	1
Left lateral segments	Bile duct atresia	3
	Byler's disease	2
	Wilson's disease	1
	Hepatoblastoma	2

Donors

The average donor age was 42.5 years (19–67). The donor operation for the right lobe included routine intraoperative cholangiography to identify variations in bile duct anatomy as well as ultrasound scanning to elicit the anatomy of the middle hepatic vein. Occlusion of the liver hilus was not applied during resection. HTK solution was used for simultaneous arterial and portal perfusion. The mean cold ischemic time was 40 ± 9 minutes. The mean graft weight was 745 ± 190 g, and mean blood loss was 397 ± 137 ml. There was no donor mortality. One donor underwent reoperation for diffuse heparine-induced bleeding. In 4 donors, a biliary leakage occurred at the resection surface, which could all be treated by interventional endoscopy. The mean graft weight of the left lateral segments was 290 ± 45 g, and mean intra-operative blood loss was 240 ± 120 ml. We did not observe any complications in this group.

Recipients

Transplantation of right lobes was performed as follows. After anastomosis of the right hepatic vein, using a veno-venous bypass only in the first 15 patients, accessory veins were implanted either directly into the vena cava or by interposition of either saphenous vein or alloplastic materials. Later, grafts were prepared with preservation of the peripheral middle hepatic vein stump which was anastomosed by graft interposition of portal vein segments (left branch) from the explanted liver to the vena cava. Whenever possible, the portal vein anastomosis was performed in a termino-terminal fashion between the right branch and the stump of the recipients vein (6×0 polypropylene, Prolene, Ethicon, Germany). In the same manner, the donor right hepatic artery was anastomosed (8×0 polypropylene, - running suture line using magnifying glasses ×4.3, focus distance 400 mm) termino-terminally to a branch or the proper hepatic artery, rarely directly onto the insertion of the gastroduodenal artery (Table 2). Reperfusion commenced after only portal ($n=31$) or after complete arterial and portal reconstruction ($n=20$).

The biliary reconstruction was performed whenever possible as an end-to-end micro-anastomosis of the donor right hepatic bile duct and the recipient's bile duct. In 12 patients, a Roux-en-Y hepaticojejunostomy was performed. A running suture technique was employed for all anastomoses using 7–0 polydioxanone (PDS, Ethicon, Germany) and they were invariably drained externally [16].

In the left lateral lobe transplantations, the donor's hepatic vein was anastomosed to the orifice of the combined left and middle hepatic vein orifices which has been prolonged into the vena cava

Table 2 Variations of arterial reconstruction in living donor liver transplantation—Berlin experience 12/99 – 6/02 ($n=59$). *AHP* Proper hepatic artery, *AHD* Right hepatic artery, *AMS* Superior mesenteric artery, *AHC/AGD* Common hepatic artery-insertion of the gastroduodenal artery

Graft	No. of patients	Central anastomosis	Graft interposition/other measures
Right lobes, $n=51$	21	AHP	–
(right hepatic artery)	19	AHD	–
	3	AMS	–
	2	AHC/AGD	–
	1	AHP	Banding AL
	1	AHP	Lig. arcuatum
	3	Aorta	Saphenous vein
	1	Aorta	Arterial homograft
Left lobes $n=8$	6	AHP	–
(left hepatic artery)	1	AHC/AGD	Middle colic artery
	1	Aorta	Arterial homograft

(in triangulation technique). Portal vein anastomosis was done between the left portal venous branch of the donor and the bifurcation of the recipients portal vein (7×0 PDS, running suture line). The arterial anastomosis was performed between the left donor hepatic artery and the proper hepatic artery of the recipient (8×0 Prolene—running suture line). Reperfusion was done simultaneously after termination of portal and arterial anastomosis. Biliary drainage was done as hepaticojejunostomy with a running suture line (7×0 PDS) with the positioning of a small silastic tube as an internal drainage.

Complex portal and hepatic artery reconstructions

As recipients hepatic artery for anastomosis served the proper or right hepatic artery in the most circumstances 51/59 (76%) (Table 2). In two adult patients, the donor artery was long enough to be anastomosed to the insertion of the gastroduodenal artery; in one child it served as the donor vessel for an arterial graft interposition. In one case, we used the middle colic artery from the living donor as an interposition (Fig. 1). In two right lobe recipients, the arterial inflow was optimized – once by resection of the arcuate ligament, because of a functional stenosis and, in the other patient, by banding of the splenic artery, because of a preexisting steal phenomenon. In 5/59 recipients (8.5%) the subdiaphragmatic aorta served as arterial inflow, which was realised by a saphenous vein (from the recipient) interpositional graft (3/5) or by using cryopreserved arterial homografts (2/5 - blood group identical). The indication for an interpositional graft was organic stenosis of the celiac trunk (3/5) and once after resection of the hepatoduodenal ligament due to tumor in the right lobe recipients. In one child with an incomplete situs inversus, polysplenia syndrome and biliary atresia who had a very small hepatic artery we performed an aortic interposition as well (cryopreserved arterial homograft).

In the one adult recipient with the Klatskin tumor, portal vein reconstruction was done using the own external iliac vein as interposition from the venous confluence to the right portal vein of the graft (Fig. 2, Table 3) after simultaneous on bloc resection of the head of the pancreas. In the child with incomplete situs inversus, the portal inflow was extremely reduced due to a very small diameter of the portal and upper mesenteric vein. We used a cryopreseved homograft (Fig. 3) for arterial inflow and partially arterialized the portal vein anastomosing the portal vein of the graft latero-terminal with a branch of the homograft (flow reduced intraoperatively). In 4/51 (8%) we had already two portal vein branches in the graft which could be unified in all situations medially in order to perform only one portal venous anastomosis (Table 3). In one adult recipient, in the course of transplantation a chronic portal vein thrombosis was desobliterated. After desobliteration, the marginal inflow was used for the graft portal perfusion.

Immunosuppression was achieved with tacrolimus, low dose steroids and sirolimus. Steroids were tapered and discontinued whenever possible 6 months posttransplant. Hepatic blood flow was assessed by Doppler ultrasound every day during the first two weeks. In sonographic unclear situations in the presence of clinical suspicion of perfusion disturbances, we performed conventional angiography. All adult recipients received a "low dose heparinization" for 14 days and pediatric recipients for the first month on a PTT between 50 and 60 s and received further low dose aspirine.

Results

In the postoperative phase we did not observe any arterial complications. In two patients a portal vein thrombosis occurred: In the adult patient described above with the chronic portal vein thrombosis, reocclusion occurred on the third day postoperatively, resulting in graft and patient loss before re-transplantation. The second patient was a child with a partial portal vein thrombosis which was observed on the first postoperative day sonographically with no other clinical sign. This thrombotic material was removed unproblematically. A cause of thrombosis could not be identified. Four months after transplantation, the inflow is patent and the patient in good condition.

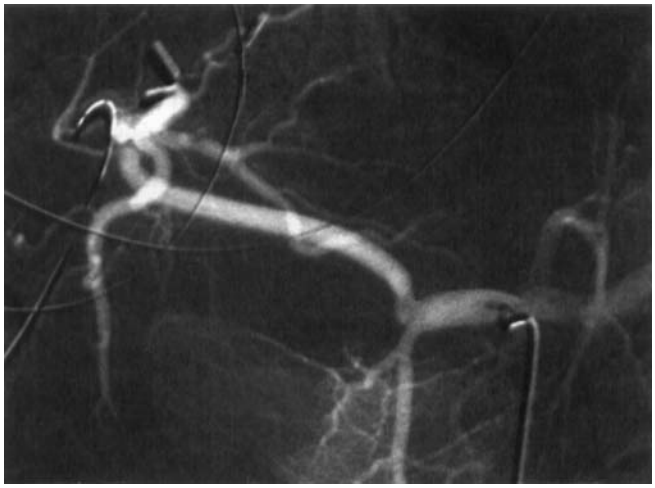

Fig. 1 Arterial interpositional graft (middle colic artery from the donor between the common hepatic artery of the recipient (insertion of the gastroduodenal artery) and the left hepatic artery

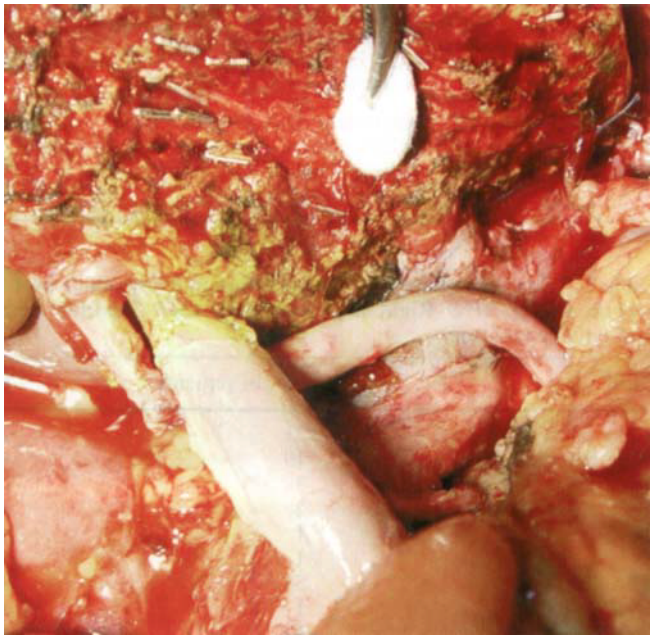

Fig. 2 Intraoperative situs after arterial and portal venous graft interposition

Table 3 Variation of portal-venous reconstruction in living donor liver transplantation—Berlin experience 12/99–6/02

Graft	No. Of patients	No. portal vein branches	Graft interposition
Right lobes $n=51$	46	1	–
	4	2	
	1	1	External iliac vein
Left lobes $n=8$	7	1	–
	1	1	Partial arterialized—homograft

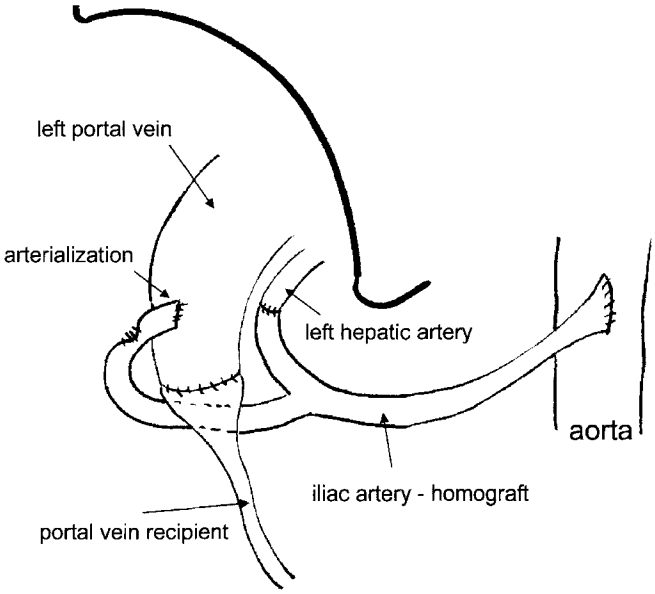

Fig. 3 Schematic presentation of arterial interpositional graft (cryopreserved arterial homograft) form the supraceliacal aorta to the donor left hepatic artery (termino-terminal anastomosis) and the second branch of the homograft for a partial arterialization of the portal vein (terminio-lateral anastomosis to the donor portal vein stump)

Discussion

Till this day, differing opinions exist concerning the optimal techniques for graft implantation in living donor liver transplantation. In all clinical series, hepatic arteries, portal-venous inflow and accessory hepatic veins are reconstructed with interpositional grafts in a variable incidence, depending upon the local situation in the recipient and the technical practice at the respective transplant unit [1, 4, 5, 6]. The results of these reconstructions depend on the type of interposition used (material, length, diameter, fresh or cryopreseved etc.), the inflow and outflow situation, position in arterial or venous system and the surgical technique [2, 5, 7, 13].

In our series of 59 living donor liver transplantations since December 1999 - utilizing for bigger recipients right lobes and for smaller recipients left lateral segments—we performed reconstructions in the arterial position in 10.2% (6/59) and in 3.3% (2/59) in the portal-venous position using different graft types as interpositions. During the postoperative follow up of 2 to 33 months we observed no early or late vascular complications following arterial or portal-venous interposition. Out of the total number of arterial and portal-vein reconstructions, we observed only two early portal vein thromboses (3.3%) after an end-end anastomosis. In one pediatric recipient, the etiology is unclear, and after simple thrombectomy the patient's further course was uneventful. In one adult recipient, a chronic thrombosed portal vein was used after thrombectomy for the grafts portal-venous inflow. Here, early graft portal vein thrombosis may have developed due to low portal inflow after thrombectomy. A partial or complete arterialization might potentially prevent this cause of graft and patient loss.

Grafts for vascular interposition were harvested from the donor or recipient during living donation operations. Later, fresh or cryopreserved arterial homografts from cadaveric donors and, rarely, alloplastic materials were used. In our opinion, native saphenous vein from the recipient give the best results in the arterial position together with native arterial homografts (from the donor, as shown here – middle colic artery or from the recipient). An alternative are, of course, cryopreserved arteries. For hepatic venous reconstructions, branches of the portal vein of the explanted liver from the recipient are favoured. For portal-venous interpositional grafts, external iliac vein from the recipient seem to have the best outcome (diameter, wall etc.) [10, 15]. With cryopreserved veins, no favourable experiences have been published [11].

Using grafts from living donors, an optimal liver parenchyma is transplanted. For all reconstructions optimal inflow has to be realized. In adult recipients, lesions like relevant ligamentary or organic celiac trunk stenoses have to be bypassed. In small children, especially in those with malformations like polysplenia syndromes, the hepatic arteries are some times hypoplastic and necessitate arterial interpositional grafts onto the aorta. In an unsatisfactory portal-venous inflow situation after thrombectomy of a chronic portal vein thrombosis, we recommend partial or complete arterialization [17].

First experiences in arterial interpositions are described from living donations in children. Here saphenous vein interpositional grafts from the donor were used. In a first step, the left hepatic artery was

anastomosed ex situ with the vein. During implantation, the vein was than anastomosed to the infrarenal aorta (with the most complications – 20%), celiac trunk or subdiaphragmatic aorta (without complications like direct anastomoses)[12].

Interpositions for portal-venous reconstruction were often necessary after implantation of the hepatic vein on the ostium of the right hepatic vein of the recipient's vena cava. Using the ostium of left and middle hepatic vein, the distance is shorter and a direct anastomosis can often be performed [12, 15]. Especially after the implantation of cryopreserved veins, complications were observed in these cases [12].

Differing opinions exist regarding surgical technique. All authors recommend magnifying glases or the operation microscope for these anastomoses [3, 9, 13]. Often an interrupted suture technique is preferred [8, 13]. Non-absorbable suture material like polypropylene in adults for the arteries was used. Here a monofil type of 7 or 8–0 diameter is preferred. Sometimes a mechanical support like a "double clip" is used [13]. We have best experiences with an open suture technique, using a running monofil suture. For the small diameter arteries as well as for veins, prevention of vessel wall traumatisation (intimal endothial lesion, vascular wall dissection, hyperextension etc.) is absolutely essential to prevent thrombogen surfaces. Furthermore, a vascular spasm is often seen during preparation and cooling, which has to be eliminated before tying the suture. We prefer tying after release of perfusion to prevent iatrogen stenosis. Diameter mismatch between stumps on the anastomosis can be compensated by lateral incision of the smaller vessel or both. In case of an arterial interpositional graft, the central anstomosis is performed first and perfusion is released for nearly the full length of the interposition. After that manoeuvre, the interposition is self positioning – important to prevent twisting.

Follow-up Doppler ultrasonography should be done daily in the first postoperative week. Intraoperatively, Doppler ultrasonography is helpful especially in children – here the mode of abdominal wall closure in bigger transplants will be decided (indication for temporary patch implantation) in dependence of sonographic examination. Anticoagulant therapy should be started immediately after transplantation with heparine (in children up to full heparinization) for 2 weeks to one month [13]. Thereafter, aspirine will be continued.

In conclusion, as material for interpositional grafts we prefer saphenous vein (from the recipient) or a native arterial homograft in the arterial position, native iliac external veins from the recipient and for hepatic vein reconstruction (stump of the middle hepatic vein for right lobes) left portal vein branch from the explanted liver (as described elsewhere) for portal-venous interposition. From the technical point of view, a running suture can nearly always be used, using polydioxanone or polypropylene (in arterial position) of 7×0 or 8×0 sutures, in our experience. The suture technique is open, and tying will be done under flow to prevent iatrogen stenosis. Postoperative midterm anticoagulation starting with heparine and followed by aspirine for 6 months is recommendable.

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