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ORIGINAL ARTICLE

Implications for the usage of the left lateral liver graft for infants ≤10 kg, irrespective of a large-for-size situation – are monosegmental grafts redundant?

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Summary

Organ donor shortage for infant liver transplant recipients has lead to an increase in splitting and living donation. For cases in which even transplantation of the left lateral graft (Couinaud's segments II + III) results in a ''large for size situation'' with an estimated graft body weight ratio (GBWR) of >4%, monosegmental liver transplantation was developed. This, however, bears complications because of greater parenchymal surface and suboptimal vascular flow. We exclusively use the left lateral graft from living donors or split grafts. Temporary abdominal closure is attempted in cases of increased pressure. We report of 41 pediatric transplants in 38 children ≤10 kg. Within this group, there were 23 cases with a GBWR of ≥4, and 15 cases with a GBWR <4. There was no statistical difference in vascular or biliary complications. Despite a more frequent rate of temporary abdominal closure, we did not find a higher rate of intra-abdominal infections. Overall, patient and graft survival was excellent in both groups (one death, three re-transplants). We noticed, however, that the ventro–dorsal diameter of the graft appears to be more relevant to potential graft necrosis than the actual graft size. In conclusion, the usage of monosegmental grafts seems unnecessary if transplantation of left lateral grafts is performed by an experienced multidisciplinary team, and temporary abdominal closure is favored in cases of increased abdominal pressure.

Introduction

Liver transplantation in infants remains challenging because of organ shortage and technical difficulties encountered in these small children. Even after its latest revision, the current Pediatric End-Stage Liver Disease (PELD) severity scores (12/2009), implies very long waiting times for pediatric patients. In addition, the number of deceased donors in Germany [12 million/year, Annual report of DSO (Deutsche Stiftung Organtransplantation)] and many western European countries has not increased in the last years. To maintain the rate of transplants, the number of accepted marginal organs has almost reached 70% (*Eurotransplant Report* 2010). These organs, however, are not adequate for pediatric recipients.

Accordingly, the waiting list mortality for these small infants is growing (Melter *et al.*, *Congress Report* 2010), which justifies and encourages the use of split and living-donor liver transplantation [1,2]. The use of grafts from living donors nearly eliminated waiting list mortality for pediatric patients. The most widely used graft for pediatric patients is the left lateral segment (Couinaud's

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segments II and III) of the liver [3,4]. This graft type usually weighs between 150 and 400 g.

Per definition transplantation of this graft in infants weighing <10 kg will result in a ''large-for-size'' situation characterized by the discrepancy between the small abdominal cavity and the large graft that can lead to a diminished blood supply of the liver graft. To prevent a graft body weight ratio (GBWR) ratio of more than 4%, some centers choose to reduce the graft into a monosegmental or ''hyperreduced'' graft. The subsequent reduction can be performed *in situ*, during the donor operation [5–7] or as a back table procedure [8–10], with the utilization of segment II [6,9,10] or III [5,7,8,11] as grafts. Recently a laparoscopic monosegmental living-related donor operation has been reported.

However, the small sample of reported data makes it difficult to draw conclusions about indications and outcomes of monosegmental grafts. In our perspective, the only benefit of creating a monosegmental graft is the reduction of liver volume. This is opposed by a number of disadvantages for both donor, in case of *in situ* reduction, and recipient. For the donor, this implies a longer operating time with an increased risk of biliary leakage and bleeding. For the infant recipient, there are a number of risks involved, such as an increased risk of biliary leakage from the parenchymal surface, impaired venous drainage and longer cold ischemic time in case of *ex situ* graft reduction.

In addition, in segment III grafts, the problem of difficult abdominal closure will not even be solved, as the ventro–dorsal diameter of the graft will not be significantly decreased.

Therefore, we exclusively use left lateral grafts with both segments even if the calculated GBWR ratio is >4%. Herein, we report the single center results of liver transplantation in infants of <10 kg exclusively using left lateral grafts.

Patients and methods

Between September 2006 and September 2010, we performed 61 pediatric liver transplantations in 56 children aged <15 years.

Altogether, 41 transplants were performed in 38 children ≤10 kg BW. Informed consent in writing was obtained from each parent and living donor for anonymous publication of results. The following data comprised this subgroup of pediatric liver transplant recipients.

Underlying indications for liver transplantation in these patients were biliary atresia in 25 cases, progressive familiar intrahepatic cholestasis (PFIC) in three cases, Alagille syndrome in two cases, propionic acidemia in two cases, Ivemark syndrome with biliary atresia in one case, secondary biliary cirrhosis in two cases, hepatocellular carcinoma (HCC) in one case, α-1 antitrypsin deficiency in one case and polycystic liver, and kidney disease in one case (Table 1).

Table 1. Indications for liver transplantation.

Indication	*N*	%
Biliary atresia	25	66
PFIC	3	8
Alagille	2	5.2
Propionic academia	2	5.2
Ivemark syndrome + biliary atresia	1	2.6
Secondary biliary cirrhosis	2	5.2
HCC	1	2.6
α-1 antitrypsin deficiency	1	2.6
Polycystic liver and kidney	1	2.6

PFIC, progressive familiar intrahepatic cholestasis; HCC, hepatocellular carcinoma.

Of the 41 initial transplants, we used two full pediatric organs, two reduced size organs, and 37 left lateral grafts (segment II and III). Of the 37 left lateral grafts, 31 were from living donors, and five were left lateral split organs, in cases where there was no suitable living donor. In one case, we performed a combined kidney and liver transplantation for polycystic kidney and liver disease. For the three re-transplants, we used two left lateral split grafts and one reduced size graft. Overall, we used 31 living donors and 10 deceased donors (Table 2).

Median body weight of the pediatric patients was 6.6 kg (3.1–10 kg). Gender distribution was 24 female and 14 male pediatirc recipients (Table 2). The mean GBWR in our cohort was 4.6 ± 1.4%, ranging from 2.4% to 8.1%. In 23 cases, the GBWR was ≥4%; in three cases, the GBWR could not be calculate because weight of the graft was not documented. In 15 cases, the GBWR was >4% (Fig. 1).

Pediatric End-Stage Liver Disease at the time of transplant was 24 ± 4.01. For living donation, PELD at time of transplant was 23.75 ± 2.01. For allocated organs at the time of transplant, PELD was 25.14 ± 0.34 (Table 2).

Standard immunosuppression included an induction therapy with basiliximab 10 mg i.v. (Simulect®; Novartis Pharma, Basel, Switzerland) on day 0 and day 4 post-transplant based on a cyclosporine (Sandimmun optoral®; Novartis Pharma) therapy with low dose prednisolone. Perioperatively until 3 days, post-transplant patients were treated with 10 mg/kg Sultamicillin (Unacid®; Pfizer, Freiburg, Germany).

Characteristics of deceased donors were as follows: The two full organs were received from pediatric donors who were 12 months and 8 months old. Eight adult grafts were

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Table 2. Characteristics of recipients and grafts.

	Total (*n* = 41)	LDLT (*n* = 31)	SLT (*n* = 10)
Recipient			
Male/female	15/26	11/19	4/6
Median age (range), years	10.2 (4–39)	9.4 (4–23)	12.4 (6–39)
Median weight, kg (range)	6.6 (3.1–10)	6.5 (3.1–10)	6.6 (4–10)
Waiting list, *n* (%)	4 (9.7)		4 (9.7)
Adult recipient, *n* (%)	3 (7.3)		3 (7.3)
High urgent, *n* (%)	3 (7.3)		3 (7.3)
PELD (SD)	24 (4)	23.8 (2)	25 (0.3)
Donor			
Left lateral grafts, *n* (%)	37 (90)	31 (75)	6 (14.6)
Whole organs, *n* (%)	2 (4.9)		2 (4.9)
Reduced size grafts, *n* (%)	2 (4.9)		2 (4.9)
Median graft weight, g (range)	288 (220–490)	270 (220–400)	331 (238–490)
Mean cold ischemic time, min (SD)	294 (136)	223 (54)	508 (56)
Mean warm ischemic time, min (SD)	33 (24)	32.5 (27)	35.66 (15)
Mean operating time, min (SD)	347 (103)	364 (199)	305 (192)
Age (range)	29.4 (1–49)	30 (19–49)	25 (1–49)
BMI (range)	24.1 (15–31)	24.6 (18–31)	22.3 (15–28)

PELD, pediatric and stage liver disease severity score; BMI, body mass index; SD, standard deviation; LDLT, living donors liver transplantation; SLT, split liver transplantation.

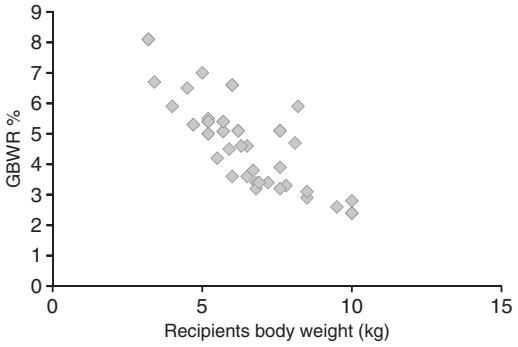

Figure 1 Body weight distribution among our children weighing ≤10 kg is plotted against graft body weight ratio (GBWR) on the *y*-axis. Low body weight is associated with a higher GBWR.

either used as split organs or organs of reduced size. Median organ donor age was 25 (range 1–49) years (Table 2).

Medical records of all living donors were analyzed retrospectively. Preoperatively, a contrast CT-scan was performed to evaluate liver vascular anatomy. The CT-scan was evaluated with a prediction of liver and graft volumetry as well as measurement of the ventro–dorsal diameter of the left lateral graft at its' greatest distance. As this analysis was performed retrospectively, data of only 25 living donors were available.

The median age of the living donors was 30.57 (range 19–49) years. Median body mass index for deceased donors was 22.8 [range 15 (baby) to 28]. Mean body mass index (BMI) for living donors was 23.88 ± 4.05. The majority of the donors were parents of the recipients [fathers 19 (61%), mothers nine (29%). The other living-related donor genetic relations included one cousin (3.2%), one grandmother (3.2%), one uncle (3.2%)] (Table 2). In all cases, recipients and donors were ABO compatible.

The surgical technique for the donor and recipient operation followed principles described previously [12,13].

Immediately after vascular anastomosis, intraoperative duplex ultrasound was performed, and portal venous, hepatic artery and venous outflow were measured. The central venous pressure (CVP) was kept below 10 mmHg; mean arterial blood pressure was aimed at 50 mmHg; and hemoglobin was kept below 11 g/dl.

The decision of leaving the abdomen open after the surgery was made according to the following criteria. In cases of limited intra-abdominal space when the macroscopic anatomic situation showed that the muscular abdominal wall could not be adapted at all, a foil was inserted. If, however, the abdominal wall could be approximated, the abdomen was only closed primarily if the portal venous perfusion was not impaired upon approximation. Therefore, duplex ultrasound was performed continuously before, during and after closure of the abdominal wall. If portal venous flow was under 10 ml/min, the abdomen was left open. The third criterion to leave the abdomen open was peak airway pressure needed for ventilation of the child. If approximations of the abdominal wall lead to increased airway pressure, the decision was made in favor for an early extubation. The

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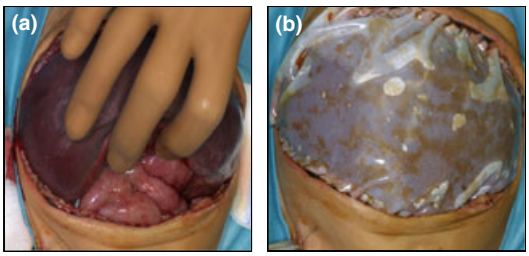

Figure 2 (a) Shows a left lateral graft *in situ* after completion of all anastomosis. The graft to body weight ratio (GBWR) in this case was 6.6. (b) This photograph shows the same abdomen after insertion of the silicon foil as temporary abdominal closure. Final closure was achieved on day 5 after transplantation.

possibility of leaving the abdomen open was discussed with the anesthetist, and the decision was made together.

Figure 2 shows the situation before and after foil insertion in a case, where the abdominal walls could not be adapted. Every 2–3 days, the patient went back into the operation theater to wash the abdomen and reduce foil size. All these procedures were accompanied by duplex ultrasound, until the permanent abdominal closure was achieved in analogy to a previously published protocol [14].

Results

Our overall patient survival and graft survival was 97% and 93%, respectively. One child with hepatopulmonary syndrome and neonatal HCC died after rescue transplantation because of acute respiratory failure within 48 h post-transplant on high frequency oscillatory ventilation. In total, three re-transplants were required in these small children. Two were because of arterial thrombosis and one was because of portal vein thrombosis. Arterial thrombosis occurred twice, both in recipients of a left lateral lobe from a living-donor. Portal vein thrombosis occurred after transplantation of a whole pediatric organ from a 12-month-old child. Two of the re-transplants were necessary in the group with a GBWR ≥4% (one arterial thrombosis after living donation from the father, one portal vein thrombosis), and one in the group with a GBWR >4% (arterial thrombosis after living donation from the mother).

We then analyzed the results and complications with regard to GBWR. The patients were divided into GBWR ≥4% (defined as ''large-for-size'' LFS, $n = 23$) and <4% (defined as ''acceptable-for-size'' AFS, $n = 16$). Two transplants in which the GBWR could not be calculated were excluded from these statistics. The mean duration of the operation for the LFS group was 346 ± 100 min and 344 ± 84 min for AFS. The mean cold ischemic time after living donation was 226 ± 83 min for LFS, and 200 ± 45 min for AFS. For split grafts and full organs

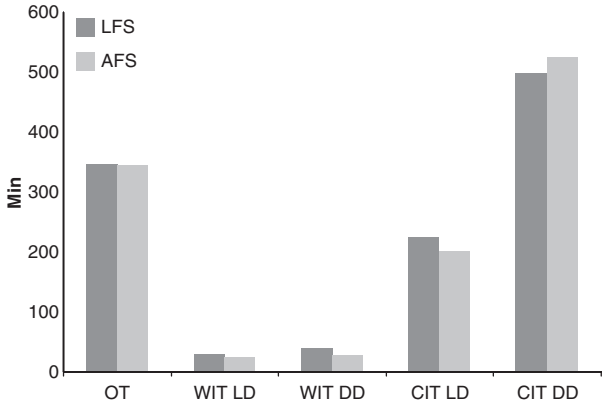

Figure 3 According to the distribution of recipients with a graft to body weight ratio (GBWR) ≥4 into the large-for-size group (LFS) and recipients with a GBWR <4 into the average-for-size group (AFS), several factors are compared. The first column shows total operating time (OT) for both groups with no statistical difference. The second column shows warm ischemic time after living donation (WITLD) in both groups. The third column shows the warm ischemic time for (split) organs from deceased donors (WITDD) in both groups. Both columns show comparable warm ischemic time ranges for both groups. The fourth and fifth columns show cold ischemic time after living donation and split transplantation for both groups (CITLD, cold ischemic time living donor; CITDD, cold ischemic time deceased donor). There is no statistical difference between the two groups. However, cold ischemic time for allocated and for split organs is significantly longer than after living donation.

obtained from the organ pool, the mean cold ischemic time was 498 ± 57 min for LFS, and 525 ± 47 min for AFS, respectively. The mean warm ischemic time after living donation was 30 ± 9 min for LFS, and 25.3 ± 9 min for AFS, respectively. Mean warn ischemic time for allocated organs was 39 ± 17 min for LFS, and 29 ± 3 min for AFS (Fig. 3).

The overall rate of silicone foil implantation was 11/39 (28%). As shown in Fig. 4a, there was no correlation between GBWR and the time period until final closure of the abdomen could be achieved. Gender distribution of the donors shows, however, that male donors predominated in cases, where temporary abdominal closure was necessary (9/11) (Fig. 4a). Of the 11 cases that needed temporary abdominal closure, one patient received a reduced size graft from a deceased male donor, two patients received the left lateral liver from their mother, and eight received their left lateral graft from their father.

Figure 4b shows the distribution of silicon foil implantation in both groups, LFS and AFS further divided into donor gender. The highest rate of foil implantation can be seen in the situation of male donor and LFS. The rate of silicon foil implantation for temporary abdominal closure was 9/23 (39%) in the LFS group with closing rates between 3 and 7 days. In eight

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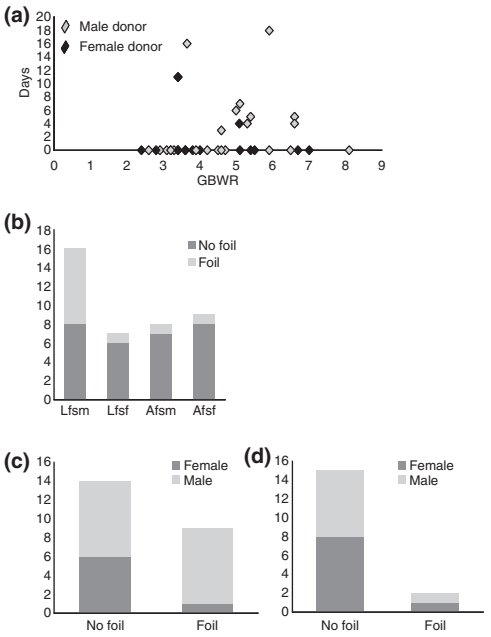

Figure 4 (a) Graft to body weight ratio (GBWR) in % is plotted against duration of temporary abdominal closure in days. Cases with female donors are marked black. Notice that there were only two female donors in the group of patients that needed temporary abdominal closure. There is no correlation between the duration of ''open abdomen'' and GBWR. (b) Shows the distribution of temporary closure (foil) and primary closure (no foil) in the following groups. LFSM, large-for-size male donor; LFSF, large-for-size female donor; AFSM, average-for-size male donor; AFSF, average-for-size female donor. (c) Shows the distribution of male and female donors in the large-for-size group (LFS). Only one case with a female donor needed temporary abdominal closure. (d) Shows the distribution of male and female donors in the average-for-size group (AFS). In only two cases, a temporary abdominal closure was needed.

of these cases, the donor was male (Fig. 4c). In the child with early portal vein thrombosis and re-transplant, we had a situation of massive sepsis and general edema, so that abdominal closure could only be achieved on day 18 (Fig. 4a). In the AFS group, we had only two cases (2/16, 12.5%) of temporary abdominal closure, which were achieved at day 11 and 16 days post-transplant. In one case, there was a male donor, and in the other case, there was a female donor (Fig. 4 d). In nine of the 11 cases, where temporary abdominal closure was necessary, the donor was male. Retrospective analysis of the ventro–dorsal diameter of the potential graft showed the greatest ''graft thickness'' in male donors (Fig. 5). Unfortunately, our retrospective analysis only allowed us to measure this distance in 25 living donors, 17 males and nine females. As there were too many missing variables, statistical analysis between the patients with permanent or temporary abdominal closure was impossible.

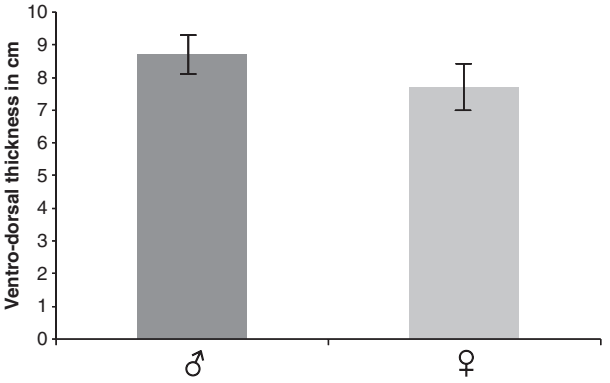

Figure 5 Ventro–dorsal distance in cm as ''thickness'' of the graft was measured in 26 living donors (17 males, nine females). Mean and standard deviations are shown in the diagram.

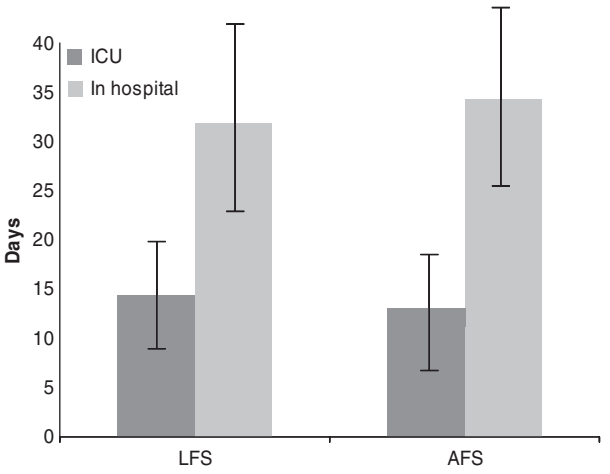

Figure 6 Shows the mean in-hospital time in days and the days spent in intensive care unit (ICU) for both the large-for-size (LFS) and average-for-size (AFS) groups. Standard deviations are included.

Mean in-hospital stay was 32 ± 19 days for the LFS group, and 31 ± 14 days for the AFS group. The difference in in-hospital and ICU stay between the two groups is not statistically significant ($P \leq 0.05$) (Fig. 6).

Besides the early vascular problems that caused re-transplantation, we had one early portal vein thrombosis that could be re-vascularized by early re-operation in the LFS group.

In the LFS group, we had two cases of late portal vein stenosis, one was managed by radiologic intervention and one could only be managed by re-operation and resection of the stenosis. Another complication was a small bowl perforation in a child with a temporary abdominal closure. Nevertheless, the abdomen could be finally closed on day 5. In addition, we had one EBV infection and

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Table 3. Update classification of complications, Ref. [12].

Grade	Definition	Example	LFS [15]	AFS [16]
Grade I	Any deviation from the normal postoperative course without the need for pharmacologic treatment or surgical, endoscopic, and radiologic interventions. Allowed therapeutic regimens are drugs as antiemetic, antipyretics, analgesics, diuretics, electrolytes, and physiotherapy. This grade also includes wound infections opened at the bedside		ND	ND
Grade II	Requiring pharmacologic treatment with drugs other than such allowed for grade I complications. Blood transfusions and total parenteral nutrition are also included	EBV infections, rejections	1 (4.3%)	2 (11.7%)
Grade III	Requiring surgical, endoscopic, or radiologic intervention	Portal vein stenosis (late), biliary leakage		
Grade IIIa	Intervention not under general anesthesia	Portal vein stenosis (late), biliary leakage, diaphragm paralysis	1 (4.3%)	
Grade IIIb	Intervention under general anesthesia	Small bowel perforation, portal vein stenosis, biliary leakage	2 (8.7%)	3 (17.6%)
Grade IV	Life-threatening complications (including CNS complications) requiring IC/ICU management			
Grade IVa	Single organ dysfunction (including dialysis)	Re-transplantation	2 (8.7%)	1 (5.9%)
Grade IVb	Multiorgan dysfunction			1 (5.9%)
Grade V	Death of a patient	Death		1 (5.9%)

LFS, large-for-size; AFS, average-for-size.

subsequent rejection episode that was managed conservatively. One patient suffered from a diaphragm paralysis after the transplantation procedure that could be handled conservatively. Fifty percent of the patients were switched from cyclosporine to tacrolimus-based immunosuppression in the LFS group either because of rejection episodes or problems with intestinal absorption of cyclosporine. There were no bile leakages in this group.

In the AFS group we had one death after transplantation during multiorgan failure. We had one early re-transplant because of early arterial thrombosis, and one bile leakage from an aberrant bile duct at the left triangular ligament of the graft that required re-operation. This patient also had kinking of the venous outflow, and so the graft was repositioned during re-operation. One patient was re-operated because of an intra-abdominal hematoma. As in the other group, approximately 50% of the patients were switched from cyclosporine to tacrolimus (Prograf®; Astellas Pharma, Munich, Germany) during the first few months.

All complications comparing the two groups with regard to severity grades according to the Clavien classification were summarized in Table 3. Grade I complications according to Claviens classification were not included in the listing because they are expected to occur after liver transplantation and cannot be defined as variation from the normal postoperative course.

Discussion

The biggest problem in liver transplantation for small infants results from LFS grafts. This situation occurs when the smallest anatomical graft, the left lateral segment, exceeds a 4–6% GBWR.

Some groups have had severe vascular problems, early graft losses, and graft necrosis because of direct pressure on the liver parenchyma using these large grafts [17–21]. Therefore, they implicated that a further reduction of the liver graft could minimize these problems [7,22,23]. Kiuchi *et al.* [24] have set their limit for using a monosegmental graft at a GBWR of >4% as estimated on the preoperative volumetry CT-scan. Authors in favor of monosegmental transplants argue that in some small infants, the proposed use of monosegmental liver transplantation could allow for an easier abdominal wall closure and avoid an insufficient blood supply to the graft. Avoiding the use of synthetic mesh and secondary closure could also reduce the chance of abdominal wall infectious complications [6,9].

Our results and previous results of our group [25], with only using left lateral grafts, however, demonstrate that these complications do not necessarily have to occur. Our rate of vascular problems in the children weighing <10 kg is comparable to the rate in larger children. We did have two re-transplantations in the LFS group as opposed to one in the AFS group. However, we lost one

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patient in the AFS group. Late vascular problems were slightly higher in the LFS group, but without statistical significance.

We never had a problem of graft necrosis because of pressure, as the decision to insert a temporary abdominal closure was made very early. Surprisingly, we found that temporary abdominal closure was more frequently needed in cases with a male donor. Our retrospective analysis verified that the ventro–dorsal diameter of the left lateral liver is greater in males than in females. However, data for this analysis were only available from 26 living donors, making an analysis for the group that needed temporary abdominal closure impossible. Graft weight and the GBWR did not differ between donor genders.

In cases of temporary abdominal closure, we could not report any cases of peritonitis as wound dressings were always handled aseptically, and abdominal closure was achieved within a few days after the initial organ swelling diminished and the vascular, in particular, arterial flow was stabilized. Infants who received a temporary abdominal closure were not treated differently postoperatively. Extubation was performed at a very early stage, and was not delayed because of the planned re-operation.

Santibañes *et al.* [6] were the first to describe a pediatric monosegmental transplant using a liver segment resected *in situ* from an living-donor. They published two cases in children weighing 7 kg, using segment II. Noujain *et al.* [10] reported on a study of 15 patients weighing <5 kg using two monosegmental grafts from cadaveric donors with back table reduction of segment II. Despite the few cases of segment II liver reduction, the paper from Santibañes *et al.* reported 100% of biliary complications, whereas the paper from Noujain *et al.* reported no vascular or biliary complications. The small sample of segment II liver reduction makes it difficult to draw conclusions about the rate of complications, in comparison to segment III liver reduction.

The larger single-center experience with MLT was at Kyoto University, especially with segment III, including 14 cases reported between September 2000 and November 2002 by Kasahara *et al* [7]. They were the first to perform and to highlight the advantage of MLT with segment III in an elective setting.

Kiuchi *et al.* described some anatomic and even immunologic disadvantages of the LFS grafts [24]. They describe a higher rate of vascular complications, and more acute rejection episodes, in the first month, in recipients of LFS grafts. Despite these drawbacks reported only in a few series, the negative impact of the LFS grafts is not nearly as pronounced in comparison to the lower survival rate of the small-for-size grafts in adults.

A 2005 published meta-analysis showed an advantage in favor of the use of monosegmental grafts among pediatric series in some centers [21]. However, complication rates were comparable between monosegmental and other grafts [21].

We believe that the rate of vascular complications is not predictable by a calculated GBWR measured in a preoperative volumetry of the potential graft. However, individual donor and recipient vascular anatomy, the presence of splenomegaly, portal hypertension, and hemodynamic state at the time of operation are values that will influence the arterial and portal venous flow much more than that of a calculated relation of volume. As a result of our findings, there might be an impact of graft thickness on the need for temporary abdominal closure. This, however, needs to be further analyzed in a prospective study. As at this point of time, scarcity of intra-abdominal space cannot be predicted, we believe that every individual situation has to be judged at the time of implantation when the vascular flow can be measured directly and adjustments, i.e., arterial jump grafts to the aorta, can be performed if insufficient flow is measured.

In our experience, it is important to include a period of adaptation after completing the arterial anastomosis. To secure an optimal arterial inflow, the artery has to be kept in an elongated position, the blood pressure has to be raised, and if necessary portal inflow has to be restricted by manual compression for a period of approximately 5–10 min to allow optimal dilatation of the artery. If necessary, papaverin can be administered locally. Only if optimal arterial inflow can be measured, the operation can proceed.

After every closure, primary or temporary, of the abdomen, we perform a final duplex ultrasound to measure the vascular flow under pressure. If there is any variation of the flow compared with the flow measured with an open abdomen, we will either insert an abdominal patch or increase the patch size.

A phenomenon that we still do not understand, the adaptation of the liver size to the size of the recipient's body, will lead to a fast reduction in graft size and minimization of intra-abdominal pressure, so that the abdominal patch can be reduced in size quickly, and abdominal closure achieved within a few days.

We believe that our results show that there is no need for monosegmental or reduced size liver grafts for very small children if the optimal surgical technique is performed by an experienced liver transplant surgeon and that intraoperative and postoperative protocol duplex ultrasound can immediately identify vascular problems that can be corrected at the time of the initial operation in the majority of cases.

Although complications such as intra-abdominal infections, wound infections, and adhesions that can lead to

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late sepsis are more likely to occur after secondary abdominal closure, we did not experience these complications in our series. Even under immunosuppression, abdominal infections seem rare if patients were under perioperative antibiotic treatment and wounds were handled aseptically.

As we did not perform monosegmental transplants, we can only assume that reported complications such as biliary leakage and late strictures [26] are of greater impact than the increased risk of abdominal infections after temporary closure.

If, however, a reduction of graft size cannot even guarantee primary abdominal closure as reported by Thomas *et al.* [26], there is no convincing benefit of graft reduction.

Authorship

MS: wrote the paper, performed surgery in pediatric recipients. BD: collected data, postoperative surgical care of the recipients. JD: collected the data. FB: performed living donor evaluation. MK: pediatric pre- and postoperative care. SS-J: postoperative follow up outpatient clinic. JB: analyzed radiological findings in donor CT-scan. MB: pediatric patient evaluation and selection. DCB: performed donor and recipient surgery.

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