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Monosegment Liver Allografts for Liver Transplantation in Infants Weighing Less Than 6 kg: An Initial Indian Experience

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ABSTRACT

Background. Living donor liver transplantation in small infants is a significant challenge. Liver allografts from adults may be large in size. This is accompanied by problems of graft perfusion, dysfunction, and the inability to achieve primary closure of the abdomen. Monosegment grafts are a way to address these issues.

Methods. Two recipients in our cohort weighed less then 6 kg. The prospective left lateral segments from their donors were large for size. Therefore, monosegment 2 liver grafts were harvested. Data regarding the preoperative, intraoperative, and postoperative events in the donor and the recipient were recorded.

Results. We were able to achieve significant reduction in the sizes of the grafts harvested. The donors underwent surgery and hospital stay uneventfully. The recipients had normal graft perfusion and no graft dysfunction, and we could achieve primary abdominal closure. One recipient had self-limiting bile leak postoperatively.

Conclusions. Monosegment 2 liver allografts are safe and effective for use in living donor liver transplantation in small infants weighing less than 6 kg.

WITH the increasing availability of transplantation services across India, liver transplantation is now within the reach of more people than ever before. Pediatric liver transplantation, however, remains available only in select centers. Transplantation in infants weighing less than 10 kg continues to be challenging even at the most experienced centers. The dearth of pediatric cadaveric donors means that most of these patients undergo living donor liver transplantation (LDLT). The donors are often parents (ie, adults). Matching the graft size and volume between the donor and the recipient is a significant challenge. The left lateral segment of the adult liver is a usual choice of graft. However, a large volume of this graft with respect to the infants' size, demands reduction in the size. Large volume grafts may not perfuse adequately and cause significant difficulty in closing the abdomen primarily. Synthetic meshes may have to be used to help with closure or at times the abdomen may have to be left open. These methods warrant repeated procedures and may increase the risk of infectious and respiratory complications [1]. To overcome these issues reduced left lateral segment grafts were introduced [2]. The reduction in grafts can either be nonanatomic or anatomic. In the former, the lateral and inferior aspects of the left lateral segment are reduced without following anatomic structures. In the latter, one segment, either 2 or 3, is removed in an anatomic fashion to yield a monosegmental graft.

In this article we describe the technique and our experience of pediatric liver transplantation with monosegment liver allografts. These grafts were used in infants weighing 6 kg or less. The segment 2 monosegment graft is our choice of graft in this group of patients. Such reduction yields a good size match, which allows good perfusion, and also results in reduced thickness permitting primary abdominal closure without graft compression.

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METHODS

From September 2018 to August 2020, 11 pediatric liver transplants were performed at our center. Out of this 1 patient received a cadaveric organ and the others received living donor liver allografts from adult parents or grandparents. Two of these cases were performed in infants weighing 6 kg or less. We usually select the left lateral segment (LLS) in an adult to pediatric transplant. If the graft-to-recipient weight ratio (GRWR) is less than 4, then the LLS graft is harvested from the donor as is. When the GRWR exceeds 4 we reduce the LLS. In the infants weighing 6 kg or less, anatomic reduction (ie, excision of segment 3) is done, which yields a segment 2 monosegment graft. The preoperative computed tomography (CT) of the donor is studied carefully with respect to the vascular and biliary anatomy of the LLS. Predicted graft volumes are calculated by computerized software analysis of CT images.

Technique

The donor surgery is started as is standard by using a right-sided reverse "L" or Maakuchi incision. The left lobe of the liver is mobilized. The left portal vein, left hepatic artery, and left hepatic duct are identified in the hepatic hilum. Parenchymal transection to the right of the falciform ligament is carried out like for harvesting an LLS graft. The left hepatic vein is identified, dissected, and looped at the end of this parenchymal transection. The pedicle to segment 3 can be identified to the left of the umbilical fissure. The Glissonian sheath over the pedicle is identified after some amount of parenchyma is dissected from over it. We prefer to stay to the left of the umbilical fissure in order to avoid inadvertent injury to the segment 2 pedicle. Once dissected, the segment 3 pedicle is clamped and a line of demarcation is observed between segments 2 and 3 as shown in Fig 1. At this stage with the segment 3 pedicle clamped an ultrasound is done to confirm Doppler flow to segment 2. Once confirmed another plane of transection is created between segments 2 and 3. The plane proceeds superiorly for a short distance after ligating the segment 3 pedicle, then laterally along the inferior aspect of the segment 2 vasculature, and finally the lateral extent is along the left hepatic vein. The schema of the reduction is shown in Fig 2, the corresponding operative picture is shown in Fig 3. Along the transection plane it is important to identify and divide only structures supplying segment 3 and preserving segment 2 structures. We then perform an operative cholangiogram and divide the left hepatic duct. The graft is then removed and perfused with University of Wisconsin solution on the back table. The grafts are weighed on the back table. If the GRWR was still found to be above 4, the plan was to reduce the graft further by doing an ex vivo excision of the parenchyma from the lateral aspect of the graft in a nonanatomic fashion.

The recipient hepatectomy was done in the usual fashion. If the infant had undergone a previous Kasai portoenterostomy, the Roux loop of jejunum was preserved for biliary reconstruction. In the other cases a new roux loop of jejunum would be created. The recipient left and middle hepatic orifices are joined to accommodate anastomosis with the graft left hepatic vein. We routinely extend the venotomy on the recipient cava if the donor outflow needs to be accommodated. The recipient main portal vein is used for the donor left portal vein. The hepatic arterial anastomosis is performed under 4.5x magnification using microsurgical techniques. The biliary anastomosis is a bilioenteric roux-en-Y anastomosis. At the end of the procedure we judge our ability to close the abdomen. A Doppler ultrasonography evaluation of liver allograft blood flow is done before and after abdominal closure. Respiratory pressures, arterial blood gas, and ability to ventilate the patient feedback are taken from the anesthesiologists after abdominal closure. Only when found acceptable is the patient shifted out of the operating room.

We reviewed the preoperative work-up, operative technique, graft and recipient status, and postoperative course of both the recipients for the purpose of this report.

RESULTS

Two out of the 11 pediatric transplants at our center were done for infants weighing 6 kg or less. The donor characteristics are shown in Table 1. The donors at our center are managed under an enhanced recovery after surgery protocol. Both had an uneventful hospital stay. The recipient

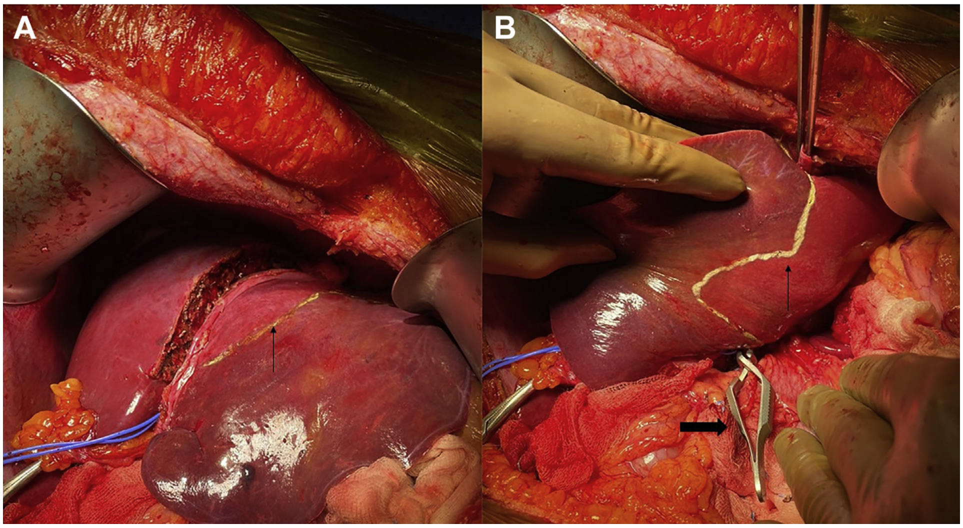

Fig 1. **(A)** The line of demarcation marked by the thin arrow on the anterior aspect. **(B)** The same seen posteriorly, the thick arrow shows the vascular clamp applied on the pedicle of segment 3.

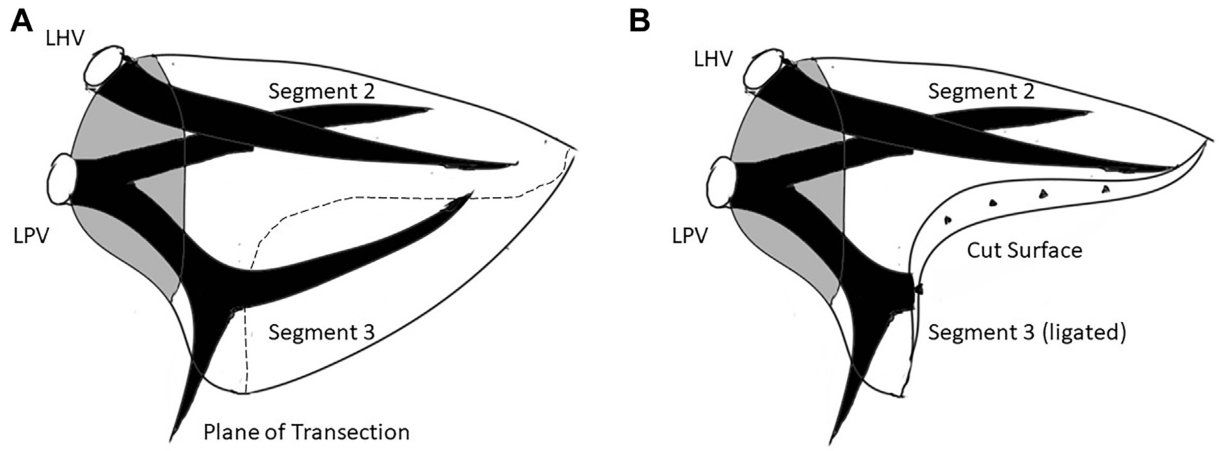

Fig 2. **(A)** Shows the left lateral segment with the dotted line representing the plane of transection. **(B)** The monosegment 2 liver graft after reduction with an anterior cut surface.

characteristics are shown in Table 2. Recipient 1 was an infant with Tyrosinemia. The family opted for an early transplant due to growth failure, cost constraints, and availability concerns of nitisinone. This was in contrast to transplantation costs, which are lesser over the long term, as our pediatric program receives substantial funding from crowdfunding organizations and charitable donations. The family also displayed reservations about being able to comply with dietary restrictions. Recipient 2 had biliary atresia and had undergone a Kasai portoenterostomy, which had subsequently failed. He had growth failure, significant portal hypertension, collaterals, and portal vein stenosis. Preoperatively we had identified collaterals from the coronary vein and a spontaneous splenorenal shunt. The native hepatectomy in both the recipients was uneventful. In recipient 2 we ligated the coronary vein and the splenorenal shunt to establish dominant hepatopetal portal blood flow. The graft implantation was also uneventful subsequently in both. Doppler evaluation before abdominal closure showed adequate blood flow in the portal vein and hepatic artery, as well as adequate drainage in the hepatic veins. Primary abdominal closure was possible in both recipients. There was no tension during closure, and no changes in respiratory pressures were observed. A Doppler evaluation of blood flow to the allograft was repeated after closure and found unchanged. Standard immune suppression protocols were followed. Recipient 1 made an uneventful recovery and was discharged on day 14 after surgery. Recipient 2 had a minor bile leak, which manifested on day 10 after surgery. It required image-guided drainage and resolved not needing further intervention. Subsequently he was discharged by day 20. Both continue to do well on follow-up, which has been over a month

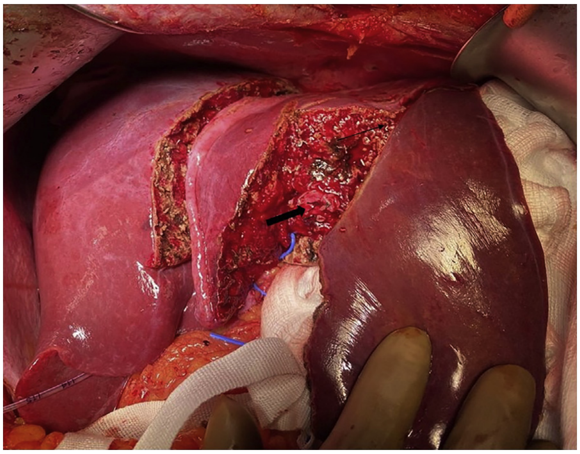

Fig 3. In situ transection plane, the thick arrow showing where the pedicle to segment 3 was ligated and the thin arrow showing the transection plane progressing superiorly.

DISCUSSION

Small infants pose a significant challenge in LDLT. The adult LLS may at times be large for size. The mismatch may lead to insufficient perfusion, graft dysfunction, and an inability to close the abdomen primarily [3]. Initial efforts to

Table 1. Donor Characteristics

Characteristic	Donor 1	Donor 2
Age (y)	49	30
Relationship	Grandmother	Mother
Height (cm)	162	167
Weight (kg)	53	66
Operative time (min)	461	402
Blood loss (mL)	500	430
Estimated LLS weight (g)	264	290
Estimated GRWR	4.5	4.8
Complications	None	None
Length of hospital stay (d)	6	7

Abbreviations: GRWR, graft-to-recipient weight ratio; LLS, left lateral segment.

Table 2. Recipient Characteristics

Characteristic	Recipient 1	Recipient 2
Sex	Male	Male
Age (mo)	6	7
Height (cm)	51	50
Weight (kg)	5.8	6.0
Disease	Tyrosinemia	Biliary atresia
Graft weight (g)	125	172
Reduction from LLS (%)	53	41
GRWR	2.15	2.86
Graft thickness (cm)	4.8	5.1
Primary closure	Yes	Yes
Complication	None	Minor bile leak

Abbreviations: GRWR, graft-to-recipient weight ratio; LLS, left lateral segment.

address the problem resulted in the use of reduced LLS grafts. The first monosegment grafts introduced were segment 3 grafts by Strong et al [4]. However, because S3 represents most of the LLS graft's anteroposterior thickness, the problem of abdominal closure remained unaddressed in some recipients. The segment 2 monosegment grafts were first used by Mentha et al [5]. This graft is usually thinner and yields substantial reduction in volume and weight. This usually permitted abdominal closure in most recipients. Some of the factors that predict the ability to achieve a primary closure have been graft thickness of more than 5 cm and the anteroposterior diameter of the recipient's abdomen [6,7]. The major issue with segment 2 grafts is that the cut surface is apposed to the anterior abdominal wall and dense adhesions may form.

In the preoperative planning, we used three-dimensional reconstruction software to study donor LLS anatomy and volumes. It helps predict the GRWR and provides landmarks for the segmental pedicles and the left hepatic vein. In the operation various methods of identifying the segmental anatomy have been described. Mentha et al used methylene blue to demarcate the line between segments 2 and 3 [5]. Sakuma et al used contrast ultrasound with Sonazoid to ensure safe graftectomy [6]. We found identifying the segment 3 pedicle and clamping it to get an ischemic line of demarcation is the simplest way to delineate the extent of reduction. A Doppler evaluation without contrast ensures flow to segment 2, while the segment 3 pedicle remains clamped. This is technically challenging and requires a working knowledge of the liver's segmental anatomy as well as diligent evaluation of the donor CT scans. The donor surgery and hospital stay were without complications. Most series describing the use of segment 2 grafts have reported that the procedure can be safely done and adds no significant risks to the donor procedure [1–7].

In the recipients we were able to achieve primary abdominal closure in both. This was mainly due to a significant reduction in the graft size. This was done without respiratory or hemodynamic compromise (to graft). Recipient 1 had an uneventful hospital stay, and recipient 2 had a bile leak. This bile leak was self-limiting and resolved on prolonged drainage. The overall rate of complications in recipients using anatomically reduced LLS graft is around 24% [8]. Vascular and biliary complications account for approximately one-fourth of complications. However, this is lesser than complications arising in nonanatomically reduced grafts [8]. The latter also resulted in higher re-operation rates and higher chances of leaving the abdomen open. Therefore monosegment 2 grafts are our choice in small infants. In the Indian setting where most of the health care expenses are out-of-pocket and insurance coverage is inadequate, a lower re-operation and complication rate is of critical importance. Also, low birth weight and high rates of growth failure seen in several pediatric liver ailments means this procedure will allow us to offer LDLT to a broader set of patients. However, there must still be an attempt made to allow these infants to grow such that they are of a healthy weight (≥10 kg) before transplant. In most such cases they can receive a LLS graft from an adult donor. The monosegment graft transplant is offered to infants who have had growth failure despite optimum interventions or in cases where transplant is more emergent, like acute liver failure.

In our experience we find monosegment 2 liver allografts suitable and safe for LDLT in small infants weighing less than 6 kg. Long-term follow-up of these recipients will give us more insight into how these allografts perform in the future.

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