Transplant International ISSN 0934-0874

ORIGINAL ARTICLE

Left and right lobe split-liver transplantation for two paediatric recipients from a 9-year-old donor

Hugo Bonatti,[1] Ruth Ladurner,[1] Walter Mark,[1] Silke Wiesmayr,[2] Helmuth Ellemunter,[2] Christoph Hörmann,[3] Raimund Margreiter[1] and Alfred Königsrainer[1]

1 Department of General and Transplant Surgery, University Hospital, Innsbruck, Austria
2 Department of Paediatrics, University Hospital, Innsbruck, Austria
3 Department of Anaesthesiology, University Hospital, Innsbruck, Austria

Keywords
liver transplantation, paediatric, split.

Correspondence
Hugo Bonatti MD, PhD, Innsbruck University Hospital, Department of General and Transplant Surgery, Anichstrasse 35, A-6020 Innsbruck, Austria. Tel.: +43-412-504-22604; fax: +43-512-504-22605; e-mail: hugo.bonatti@uklibk.ac.at

Received: 18 December 2004
Revision requested: 10 February 2005
Accepted: 22 March 2005

doi:10.1111/j.1432-2277.2005.00149.x

Summary

Liver splitting increased the number of grafts for paediatric recipients. Usually the two left lateral segments are given to a child and the remaining liver to an adult recipient. Splitting into a right and a left lobe may allow a small adult to benefit from the left lobe while the right lobe goes to another adult recipient. Splitting of paediatric grafts, however, has rarely been performed. We here report on a case where the liver from a 9-year-old donor was *ex situ* split along the principal fissure creating a right and left lobe which provided grafts for two children aged 2 and 3 years. Immunosuppression consisted of Tacrolimus-based triple drug therapy. Recovery was completely uneventful in both children who are alive and well with normally functioning grafts 11 months following transplantation. These cases demonstrate the feasibility of splitting even paediatric grafts for two small children.

Background

Split liver transplantation has emerged as feasible option to increase the number of liver grafts for the paediatric population [1–3]. The classical split provides left lateral segments for a paediatric recipient and a right lobe with or without segment IV for an adult recipient. This procedure produces results comparable with full-size liver transplantation [4]. Successful transplants have also been accomplished by using the left lateral segments for small adults. Splitting the graft through the principal plane thus providing a left lobe including the inferior vena cava (IVC) for one adult and a right lobe with outflow through the right hepatic vein for a second adult recipient has proven a viable option [5]. The technical problems of this procedure have been solved to a large extend and it has been accepted by transplant surgeons that the hepatic artery and portal vein should be left with the left lobe whereas the bile duct should be given to the right lobe, although other technical variants have been described as well [6–8]. Allocation of the middle hepatic vein and the choice between *in situ* or *ex situ* splitting remain matters of discussion [9–11]. Other points such as size, age, body mass index and other donor parameters require further research. Splitting creates a number of logistic problems. Many centres are reluctant to accept grafts which were split by another team. Therefore, a longer cold ischaemia time for the second graft has to be accepted because staff for two simultaneous transplants is often not available at a single centre.

Paediatric grafts should preferably be transplanted as full-size grafts. Division of paediatric livers is delicate and implies handling of tiny vascular structures and bile ducts thus bearing a high risk of surgical complications. Therefore, splitting of a paediatric liver has been reported rarely in the literature thus far [12]. In the absence of a size-matched paediatric full-size liver recipient, we have split a paediatric graft through the cava-gallbladder fissure providing a left lobe including

the IVC for a 2-year-old child and a right lobe for a 3-year-old recipient.

Case report of paediatric liver splitting

Donor was a 9-year-old boy who died of an isolated head injury. The cytomegalovirus (CMV)-positive donor measured 130 cm in height and 18 kg in weight. The heart, liver and both kidneys were procured for transplantation. The lungs were discarded because of aspiration pneumonia and the pancreas was not accepted because of the young age of the donor. The abdominal organs were perfused with a total of 1500 ml of University of Wisconsin (UW) solution via the infrarenal aorta.

The liver was allocated to a 2-year-old girl who had developed recurrent episodes of cholangitis after portoenterostomy for extrahepatic bilary atresia (EHBA) 1 year earlier. EHBA led to cirrhosis and finally to liver failure. This girl weighed 11.3 kg and was 91 cm in height.

At the back table the graft was found to be of excellent quality. Because of the size mismatch between the donor liver and the small recipient it became evident that a size reduction had be carried out. At this stage the idea came up to split this liver as another blood group identical 3-year-old girl suffering from α-1-antitrypsin deficiency was on the waiting list. Her weight was 12.8 kg at a height of 90 cm. Hepatectomy of the first child was begun simultaneously with the splitting procedure. Magnification loops (2.5 times) were used for back table preparation and during transplantation.

Splitting procedure

Initially it was planned to perform a left lateral segmentectomy. However, as the right lobe including segments I and IV would have been too large for both children it was decided to split the graft through the principal plane. The venous anatomy was found to be favourable insofar, as the middle hepatic vein could safely be left with the left lobe because for segments V and VIII large posterior veins were identified. The right hepatic vein was divided at its origin and the two large segmental veins were cut at their caval orifices. Following cholecystectomy, the hepatic artery was divided leaving the coeliac trunc with the left lobe. After division of the left bile duct and the right portal vein just behind the bifurcation the transection of the parenchyma was begun using an ultrasound dissector. Major vascular and biliary structures were ligated or suture ligated with 4-0 Vicryl or secured with haemoclips. The presence of bile leaks was excluded by injection of saline solution into the bile ducts. The cut surfaces were finally sealed with fibrin glue.

Recipient hepatectomies and implantation of the split grafts

Meanwhile the hepatectomy of the first child was about to be completed. Despite major adhesions from the previous Kasai procedure, blood loss was minimal. The portojejunostomy was taken down and the Roux loop later used for biliary drainage. After division of the hepatic artery and division of the portal vein the liver was dissected from the IVC. After ligation of posterior veins, the right hepatic vein was clamped and divided followed by division of the middle and the left hepatic vein. Finally, the native liver was removed.

While the implantation of the right lobe in the 2-year-old patient was begun the 3-year-old recipient was brought to the operation room (OR) and the second hepatectomy was carried out at the same time as the implantation of the first graft took place.

In the right lobe recipient, the vein of the graft was anastomosed to the recipient's right hepatic vein after having performed a cavoplasty. Two posterior veins with a diameter of more then 0.5 cm each were anastomosed to the IVC. The portal anastomosis was completed using a 6-0 PDS running suture. After reperfusion the recipient's hepatic arterial bifurcation patch was anastomosed to the graft right hepatic artery using 7-0 PDS interrupted sutures. After good initial arterial reperfusion, few minutes later no arterial blood flow was detected. Doppler ultrasound examination revealed absence of arterial and portal perfusion and therefore thrombectomy of both vessels had to be performed which resulted in good arterial and portal flow. The graft was placed in a better position to avoid kinking or compression of the artery or portal vein. Thereafter, a hepaticojejunostomy with the existing Roux limb was performed. After abdominal closure the child was brought to intensive care unit (ICU) in excellent condition with satisfactory initial graft function.

At this stage the implantation of the second split graft was started. Anastomoses of the supra- and infra-hepatic vena cava and the portal vein were performed in the usual way using 4-0 and 6-0 PDS, respectively. After uneventful reperfusion, arterial anastomosis was performed between recipient hepatic artery and donor coeliac trunk. For biliary reconstruction a Roux loop was created. Initial graft function was good. The second liver transplant was completed 5 h after the first transplant. Total time for splitting and the two liver transplants was 14 h. Cold ischaemia for the first graft was 8 h 56 min and for the second 13 h 4 min, operating time for the first transplant was 6 h and for the second 6.5 h. Figure 1 shows ultrasound images of the left and the right liver lobe 4 weeks post-transplant. In both children immunosuppression consisted of Tacrolimus (trough levels of

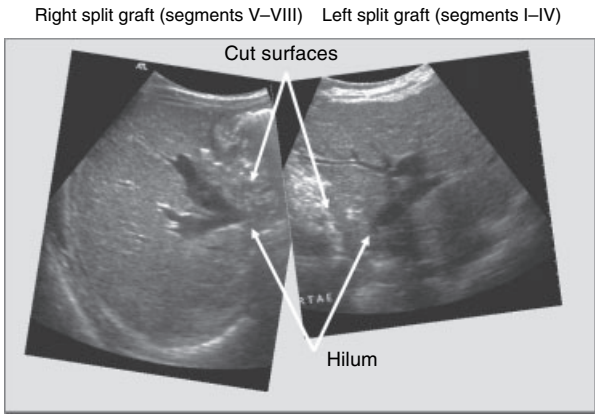

Figure 1 Abdominal ultrasound image of the two children 4 weeks post-transplant.

12–16 ng/ml), Mycophenolate mofetil and rapidly tapered steroids. Valganciclovir (225 mg daily) was given for CMV prophylaxis and Piperacillin/Tazobactam for perioperative antibacterial prophylaxis. Heparin was administered intravenously [aimed partial thromboplastin time (PTT) 45 s] and was replaced by acetylsalicylic acid on day 4 post-transplant. Whereas the heart of this donor was transplanted in another centre, kidneys were given to an adult and to a 6-month-old child at our centre.

Because of reperfusion injury, which was demonstrated on histology of postreperfusion biopsy, in the right lobe recipient liver enzymes improved slowly and were at the end of the first postoperative week: total bilirubin 2.3 mg/dl, aspartate aminotransferase (AST) 41 U/l, alanine aminotransferase (ALT) 136 U/l, γ-GT 83 U/l, alkaline phosphatase 138 U/l, lactate dehydrogenase 170 U/l, prothrombin 109% and normalized after 3 weeks: bilirubin 1.3 mg/dl, AST 52 U/l, ALT 70 U/l, alkaline phosphatase 156 U/l, γ-GT 46 U/l and lactate dehydrogenase 180 U/l. A mild rejection episode was treated by increasing the Tacrolimus dosage. Apart from an enoral herpetic infection, which was successfully treated with Acyclovir, the post-transplant course was largely uneventful and the patient discharged on day 31. CMV infection developed despite oral Valganciclovir prophylaxis during the second post-transplant month, which was successfully treated by increasing the Valganciclovir dosage. Ebstein–Barr virus (EBV) reactivation was detected 10 weeks post-transplant. At 6 months post-transplant the child developed varizella-zoster-virus (VZV) infection which was followed by an adenovirus infection. Both episodes were managed successfully.

In the left lobe recipient initial graft function was good with a total bilirubin of 0.7 mg/dl, AST 64 U/l, ALT 278 U/l, γ-GT 250 U/l, alkaline phosphatase 154 U/l, lactatedehydrogenase (LDH) 203 U/l, PT 102% at the end of the first week. Liver enzymes normalized during the second post-transplant week. No immunological or infectious complications occurred during the early post-transplant course and the patient was discharged on the 31st postoperative day. About 6 weeks post-transplant the patient experienced *Clostridium difficile*-associated colitis, which was successfully treated with oral Vancomycin. CMV infection also developed in this child during the second post-transplant month despite oral Valganciclovir prophylaxis. Like in the first child, this infection was successfully treated by increasing the Valganciclovir dose. Also in the second recipient a reactivation of EBV was observed 4 months post-transplant.

After a follow up of 14 months both girls are alive and well with normally functioning grafts.

Discussion

Split graft liver transplantation was shown to give results comparable with whole graft transplantation in children and adults. This case report demonstrates the feasibility of splitting paediatric grafts through the principal fissure. No surgical complications occurred in both recipients.

The use of liver splitting had an enormous effect on paediatric liver transplant programmes worldwide [13]. In some centres up to 60% of paediatric recipients are transplanted with such split grafts. In more than 90% the left lateral segments are used for paediatric recipients in particular in case of *in situ* splitting [14]. Several studies have shown that liver splitting provides allografts of optimal quality for paediatric transplantation [15,16]. A liberal splitting policy led to a dramatic decrease in mortality on the waiting list as well as in overall waiting time for transplantation [17]. Excellent results have been reported after splitting for an adult and a paediatric recipient with 2 year patient and graft survival rates for right split-liver grafts of 84% and 79%, respectively and 2-year survival rates of 84% and 76% for the left lateral segmental counterparts [17–22]. In contrast, outcome of liver splitting between two adults is less favourable in particular with regard to the left lobe [23]. Relative outflow obstruction and small for size syndrome have been responsible for the less favourable outcome when compared with that of the right lobe [23].

Paediatric grafts should be given to size-matched paediatric recipients [16]. However, such grafts are sometimes allocated to adults in case there is no suitable recipient available. Most children listed for liver transplantation are 2 years of age or less and, therefore, a graft from an older child may be too large thus requiring size reduction. Some cases of splitting paediatric grafts in a left lateral segment graft and an extended right lobe have been reported [12]. To our knowledge, the technique described in this article

has to our knowledge not been applied thus far. Splitting of such small livers is basically the same as splitting of adult livers. Because of the small size of all vascular structures it is certainly more demanding. Good size matching achieved by splitting paediatric livers facilitates primary abdominal closure even in very small children [24].

Liver splitting remains a challenge in terms of logistics and only few centres will be able to simultaneously transplant two recipients. Therefore, when utilizing two grafts at the same centre a consecutive or overlapping surgical approach might solve this problem. We have adopted such a strategy in that the hepatectomy of the second recipient was begun shortly after reperfusion of the first graft. For a multiorgan transplant centre, this requires significant manpower as in many instances also a cardiac and possibly a lung transplant are preceding the liver transplant. A pancreas/kidney and/or renal transplant will follow the two split-liver transplants. The optimal approach in these cases would entail the close cooperation between two centres utilizing one split graft each.

The split-liver technique should be considered the method of choice for expanding the cadaveric liver donor pool [25–27]. If the donor–recipient body weight ratio (DRWR) is >2, the grafts should be evaluated for a split. Our case clearly demonstrates the feasibility of splitting of paediatric liver allografts without unacceptable vascular or biliary complications.

References

1. McDiarmid SV, Anand R, SPLIT Research Group. Studies of Pediatric Liver Transplantation (SPLIT): a summary of the 2003 Annual Report. *Clin Transpl* 2003; **30**: 119.
2. Hendrickson RJ, Karrer FM, Wachs ME, Slater K, Bak TE, Kam I. Pediatric liver transplantation. *Curr Opin Pediatr* 2004; **16**: 309.
3. Renz JF, Yersiz H, Reichert PR, *et al.* Split-liver transplantation: a review. *Am J Transplant* 2003; **3**: 1323.
4. Martin SR, Atkison P, Anand R, Lindblad AS, SPLIT Research Group. Studies of Pediatric Liver Transplantation 2002: patient and graft survival and rejection in pediatric recipients of a first liver transplant in the United States and Canada. *Pediatr Transplant* 2004; **8**: 273.
5. Azoulay D, Castaing D, Adam R, *et al.* Split-liver transplantation for two adult recipients: feasibility and long-term outcomes. *Ann Surg* 2001; **233**: 565.
6. Zamir G, Olthoff KM, Desai N, Markmann JF, Shaked A. Toward further expansion of the organ pool for adult liver recipients: splitting the cadaveric liver into right and left lobes. *Transplantation* 2002; **74**: 1757.
7. Malago M, Hertl M, Testa G, Rogiers X, Broelsch CE. Split-liver transplantation: future use of scarce donor organs. *World J Surg* 2002; **26**: 275 (Epub 2001 Dec 21).
8. Noujaim HM, Gunson B, Mirza DF, *et al.* Ex situ preparation of left split-liver grafts with left vascular pedicle only: is it safe? A comparative single-center study. *Transplantation* 2002; **74**: 1386.
9. Yersiz H, Renz JF, Farmer DG, Hisatake GM, McDiarmid SV, Busuttil RW. One hundred in situ split-liver transplantations: a single-center experience. *Ann Surg* 2003; **238**: 496; discussion 506.
10. Yersiz H, Renz JF, Hisatake GM, Farmer DG, Busuttil RW. The conventional technique in in-situ split-liver transplantation. *J Hepatobiliary Pancreat Surg* 2003; **10**: 11.
11. Noujaim HM, Gunson B, Mayer DA, *et al.* Worth continuing doing ex situ liver graft splitting? A single-center analysis. *Am J Transplant* 2003; **3**: 318.
12. Deshpande RR, Bowles MJ, Vilca-Melendez H, *et al.* Results of split liver transplantation in children. *Ann Surg* 2002; **236**: 248.
13. Colledan M, Segalin A, Spada M, Lucianetti A, Corno V, Gridelli B. Liberal policy of split liver for pediatric liver transplantation. A single centre experience. *Transpl Int* 2000; **13**(Suppl 1): S131.
14. Otte JB, de Ville de Goyet J, Alberti D, Balladur P, de Hemptinne B. The concept and technique of the split liver in clinical transplantation. *Surgery* 1990; **107**: 605.
15. Azoulay D, Marin-Hargreaves G, Castaing D, Bismuth H. Ex situ splitting of the liver: the versatile Paul Brousse technique. *Arch Surg* 2001; **136**: 956.
16. McDiarmid SV, Davies DB, Edwards EB. Improved graft survival of pediatric liver recipients transplanted with pediatric-aged liver donors. *Transplantation* 2000; **70**: 1283.
17. McDiarmid SV, Anand R, Lindblad AS, SPLIT Research Group. Studies of Pediatric Liver Transplantation: 2002 update. An overview of demographics, indications, timing, and immunosuppressive practices in pediatric liver transplantation in the United States and Canada. *Pediatr Transplant* 2004; **8**: 284.
18. Santori G, Andorno E, Antonucci A, Morelli N, Panaro F, Valente U. Putative survival predictors in right-graft (adult) recipients after in situ split-liver transplantation: a retrospective single-center analysis. *Transpl Int* 2003; **16**: 476 (Epub 11 April 2003).
19. Margarit C, Asensio M, Iglesias J, *et al.* Outcome of 28 split liver grafts. *Transplant Proc* 2003; **35**: 1812.
20. Merion RM, Rush SH, Dykstra DM, Goodrich N, Freeman RB Jr, Wolfe RA. Predicted lifetimes for adult and pediatric split liver versus adult whole liver transplant recipients. *Am J Transplant* 2004; **4**: 1792.
21. Abt PL, Rapaport-Kelz R, Desai NM, *et al.* Survival among pediatric liver transplant recipients: impact of segmental grafts. *Liver Transpl* 2004; **10**: 1287.
22. Roberts JP, Hulbert-Shearon TE, Merion RM, Wolfe RA, Port FK. Influence of graft type on outcomes after pediatric liver transplantation. *Am J Transplant* 2004; **4**: 373.

23. Heaton N. Small-for-size liver syndrome after auxiliary and split liver transplantation: donor selection. *Liver Transpl* 2003; **9**: S26.
24. Jones WT, Ratner I, Abrahamian G, *et al.* Use of a silastic silo for closure of the abdominal wall in a pediatric patient receiving a cadaveric split liver. *J Pediatr Surg* 2003; **38**: E20.
25. Gridelli B, Spada M, Petz W, *et al.* Split-liver transplantation eliminates the need for living-donor liver transplantation in children with end-stage cholestatic liver disease. *Transplantation* 2003; **75**: 1197.
26. Anselmo DM, Baquerizo A, Geevarghese S, Ghobrial RM, Farmer DG, Busuttil RW. Liver transplantation at Dumont-UCLA Transplant Center: an experience with over 3,000 cases. *Clin Transpl* 2001; 179.
27. Azoulay D, Samuel D, Adam R, *et al.* Paul Brousse liver transplantation: the first 1,500 cases. *Clin Transpl* 2000; 273.