In Situ Splitting of the Cadaver Liver for Two Adult Recipients by LDLT Technique

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Background: To expand the donor pool, split liver transplantation is conventionally performed for one adult and one pediatric recipient. Application of this technique for two adult recipients can produce remarkable impact on the waiting list. Proper donor and recipient selection is crucial for the favorable outcome following full-right and full-left liver split. Right lobe adult to adult living donor liver transplantation (LDLT) is essentially a full right and full left split. However, LDLT techniques have not been used for full right and left split. **Methods:** We performed in situ splitting of the whole liver using LDLT techniques from a hemodynamically stable young deceased donor and transplanted into two adult recipients, both with model for end-stage liver disease score of 17. The transection was carried out through the midplane of liver, generating a right lobe and a left lobe graft. **Results:** Both the recipients had uneventful postoperative recovery. At ten months of follow up, both the recipients are doing well with good liver function. **Conclusion:** Based on the concept of living related liver transplantation, our case explores the technical feasibility of full-right and full-left in situ liver split. (J CLIN EXP HEPATOL 2017;7:179–183)

SLT (split liver transplantation) is commonly performed for an adult and a pediatric recipient. There are very few reports of the in situ procedure being performed for two adult recipients. On the back ground of a large experience of LDLT (living donor liver transplantation), it is technically feasible to perform in situ splitting of one cadaver liver for two adult recipients. Here, we report our first case of full-right and full-left in situ liver split and also discuss the surgical technique of the procedure.

SURGICAL TECHNIQUE

Donor Procedure

The donor was a young male (age: 25 years) with an average build (weight: 70 kg). The cause of death was intracerebral hemorrhage. Immediately before procurement, he was hemodynamically stable with minimal inotropic support and his liver function tests were essentially normal.

After performing two-dimensional echocardiogram and ultrasound abdomen, the donor underwent a multiorgan

procurement in presence of a thoracic and abdominal surgical team. Following a sternolaparotomy, thorough inspection of the abdominal organs was performed. Fat content of the liver was assessed by finger printing test.

Dissection of Porta Hepatis

Following cholecystectomy, the cystic duct was cannulated and an intraoperative cholangiogram was performed. Donor had type I biliary anatomy. Arterial dissection was done next. Left hemi liver had dual blood supply: segment 4 artery from RHA (right hepatic artery) and segment 2/3 branch as a common LHA (left hepatic artery). There was a single RHA with division into right anterior and right posterior artery approximately 2 cm beyond the origin of segment 4 artery. MPV (main portal vein) was dissected and found to have type A anatomy.

Plan of Division of Porta Hepatis (Figure 1)

- Right lobe with
 - Right hepatic duct with CHD (common hepatic duct)
 - RHA beyond segment 4 artery
 - Right portal vein with MPV
- Left lobe with
 - LHD (left hepatic duct)
 - Segment 4 and segment 2/3 artery as a common stump by dividing RHA beyond the origin of segment 4 artery
 - Left portal vein

Right and left hemi livers were mobilized from their diaphragmatic attachments. The IVC (inferior vena cava) was dissected free from retrocaval attachments.

Ischemic Line Marking (Figure 2)

The RHA and right portal vein were occluded with Bulldog clamps and the ischemic line of demarcation between right and left hemiliver was marked with electrocautery.

Keywords: split liver transplantation, waiting list, MELD score, deceased donor, partial grafts

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Abbreviations: CHD: common hepatic duct; GRWR: graft/recipient's body weight ratio; IVC: inferior vena cava; LDLT: living donor liver transplantation; LHA: left hepatic artery; LHD: left hepatic duct; LHV: left hepatic vein; MELD: model for end-stage liver disease; MHV: middle hepatic vein; MPV: main portal vein; RHA: right hepatic artery; RHV: right hepatic vein; SLT: split liver transplantation

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Figure 1 The in situ splitting technique.

Anterior Sector Congestion

The Bulldog clamp over right portal vein was removed leaving only the RHA occluded. The MHV (middle hepatic vein)/left hepatic vein (LHV) junction was then clamped using an angled Satinsky clamp to allow for congestion of right anterior sector with deoxygenated blood and then marking out an area with a sterile skin marker. The Satinsky clamp over the MHV/LHV junction and the Bulldog clamp over the RHA were then removed. The anterior section congestion volume calculated was approximately 35%.

Plan of Parenchymal Transection

- Modified right lobe graft and
- Left lobe graft with MHV

Parenchymal transection was done with Cavitron Ultrasonic Surgical Aspirator. The MHV was traced. Segment 5

and 8 veins were looped over silastic slings at their junction with MHV for a modified right lobe graft. Their vessels were not cut initially to allow for proper liver perfusion later.

A retrohepatic tunnel was created deep to caudate process/segment 6 junction caudally to area between RHV (right hepatic vein) and MHV insertion into IVC cranially. This was done using a technique termed the 'liver hanging manoeuvre', described by Belghiti et al.¹ The liver was hung using a 12 French Ryle's tube. Since, decision had taken to keep the CHD with the right hepatic duct; the caudate process/segment 6 junction was transected from left after retracting porta hepatis to right side. Following this transection, the left portal pedicle was looped using a silastic sling and the LHD and hilar plate were then isolated in the sling by excluding the left portal vein and LHA plus segment 4 arteries from sling. A radio-opaque marker was placed at the LHD/CHD junction and an intraoperative cholangiogram was repeated. After confirming the position of the radiopaque marker, the LHD/CHD junction was transected, taking care not to damage the CHD. The hilar plate was transected and the plate was sutured with 5-0 prolene on either side to occlude the caudate ductule openings present in the transected hilar plate. The CHD opening (of the LHD) was then sutured closed with 6-0 polydioxanone suture.

The caudate lobe transection was done using the help of liver hanging maneuver, leaving the junction of segment 5 and segment 8 veins with MHV intact. The LHA, CHA and celiac axis were then dissected. The MPV was dissected to its origin from superior mesenteric vein/splenic vein junction. The CHD was transected at the duodenal end and the right hepatic duct/CHD and LHD were irrigated with normal saline solution.

At this point, the two lobes remained joined by the segment 5 and 8 vein junctions to MHV, and the short hepatic veins and RHV/MHV/LHV draining into IVC. This was done to allow for perfusion of University of Wisconsin solution to all parts of liver.

Once the kidney team had completed their dissection, the infrarenal aorta was clamped followed by supra celiac aorta and then IVC/atrial junction was transected to bleed out the donor. 5 L University of Wisconsin solution was perfused: 4 L through aorta and 1 L through portal vein. The left portal vein/MPV junction was then cut, the RHA was cut beyond the origin of segment 4 artery, the celiac axis with cuff of aorta was taken and the both lobes of liver with IVC intact were removed and perfused on back bench with 1 L of University of Wisconsin solution. Following this, separation of the two lobes commenced. The segment 5 and segment 8 veins were transected at their junction with MHV and the MHV was repaired with 6-0 prolene suture. The IVC was left behind with the left lobe and hence, RHV/IVC junction was transected and IVC repaired. One large inferior hepatic vein from right hemi

Figure 2 Marking of the ischemic line for liver split.

liver was preserved, while other short hepatic veins were ligated.

Finally, the two grafts obtained (Figure 1) were

1. Right lobe with
 - a. RHV and one large inferior hepatic vein
 - b. RHA beyond segment 4 artery
 - c. Right portal vein with MPV
 - d. Right hepatic duct with CHD
2. Left lobe
 - a. Segment 4 artery with LHA, CHA and celiac axis
 - b. Left portal vein
 - c. LHD

The anterior sector of right hemi liver was reconstructed. A neo MHV was fashioned using iliac vein graft to which the segment 5 and 8 veins were anastomosed.

Recipient Surgery

A 35 years old 65 kg male patient with alcoholic liver cirrhosis and a 41 years old 47 kg female patient with secondary biliary cirrhosis due to primary sclerosing cholangitis, both with model for end-stage liver disease (MELD) score of 17 were selected as recipients.

For right lobe recipient, hepatectomy was performed with preservation of IVC. The RHV orifice was enlarged by caudal slit on IVC to optimize the venous outflow. The donor RHV was anastomosed to the enlarged orifice of the recipient RHV, creating a large anastomosis. The inferior hepatic vein was directly anastomosed to IVC. Then, the neo MHV was sewn to the recipient MHV/LHV junction. The graft portal vein was anastomosed to the recipient MPV and the hepatic artery was sewn to the LHA. Biliary reconstruction was performed with a choledochocholedochostomy (Figure 3).

In left lobe recipient, hepatectomy was performed in the standard manner with resection of IVC. The recipient IVC was replaced by sewing the left graft into place. The standard method was used for portal venous and hepatic arterial anastomosis, while biliary reconstruction was

Figure 3 Implantation of right hemi liver.

Figure 4 Implantation of left hemi liver.

carried out with a choledochocholedochostomy (Figure 3). Both the patients had uneventful postoperative recovery (Figure 4).

DISCUSSION

As liver transplantation has evolved, shortage of suitable donor organs has been overcome by utilization of a variety of methods such as use of living donors and splitting cadaveric livers. Since 1989, LDLT has been carried out successfully with results equivalent or superior to a standard cadaveric transplantation. The risk of significant morbidity and mortality to the living donor is the major disadvantage of living donor transplantation. On the other hand, in SLT, the whole adult cadaveric liver is divided into two functioning allografts. This technique was firstly demonstrated by Pichlmayr's team in 1988² and subsequently several centers followed this method. In the beginning, the results of SLT were discouraging, with a high biliary complication rate, an inferior patient survival and a higher retransplantation rate than with a standard cadaveric donor. However, due to growing experience in LDLT, the interest in SLT persisted and the technique was justified by the equivalent patient survival rates with that of a standard cadaveric liver transplantation. At present, there are two techniques of SLT. In the ex vivo technique, after retrieval of the whole liver in the standard fashion, the splitting is carried out on the back table in recipient center. The in situ split is a natural evolution from LDLT over the last 2 decades and the liver splitting procedure is performed in a heart-beating deceased donor. The potential advantages of this technique are shorter cold ischemia time, in situ assessment of the viability of segments 1 and 4 prior to cross clamping and perfusion and perfect hemostasis during retrieval leading to reduction in blood loss during the transplantation procedure. In addition, it

avoids prolonged bench surgery and may facilitate long-distance graft sharing between two liver transplant centers. As compared to the *ex vivo* technique, it has reduced the occurrence of biliary complications and primary nonfunction. Also, since its inception, it has significantly improved graft and patient survival. SLT is usually performed for one adult and one pediatric recipient, but the majority of patients on the waiting list are adults. So, on the background of growing experience in LDLT, SLT can be performed on two adult recipients, which will have a significant impact on the waiting list and will optimize the use of cadaver donors. Till now, most of the series of full-right and full-left *in situ* liver split are from single centers and not all the reported results are positive. At the University of Minnesota, 12 adult patients received grafts from *in situ* splitting of 6 cadaveric livers, performed by Humar et al.³ They reported graft and patient survival of 80% each, and arterial and biliary complications in 16% and 25% of recipients, respectively. Recently, one center from Italy reported the experience of 16 adult patients who underwent *in situ* SLT using 9 full right lobe grafts and 7 full left lobe grafts. They reported a high incidence of complications (50%) and graft loss (5-year overall survival rate of 69% for patients and grafts).⁴ However, Cescon et al. demonstrated superior results on 22 adult patients receiving *in situ* SLT. In their series, overall patient and graft survival were 90% and 86%.⁵

Regarding selection of donors for SLT, the clinically ideal donors are preferred to decrease the risks of primary nonfunction, especially for left lobe recipients. As recommendations given by Busuttil and Goss,⁶ young, hemodynamically stable donors (as in our case) with near normal liver function test results and short intensive care unit stay (<5 days) are usually preferred. In addition, suitability of right lobe/left lobe splits is determined by the donor size, as the size of the grafts generated by splitting is the key predictor of successful outcome in recipients. The size of liver correlates with the size of donor and generally constitutes 2% of the total body weight. The right lobe graft from an average-sized donor (70 kg) is sufficient for transplantation into most adult recipients, as it is usually constant in size, weighing 800–900 g. Depending on the size of the lateral segment; the weight of the left lobe tends to vary more frequently. However, in a 70 kg donor, the weight of left lobe can be in the range of 400–500 g, which would be sufficient for transplantation into a small adult recipient (up to 60 kg), as in our case.³ Further, graft inflow modulation can be applied for the use of left lobe in adult recipients. One must remember that this very lobe is left in the majority of adult donors without any harm. Therefore, owing to a large experience in LDLT as in our center, the donor surgery can be carried out without any preoperative imaging such as contrast enhanced computed tomography of abdomen for delineation of vascular anatomy and estimation of liver mass.

Graft size, cause of liver failure, and severity of illness are the important issues to be taken into consideration when selecting appropriate recipients for SLT. The appropriate candidates for right lobe/left lobe splits may be patients with tumors, metabolic diseases and MELD score less than 30 (as in our case). The critically ill patients with severe portal hypertension and high MELD score are generally not preferred for partial grafts, especially from a cadaver liver.⁷ Regarding graft size requirement, the experience from LDLT suggests that a graft/recipient's body weight ratio (GRWR) of 0.8% is sufficient for optimal function of the graft in the immediate post-transplant period.⁸ However, in deceased donors, factors such as donor hemodynamic stability and cold ischemic time can influence the minimum liver mass that needed. So, it may not be entirely correct to extrapolate 0.8 value of LDLT for SLT from a cadaver donor. Nonetheless, our preference has been to try to select the patients in whom GRWR will be 0.8 or >0.8. In addition, during the procurement surgery, careful inspection of donor liver and estimation of the graft size by an experienced surgeon can help in taking the final decision regarding selection of appropriate recipients. In our case, the GRWR for the right lobe graft recipient was 1.5 (990 g/65 kg) and that for the left lobe graft recipient was 1.1 (525 g/47 kg).

Regarding donor surgery, several technical points need to be emphasized. As segment 4 constitutes the important part of left lobe, the plane of parenchymal transection should be kept to the right of MHV to ensure adequate drainage of segment 4. In case of hilar dissection, Humar's team³ preferred to keep the main vessels and bile duct intact with the left lobe due to larger size of the right sided hilar structures as compared to the left sided structures. But, our practice is to leave the main portal vein and common bile duct with right lobe as there is higher incidence of anatomical variations on the right side. As the RHA is usually larger and the blood supply of caudate and segment 4 depends mostly on LHA, we keep the main arterial trunk with left lobe. In addition, the IVC is retained with left lobe graft, as the small retro hepatic veins from segment 1 directly drain into IVC. In case of recipient operation, one crucial technical point is to ensure adequate venous outflow of the graft to avoid congestion. In contrast to Humar's Technique,³ especially with a right lobe graft, our preference is to reconstruct the MHV on back table by using vein grafts from donor. It helps in optimal functioning of the right lobe graft by adequate drainage of the segments 5 and 8. It is important to note that both the recipients did not have any evidence of primary nonfunction or early graft dysfunction immediately post-transplant. At ten months of follow up, both the recipients are doing well with good liver function.

In conclusion, our case has revealed that reliable *in situ* splitting of one cadaver liver for two adult recipients is technically possible using LDLT technique. In addition,

with on-going surgical refinements and innovations in LDLT, it is feasible to do widespread application of this challenging technique.

CONSENT

Written informed consent was obtained from the patients for publication of this case and accompanying images.

CONFLICTS OF INTEREST

The authors have none to declare.

REFERENCES

1. Belghiti J, Guevara OA, Noun R, Saldinger PF, Kianmanesh R. Liver hanging manoeuvre: a safe approach to right hepatectomy without liver mobilization. *J Am Coll Surg*. 2001;193:109–111.
2. Pichlmayr R, Ringe B, Gubernatis G, Hauss J, Bunzendahl H. Transplantation of a donor liver to 2 recipients (splitting transplantation) – a new method in the further development of segmental liver transplantation]. *Langenbecks Archiv Chir*. 1987;373(2):127–130.
3. Humar A, Ramcharan T, Sielaff TD, et al. Split liver transplantation for two adult recipients: an initial experience. *Am J Transplant*. 2001;1:366–372.
4. Giacomoni A, Lauterio A, Donadon M, et al. Should we still offer split-liver transplantation for two adult recipients? A retrospective study of our experience. *Liver Transpl*. 2008;14(7):999–1006.
5. Cescon M, Grazi GL, Ravaioli M, et al. Conventional split liver transplantation for two adult recipients: a recent experience in a single European center. *Transplantation*. 2009;88(9):1117–1122.
6. Busuttil RW, Goss JA. Split liver transplantation. *Ann Surg*. 1999;229(3):313.
7. Lee KW, Cameron AM, Maley WR, Segev DL, Montgomery RA. Factors affecting graft survival after adult/child split-liver transplantation: analysis of the UNOS/OPTN database. *Am J Transpl*. 2008;8(6):1186–1196.
8. Lo CM, Fan ST, Liu CL, et al. Extending the limit on the size of adult recipient in living donor liver transplantation using extended right lobe graft. *Transplantation*. 1997;63(10):1524–1528.