TO THE EDITOR:

The outflow congestion of liver grafts is potentially life-threatening in living donor liver transplantation (LDLT) using the right liver graft (RLG) devoid of the middle hepatic vein (MHV) or the right posterior section graft (RPSG). To prevent congestion of the right anterior section of an implanted RLG, it is crucial to reconstruct donor MHV tributaries using vascular grafts. Congestion of the right hepatic vein (RHV) due to an anastomotic stricture or trunk twisting can also be prevented by effective venoplasty using vascular grafts. Among such grafts, cryopreserved homologous vein grafts are common, but they are limited in availability and long-term patency. Although prosthetic graft use has increased, these grafts have risks of infection and thrombosis formation. In this context, the procurement of autologous vascular grafts from the recipient liver (which will be discarded) is a viable option from technical, economical, and patient safety-related standpoints. Although autologous portal vein grafts (PVGs) have been reported, we considered recovering autologous hepatic vein grafts (AHVGs) as another source of vascular grafts. Herein, we present our techniques for procuring AHVGs by ex situ and in situ methods and describe the AHVG and patient outcomes in 4 patients receiving LDLTs. The study was conducted in accordance with the Declaration of Helsinki (2000) and approved by the institutional research board (HM19-064). Informed consent was obtained from all patients.

Surgical Techniques for the Recovery of AHVG

THE EX SITU METHOD

After liver explantation, the RHV trunk was dissected as a vein graft out of the explant, with the branches being meticulously ligated and divided (Fig. 1). To prevent injury to the vein wall, we carefully dissected between the RHV trunk wall and the surrounding liver parenchyma, from the RHV root-side stump. This preserved the fibrous tissue on the vein wall. The obtained graft was checked for leakage with a saline infusion.
FIG. 1. The ex situ (A and B, patient 1) and in situ (C–E, patient 2) methods for recovering the RHV trunk as an AHVG. (A) Dissection between the liver parenchyma and the vein wall of the RHV (arrow) of the explanted liver. (B) The AHVG (RHV graft) was used as an interposition graft between the donor V5 and the recipient IVC. (C) Schematic illustration of the in situ splitting of the recipient liver parenchyma for recovering the RHV graft. Note that the right portal vein (RPV), RHA, LHA, and common bile duct (CBD) were already divided, though the LPV, LHV, and MHV were left open. The root of the RHV was taped, and its trunk was exposed from the right side along with its major tributary from the segment 7 (V7). Minor venous branches were treated by pinching with bipolar coagulation. (D) An RHV graft (10 cm long) in conjunction with a V7 piece (2 cm long) was recovered as an AHVG. It was divided into the proximal and distal parts, and each piece was used as a separate vein graft. (E) The V7 stump of the proximal part of the RHV graft was anastomosed to the donor V8, and the trunk of the proximal part of the RHV graft was longitudinally opened and worked as an anterior wall patch for the anastomosis between the donor RHV orifice and IVC. The distal part of the RHV graft was used as an interposition graft between the donor V5 and PVG, which was anastomosed to the IVC.

THE IN SITU METHOD

During hilar dissection and heptectomy in the recipient, the left portal vein (LPV) and the 3 major hepatic veins were retained. Then, the recipient RHV was exposed and isolated from its root side by transecting the liver parenchyma in the cranial-to-caudal direction using ultrasonic shears and a bipolar coagulator (Fig. 1C). During the procedure, the right liver inflow was blocked to reduce blood loss, but the LPV and the left hepatic veins (LHVs) and MHV were kept open to retain blood flow to the left liver (Fig. 1C). Adequate manual compression of the RHV root with the surgeon’s left fingers was useful for the outflow control (Fig. 1C). We were able to obtain RHV grafts of any desired length up to approximately 10 cm. When necessary, a significant V7 could be procured in conjunction with the RHV trunk (Fig. 1D). The AHVG procurement was followed by a total heptectomy.

AN EXAMPLE PATIENT USING THE AHVG

A 59-year-old male with end-stage nonalcoholic steatohepatitis (NASH) underwent an LDLT using an RLG (Table 1, patient 2). As complex hepatic vein reconstructions (HVRs) of the RHV, V5, and V8 were necessary, we recovered both AHVG and PVG. An RHV trunk (10 cm long) in conjunction with a V7 piece (2 cm long) was procured en bloc as an AHVG using the in situ method (Fig. 1D). An autologous PVG was also procured in situ. The obtained AHVG was divided...
into 2 pieces, each of which was used separately (Fig. 1D,E). The donor liver had separate V5 and V8 orifices that needed to be reconstructed. The V7 stump of the proximal AHVG was anastomosed to the donor V8 orifice, and the posterior wall of the longitudinally opened AHVG was anastomosed to the anterior wall of the donor RHV (Fig. 1E). This composite graft worked as the anterior wall patch for the RHV reconstruction. Separately, the distal AHVG was used as an interposition graft between the donor V5 and PVG that was anastomosed to the vena cava (Fig. 1E).

Results

Details of the AHVGs and outcomes of the 4 patients are shown in Table 1. In our series, 3 males and 1 female between 18 and 59 years of age with the indicated liver diseases underwent LDLTs using AHVGs. There were 2 patients who underwent transplantation with RLGs, whereas the other 2 underwent transplantation with RPSGs. The ex situ method was used in 1 patient, whereas the in situ was used in the other 3. The length of the procured RHV trunks ranged from 3 to 10 cm. In 2 patients, the adjoining V7 was recovered with the RHV trunk. The time needed for AHVG recovery did not exceed 30 minutes in the in situ patients and was 46 minutes in the ex situ patient. The estimated blood loss (EBL) in the in situ patients was minimal. The anhepatic phase during LDLT was 274 minutes in the ex situ patient and 151, 175, and 229 minutes in the in situ patients. The AHVGs were used for interposition in patient 1 and partly in patient 2. In patient 3 and partly in patient 2, the AHVGs were used for combined interposition and wall patch venoplasty. In patient 4, the AHVG was used for wall patch plasty.

**Table 1. Summary of 4 LDLT Patients Using AHVG**

| Patient | Patient 2 | Patient 3 | Patient 4 |
|---------|-----------|-----------|-----------|
| Patient age, years | 56 | 59 | 55 | 18 |
| Sex | Male | Male | Male | Female |
| Indication | CLC | NASH | PBC | BA |
| MELD score | 13 | 11 | 17 | 9 |
| PT-INR | 1.37 | 1.27 | 0.96 | 0.98 |
| PC, ×10⁹/mm³ | 3.6 | 1.8 | 13.4 | 21.2 |
| Liver graft type | RLG | RLG | RPSG | RPSG |
| Liver graft weight, g | 681 | 553 | 436 | 372 |
| Actual GRWR, % | 0.83 | 0.83 | 0.67 | 0.54 |
| Method of AHVG recovery | Ex situ | In situ | In situ | In situ |
| AHVG (length) | RHV (3 cm) | RHV (10 cm) with adjoining V7 (2 cm) | RHV (8 cm) with adjoining V7 (3 cm) | RHV (5 cm) |
| Time needed for AHVG recovery, minutes | 46 | 22 | 18 | 30 |
| EBL during AHVG recovery, ml | NA | 5 | 10 | 30 |
| Warm ischemia time, minutes | 66 | 70 | 92 | 101 |
| Cold ischemia time, minutes | 197 | 179 | 90 | 109 |
| Anhepatic phase, minutes | 274 | 229 | 151 | 175 |
| Pattern of AHVG usage | Interposition (V5) | Proximal part: Interposition and AWP (RHV with V8) | Interposition and AWP (RHV with V7) | AWP (RHV) |
| Outcomes | | | | |
| Patency of AHVG (duration) | V5: Patent (18 months) | V8: Patent (7 months) | RHV: Patent (51 months) | RHV: Patent (31 months) |
| Postoperative complications | PVT, BD stricture | Bile leak, TMA | Stricture of V7 | ACR |
| Survival (duration) | Dead (18 months) | Dead (7 months) | Alive (51 months) | Alive (31 months) |
| Cause of death | Suicide | Sepsis | NA | NA |
FIG. 2. Postoperative CT findings in patients (A) 1, (B) 2, and (C and D) 3 and (E) changes in representative serum biomarkers until posttransplant month 3 in all patients. (A) In patient 1, the interposition RHV graft for reconstruction of donor V5 was patent (arrows). (B) In patient 2, the RHV and V8 conduit reconstruction using the proximal part of the RHV graft was patent (arrowheads). (C) In patient 3, the RHV and donor V7 were patent at 1 month after transplantation (arrows); (D) however, occlusion of the donor V7 was found at 2 months (single arrow), and the RHV reconstruction was patent (arrows). (E) Changes in the serum levels of TB, PT-INR, and albumin in all 4 patients.

Postoperative patency of HVRs using AHVGs evaluated by computed tomography (CT) and changes in representative serum biomarkers are presented in Fig. 2. Of the 7 HV anastomoses using pieces of AHVGs (n = 7: V5 in patient 1; RHV, V8, and V5 in patient 2; RHV and V7 in patient 3; and RHV in patient 4), 6 were patent for 7-51 months after LDLT. However, the V7 reconstruction in patient 3 presented a stricture at 2 months (Fig. 2D). Therefore, the patency rates on a patient basis were 75% at 6 months (patients 1, 2, and 4) and 50% (patients 1 and 4) at 12 months, respectively. The biomarkers showed an acceptable recovery, except for sustained high total bilirubin (TB) and low albumin levels in patient 2, due to bile leak and infection (Fig. 2E). Of the patients, 2 died of causes unrelated to HVRs, and the remaining 2 have been alive for 31 and 51 months, respectively.

Discussion

Although this is a small patient series, our findings suggest that AHVGs can be successfully procured by both ex situ and in situ methods and that they are applicable even to multiple or complex HVRs in LDLT. There are few reports on AHVG in LDLT. One study describes MHV tributary reconstructions using the recipient MHV preserved in situ, not as an isolated vein graft. To the best of our knowledge, the in situ procurement of isolated AHVGs has not been previously reported. Such limited use of AHVGs may stem from the belief that safely isolating hepatic veins from cirrhotic livers is difficult and that the vein wall is too thin to be used for HVR. In our method, however, the RHV trunk can be isolated with a thick wall by attaching the fibrous tissue around it. This tissue (“Laennec’s capsule”) essentially covers the liver parenchyma and
can be intentionally preserved on the RHV wall by exposing it from the root side (Fig. 1). Furthermore, the RHV grafts available by our methods can be long and, whenever necessary, obtained with significant V7 branches. Such vein grafts are useful in multiple or complex HVRs. For instance, they can be used as multiple split pieces, as in patient 2.

In our cohort, 6 of the 7 anastomoses using AHVGs were patent for more than 6 months, and the 6- and 12-month patency rates on a patient basis were 75% and 50%, respectively. Because this is a small patient series, any conclusions regarding AHVG patency are unlikely to be drawn. Therefore, further accumulation of data on patients undergoing systematic and standardized ultrasound or CT surveillance to document patency rates at 6 and 12 months is warranted in future studies. Patient outcomes, including laboratory data, seemed satisfactory, and the 2 deaths were unrelated to HVR.

When comparing the ex situ and in situ methods, we consider that the latter may be superior to the former in terms of technical simplicity, procedural time, and the length of the anhepatic phase. The former requires meticulous ligation of tributaries as well as leak tests and wall repair. In the latter, the division of venous branches is completed in an acceptable length of time with minimal blood loss, mostly by bipolar coagulation. Ultrasonic aspirators could be another useful device for vein exposure. Furthermore, the ex situ recovery after explantation lengthens the anhepatic phase, while the in situ procurement does not require additional anhepatic time because the LPV flow is maintained during the procedure.

In recipients with hepatocellular carcinoma (HCC), tumor cell implantation on AHVGs is a potential concern. Patient 1 received a hepatectomy at 1.5 pre-transplant years because of HCC, which did not recur until his death 18 months after transplant. A study on LDLTs using the native MHV trunks for HVRs in 14 patients with nonruptured HCC reported no post-transplant tumor recurrence. (4) Nevertheless, even in well-selected recipients with HCC, the possibility of spreading microscopic tumor cells on the hepatic vein wall must be considered. Therefore, our current opinion is that AHVGs should not be procured from livers carrying overt malignancy.

In conclusion, an AHVG is a viable vascular graft that is safely recoverable and usable in HVR during LDLT. Further studies are necessary to confirm the safety and efficacy of using AHVGs. Their use may serve to expand the source of vascular grafts and decrease the need to sacrifice nonhepatic vessels from LDLT recipients or donors, thereby increasing their safety.

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