Extracorporeal Hepatic Venous Bypass During En Bloc Resection of Right Trisection, Caudate Lobe, and Inferior Vena Cava: A Novel Technique to Avoid Hypothermic Perfusion

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Complete resection can provide the best chance for long-term survival in primary and secondary liver tumors. With the advances in surgical techniques, perioperative management, and frequent use of effective neoadjuvant chemotherapy, there is a higher rate of liver tumors being resected than ever before. However, depending on the size, extent of the tumor, or its location close to critical structures, some liver tumors cannot be resected using a conventional approach. In selected cases for these types of situations, the techniques of total vascular exclusion with hypothermic perfusion such as in situ,[1] ex situ,[2] and ante situm[3] liver resection can be used and offer new chances for R0 resection in otherwise unresectable cases.[4] Hypothermic perfusion with organ preservation solution under total vascular exclusion is the essential part of these procedures, so that the liver can tolerate ischemia for an extended period of time. However, prolonged cold ischemia can act as another source of ischemia-reperfusion injury to the future liver remnant with marginal volume in most cases, which can potentially be critical to patient recovery. In addition, the portal vein has to be divided or cannulated for infusion of preservation solution in all techniques, and the hepatic artery and bile duct have to be divided in ex situ liver resection, which increases the risk of potential complications.

We report here, for the first time, a novel technique of extracorporeal hepatic venous bypass to avoid hypothermic liver perfusion during complex hepatectomy. This technique could obviate hypothermic perfusion and unnecessary hilar structure division and reanastomosis. It required 3 times of inflow control similar to conventional Pringle maneuver, which could minimize potential injury to the remnant liver from prolonged cold ischemia.

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METHODS

Preoperative patient course

A 31-year-old female was diagnosed with sigmoid colon cancer and synchronous liver metastasis (Video 1). The patient had undergone neoadjuvant chemotherapy with 3 cycles of FOLFOX (folinic acid, 5-FU, and oxaliplatin) and 5 cycles of FOLFIRI (folinic acid, 5-FU, and irinotecan). Initial serum CEA level was 2,637 ng/mL. The level decreased to 408 ng/mL after FOLFIRI, rising again after the 4th cycle. Preoperative CEA level was 805.2 ng/mL.

Preoperative MRI (Fig. 1, Video 2) showed a huge liver mass occupying the entire right hemiliver and parts of the left medial section. The left lateral section was hypertrophied due to right portal vein obstruction by the tumor. Right and middle hepatic veins were not visualized, and retrohepatic IVC was narrowed by the tumor. Left hepatic vein also seemed to be invaded by the tumor at its insertion to IVC. The estimated volume of the left lateral section was 816 cm^3 and that of the right trisection and caudate lobe including the tumor was 882 cm^3. The volume ratio of the remnant liver to the patient body weight was 1.6. Transaminases and bilirubin level were within normal range and indocyanine green 15 minutes retention rate was 25.1%.

Operative procedures

The patient was placed supine with the left groin exposed for venovenous bypass. A large bore double lumen catheter was placed in the left internal jugular vein as the return channel of venovenous bypass. An inverted T-incision was made. After exploration of the abdominal cavity for potential extrahepatic disease, intraoperative ultrasound was performed (Fig. 2, Video 3). The tumor

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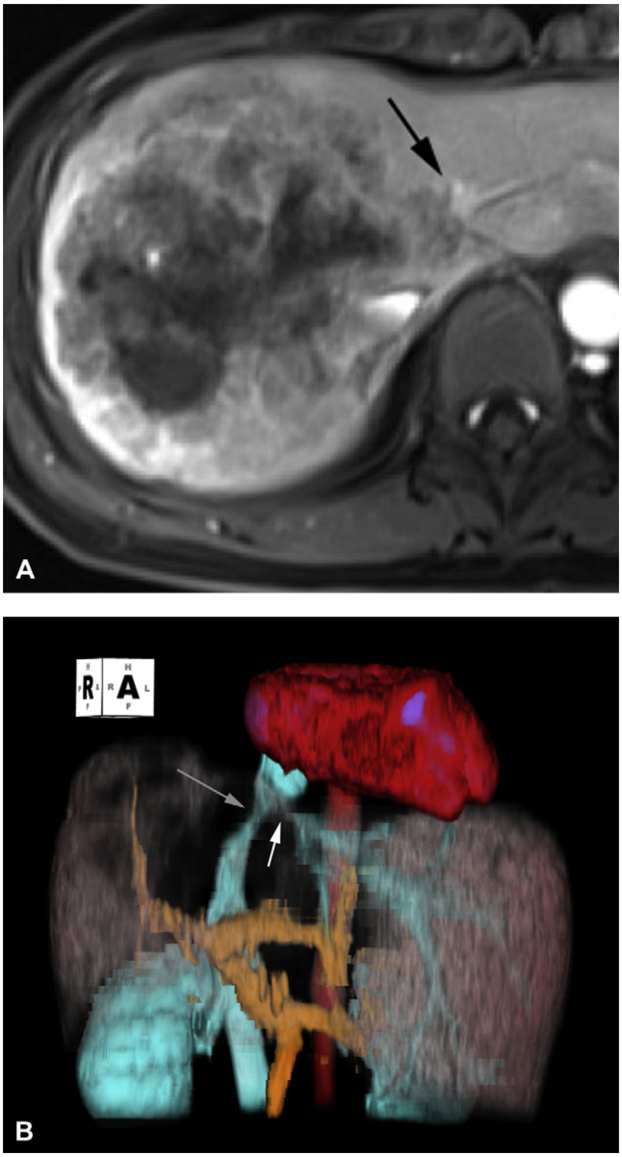

Figure 1. Preoperative magnetic resonance images. (A) Tumor occupies mainly the right hemiliver and part of the left medial section. Note that left hepatic vein is invaded by tumor at its insertion to inferior vena cava (arrow). (B) Three-dimensional reconstruction image shows narrowing of retrohepatic vena cava (long and gray arrow) and left hepatic vein (short and white arrow). Right and middle hepatic veins are not visualized from the obliteration by tumor.

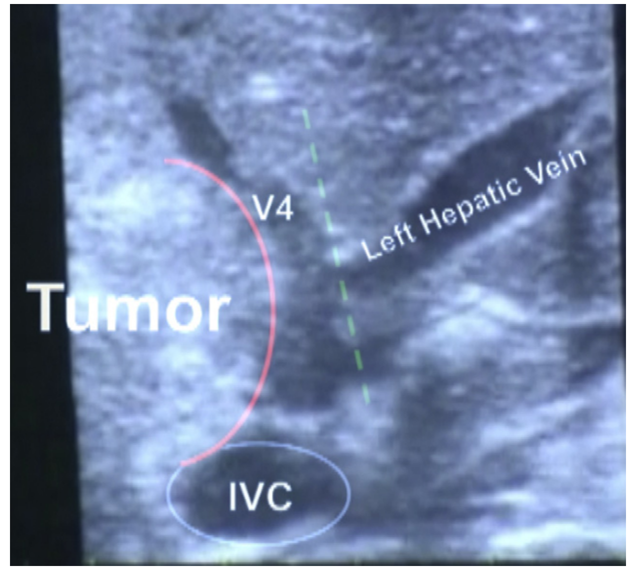

Figure 2. Screen capture of intraoperative ultrasonogram. The tumor is compressing the main left hepatic vein and the segment 4 vein draining to left hepatic vein. The dotted green line represents planned resection line. V4; hepatic vein of segment IV.

was compressing the hepatic vein draining segment IV (V4) and the IVC insertion site of left hepatic vein. No lesion was found in the left lateral section. Planned transection line including about 1 cm of safety margin was marked with electrocautery.

The entire liver was fully mobilized, including suprahepatic and retrohepatic IVC. After removal of the gallbladder, the right hepatic artery and bile duct were isolated and divided. Because the right portal vein was obliterated by tumor, the portal bifurcation was isolated and resected. The left portal vein stump was anastomosed with the main portal vein using 6-0 Prolene (Ethicon) (Video 4).

The cryopreserved iliac vein was prepared for future use as a conduit between the intrahepatic left hepatic vein stump and the pump cannula of hepatic venous bypass. The left greater saphenous vein was isolated and a venous catheter was placed in left iliac vein through the left greater saphenous vein. Venovenous bypass was started (Video 5). The flow volume through the Bio-Pump (Medtronic, Inc.) at this time was measured around 0.8 L/min.

Parenchymal transection was continued along the planned plane using Cavitron ultrasonic surgical aspirator without inflow control. Glissonian pedicles from the umbilical portion to the left medial section and caudate lobe were individually ligated. When the junction between V4 and left hepatic vein was identified, the surrounding liver parenchyma was carefully dissected to expose the whole circumference of left hepatic vein for application of a vascular clamp. A vascular clamp was applied to the left hepatic vein and Pringle maneuver was applied at the hilum, and the intrahepatic portion of left hepatic vein was divided. Cryopreserved iliac vein was sutured to the hepatic vein stump of the remnant liver using 6-0 Prolene. A cannula for hepatic venous bypass was placed in a conduit made of cryopreserved iliac vein, and it was filled with heparinized saline. Inflow control was released and hepatic venous bypass was initiated (Fig. 3). The flow volume through the pump was measured around 1.3 L/min. A large vascular clamp was applied across the suprahepatic IVC, and another vascular clamp was placed at the level of infrahepatic IVC. The specimen, including right trisection, caudate lobe, and retrohepatic IVC, was removed en bloc (Video 6). The IVC was reconstructed using polytetrafluoroethylene graft, and flow was resumed. After application of Pringle maneuver at the hilum, hepatic venous bypass was stopped. The cannula was removed and the conduit was tailored for left hepatic vein reconstruction. The anastomosis was made as wide and short as possible to prevent distortion. Inflow control was released after completion of the reconstruction. The lower extremity cannula was removed. The total duration of bypass was 134 minutes. Doppler study of the left hepatic vein showed triphasic flow pattern. After placement of drains, the abdomen was closed layer by layer (Video 7).

Operation time was 10 hours and 55 minutes. Twelve units of red cells were transfused. Inflow control was performed 3 times for a total duration of 50 minutes. The first one was for portal vein only for 15 minutes for portal bifurcation resection and anastomosis; the second one was for 20 minutes for hepatic vein conduit anastomosis; and the third one was for 15 minutes for hepatic vein reconstruction. Postoperatively, peak serum aspartate aminotransferase (AST) and alanine aminotransferase levels were 109 IU/L and 74 IU/L, respectively. Peak serum bilirubin was 2.55 mg/dL and peak prothrombin time (international normalized ratio) was 1.77. Laparoscopic anterior resection was performed on postoperative day 35. The patient was discharged on the 49th postoperative day. Follow-up examination of the 17th postoperative month did not show any evidence of recurrence.

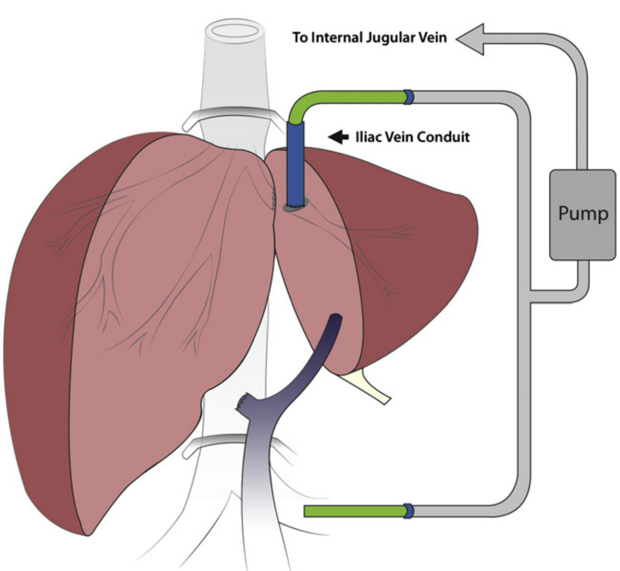

Figure 3. Schematic drawing of extracorporeal hepatic venous bypass. Intrahepatic portion of left hepatic vein stump is anastomosed to cryopreserved iliac vein conduit (colored in blue). Conduit is connected to pump cannula (colored in green).

DISCUSSION

Techniques of total vascular exclusion with hypothermic perfusion are challenging but have been justified by providing new chances for R0 resection in selected cases.[5,6] These techniques use hypothermic perfusion to protect the liver from extended periods of warm ischemia. However, considering that most candidates for this type of surgery have to undergo massive liver resection and eventually have to recover from surgery with a limited volume of remnant liver, ischemia-reperfusion injury after prolonged cold ischemia cannot be underestimated. In addition, these techniques essentially include portal vein resection or cannulation, which increases the risk of potential complications. Mehrabi and colleagues recently reported an overall morbidity and mortality rate of 30% in their literature review.[7]

When all 3 hepatic veins are involved by tumor, the least involved hepatic vein tends to be the right or left hepatic vein, where this technique might be feasible. To obtain a tumor-free resection margin on a hepatic vein, the hepatic vein has to be divided at intrahepatic location, but this makes placement of bypass cannula difficult. Therefore, a conduit using cryopreserved iliac vein was used in this case, but an artificial graft could also be used if cryopreserved vessel was not available.

Although the use of venovenous bypass is decreasing in the transplantation setting, incidence of its use in procedures including total vascular exclusion is relatively high due to hemodynamic intolerance characterized by a decrease in mean arterial pressure >30% and/or a decrease in cardiac index >50%.[8] In the Paul Brousse experience, venovenous bypass was used in 95% of cases when hypothermic perfusion was used.[9]

This technique of extracorporeal hepatic venous bypass can obviate hypothermic perfusion; instead, it uses conventional Pringle maneuver for inflow control during anastomoses of conduit for hepatic venous bypass and maintains blood flow to the remnant liver during IVC clamping and reconstruction, which decreases the risk of potential liver injury by prolonged cold ischemia and ischemia-reperfusion injury. In comparison to ex situ liver resection, this strategy helps to avoid portal transection or cannulation, as well as hepatic artery and bile duct transection. Although the portal vein had to be divided and reconstructed in this case, because of potential presence of tumor near bifurcation, this technique does not mandate portal vein resection or cannulation because hypothermic perfusion is not necessary.

Dubay and colleagues[10] reported excellent results of in situ hypothermic perfusion. In their literature, duration of cold flush ranged from 23 to 90 minutes (mean 40 minutes), which means there was a substantial diversity in duration of cold flush. Mean of peak AST and bilirubin levels were 10.3 and 4.7-fold increased, respectively, which reflects that the risk of postoperative hepatic failure is still not negligible. There was 1 mortality from posthepatectomy hepatic failure among 9 patients. Azoulay and colleagues[9] also reported mean duration of total vascular exclusion as 101 minutes with incidence of liver failure as 15%. Despite their excellent report, we believe that there is room for improvement. Especially avoiding hypothermic perfusion can be a key player in this group of patients with marginal liver function, for example, after many cycles of chemotherapy or with significant steatosis. Dubay and colleagues[10] also described, "*in situ* hypothermic preservation was used whenever total hepatic vascular exclusion was required for major vascular reconstruction even if a relatively short period of exclusion was anticipated. It is particularly difficult to predict exactly how long a period of vascular exclusion will be needed and gives the surgeon time in the worst-case scenario." Therefore, adding hepatic venous bypass and avoiding hypothermic perfusion can be an added safety measure to both hepatic function and technical aspects.

CONCLUSIONS

We believe that this novel technique of extracorporeal hepatic venous bypass can provide a new surgical strategy for selected cases requiring complex liver resection that is otherwise unresectable.

Author Contributions

Study conception and design: Kim
Acquisition of data: Jung, Ji
Analysis and interpretation of data: Kim
Drafting of manuscript: Kim
Critical revision: Yu, Suh

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