Manuscript ID LT-14-389.R1

Preoperative simulation with 3D printed solid model for one-step reconstruction of multiple hepatic veins during living donor liver transplantation

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Running title: 3D printed model for one-step reconstruction in LDLT

Keywords: Living donor, Liver transplantation, 3D printed solid model, Autologous portal vein graft, 3D imaging

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List of all abbreviations:

LDLT: living donor liver transplantation

MHV: middle hepatic vein

PV: portal vein

RHV: right hepatic vein

RIHV: right inferior hepatic vein

All authors meet the criteria for appropriate authorship and no author indicates any potential conflicts of interest. Authors do not have any financial support for this work.

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Abstract

Meticulous preoperative volumetry of the partial liver graft is essential for both assessing the postoperative graft function and to ensure the donor safety in the field of living donor liver transplantation (LDLT).

We herein report the case of a 53-year-old patient who underwent LDLT for hepatitis C virus-infected liver cirrhosis complicated with hepatocellular carcinoma. Preoperative 3D images were obtained using a 3D image analysis system to evaluate the graft volume and possible congested volume after implantation in LDLT, which revealed that a large middle hepatic vein drained a vast area in the right lobe. The extended left graft was considered to be small for size of the recipient, with an estimated congested area of 407 ml, which was equivalent to 39% of the donor's liver volume in the remnant right lobe.

We decided to use a right lobe graft with the middle hepatic vein, because the volume was considered to be sufficient. A preoperative contrast-enhanced CT scan revealed a distance of 2 cm between the donor's right hepatic vein and middle hepatic vein at the estimated Cantlie line. Because of the location, we planned to use autologous portal vein Y-graft interposition for the hepatic venous anastomosis. Three-dimensional printed solid models of the donor's right lobe graft and the Y-graft from the recipient's portal vein were also made for preoperative simulation using the Vincent program.

Based on the estimation, we were able to evaluate whether to reconstruct the middle hepatic vein tributaries or anomalous hepatic veins in LDLT. The 3D solid model was effective for preoperative simulation and planning, which made it easy to imagine the reconstructed shape of the anastomosis with appropriate spatial perception.

To the editors:

A 53-year-old male patient underwent LDLT for hepatitis C virus-infected liver cirrhosis complicated with hepatocellular carcinoma. Preoperative three-dimensional images were obtained using a 3D image analysis system (Synapse Vincent; FUJIFILM Medical, Tokyo, Japan) to evaluate the graft volume and possible congested volume after implantation in LDLT, which revealed that a large middle hepatic vein drained a vast area in the right lobe (Figs. 1 A, B). The estimated volume of the donor's whole liver was 1,048 ml. The extended left graft was considered to be small for the size of the recipient, corresponding to 30% of the recipient's standard liver volume, and also with an estimated congested area of 407 ml, which was equivalent to 39% of the donor's liver volume in the remnant right lobe (Fig. 1C). As a result, if a left lobe graft was procured, the functional remnant liver volume was estimated to become 20% of the donor's liver volume. Hence, the left lobe was considered inappropriate not only because of the small-for-size graft for the recipient, but also because of the safety concerns for the donor.

After ensuring sufficient drainage of the left lobe by V4 and the left hepatic vein, we decided to use a right lobe graft with the middle hepatic vein, because the volume was considered sufficient, and was equivalent to 47.5% of the standard liver volume of the recipient. A preoperative contrast-enhanced CT scan revealed a distance of 2 cm between the donor's right hepatic vein (RHV) and middle hepatic vein (MHV) at the estimated Cantlie line. Because of the location and alignment, we planned to use autologous portal vein Y-graft interposition for the hepatic venous anastomosis. The image of the Y-graft from the recipient's portal vein was also made by the SYNAPSE Vincent program (Fig. 2).

An extended right lobe graft was transplanted from the patient's wife, and the actual graft weight was 493 g, corresponding to 42.3% of the recipient's standard liver volume. A hilar portal vein was harvested from the recipient, and *ex-vivo* hepatic vein reconstruction was performed by connecting a right portal branch to the MHV and a left portal branch to the RHV using 5-0 polypropylene monofilament continuous sutures. End-to-end anastomosis was performed between the explanted main portal vein graft and the inferior vena cava using 5-0 polypropylene monofilament continuous sutures. In addition, the right inferior hepatic vein was directly anastomosed to the inferior vena cava. After reperfusion, intraoperative Doppler ultrasound showed a stable and sufficient hepatic inflow and outflow from the three anastomosed hepatic veins. The length of the recipient operation was 13 hours and 15 min, and the blood loss was 11,700 g. At the time of writing, eight months after LDLT, the patient is doing well with good liver function. The fact that both the middle hepatic vein and right hepatic vein were patent in the early postoperative period is considered to have contributed to the patient’s recovery. The donor favorably recovered without any complications.

Discussion

An extended right lobe graft is uncommon based on concerns about the donor safety in Japan. On the other hand, about 58% of individuals have a MHV that is larger than or the same size as the RHV; and in 13% of the right liver lobes, the MHV partially or totally drains a vast area including segment 6 [1], like it was in our case. A preoperative 3D image simulation depicting the meticulous anatomy and providing accurate estimation of the possible congested volume prompted us to make the decision to use an extended right lobe graft in this case.

The usefulness of explanted autologous portal vein grafts for hepatic vein tributaries in LDLT has recently been reported [1, 2]. Although previous reports presented the use of a portal vein graft for MHV tributaries, including segment 5 and 8 veins, in our case, both main drainage veins, including the MHV and RHV, were reconstructed with an interposition Y-shaped portal vein graft. Subsequently, the main outflow of the liver graft depended on this reconstruction. The reconstruction of the main drainage veins of the right liver graft using an explanted hilar portal vein graft was considered to be an effective management strategy for cases with a large distance between the hepatic veins in LDLT.

The useful application of a 3D volume analyzer in the field of liver surgery has recently been reported [3, 4]. Preoperative meticulous volumetry of the partial liver graft is essential in terms of both the postoperative graft function and the donor safety. One of the strongest merits of using the 3D volume analyzer is that it makes it possible to estimate each vessel's circulating and draining area. Based on the estimation, we were able to evaluate whether to reconstruct the MHV tributaries or anomalous hepatic veins in LDLT.

With the recent development of 3D printers, solid 3D model can be made from images obtained by the 3D volume analyzer. In this case, we made a 3D model from the data generated by the SYNAPSE Vincent program (Figs. 3 A, B). The 3D solid model was effective as a preoperative simulation, and handling the plastic made liver and gum-like material made to represent the vessels made it easy to imagine the reconstructed shape and angle of the anastomosis with appropriate spatial perception (Figs. 3 C, D), which helped us to choose an appropriate surgical strategy. It should also be noted that the use of a 3D printed model during surgical planning was helpful not only for the operating surgeons, but also for young surgeons as training, so that they could understand the detailed representation of the future complex anastomosis in LDLT.

Although making a 3D solid model for every case is currently expensive, it is considered to be worthwhile for selected cases, such as our case, because of its efficacy for planning the operation. We highly recommend using a 3D printed model in cases with complex vascular or biliary anatomy, which require multiple or complicated anastomoses with or without the use of graft interposition.

References

1. Lee SG. Techniques of reconstruction of hepatic veins in living-donor liver transplantation, especially for right hepatic vein and major short hepatic veins of right-lobe graft. J Hepatobiliary Pancreat Surg 2006;13:131-8.

2. Ikegami T, Soejima Y, Taketomi A, Yoshizumi T, Harada N, Uchiyama H, et al. Explanted portal vein grafts for middle hepatic vein tributaries in living-donor liver transplantation. Transplantation 2007;84:836-41.

3. Ohshima S. Volume analyzer SYNAPSE VINCENT for liver analysis. J Hepatobiliary Pancreat Sci 2014;21:235-8.

4. Mochizuki K, Takatsuki M, Soyama A, Hidaka M, Obatake M, Eguchi S.
The usefulness of a high-speed 3D-image analysis system in pediatric living donor liver transplantation. Ann Transplant 2012;17:31-4.

Figure legends:

Fig. 1. A preoperative three-dimensional image evaluation of the donor's graft revealed that the large middle hepatic vein drained a vast area in the right lobe (white arrows; **A** and **B**). The estimated volume of the congested area (yellow colored area with white arrowheads) was 407 ml, which was equivalent to 39% of the donor's liver volume in the remnant right lobe **(C).**

Fig. 2. The preoperative 3D simulation of the autologous portal vein Y-graft interposition for the hepatic venous anastomosis by connecting a right portal branch to the MHV and a left portal branch to RHV was made using the SYNAPSE Vincent program (PV - Portal vein; RIHV – Right inferior hepatic vein).

Fig. 3. A 3D solid model of the graft obtained using a 3D printer was constructed from the data made using the SYNAPSE Vincent program **(A** and **B).** A gum-like material was used to make the recipient's portal vein tree **(C)** with a portal vein Y-graft **(D),** and these models were effective for allowing the reconstructed shape of the anastomosis to be understood with appropriate spatial perception.

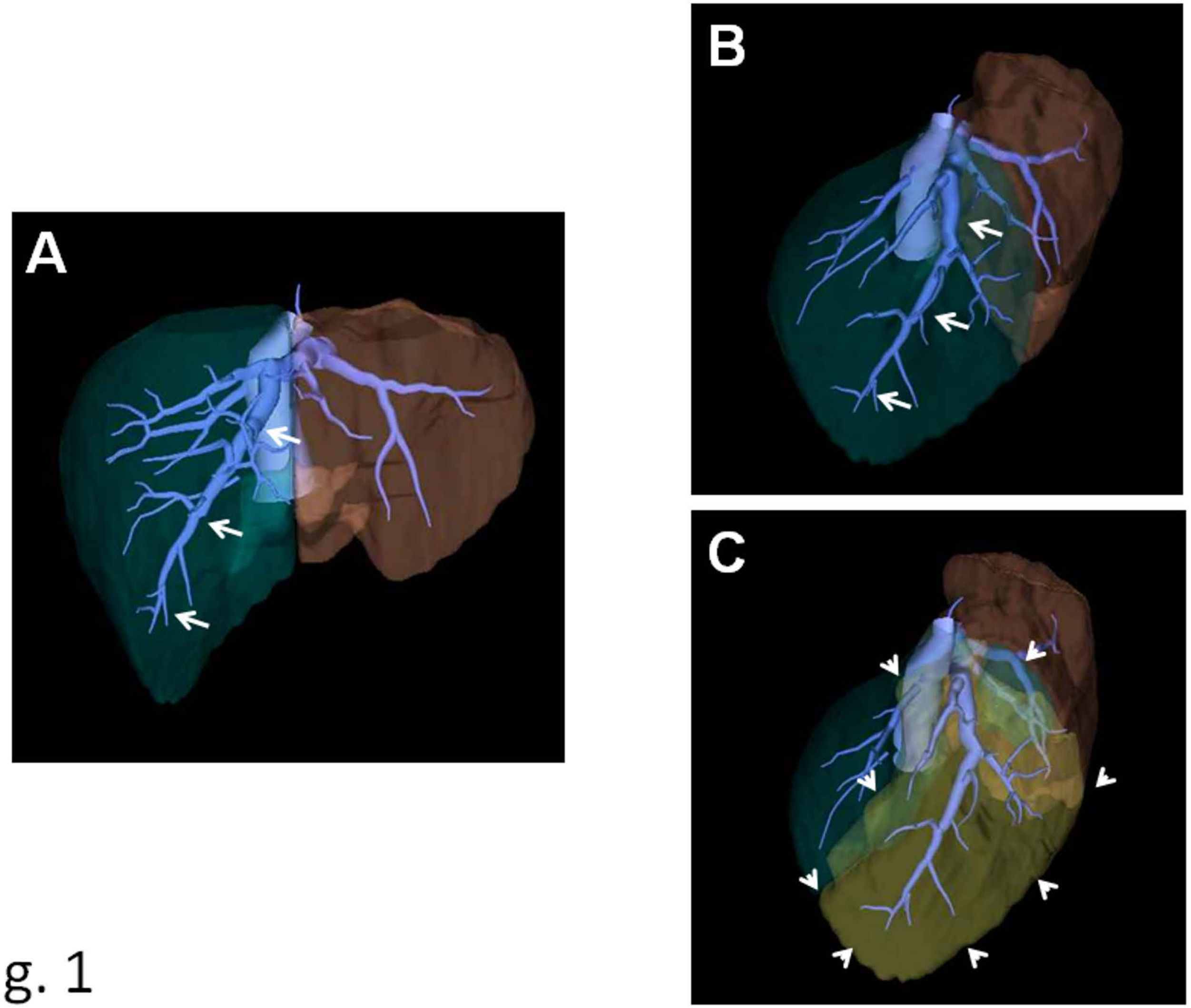

Fig. 1

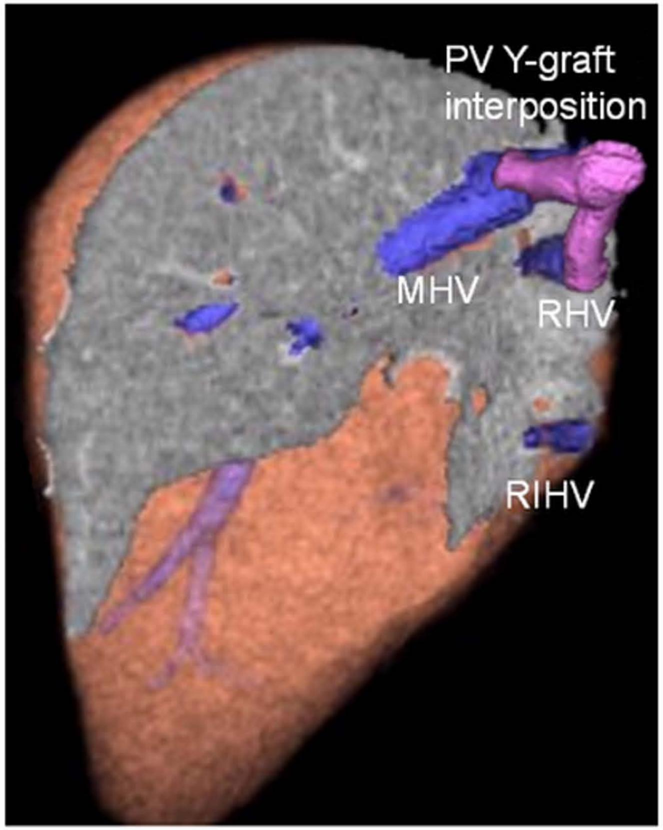

Fig. 2

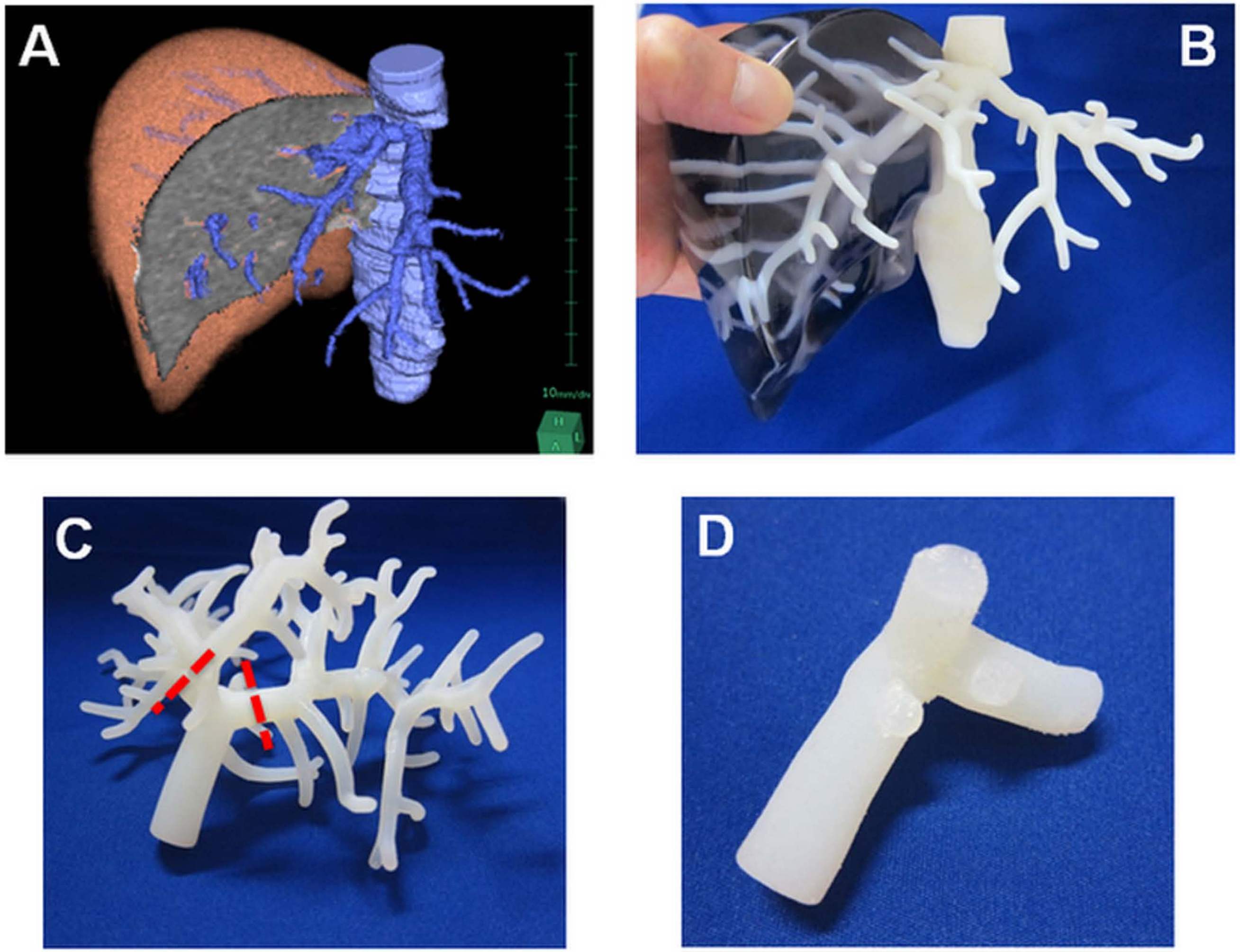

Fig. 3