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Case Report

Utilizing 3 Dimensional Print of The Liver in Living Donor Liver Transplantation for Preoperative Evaluation

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ABSTRACT

Objectives: To obtain a liver prototype by using a 3 dimensional printer for preoperative evaluation of vascular structures (hepatic artery, portal vein, hepatic vein) based on living donor candidate's angiographic computed tomography data in living donor liver transplantation.

Materials and Methods: First, we obtained angiographic computed tomography data with a stereolithography extension of the living donor candidate. Then, we made this data suitable for the 3 dimensional printer by using a special software. We used a J750 (Stratasys) 3 dimensional printer to create the model.

Results: In the three-dimensional model, macroscopic liver structure and vascular structures were obtained as planned (hepatic artery, portal vein, hepatic vein) and in accordance with angiographic computed tomography data.

Conclusion: Before living donor liver transplantation, models obtained from 3 dimensional printers can be used to evaluate the anatomic structure of the donor candidate's liver. Similarly, prior to complicated liver resections, this model can provide surgeons with a different perspective for more effective preoperative planning and assessment for safer surgery.

Keywords: Three dimensional printing, liver transplantation, liver surgery, prototype

INTRODUCTION

While there is a globally growing need for liver transplantation (LT), cadaver grafts are inadequate to meet this need. For this reason, in recent years, living donor liver transplantation (LDLT) has increased steadily (1). In living donor liver transplantation, donor safety is of utmost importance. Therefore, it is very important to evaluate liver anatomy and volume measurements of donor candidates. For this purpose, computed tomography (CT) or angiographic magnetic resonance (MR) is used routinely (2) .

In recent years, 3 dimesional (3D) printing technology has also been widely used in medicine for highly practical reasons and it has created unprecedented results (3). One of the most important examples of this in surgery is that Zein and his colleagues obtain a liver prototype with a 3D printer in pre-LDLT planning (2). Zein et al. used the ACT data of pre-LDLT donor candidates and obtained the liver's vascular, biliary structures and volumetric measurements with high similarity ratios to the real tissue. This study suggests that the use of 3D printing liver prototypes of donor candidates in LDLT may provide a safer preoperative evaluation.

In this study, we aimed to present a 3D printing liver prototype obtained by using the ACT data of a living donor hepatectomy candidate for LDLT in our clinic.

MATERIALS AND METHODS

This study was done with multidisciplinary cooperation. The project was codesigned by researchers and scientists from Dokuz Eylul University Faculty of Medicine, Department of General Surgery, Hepatopancreaticobiliary Surgery and LT unit, and department of Radiodiagnostics; from Faculty of Engineering, department of

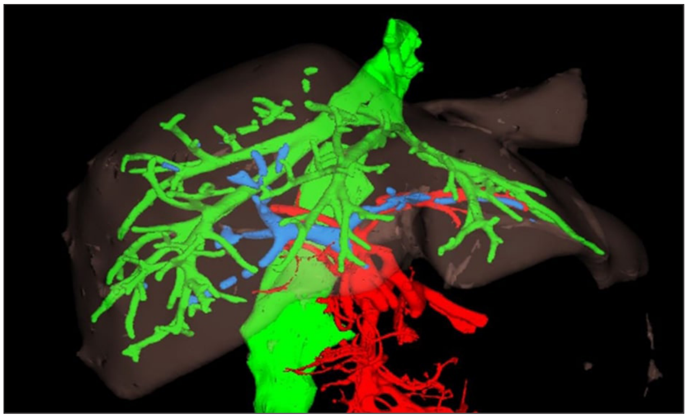

Figure 1. Drafting of the 3D prototype by coloring the vascular structures in an angiographic computed tomography section (colors were changed before 3D printing).

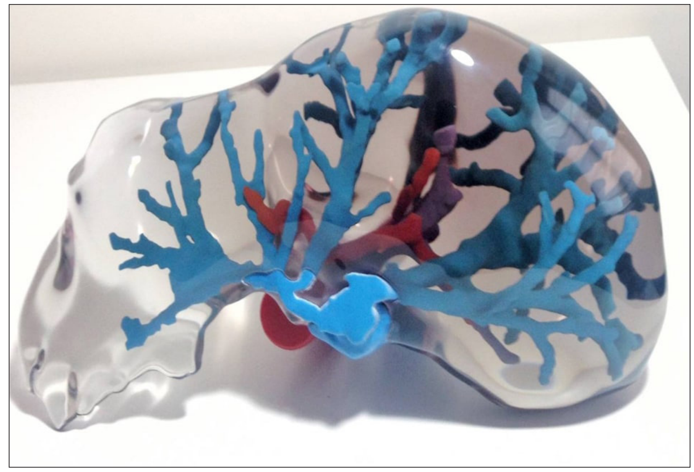

Figure 2. 3D liver prototype. Liver parenchyma transparent; hepatic veins look blue; hepatic artery looks red, and portal vein looks purple. Radiology seems to be compatible with the draft image

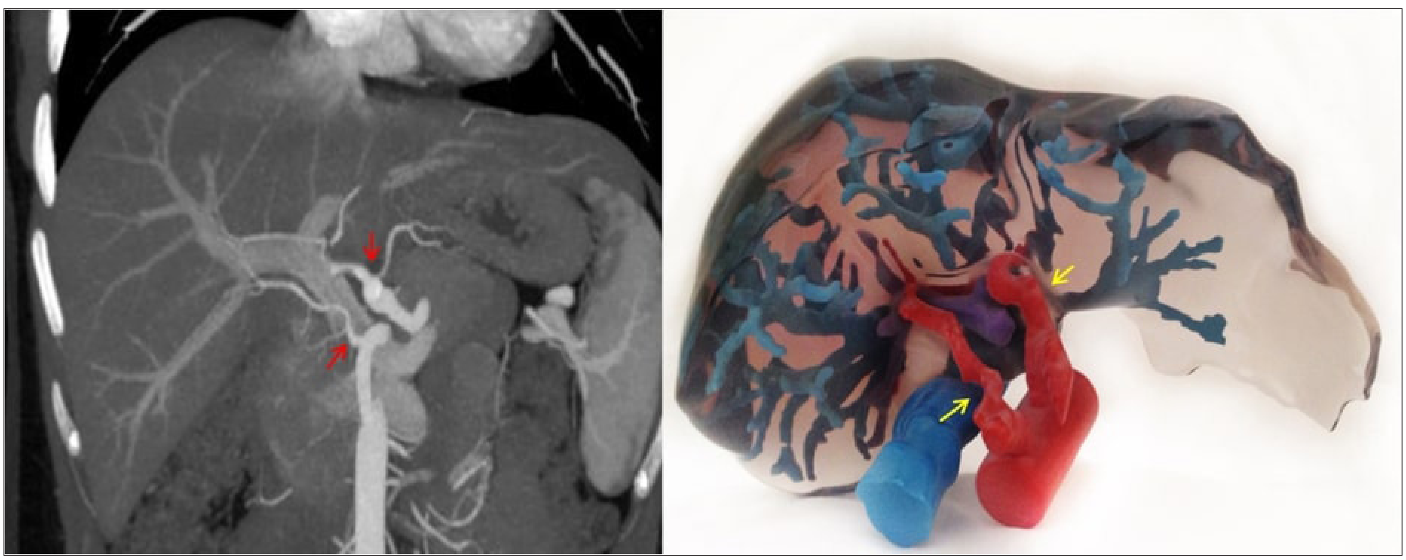

Figure 3. Arterial variation in an angiographic computerized tomography scan of a donor candidate. Proper hepatic artery originates from the truncus celiacus, while the right hepatic artery is replaced by the superior mesenteric artery *(red arrows)*. This variant detail is clearly seen on the 3D printing prototype *(yellow arrows)*.

Electrical and Electronics Engineering, and from the Institute of Health Sciences, Department of Translational Medicine. Later, in order to realize the 3D printing process, we contacted the firm that would supply J 750 (Stratasys, 3D Printing and Additive Manufacturing, Eden Prairie, Minnesota, USA) 3D printer device. After receiving the informed consent, we decided to use the CT data of an LDLT living donor hepatectomy candidate, and to obtain a 3D printing liver prototype with transparent tissue suitable for evaluating liver vascular structures (hepatic artery, portal vein, hepatic vein).

The donor candidate's CT was taken by using a 0.9 mm cross-sectional area. The existing two-dimensional DICOM extension image on the axial plane was transferred to MATLAB® (The MathWorks, Inc. 3 Apple Hill Drive, Natick, Massachusetts 01760, USA) software and rendered into 3D. Then various segmentation algorithms were used from the obtained 3D data and all of the liver, hepatic veins, hepatic artery and portal vein structures were segmented separately.

During this segmentation process, various preprocessing and postprocessing techniques were used in addition to segmentation algorithms. The draft images of the four different structures obtained from the present data were again positioned in the same axis in the MATLAB® platform and ready-to-print images of the liver and vessels were obtained. Then, the images were saved in ".stl" format so that they could be transferred to 3D printer systems. Prior to the 3D printing, we asked the supplier firm's engineers to design the final product to make the hepatic artery look red, portal vein look purple, hepatic vein look blue, and liver parenchyma look transparent.

We planned the model to be 1.5 times larger than the original size. The prototype was produced by a J 750 3D printer using photopolymer resin raw materials (all materials by Stratasys) with a layer thickness of 14 microns at 71 hours, 58 minutes. In the post-printing review, we observed that the structures obtained in the model were compatible with the two-dimensional draft at the beginning of the process (Figure 1-3).

DISCUSSION

The safety of the donor is crucial issue in LDLT. Therefore, the evaluation of CT or MR of the anatomical structure of the donor candidate's liver before surgery and the residual liver remnant volume is of great importance (2). In recent years, 3D printing technology has become very popular in several medical fields. This technology provides physicians with important advantages especially in orthopedics, plastic surgery and neurosurgery (3). As liver usually shows variations due to its complicated biliary and vascular (hepatic artery, portal vein, hepatic vein) anatomical structure, it is one of the organs that 3D printing technology can be extremely advantageous.

Only a few articles in the literature report that 3D printing liver prototypes are used preoperatively in complicated liver surgeries such as liver transplantation (3). These studies suggest that 3D prototypes of the liver allow surgeons to directly view the anatomy of the vascular and biliary structures of the liver, to easily manipulate it, and to comprehend its various aspects better. They argue that this provides better surgical planning and promises fewer complications (2-7).

The most noteworthy of these studies was done by Zein et al (2). In this study; 6 3D printing prototypes were obtained: 3 prototypes for donor hepatectomy and 3 for liver tumor surgery. In donor operations, prototypes and native livers were compared in terms of weight, and vascular and biliary structures. In the examination, dimensional and anatomical structures were found to be identical in prototypes and native livers. In terms of the accuracy of assesing the explanted liver volume, Zein et al. reported that the %95 confidence interval was 28.8 ml (2.8% of the mean native liver volume), which suggests that the method is very accurate, especially compared with earlier reports of the 3D virtual volumetry, for which the accuracy ranged from 5-25% (5,8,9). Future remnant liver volumetric calculation is very important in donor surgery planning. This finding indicates that the calculation can be performed with higher accuracy with 3D printing prototypes, which is vitally important in terms of donor safety.

In addition, 3D printing liver prototypes can provide educational and demonstrative benefits. They can contribute to training of surgical assistants and nurses and improve their adaptation process to the surgery. Likewise, they can be used as a tool to facilitate the informing of patients and their relatives.

Our study was designed as a translational medicine project. Based on the current technology and financing conditions, we did a multidisciplinary study. We decided to obtain a liver prototype of transparent 3D printing parenchyma structure to evaluate vascular structures (hepatic artery, portal vein and hepatic veins) using CT data from a donor candidate with a live donor hepatectomy plan.

Due to technical limitations, we could not include biliary structures in the prototypes. Due to technological limitations, we could plan the prototype dimensions 1.5 times larger the native liver. For this reason, we could not include the biliary anatomy and the volumetric evaluation. Nonetheless, just as we planned, we obtained a 3D printing prototype liver, designed in 2D, and reflecting liver parenchyma and vascular structures.

We believe that under better conditions, we can produce prototypes of superior quality, which can also include volumetric calculations and biliary structures.

Just as with every new technological product, 3D printing prototypes have limitations such as high cost and long production time. However, we think that these difficulties will be overcome and their usage will become widespread in the near future.

We believe that 3D printing liver prototypes will introduce unique contributions to LDLT and complicated liver surgeries and will potentially reduce complications.

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