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3D printing technology in open living donor nephrectomy

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To the Editor: There is currently a serious shortage of organ sources. Therefore, living donor kidney is a critical source in addition to deceased donor kidney. Open donor nephrectomy is one of the most difficult operations in the field of kidney transplantation, and the core issues are the safety of the donor and the psychological stress to the surgeon, such as trying to minimize the surgical complication to the donor, maximize the success rate, and deal with the high expectation from the recipient.[1] By using 3D printing techniques, the relationship between the surgical site and the surrounding tissue structures can be displayed more intuitively and accurately before the start of surgery. This can help the surgeon to understand the anatomical structure of the surgical site more accurately before the beginning of surgery, and create an operational plan or carry out a simulated operation according to the printed model that is specific to the patient.[2]

This study was approved by the Institutional Review Board/Ethics of The First Affiliated Hospital of Xi'an Jiaotong University, China (No. XJTU1AF2018LSL-3D001). All patients signed an informed consent form, were informed about the study, and agreed to have their clinical information used in the reported research. A total of 120 living kidney donors and their corresponding 120 transplant recipients who underwent living kidney transplantation were recruited at The First Affiliated Hospital of Xi'an Jiaotong University from January 2016 to December 2019. We randomly divided the donors and their transplant recipients into the 3D printing group and the traditional operation group. The 3D printing group was treated as follows: (1) To obtain raw data images of Digital Imaging and Communications in Medicine from donor kidney computed tomography angiography (CTA) and CT urography (CTU); (2) To use the Mimics software 21.0[3] system (Materialise, Belgium) to segment cross-section images, to extract printed tissue using the segmentation method of threshold and regional growth, and then to transmit to 3D printers in Laplace smoothing and StL format; (3) The 3D printer uses photoreceptor resin to finish model printing, and static 4 to 6 h is to make the model dry and stable. According to the printed models, an operation plan was created or a simulated operation was performed. One example of the donor's 3D-printed physical model is shown in Figure 1. The traditional operation group underwent routine pre-operative preparation that consists of CTA, CTU, and B ultrasound.

During CTA examination, 42 patients with accessory renal arteries were identified, including five with bilateral renal accessory arteries, 18 with right accessory renal arteries, and 19 with left accessory renal arteries; there were 14 cases of the accessory renal arteries in each group. Vascular variation was found in 22 cases (37%) of the 3D printing group before surgery, and in 11 cases (18%) of the traditional operation group after CTA and other routine examinations before surgery. The differences in the diagnostic rate of vascular variation between the two groups were statistically significant ($\chi^2 = 5.06, P < 0.05$). In the 3D reconstruction group, 24 cases of vascular variation that needed to be treated were found intraoperatively, with a consistent rate of 92% (22/24). Totally, 20 cases of vascular variation were found in the traditional operation group, and the diagnostic consistency rate was 55% (11/20), the difference between the two groups was statistically significant ($\chi^2 = 7.82$, $P < 0.05$).

Total operation time (88.8 ± 8.2 min) of the 3D printing group was significantly shorter than that of the traditional operation group (100.4 ± 11.4 min), and the amount of intra-operative bleeding in the 3D printing group (79.9 ± 18.7 mL) was also lower compared with the traditional operation group (92.1 ± 19.4 mL; $P < 0.05$ for each). The first day after the operation, serum creatinine (sCr) in the 3D printing group was significantly lower than that of the traditional operation group (69.4 ± 14.4 μmol/L *vs.* 86.8 ± 12.9 μmol/L; $P = 0.001$). The recovery time of function for the transplanted kidney was faster in the 3D printing group than that in the traditional operation group (3.7 ± 2.7 days *vs.* 5.1 ± 1.6 days; $P = 0.040$). As was observed in the donor patients, the sCr decreased more

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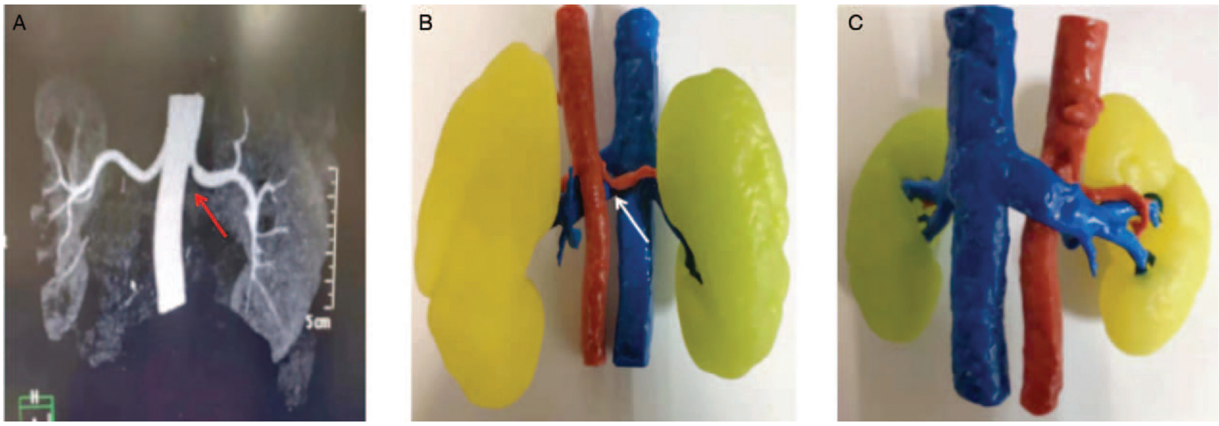

Figure 1: CTA imaging report shows a single branch of the right renal arteriovenous type and a thickening of the wall at the opening of the left renal artery with fibrous plaques, resulting in moderate stenosis of the lumen (as shown by the arrow) (A); By printing the models, multiple angles can be visually observed, and renal structures could be touched (B and C). CTA: Computed tomography angiography.

rapidly on the first day after operation in the 3D printing group than that in the traditional operation group (430.2 ± 134.1 μmol/L *vs*. 565.7 ± 193.7 μmmol/ L; $P = 0.001$).

In this study, the 3D printing group had advantages in terms of the operation time, intra-operative bleeding volume, the diagnosis rate of vascular variation, sCr change on the first day after the operation, and functional recovery time of the transplanted kidney. We found that 3D-printed models help the surgeon to better determine and plan for expected anatomical structures of the operation site before starting the procedure, make a more detailed operation plan according to the printed model, carry out a simulated operation on the model, find the operation site quickly, and avoid unnecessary steps, thus reducing the overall risks and improving the success rate of the operation. Especially for the vascular variation, the anatomical structures such as the initiation and the shape of the vessel can be defined by the 3D printing models, and are of great significance for preserving renal function as much as possible after transplantation. Furthermore, 3D-printed models can also help patients to better understand their conditions and the operation plans, and help improve the doctor-patient communication and relationship. sCr on the first day after operation in the 3D printing group was lower than that in the traditional operation group, which was mainly related to less intra-operative bleeding, shorter operation time, and anesthesia time.[4] The difference between the two groups is not statistically significant in terms of renal warm ischemia time, the incidence of perioperative complications, and the length of hospital stay. The 3D printing group had a shorter recovery time of the transplanted kidney function, which was likely due to the reduction of mechanical injury during the surgical procedure, a maximum degree of protection of the accessory renal artery, and effective renal unit retention after transplantation.

3D printing technology is a breakthrough in the field of kidney transplantation and it enriches the diagnosis and treatment of renal diseases. This study confirmed that using a 3D-printed model can optimize the living donor nephrectomy procedures in terms of the operation time, intra-operative bleeding volume, acute sCr changes, and recovery time of transplanted kidney function. All of these measures protect the kidney, reduce the difficulty of the operation, and facilitate doctor-patient communication, thereby improving patients' outcomes. With a continual innovation of 3D materials and technologies, the application of this technology in transplanted kidney ureteral obstruction, renal tumor, stone, and organ printing has a broad prospect.

Conflicts of interest

None.

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