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Three-Dimensional Printing as an Interdisciplinary Communication Tool: Preparing for Removal of a Giant Renal Tumor and Atrium Neoplastic Mass

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ABSTRACT

Three-dimensional (3D) printing involves preparing 3D objects from a digital model. These models can be used to plan and practice surgery. We used 3D printing to plan for a rare complicated surgery involving the removal of a renal tumor and neoplastic mass, which reached the heart atrium. A printed kidney model was an essential element of communication for physicians with different specializations.

CASE REPORT

Three-dimensional (3D) printing involves preparing 3D objects from a digital model. This concept has been known for over 30 years. In the field of medicine, personalized 3D models, which reflect a given fragment or organ of a patient's body, can be generated from computed tomography (CT) images. These models can be used to plan and practice surgery. 3D printing is primarily applied to implant evaluation in orthopedic and oral surgery, as well as in reconstructive surgery. It has recently been used in urology, and few reports are available on 3D printing in kidney surgeries [Silberstein 2014; Zhang 2016]. We used 3D printing to plan for a rare complicated surgery involving the removal of a renal tumor and neoplastic mass in the venous system, which reached the heart atrium. The printed kidney model was an essential element of communication for physicians with different specializations.

A 56-year-old man with hematuria presented to the urology outpatient clinic. Ultrasonography and CT showed a large tumor in the left kidney (diameter 19 cm), with a neoplastic mass in the inferior vena cava (IVC) and right atrium. The IVC was filled with thrombi from the common iliac veins to the origin of the renal veins. On transesophageal echocardiography (TEE), a mobile mass was observed in the right atrium. The urology and cardiac surgery teams jointly evaluated the CT images with digital 2D and 3D reconstructions; however, the teams could not agree on a surgical plan. It was decided to prepare a 3D model of the kidney with the tumor,

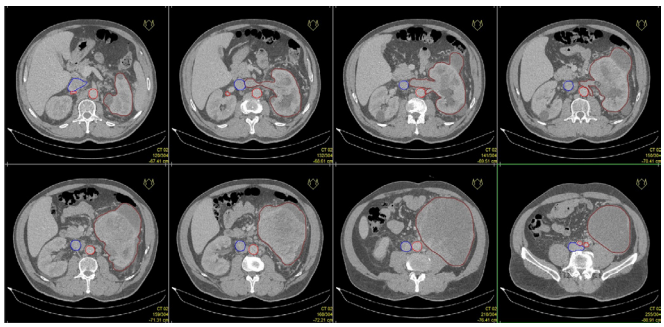

Figure 1. Preparation of digital three-dimensional model of the kidney with the tumor and vessels, based on the patient's computed tomography images.

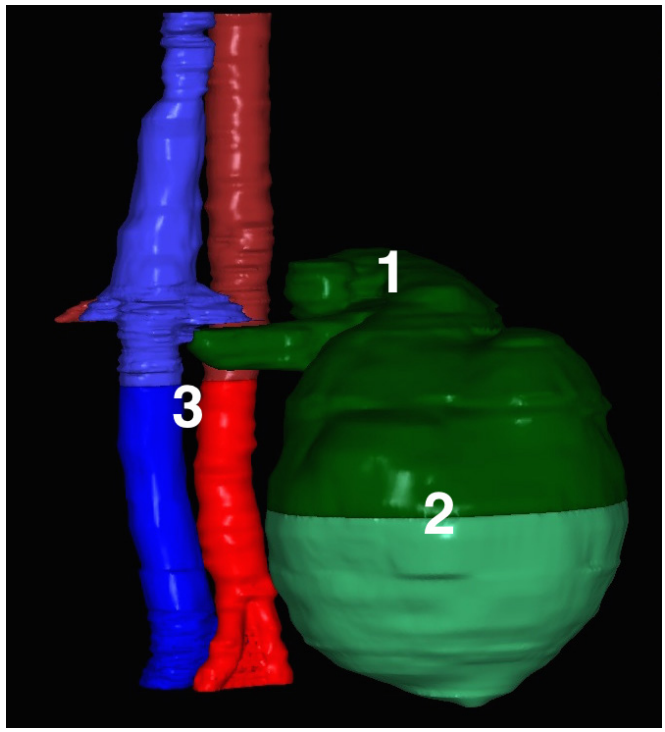

Figure 2. A digital model prepared for printing. 1, the kidney; 2, the tumor; 3, the inferior vena cava with the aorta.

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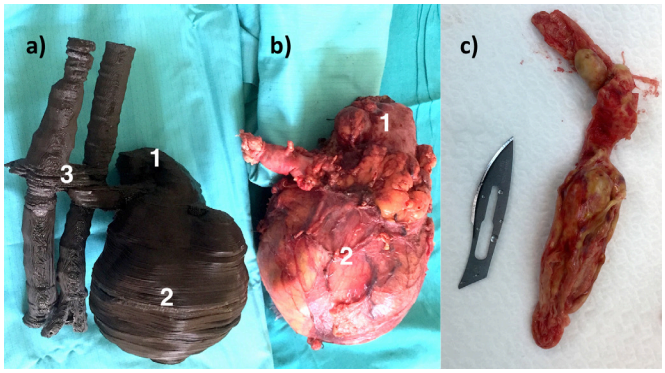

Figure 3. (a) The final three-dimensional model; (b) the postoperative specimen; (c) the neoplastic mass from the inferior vena cava (IVC) and atrium. 1, the kidney; 2, the tumor; 3, the IVC with the aorta.

IVC, and aorta based on CT images (Figures 1 and 2). The model was prepared with a 3D printer (CB-printer.com) using the fused deposition modeling technique in cooperation with Index Copernicus International. The printing took 22 hours. The model was used to specify elements of the surgery that could not be agreed on earlier owing to limited experience of cardiac surgery among the urologists and limited experience of urologic surgery among the cardiac surgeons. Through in vitro manual simulations with the model, the teams discovered that the main part of the tumor extension to the IVC could be removed by the cardiac surgeons. It minimized the range of the operation in the peritoneal cavity and shortened operating time.

Finally, with cardiopulmonary bypass cannulation of the aorta and vena cava superior and under TEE control, cardiac surgeons opened the atrium. They then manually removed the neoplastic mass from the IVC up to 2 cm above the origin of the renal veins. At this time, the blood from the right atrium and the superior vena cava was sucked by the vent line to the oxygenator. After stopping heparinization, urologists dissected the kidney together with the tumor and removed it along with the renal vein filled with tumor masses (Figure 3). A relatively small incision of the temporarily cross-clamped IVC was sufficient to remove the remaining inside the neoplastic mass and thrombi located below. An intraoperative blood recovery system helped reduce the amount of blood loss, and the surgery duration was 170 minutes.

DISCUSSION

Approximately 1% of patients with renal cell carcinoma are diagnosed with a neoplastic mass in the atrium [Marshall 1996]. In such cases, surgery requires the involvement of a multidisciplinary team, and planning for such a rarely performed surgery is difficult. A personalized 3D model of the kidney with large vessels provides a realistic picture of the condition, altered anatomy, and location of key structures such as the renal hilum. Additionally, information on the dimensions of vascular elements and their potential manual and instrumental accessibility from the chest and abdominal cavity can be obtained. In our case, the 3D model helped draft a surgical plan that was accepted by all surgical teams involved. Additionally, the model helped identify anatomical structures during the course of the surgery, which improved safety and reduced the surgery duration to less than 3 hours. A previous study reported a mean surgical duration of 8 hours in 10 patients with a venous bridge [Casey 2013].

Personalized 3D models are a new type of visual-manual communication. They can be used in physician-patient communication as well as in professional communication between physicians [Silberstein 2014]. Moreover, these 3D models can supplement currently applied radiological tools. A previous study demonstrated that physical 3D models are more efficient than traditional two-dimensional CT images in training medical students [Knoedler 2015].

We used a basic 3D printer and found that the basic printer could print a 3D model at a low cost of approximately 100 euro, and that this 3D model was sufficient for surgical planning. We believe that devices capable of generating high-quality 3D models, which are often used in research studies, can be replaced with cheaper devices for surgical planning, resulting in lower costs [Zhang 2016]. Low-budget printers may rapidly become an indispensable element in surgery departments.

Conclusion

We successfully used a 3D model to plan and perform a complicated surgery involving the removal of a renal tumor and neoplastic mass in the venous system, which reached the heart atrium. Physical 3D models can facilitate communication between physicians of various specializations, thus expediting treatment decisions.

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