Challenges of 3D printing from MRI data: Our Experience with a Kidney Tumor Model

Nicole Wake[1,2], William Huang[3], Todd Pietila[4], and Hersh Chandarana[1]

[1]The Center for Advanced Imaging Innovation and Research (CAI2R), Department of Radiology, New York University School of Medicine, New York, New York, United States, [2]The Sackler Institute of Graduate Biomedical Sciences, New York University School of Medicine, New York, New York, United States, [3]Department of Urology, New York University School of Medicine, New York, New York, United States, [4]Materialise USA, Plymouth, Michigan, United States

Target Audience: Researchers and clinicians interested in MR image segmentation, 3D visualization, and rapid prototyping

Purpose: Three dimensional (3D) printing in radiology is the fabrication of physical objects from imaging data, with the hope of impacting patient care. A 3D model can be printed from any image data set that has sufficient contrast and resolution to separate structures and can be reformatted volumetrically. Computed tomography (CT) images are most commonly used to generate 3D printed models due to the wide spectrum of applications of CT, near isotropic volumetric high resolution acquisition, and the relative ease of post-processing of the CT datasets.[1,2] While many magnetic resonance (MR) acquisition sequences, such as T1-weighted GRE post-contrast imaging in the abdomen, allow for volumetric coverage, image segmentation from MR data is inherently difficult due to MR field inhomogeneity, higher noise/artifacts, and lower spatial resolution compared to CT. Furthermore, signal intensity in MR does not have a physiologic basis similar to attenuation measurements in CT. As a result, there have only been a few case reports on 3D printing techniques using magnetic resonance (MR) imaging data, with the majority focusing on cardiovascular applications.[3-6] We performed 3D segmentation of an abdominal MR dataset and created a high-fidelity physical 3D model of a kidney and in-situ renal tumor for pre-operative surgical planning.

Methods: 3D-T1 weighted fat-saturated gradient echo Volume Interpolated Breath-hold Exam (VIBE) acquisition after administration of contrast was performed on a 1.5-T system (Avanto, Siemens, Erlangen, Germany). Imaging parameters were as follows: TR=3.58ms, TE=1.3ms, FA=12°, pixel spacing=1.37mm, and slice thickness=2mm. 3D visualization, segmentation, and generation of a stereolithography (STL) file were performed using a 2D workstation (Mimics, Materialise, Leuvin, Belgium). The kidney and arteries were segmented as one object and the tumor was segmented as a second object using a thresholding technique that allows the user to select specific gray-scale intensity values. Two masks were created and were manually edited to ensure that only the regions of interest were selected (Figure 1). The STL file was used to print a true-sized anatomical model with two different photopolymers: Vero Black for the tumor and Vero Clear for the kidney and vessels (Connex500, Stratasys Ltd, Eden Prairie, MN). The projected print time and resolution were measured. The model was used to both plan the surgical procedure and assist during the surgery.

Figure 1: MR Images with segmentation masks (green = tumor, pink = kidney and vessels)

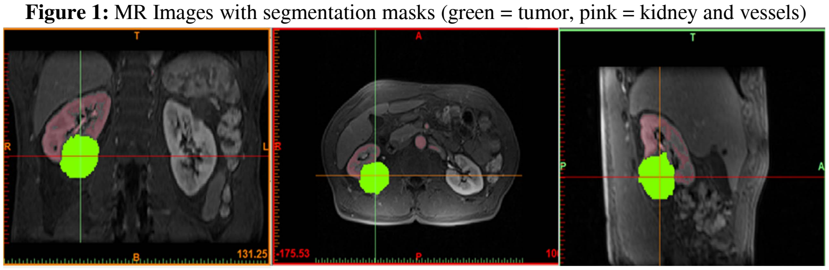
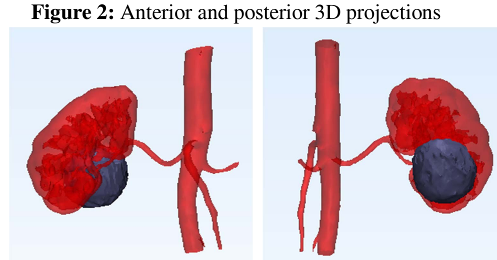


Figure 2: Anterior and posterior 3D projections



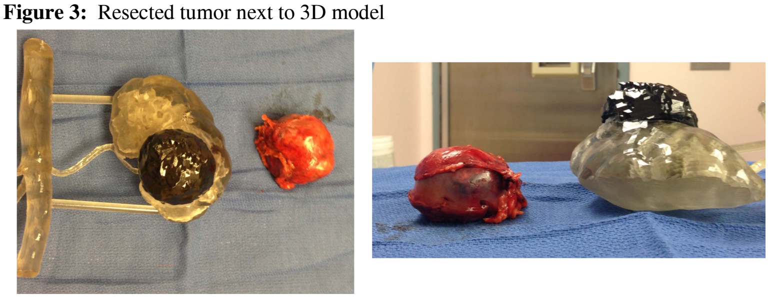
Results:

Segmentation time, printing time, and resolution were six hours, 14 hours 10 minutes, and 16 microns respectively**.** MR Images were well visualized using the post-processing software. The aorta, renal artery, kidney, and superior mesenteric artery were visualized in 3D (Figure 2). Vessel measurements made on the model correlated with those made using orthogonal views and straightened out multi-planar rendering from the 2D data sets. The model helped the surgeon with regards to surgical approach for partial nephrectomy – retroperitoneal versus transperitoneal. During the operative procedure, the model was referred to and was utilized instead of intra-operative ultrasound to guide resection. The patient successfully underwent partial nephrectomy with complete excision of the suspicious renal mass. The resected tumor was compared to the 3D model (Figure 3).

Discussion and Conclusions:

Soft tissue 3D printing from MR data is feasible, but implementation is challenging and time consuming. Hybrid or semi-automatic segmentation methods specific for MRI data would facilitate rapid prototyping from MRI data in the future. Preoperative physical 3D models created from MRI data may influence surgical planning and provide intraoperative guidance for renal tumors. In addition, 3D printed models may enhance the understanding of patients and their families regarding the goals of their surgery; leading to higher satisfaction by the choice of treatment plan.

Figure 3: Resected tumor next to 3D model



References:

[1] Rengier et al. 3D printing based on imaging data: review of medical applications. Int J CARS 5: 335-341, 2010.
[2] Esses et al. Clinical Applications of Physical 3D Models Derived from MDCT Data and Created by Rapid Prototyping. AJR 196: W683-688, 2010.
[3] Markl et al. Rapid vessel prototyping: vascular modeling using 3t magnetic resonance angiography and rapid prototyping technology. MAGMA 18:288-292, 2005.
[4] Schievano et al. Percutaneous pulmonary valve implantation based on rapid prototyping of right ventricular outflow tract and pulmonary trunk from MR data. Radiology 242:490-497, 2007.
[5] Mottl-Link. Physical Models Aiding in Complex Congenital Heart Surgery. Ann Thorac Surg 86:273-277, 2008.
[6] Riesenkamff et al. The practical clinical value of three-dimensional models of complex congenitally malformed hearts. J Thorac Cardiovasc Surg 138:571-80, 2009.