COMPUTER AIDED TECHNOLOGY

Roadmap to Success

3D Printing Points the Way to Minimally Invasive Brain Tumor Removal

3D printing is making great strides in the field of neurosurgery and enabling the delivery of personalized medicine to children with complex brain and spinal cord tumors. Three years ago, the neurosurgical team at SSM Health Cardinal Glennon Children's Hospital, a pediatric medical center in St. Louis, Missouri, embraced 3D printing as a solution for better surgical planning for these patients. Although rare, brain and spinal cord tumors are the second most common cancers in children after leukemia and account for about one out of four childhood cancers, according to the American Cancer Society. About half are gliomas that start in the supporting cells of the brain. As a pediatric referral center, SSM Health Cardinal Glennon Children's Hospital sees some of the most complex patients requiring resection.

One such patient was a 10-year-old child who presented with a low-grade deep-seated glioma. Deep-seated gliomas present a unique surgical challenge because they reside deep within critical cortical and subcortical structures and infiltrate functional areas of the brain that serve as control centers for thought, memory, sensation, emotion, vision and movement.

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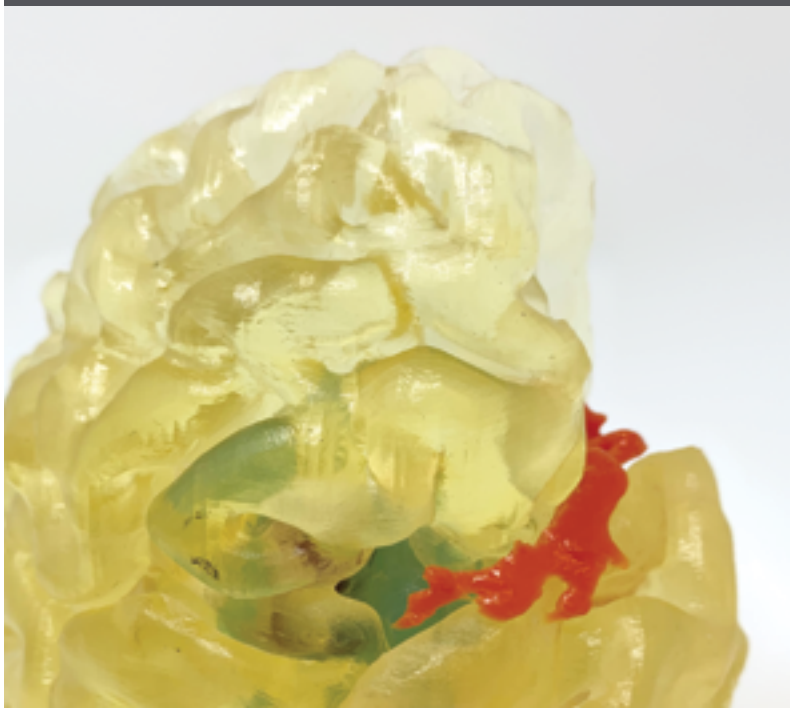
>
> Philippe Mercier, M.D., Ph.D.
> **SSM Health Cardinal Glennon Children's Hospital**



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Mapping the Way to Minimally Invasive Resection

Excision requires great accuracy and precision to avoid devastating consequences to these functional areas.

To reach and remove the child's deep-seated brain tumor, Philippe Mercier, M.D., Ph.D., turned to 3D printing to map out the safest and most efficient route. The simplest method to access a deep tumor is to dissect through brain tissue. However, that approach is damaging to functioning brain tissue. In order to minimize damage to normal-functioning brain tissue, Dr. Mercier chose to pursue a transsulcal approach. "My objective was to identify a sulcus between two gyri that would allow access to this very deep-seated tumor. With 2D or even 3D imaging it was impossible. (Figures 1A-1C) A sulcus can proceed medially, posteriorly and go in far too many directions to be able to tell exactly where it is, how much it can be opened, and how much access it will give me to the tumor."

To overcome that challenge, the staff at Cardinal Glennon used imaging data to model the child's brain in soft, tissue-like material with a Stratasys® J750™ 3D printer. The 3D printed model recreated the brain and tumor in precise detail. This allowed Dr. Mercier to physically identify the best path for resection before entering the operating room.

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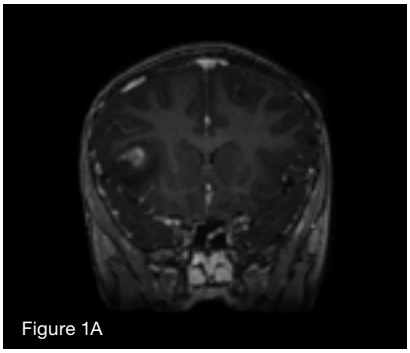
Figure 1A

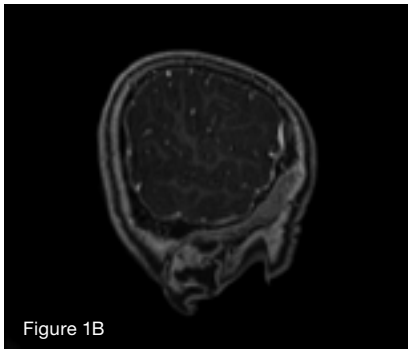
Figure 1B

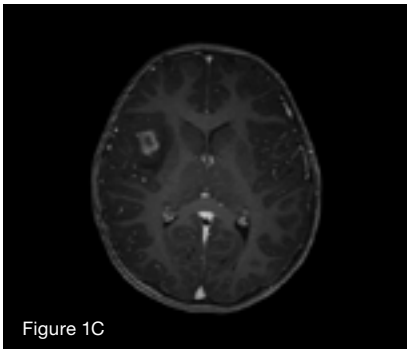
Figure 1C

Preoperative MRI of a patient with a right frontal low-grade glioma. Figures 1A (coronal), 1B (sagittal) and 1C (axial) views point out the sulcus ultimately utilized for entry and the large blood vessel within the sulcus.

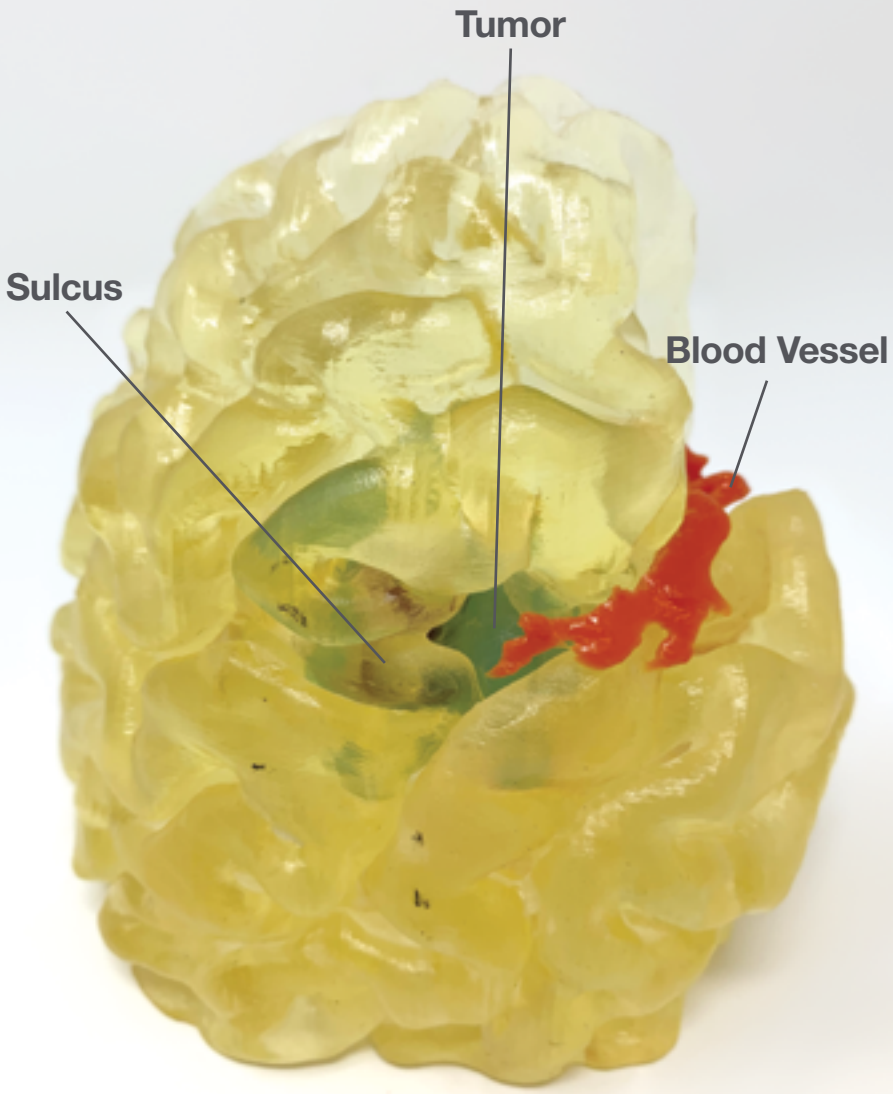

Figure 2. Photo of the 3D model used for surgical planning. The sulcus utilized and blood vessel avoided are labeled.

"By printing the model with soft material, I can actually perform the dissection with my fingers and see how close I am to the edge of the tumor. With 2D and 3D imaging it was impossible to identify a deep sulcus that would allow access to the tumor, set the depth of it, and identify the angles required to dissect it out. What was impossible with 2D and 3D imaging became possible with the 3D patient-specific model." (Figure 2)

The multimaterial and color capabilities of the J750 proved particularly helpful in this case. The color purple was used to distinguish the tumor and blue was used to distinguish the T2 FLAIR signal surrounding it. Blood vessels (in red) were overlaid onto the model to help identify the location of the sylvian fissure in relation to the tumor. The use of transparent VeroClear™ material allowed the visualization of the otherwise hidden tumor deep within the cortex. Soft Tango™ material provided the flexibility to probe the model's fissures. "The model's soft material allowed me to easily manipulate using my finger within the sulci. I was able to feel, open up, and trace the very convoluted routes of the sulci which were not apparent on imaging studies. From that, I was able to determine the sulcus that would provide the safest path to reach and remove the tumor without risking other functional areas," said Dr. Mercier.

Instilling Confidence in the Approach

Besides surgical planning, 3D printed patient-specific models enhance the confidence for successful outcomes — both for the physician and the patient's family. Dr. Mercier added, "Based on the model, I was very confident going into surgery that I could remove the tumor by going through very little brain tissue and I did — only a few millimeters. I knew I had selected the best fissure and I knew in advance exactly how deep it was, what angles I would have to use, and how close it would get me to the tumor."

Without the model, Dr. Mercier would have had to explore other options and performed more dissection, exposing the patient to added risk. "The model truly allowed for a complication-free surgery and shortened operating room time. The 3D print was invaluable in navigating the complex structure and angles I was looking at in this case," said Dr. Mercier.

The model was also helpful in educating the child's parents and putting them at ease during the informed consent process. "It serves as an extra tool to help parents and families understand their child's situation. When you can actually show them that you put their child first and truly understand their child's problem, they are assured you are delivering a personalized treatment approach," concluded Dr. Mercier.

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