**Thesis Project Portfolio**

**Development of Hepatic Vasculature Models for Preoperative Planning**

(Technical Report)

**Beyond the Body: Theorized Implications of Medical 3D Printing on Anatomical Perception**

(STS Research Paper)

An Undergraduate Thesis

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## Sociotechnical Synthesis

My technical and STS research revolve around the development and use of 3D printed anatomical models in the medical space as preoperative planning and teaching tools. These models are made of synthetic resins or other plastics and are being explored as a way for surgeons to hone surgical skills and improve the education of medical students and residents. My technical project consists of the development and prototyping of such anatomical models. Taking a more theoretical approach, my STS research infers how the creation and use of 3D printed models of human anatomy may alter the depiction and perception of the body.

The overarching aim of my technical work was to develop an accurately scaled model of the liver vasculature that could be catheterized by the user to practice hepatic arterial embolization, a procedure done to treat liver tumors. After acquiring real patient CT scans from the hospital, we utilized the program 3D Slicer to isolate the liver vessels from the rest of the anatomy and develop a digital 3D model. While my team and I had initially only intended to 3D print a vasculature tree with a hollow lumen, we pivoted our approach to include two additional manufacturing techniques to assess how to best create these anatomical models. We made this change in direction due to the time-consuming digital modeling process and inadequate resolution of the hollow print that we experienced in our design process. Both additional methods we tested involved multistep manufacturing processes. The second model was created by developing and printing a solid vasculature model in hard resin, then casting it in liquid silicone until it cured and hardened. The 3D printed vessels were carefully removed, leaving the flexible model behind. The third model was created using the same non-hollow digital model of the vasculature. A solid box was designed in the 3D modeling software to surround the vasculature and then the vessels were deleted from within the box; this box was then 3D printed to result in our final model. We produced the three models using elastic resins and silicone to replicate the elasticity and mechanical properties of the human blood vessels. We determined that our third method, 3D printing of a negative space model, was the most feasible choice for the future development of vascular models, but the process will require additional refinement moving forward.

My STS research analyzes and theorizes the implications of 3D printed anatomical models becoming incorporated as commonplace tools in the medical field. I was specifically interested in examining how 3D printed visualizations fit into the existing dialogue about 2D medical visualizations and how error is incorporated during their production process, leading to inaccurate understanding of the anatomy. I relied upon Donna Haraway's perspectives on Cyborg Theory, through which she indicates how technology is described as granting an all-seeing perspective. In actuality, Haraway argues this vision is dependent on the context and the viewer rather than being removed and impartial. Using this framework, I posit that 3D printed medical visualizations are a form of scientific knowledge that is thought to be a one-to-one representation of the anatomy, but that these models are instead reflective of the biases of the producer and the imaging technology involved in the production process. I argue that there are many overlapping challenges between 2D and 3D visualization processes, and I find that there are additional complexities specific to 3D printed anatomical models that lead to distortion of these models. Another key effect that I believe to be shared by both 2D and 3D medical visualizations is disciplining of the human body, in which these depictions serve to disregard nuance and variations in the anatomy in favor of idealized models. Despite these current issues, I suggest that 3D anatomical models can play a valuable role in medical training as long as their limitations are more clearly acknowledged and discussed.

Working on these projects simultaneously proved to be incredibly valuable for me and allowed me to have a well-rounded understanding of the conceptualization and creation of 3D printed anatomical models. Throughout the technical project, I worked directly with Dr. John Angle, an interventional radiologist at UVA Health, to shadow in the operating room, observe CT and X-ray imaging processes, and learn about the medical visualization software used by clinicians. Much of my underlying understanding of the 3D model production processes that I used for my STS analysis stemmed from these experiences, as I gained first-hand experience with the challenges and manual manipulation required to transform 2D medical images into 3D models. My technical project also exemplified the value and hope that physicians put on the 3D printing manufacturing method, which informed my thoughts about the impact of physicians' diction and opinions on the acceptance of 3D printed anatomical models that I outlined in my STS work. In return, my STS analysis helped me to be critical of how I was creating my own anatomical model during my technical project. When determining which design steps to take, the implications of these choices on the model and on the viewer were present on my mind. The connection between my STS and technical work allowed me to bring a nuanced perspective to how I addressed each project and provided an integrated understanding of the roles of various stakeholders involved in the production and adoption of 3D printed anatomical models.