3D Printing to Improve Patient Outcomes

An Analysis on Mini-Thoracotomy Aortic Valve Replacements

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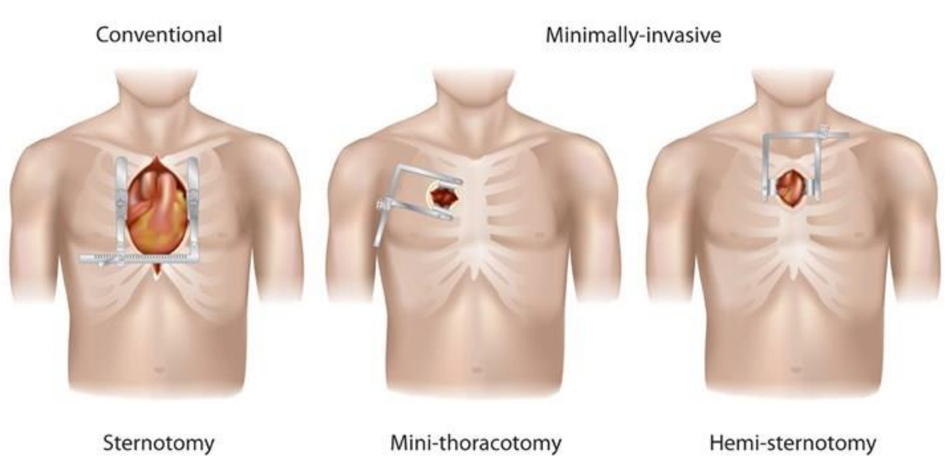
Introduction

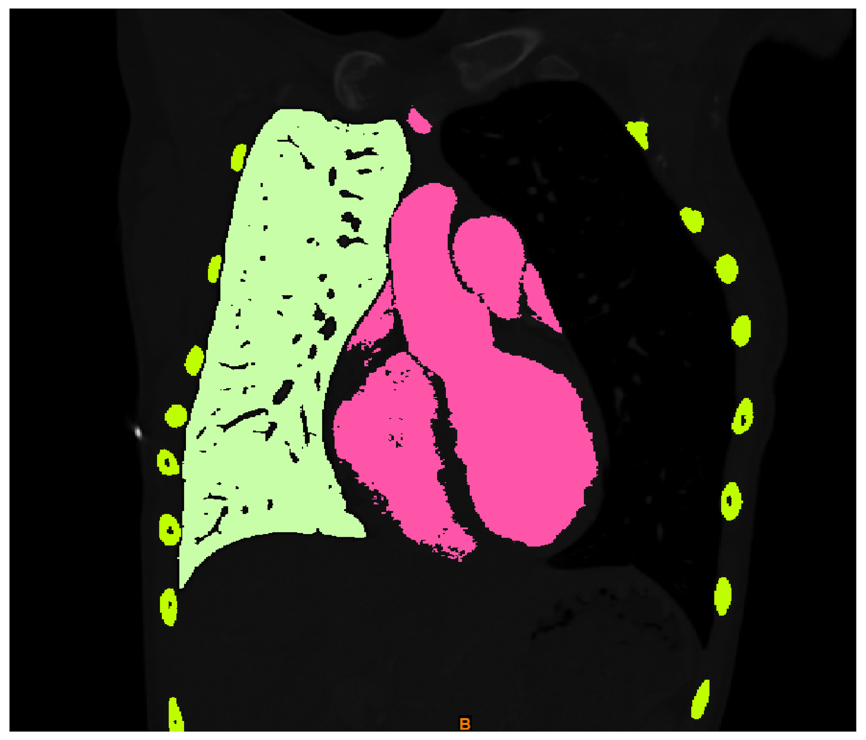
ABSTRACT

Aortic valve replacement (AVR) was established in the 1960's and has become a routine therapy to treat patients with severe aortic valve dysfunction. AVR is usually performed using a full sternotomy and cardiopulmonary bypass support. Since the late 1990's, minimally invasive procedures have been developed for aortic valve surgeries, such as the mini-thoracotomy AVR. These less invasive procedures claim reduced post-operative complications, shorter lengths of stays in the hospital, and lower mortality. This project will provide the 3D printing capabilities needed to investigate if using 3D printed anatomical models result in better patient outcomes for mini-thoracotomy AVR surgery. The 3D printed models will also be used for educational purposes with providers at Mayo Clinic.



PROJECT AIMS

The goal for this project will be for the Mayo clinicians to provide the UWEC research team with medical imaging files to be modeled and 3D printed, which can then be evaluated by the physicians for efficacy in better patient outcomes for mini-thoracotomy aortic valve replacement surgery and patient education.



PROCESS & METHODOLOGY

To create a physical 3D anatomical model, computer programming is used to select the correct information from medical imaging files through a process called segmentation. Segmentation is the most intricate and time-consuming aspect of this project as it is crucial to retrieve information that is as accurate to the actual patient anatomy as possible. After segmentation, the preliminary file is converted to a stereolithography file that can be read by the 3D printing slicer software. Final touches are then made to the file, and the slicing software sends the print information to the 3D printer for printing of the physical model. More information on the computer programming used for this process is located in the section "Materialise Software" to the right.

Thus far, the research team has developed an expertise in segmenting medical imaging files provided by the Mayo Clinic. The next step is to send completed 3D printed models to Mayo Clinic physicians for feedback.

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Materialise Software

Two computer programs are used to convert 2D images into 3D printable models.

MIMICS

MIMICS analyzes the greyscale of DICOM files from CT Scans or MRIs to transform 2D pixels into a mask, a graphic that contains voxels (3D pixels) . Because image quality can highly affect the quality of a 3D model, live editing is allowed on the mask to create a model that is accurate to the source imaging. Once the mask is edited to desire, the program can convert the mask into a part, which cannot be edited in real time.

3-MATIC

3-Matic imports the part produced by MIMICS and converts it into a Standard Tessellation Language (STL) file, which is the file format accepted by the 3D printers utilized in this project. STL files define surfaces in 3D spaces in terms of triangles and are used particularly in biomedical engineering for their ability to accurately approximate organic structures, such as human anatomy. The program is also used to complete edits on the part, such as hollowing, that cannot be done on a mask to create a better representation of human organs.

Results

Using MIMICS software, complex soft tissue is segmented into a 3D model then printed with a variety of materials including hard plastic, flexible elastic, and a colored sandstone material.

Complex Soft Tissues Printed:

- Abdominal Aortic Aneurysm
- Trachea and Bronchi
- Non-Diseased Heart
- Heart with Hypoplastic Left Heart Syndrome (HPLH)
- Heart with Tetralogy of Fallot (TOF)
- Heart with Transposition of the Great Arteries (TGA)
- Chest Cavity

Chest Cavity Model

A chest cavity model was printed in multiple pieces and assembled spring 2022 to aid in displaying the intricacies of a mini-thoracotomy aortic valve replacement procedure.

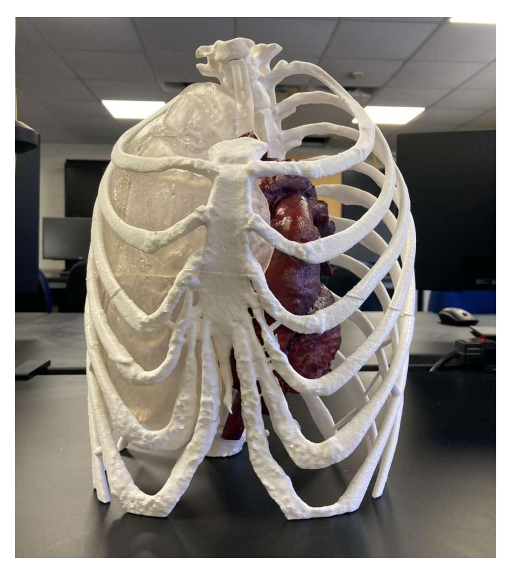

Figure 1: 3D Print of an Abdominal Aortic Aneurysm. Printed on a FormLabs 3 printer in flexible material.

Figure 2: 3D Print of Hypoplastic left heart syndrome. On the left is a section model and on the right is the full model. The models were printed in flexible elastic on a Form Labs 3 printer.

Figure 3: 3D Print of Transposition of the Great Arteries, a rare congenital defect in which the pulmonary artery and the aorta switch positions. Printed in color on a 3D Systems Projet 460 Plus.

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