Virtual Total Artificial Heart Implantation for Improved Device Eligibility Criteria

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INTRODUCTION

In 1985, SynCardia’s Total Artificial Heart (TAH) was approved by the US Food and Drug Administration (FDA) for patients awaiting heart transplantation. Other forms of circulatory support, such as ventricular assist devices, have since emerged as options for pediatric patients. However, the TAH has not been extensively used in pediatrics. In fact, of the 1,061 patients implanted with the TAH, only 21 (2%) were under the age of 18 [1].

PEDiatric CHAllenges

As implantation of TAH devices increases in pediatrics, the criteria for patient eligibility must be better understood and established. Current eligibility standards recommended a minimum body surface area (BSA) of 1.7 m² and 10 cm between sternum and spine at T10 [2]. However, the current standards do not consider the vast differences in cardiovascular, respiratory, and skeletal morphologies among pediatric patients. This study describes the use of 3D reconstruction models to aid in TAH eligibility and support virtual surgical planning in small patients, with the ultimate goal of avoiding potentially problematic surgery.

SEGMENTATION & 3D RECONSTRUCTION

- Phoenix Children’s Hospital provided contrast-enhanced CT scans of two patients.
- The data was reconstructed as a 3D model in Mimics.
- The complete occlusions that occur with the segmental pulmonary artery and vein imply that the blood flow in the vessels would be completely cut off following an actual surgery. The volumetric long-compression implied after virtual implantation would be serious, but not life-threatening [2]. Unfortunately, the volumetric overlap with the sternum would be a major concern; the device would not fit within the thoracic cavity. It is unlikely that the patient would be implanted with the device if the surgeon wished to close the chest. If an artificial heart was needed, a different ventricular assist device would most likely be used.

METHODS

TAH SPECIFICATIONS

- 160 grams
- 400cc of displaced volume
- Adjustable cannula orientation
- Within diaphragmatic volume
- Right heart chambers:
  - Pulmonary arteries
  - Inferior vena cava
- Electro-mechanical force
- Atrial cuffs, grafts, and pneumatic tubes are attached.

VIRTUAL IMPLANTATION

- Computational models were imported into Geomagic Studio and Mimics.
- A surface mesh was generated from laser scanning. Data was loaded into Mimics to analyze TAH fit and support virtual surgical planning in small patients, with the ultimate goal of avoiding potentially problematic surgery.

DISPLACEMENT ANALYSIS

- For the trial dataset, the complete occlusions that occur with the segmental pulmonary artery and vein imply that the blood flow in the vessels would be completely cut off following an actual surgery. The volumetric long-compression implied after virtual implantation would be serious, but not life-threatening [2]. Unfortunately, the volumetric overlap with the sternum would be a major concern; the device would not fit within the thoracic cavity. It is unlikely that the patient would be implanted with the device if the surgeon wished to close the chest. If an artificial heart was needed, a different ventricular assist device would most likely be used.

RESULTS

DISCUSSION & CONCLUSION

The total artificial heart continues to evolve to meet patient needs in this growing field. Many improvements and new technologies have been developed to improve the longevity and success rate of patients receiving a TAH. This study describes the use of 3D reconstruction models to aid in TAH eligibility and support virtual surgical planning in small patients, with the ultimate goal of avoiding potentially problematic surgery.

REFERENCES