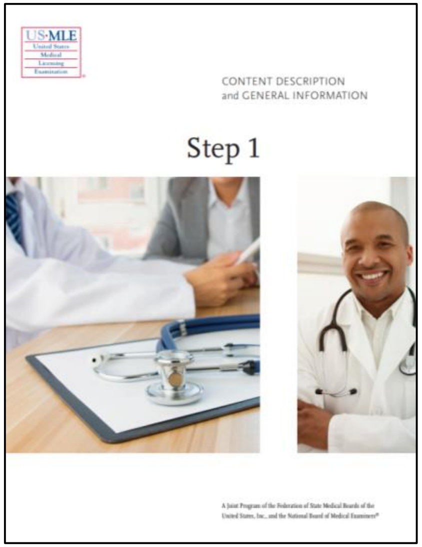
Cardiovascular Pathology Education Optimization and Improvement: A Critical Review of Topics and Teaching Modalities

Andrew T. Ray#, William H. McAllister#,
Connor L. Pratson#, Connor J. Karr#, Philip J. Boyer, M.D., Ph.D.*, Andrea T. Deyrup, M.D., Ph.D. ^, Joshua R. Butler~, William W. Godwin@, Karen L. Kelly, M.D.*

*Department of Pathology and Laboratory Medicine, #Brody School of Medicine, ~Department of Engineering, and @Innovation and Design Laboratory, East Carolina University, Greenville, North Carolina and ^Department of Pathology, Duke University, Raleigh, North Carolina

Rationale / Need

- Pathology is a **foundation topic** in basic science undergraduate medical education eduction:
  - It provides a **critical infrastructure** for subsequent medical eduction
  - It is **heavily tested** on the National Board of Medical Examiners **United State Medical Licensing Step 1** Examination



Discipline Content on USMLE Step 1

This booklet was updated February 2019.

Table 4: Step 1 Discipline Specifications*

Discipline	Range, %*
Pathology	45–52
* Physiology	26–34
* Pharmacology	16–23
Biochemistry & Nutrition	14–24
* Microbiology & Immunology	15–22
* Gross Anatomy & Embryology	11–15
* Histology & Cell Biology	9–13
Behavioral Sciences	8–12
* Genetics	5–9

*Percentages are subject to change at any time. See the USMLE website (www.usmle.org) for the most up-to-date information.

(usmle.org/pdfs/step-1/content_step1.pdf)

Rationale / Need

- With the introduction of a **revised, organ system-focused curriculum** at the Brody School of Medicine, it is appropriate and timely to:
  - **Assess what is being taught** in the Pathology course
  - **Assess how is content being taught**
- **Ideal**
  - **Make changes based on data rather than opinion**

Preliminary Steps

- **Second-year medical students** enrolled in the pathology course were **surveyed** regarding laboratory sessions.
- **Collaboration** with the **Duke University Pathology Course Director** was undertaken.
- **Literature and Google searches** were undertaken to identify resources detailing validated **topics** and **teaching modalities** for the cardiovascular component of undergraduate medical pathology courses.
- Brody **learning objectives** were compared to those deployed at Duke and those cited in widely-used resources.

→ implementation of a **Congenital Heart Disease Laboratory** in the M2 Pathology Course

Index of Learning Styles: Brody 2018 - 2021

- Very similar from year-to-year
- The learning preferences of a majority of Brody Students include elements which are:
  - Sensory
  - Visual
  - Sequential

(Assessment Tool: North Carolina State University: www4.ncsu.edu/unity/lockers/users/f/felder/public/ILSpage.html)

Information Processing

Reflective (50%, 55%, 46%, 46%)
Reflective Learners prefer to think through, to evaluate options, and learn by analysis. They enjoy figuring out a problem on their own. Be involved in group decision-making whenever possible.

Active (50%, 46%, 54%, 54%)
Active learners prefer to manipulate objects, do physical experiments, and learn by trying. They enjoy working in groups to figure out problems. Concentrate on summarizing situations.

Perception

Sensing (84%, 88%, 77%, 74%)
Sensory learners prefer concrete, practical, and procedural information. They look for the facts instead of being innovative. Seek out theoretical information.

Intuitive (16%, 13%, 23%, 26%)
Intuitive learners prefer conceptual, innovative, and theoretical information. They look for the meaning, but risk missing important details. Slow down and look at details that are typically skimmed.

Input

Visual (81%, 90%, 86%, 90%)
Visual learners prefer graphs, pictures, and diagrams. They look for visual representations. Improve note taking and explaining information to others using words.

Verbal (19%, 10%, 14%, 10%)
Verbal learners prefer to hear or read information. They look for explanations with words. When reviewing notes, group information according to concept and create visual links.

Progression towards understanding

Sequential (70%, 74%, 64%, 67%)
Sequential learners prefer to have information presented linearly and in an orderly manner. They put together the details in order to understand how the big picture emerges. Practice "big picuture" thinking.

Global (30%, 28%, 36%, 33%)
Global learners prefer a holistic and systematic approach. They see the big picture first and then fill in the details. Self-test to explain the why, if the way can't be explain you missed critical details.

Index of Learning Styles Classes of 2018, 2019, 2020 & 2021

(Terri Edwards, Office of Student Development and Academic Counseling, Brody School of Medicine, ECU)

CV Session Construct: Current

9 Lecture Sessions:

Formative Assessment: All sessions include case-based, poll-style questions (**TurningPoint**, TurningTechnologies.com)

- **Attendance**: Optional
  - Attendance Bonus Points: 70% attendance

2 Laboratory Sessions:

Small Groups of Students: Groups respond and review case-based questions reviewed

- **Gross Organs - Normal and Abnormal:** Demonstration and discussion
- **Attendance**: ≥ 50% of total sessions required

Course Survey: 2017

Congenital heart disease specimens had not been demonstrated in the past

- Time constraints → 20 participants
- Small size of specimens

- Since the **specimens** were **so small**, it would have been nice to have a **smaller group** that allowed us to get closer. It was a lot of blue and pink strings going in and out of places I couldn't quite see.

- These defects in general were just hard for me to picture, so seeing a specimen and a **3-D model** will **help me better conceptualize these defects** and remember the effects they have on blood flow.

Methods and Materials

- A new, optional **Congenital Heart Disease Laboratory** session was implemented based on the previous year's feedback utilizing **3-D model constructs** of various congenital heart pathologies based on prior survey data.
  - **Survey**: Students participating in the Congenital Heart Disease Laboratory session were polled regarding:
    - **Usefulness** of the congenital heart lab relative to other pathology lab sessions
    - **Usefulness of 3-D printed models** in student understanding of congenital heart defects

3D Printing Models of Congenital Heart Disease Defects

Use of 3D Models in Education

- Limited published use of 3D models in medical education to date
- **<u>Pediatric Resident congenital heart disease session</u>**
  - 3D Models vs.
  - Photographs (2D)
- **<u>Conclusion</u>**:
  - Physical 3D models enhance resident education around the topic of tetralogy of Fallot by improving learner satisfaction.

RESEARCH ARTICLE — Open Access

Usage of 3D models of tetralogy of Fallot for medical education: impact on learning congenital heart disease

Yue-Hin Loke[1*], Ashraf S. Harahsheh[1], Axel Krieger[2] and Laura J. Olivieri[1,2]

Abstract

Background: Congenital heart disease (CHD) is the most common human birth defect, and clinicians need to understand the anatomy to effectively care for patients with CHD. However, standard two-dimensional (2D) display methods do not adequately carry the critical spatial information to reflect CHD anatomy. Three-dimensional (3D) models may be useful in improving the understanding of CHD, without requiring a mastery of cardiac imaging. The study aimed to evaluate the impact of 3D models on how pediatric residents understand and learn about tetralogy of Fallot following a teaching session.

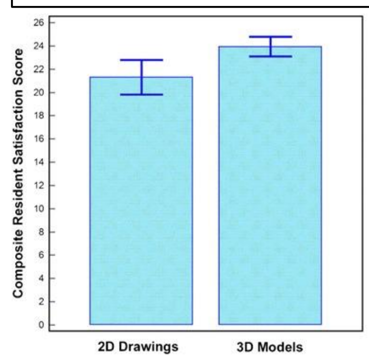
Methods: Pediatric residents rotating through an inpatient Cardiology rotation were recruited. The sessions were randomized into using either conventional 2D drawings of tetralogy of Fallot or physical 3D models printed from 3D cardiac imaging data sets (cardiac MR, CT, and 3D echocardiogram). Knowledge acquisition was measured by comparing pre-session and post-session knowledge test scores. Learner satisfaction and self-efficacy ratings were measured with questionnaires filled out by the residents after the teaching sessions. Comparisons between the test scores, learner satisfaction and self-efficacy questionnaires for the two groups were assessed with paired *t*-test.

Results: Thirty-five pediatric residents enrolled into the study, with no significant differences in background characteristics, including previous clinical exposure to tetralogy of Fallot. The 2D image group ($n = 17$) and 3D model group ($n = 18$) demonstrated similar knowledge acquisition in post-test scores. Residents who were taught with 3D models gave a higher composite learner satisfaction scores ($P = 0.03$). The 3D model group also had higher self-efficacy aggregate scores, but the difference was not statistically significant ($P = 0.39$).

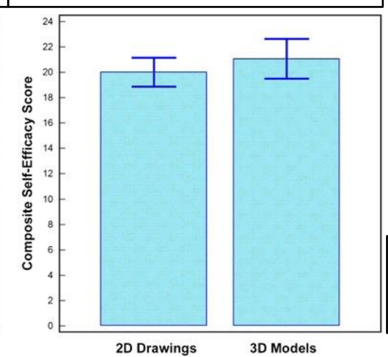
Conclusion: Physical 3D models enhance resident education around the topic of tetralogy of Fallot by improving learner satisfaction. Future studies should examine the impact of models on teaching CHD that are more complex and elaborate.

Keywords: Congenital heart disease, 3D printing, Resident education

Satisfaction	Testing



Statically Significant Difference



Not Statically Significant Difference

Innovation and Design Laboratory, East Carolina University

William W. Godwin: Director

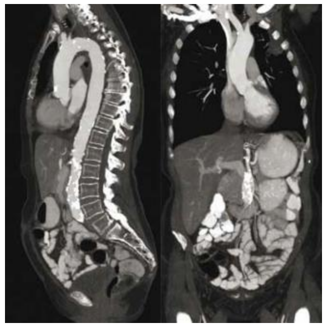
Collaboration with ECU College of Engineering Students:

- **Kevin C. Nguyen**
- **Joshua R. Butler**

(bwarchitecture.info/about1-c12qf)

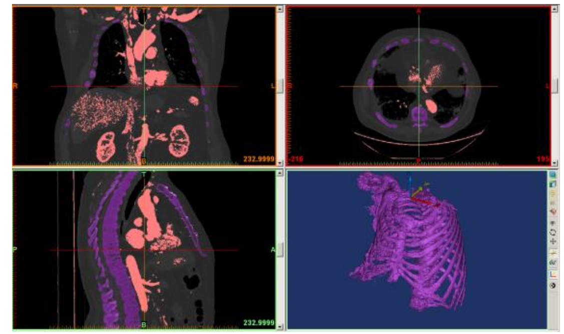
Overview: 3D Printing Process

Step 1: Obtain Patient-Specific Images

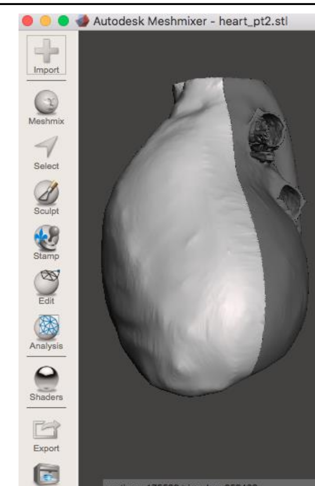


(doylestownhealth.org/medical-services/medical-imaging-radiology/ct-scan)

Step 2: Create 3D Model Using Imaging Processing Software



Step 3: Optimize Model for Printing



Step 4: Print Model

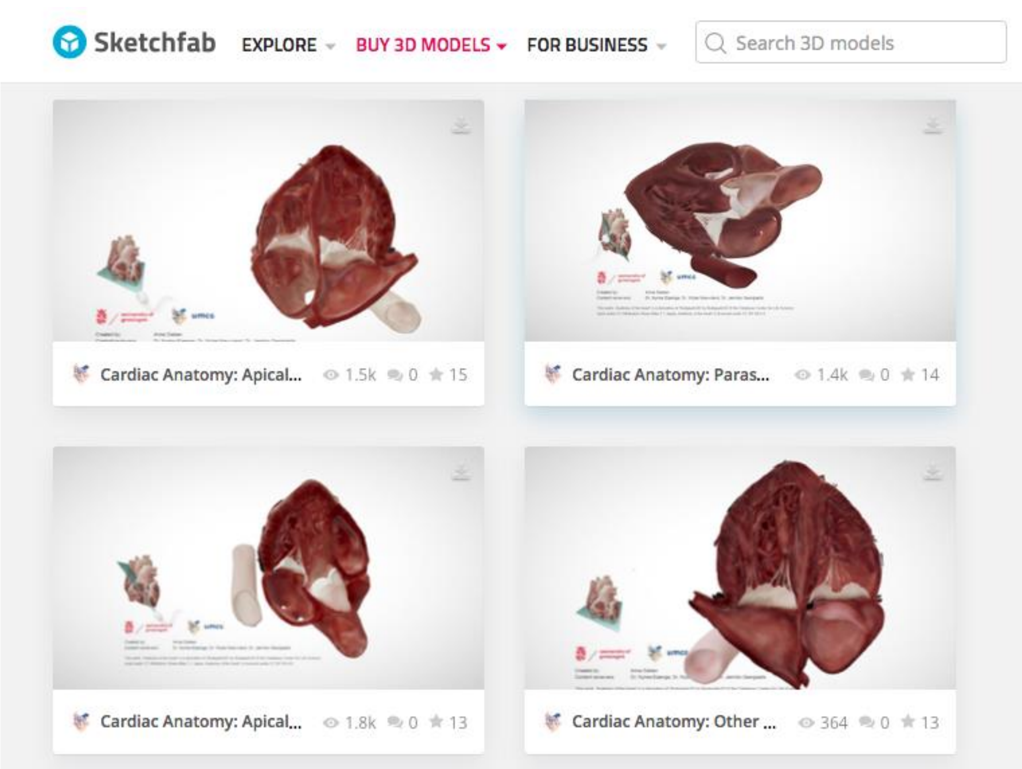
(3dhubs.com/3d-printers/makerbot-replicator-5th-gen)

Simplified 3D Printing Process

Step 1: Access www.SketchFab.com

Step 2: Optimize Model for Printing

Step 3: Print Model

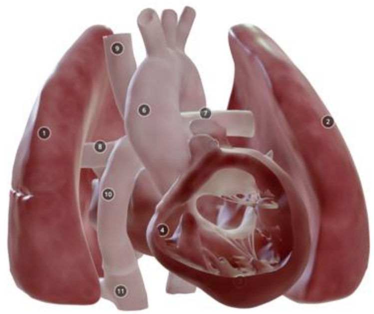


E-Learning University Medical Center Groningen

BIO

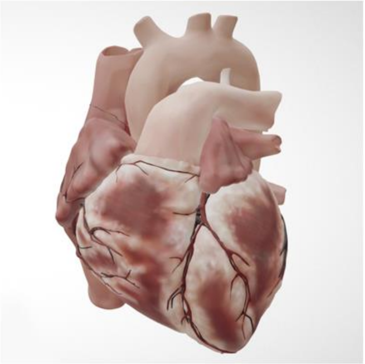
That's me, Anna Sieben. I am a medical artist with professional experience in creating visual and interactive resources to make medicine accessible, comprehensible and engaging. As a medical illustrator with a background in medicine, I love to work where science and art meet, combining two passions of mine: the art of medicine and medical art.

RECENT PROJECTS



VISUALISING HEART DISEASE

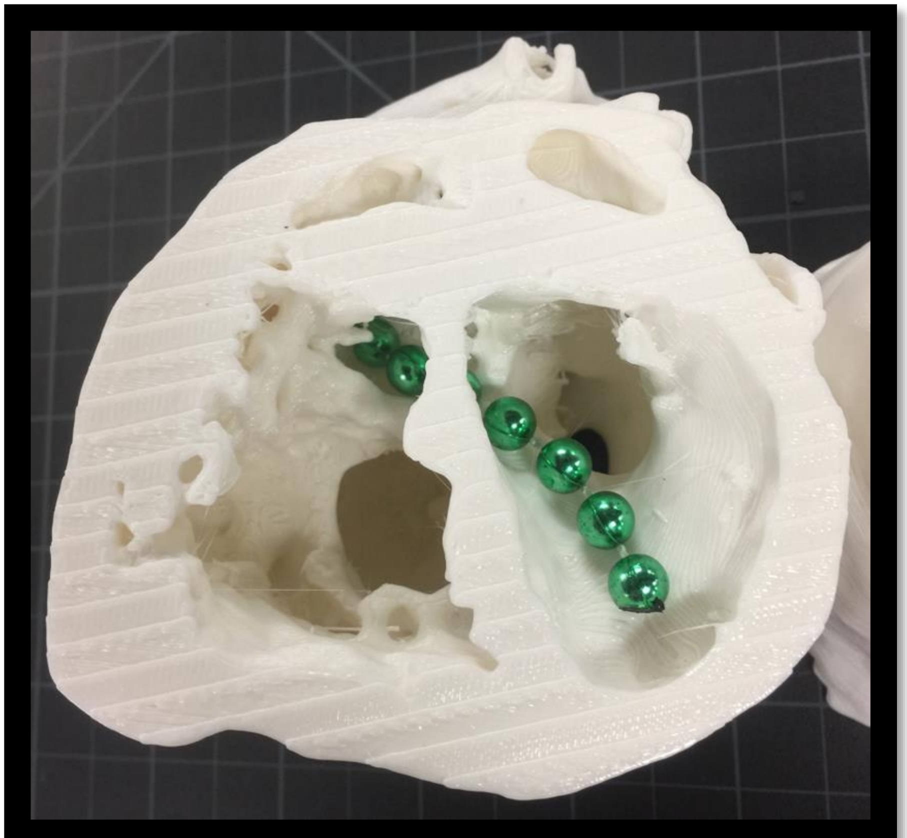
3D SCAN DENTISTRY MODELS



ECHOCARDIOGRAPHY AND 3D ANATOMY

Check out her website at http://www.annasieben.com

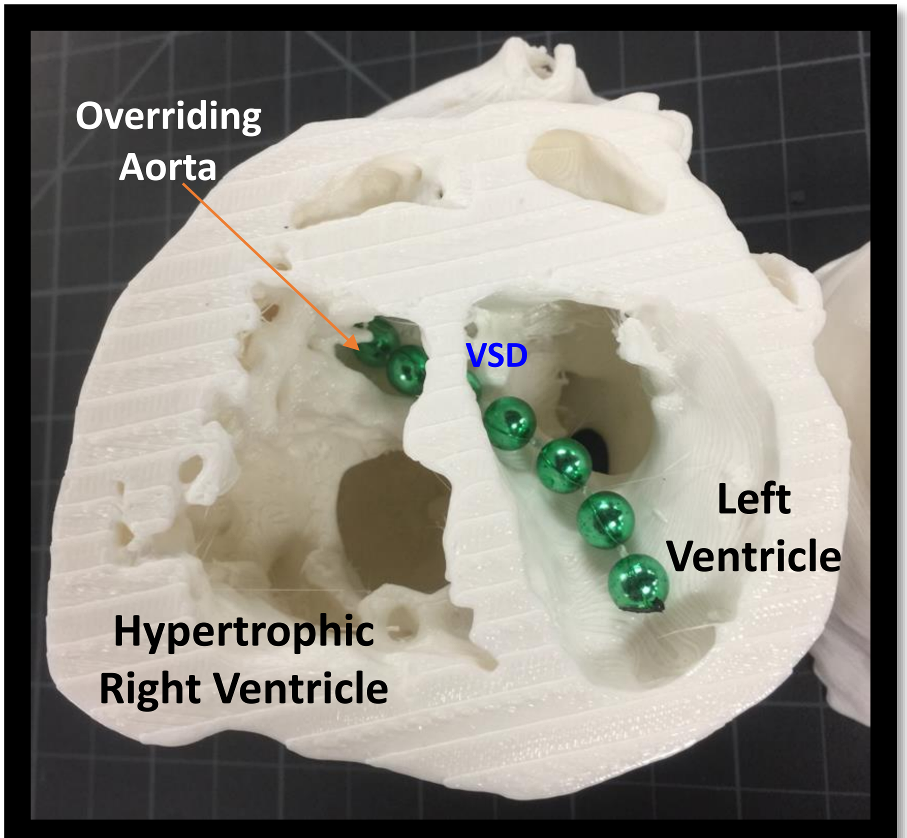
Tetralogy of Fallot: Medical Art vs Patient Specific Design



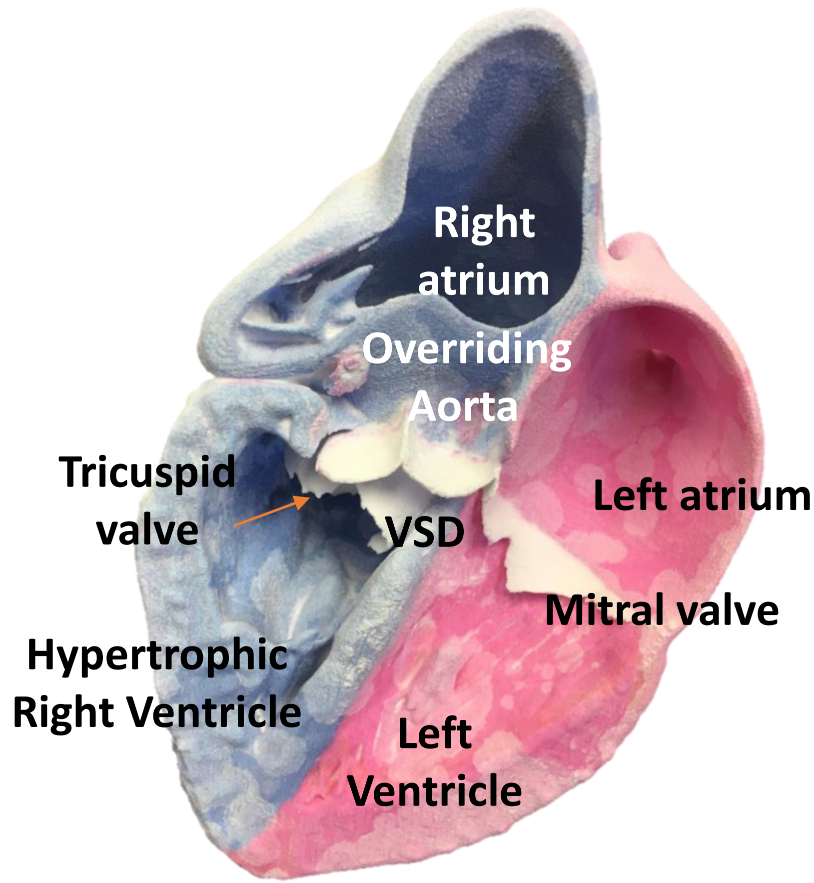
Patient Specific

Medical Art

Tetralogy of Fallot: Medical Art vs Patient Specific Design



Patient Specific



Medical Art

Course Survey: 2017

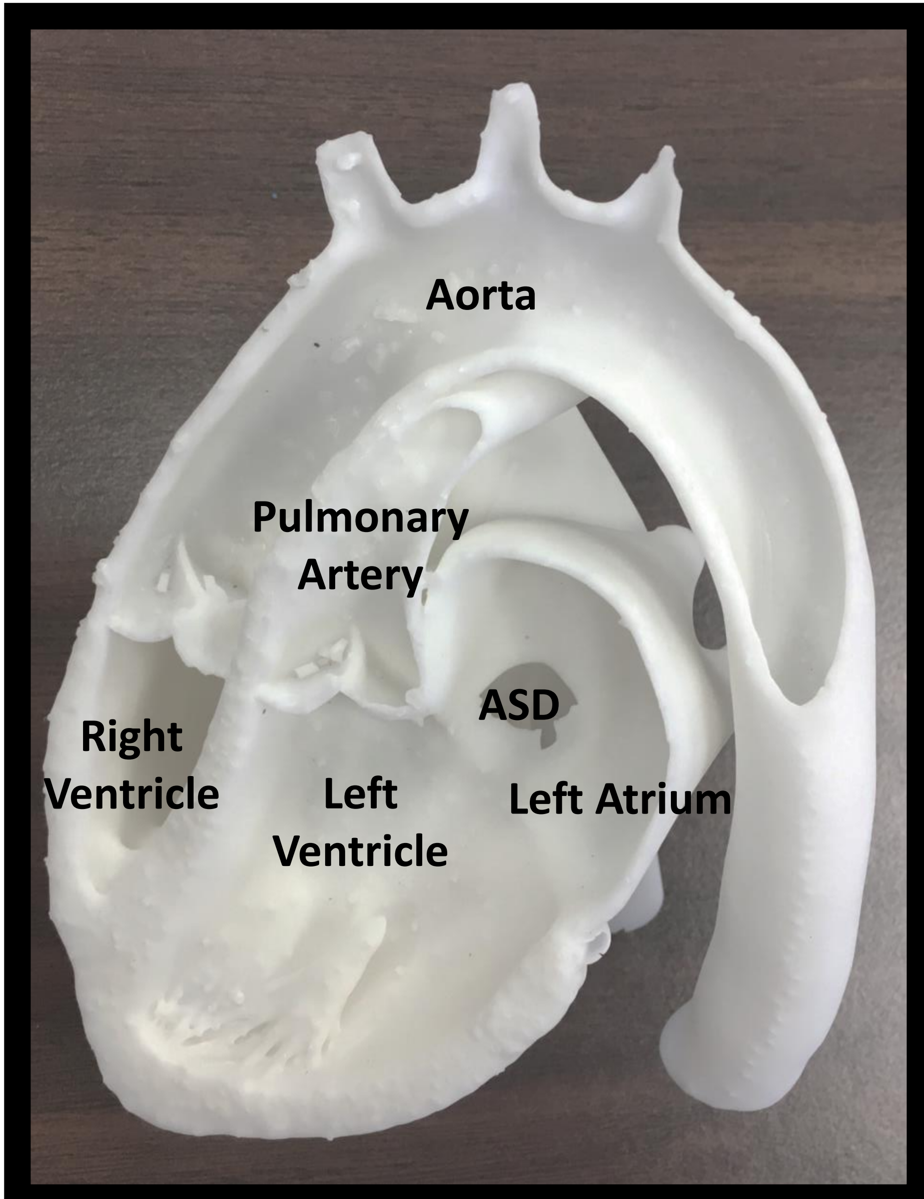
- **Most Useful Congenital Heart Disease Specimens:**

Specimen	CV Lab Attendees
Tetrology of Fallot	60% (n=12)
Transposition of the Great Vessels	50% (n=10)
Patent Foramen Ovale	40% (n=8)
Ventricular Septal Defect	35% (n=7)
Coarctation of the Aorta	30% (n=6)
Atrial Septal Defect	20% (n=4)
Patent Ductus Arteriosus	20% (n=4)
Persistent Truncus Arteriosus	10% (n=2)
Tricuspid Atresia	5% (n=1)

- **Which specimens would most benefit from a 3D model for demonstration and evaluation?**
  - **Tetrology of Fallot 7**
  - **Transposition of Great Vessels 3**
  - **Truncus Arteriosus 3**
  - **Coarctation of Aorta 1**

(Responses: N = 7)

Transposition of the Great Vessels



3D Prints

Fused Deposition Modeling

Stereolithography

Powder Bed Fusion

3D Prints

Fused Deposition Modeling

Stereolithography

	Fused Deposition Modeling	Stereolithography
Price	Cheap	Expensive
Durability	Durable	Durable
Finish	Rough	Smooth
Color	Unicolor	Unicolor

3D Prints

Fused Deposition Modeling

Powder Bed Fusion

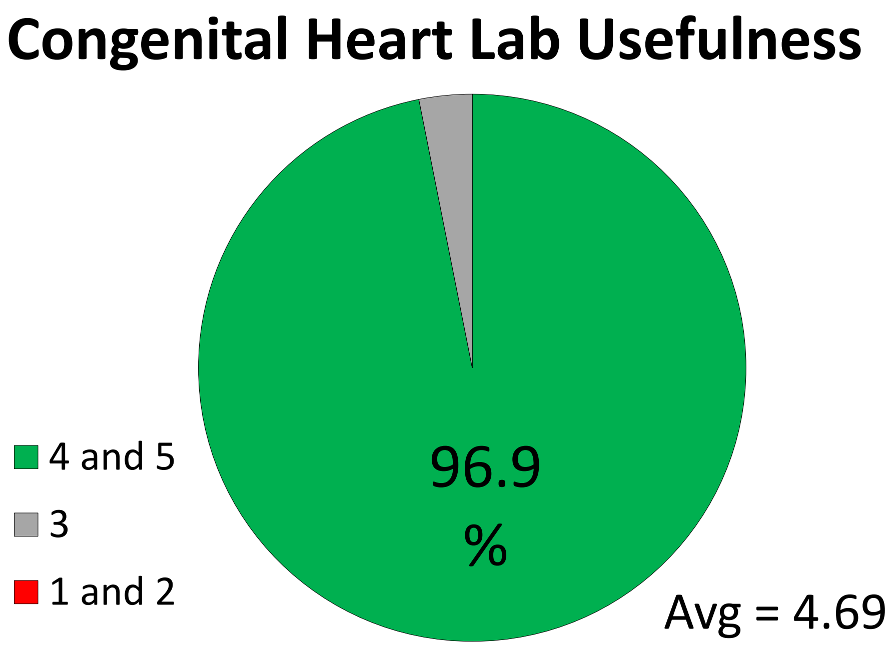
Price
Durability
Finish
Color

Cheap
Durable
Rough
Unicolor

Moderate
Fragile
Smooth
Multicolor

Survey Results from 2021 Congenital Heart Lab 2018

Utility of Congenital Heart Pathology Lab



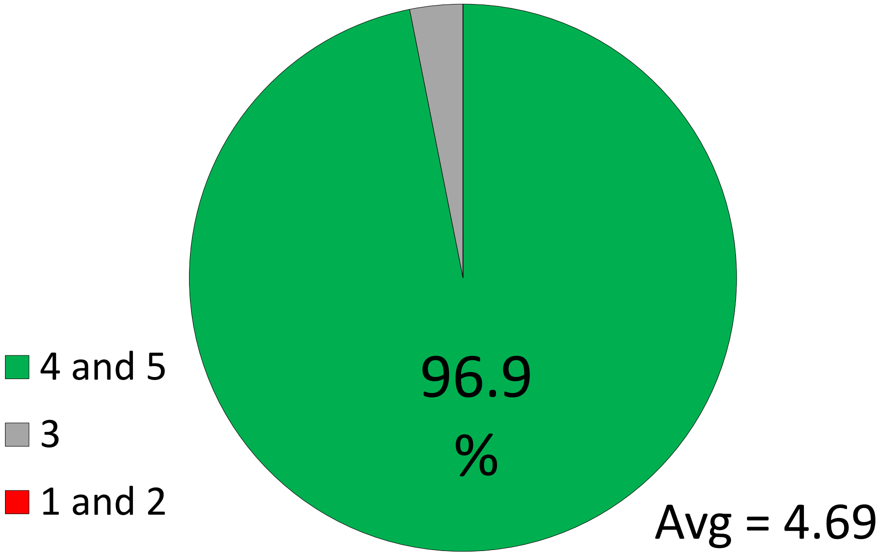
Likert Scale:

- 1 = Not Useful
- 5 = Very Useful

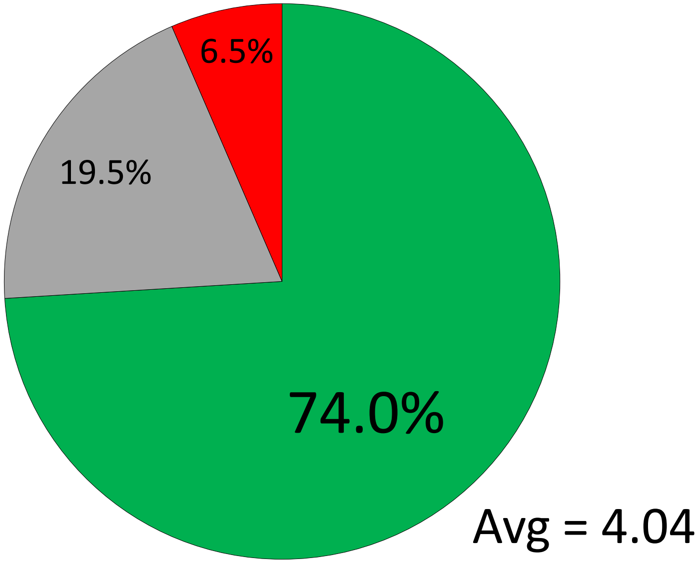
- Response Rate = 100% (32/32) participants
- Extra Credit Awarded to Students who completed the survey
  - Opportunity available to the entire class even if they did not attend congenital heart lab (77/85 total M2 students = 90.5%)
  - Students made aware that names were only collected for extra credit purposes and rest of survey was anonymous
  - Data collected by classmate

Utility of Congenital Heart Pathology Lab

Congenital Heart Lab Usefulness



Overall Path Lab Usefulness

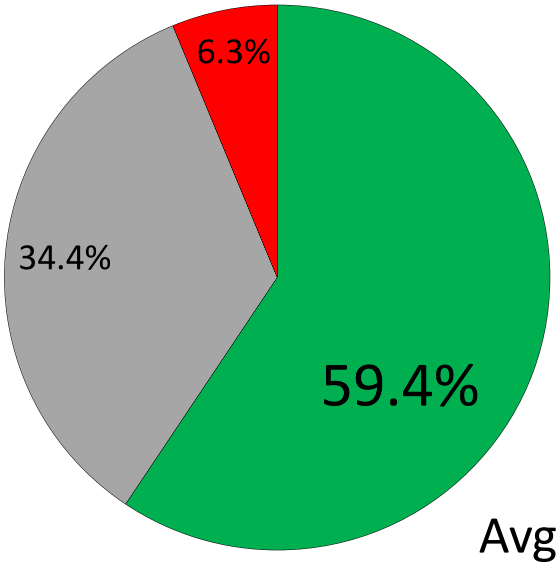


Likert Scale:

- 1 = Not Useful
- 5 = Very Useful

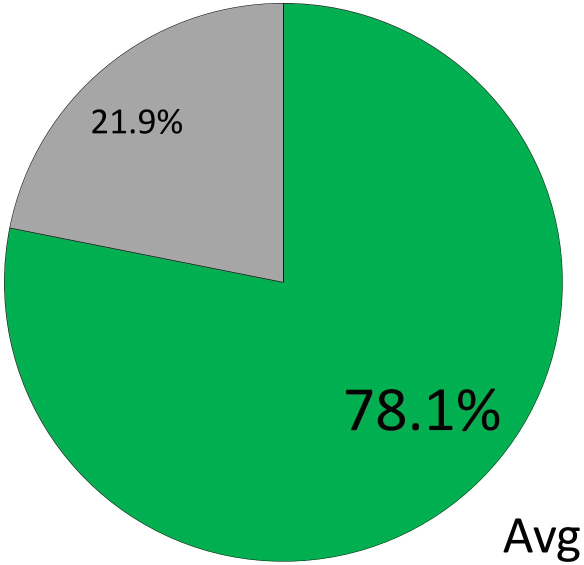
Utility of 3-D Printed Heart Models

3-D Printed "Normal" Anatomy Model Usefulness



Avg = 3.94

3-D Printed Congenital Pathology Models Usefulness

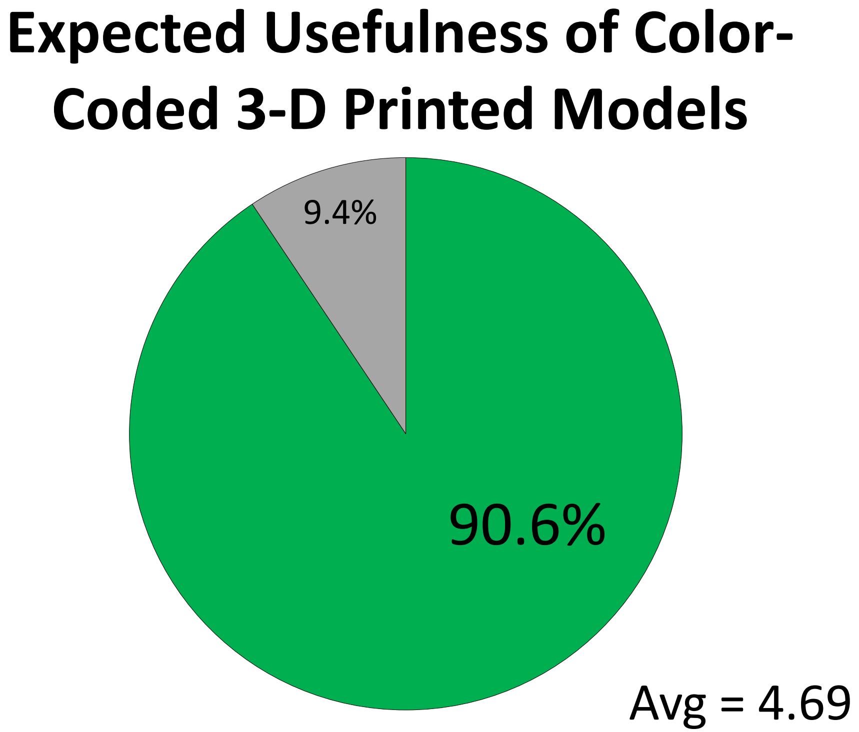


Avg = 4.25

Likert Scale:

- 1 = Not Useful
- 5 = Very Useful

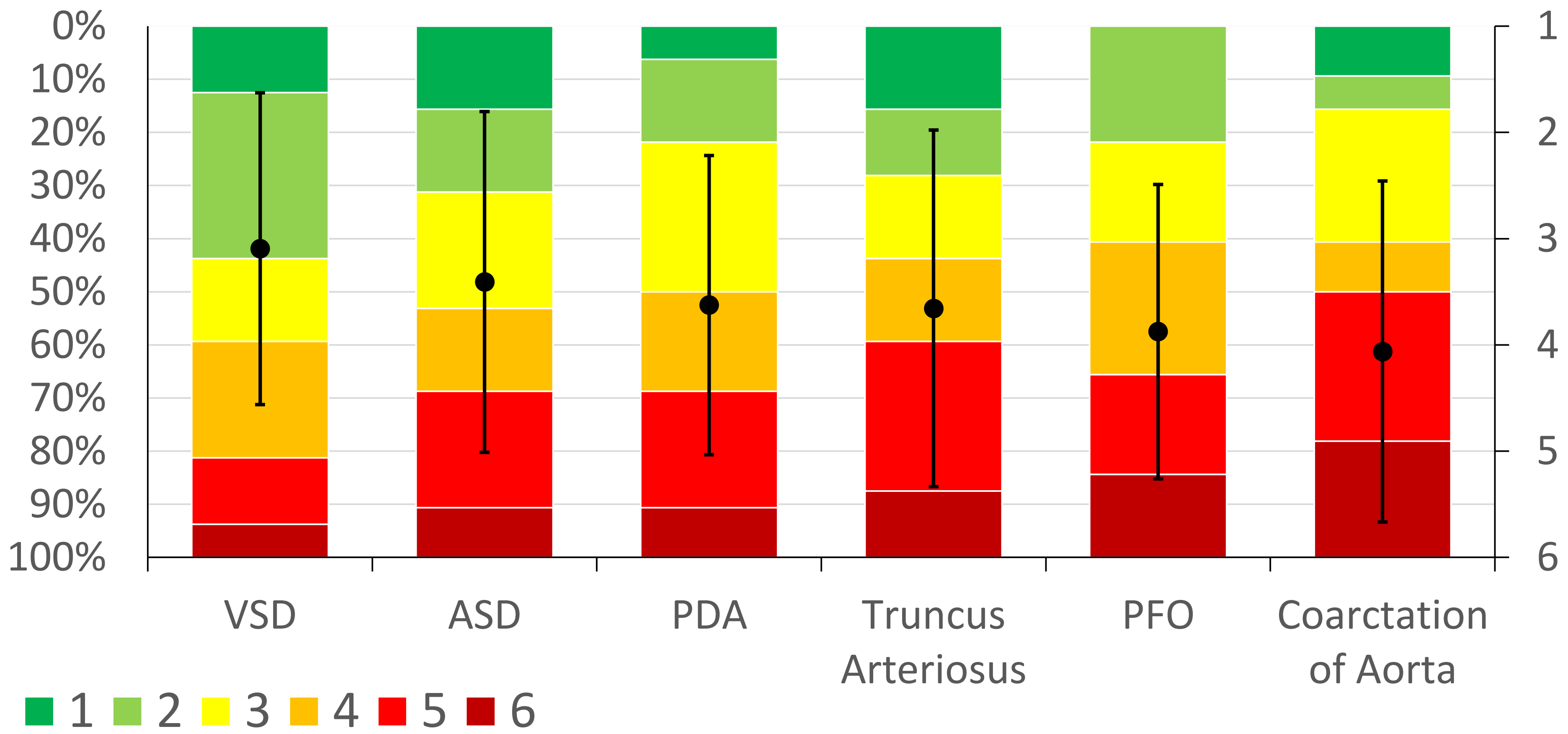
Exploration into Using Color Coded Models



Likert Scale:

- 1 = Not Useful
- 5 = Very Useful

Most Desired Models for Future Classes



The 6 choices were ranked against one another as priority for being printed as a model with a Ranking of 1 = Highest Priority

- VSD (highest priority by ranking) = 3.1 average ranking

Conclusions

Conclusions

Created multiple 3D heart models

- Normal Neonatal
- Tetralogy of Fallot
- Transposition of the Great Vessels
- Atrioventricular septal defect

Students confirm usefulness of 3D printed cardiac models

- Multicolor models highly desired by students

Optimized the 3D model for medical education

- Artistic design
- Color
- Print method

Future directions for 3D printing

Future Directions and Next Steps

Medical Education in “Basic Science” Coursework

- Manufacture more models
- Create models of more congenital heart pathologies
- Expand student-model interaction

Medical Education in “Clinical” Coursework

- Echocardiographic models for clinical learning

Patient Education

- PFO closure

Surgical Planning

- Rib resection
- Tracheal stenosis

Basic Science Medical Education

Manufacture more models

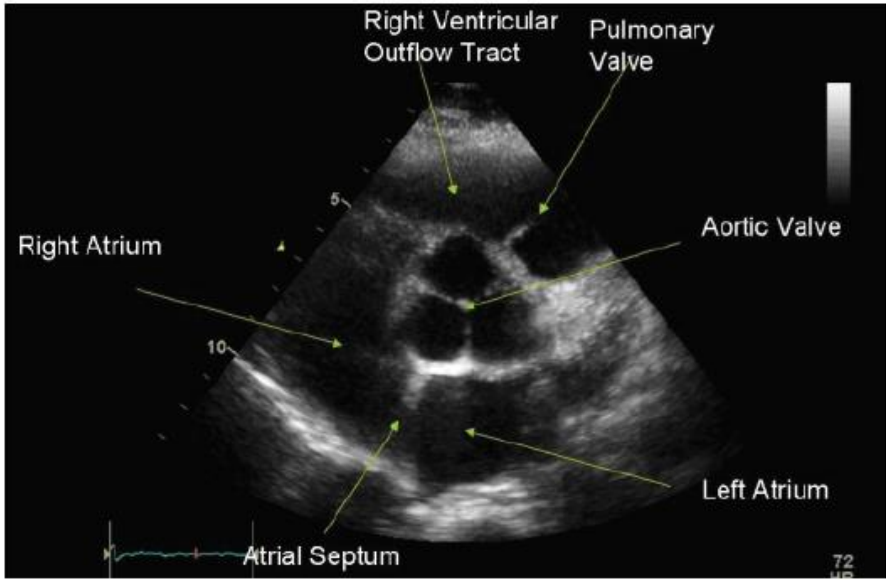
Student-Model interaction

Survey

Explore different pathology

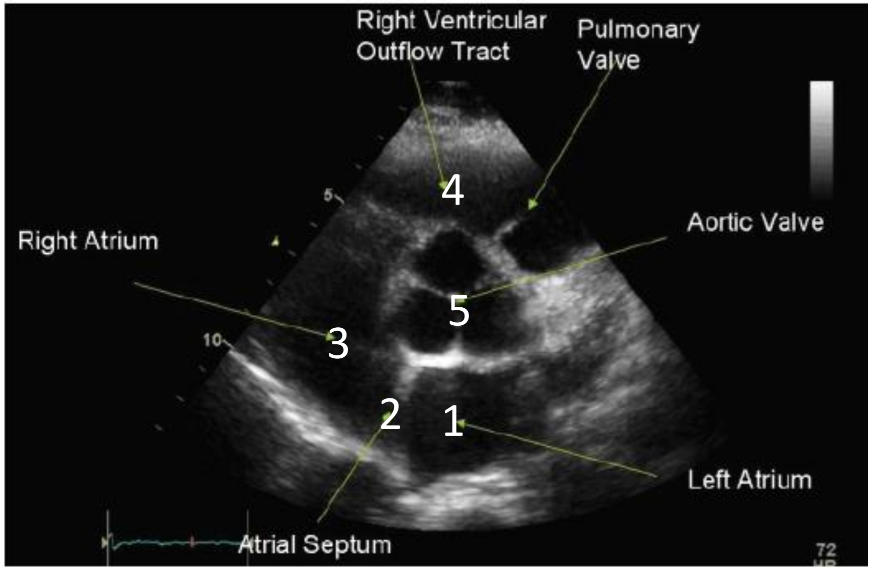
Clinical Medical Education

Echocardiography



Medical Education

Echocardiography



Future Directions for 3D Printing

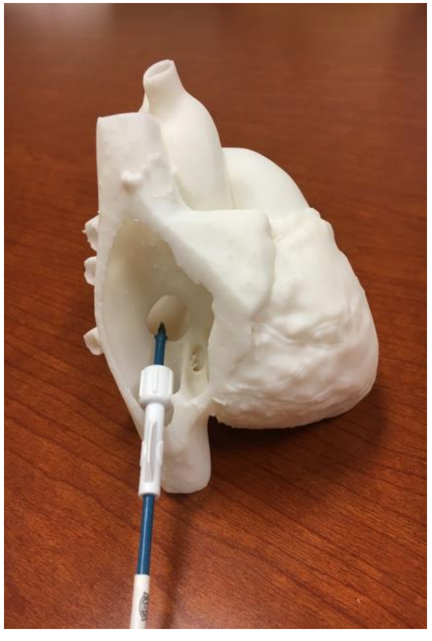
Medical Education

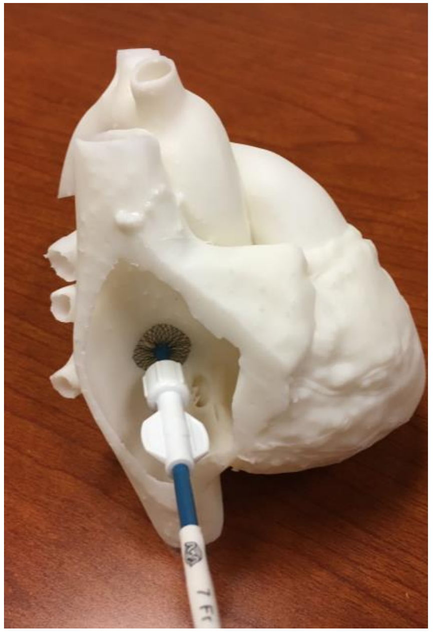
Surgical Planning

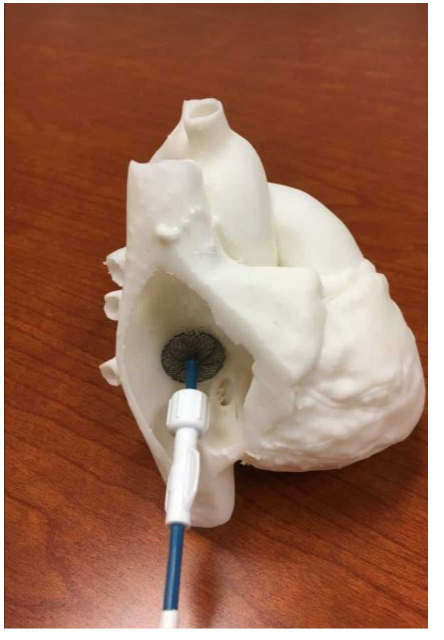
Patient Education

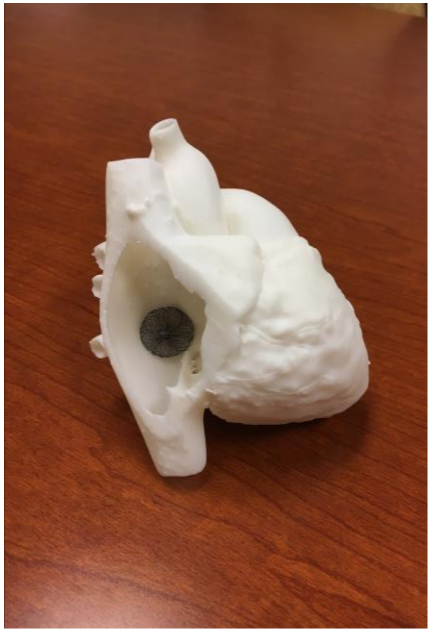
Patient Education

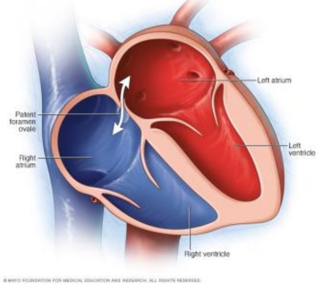
Percutaneous closure of patient foramen ovale



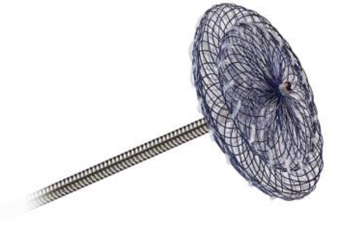




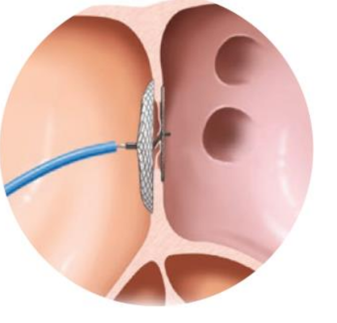




+



=



Future Directions for 3D Printing

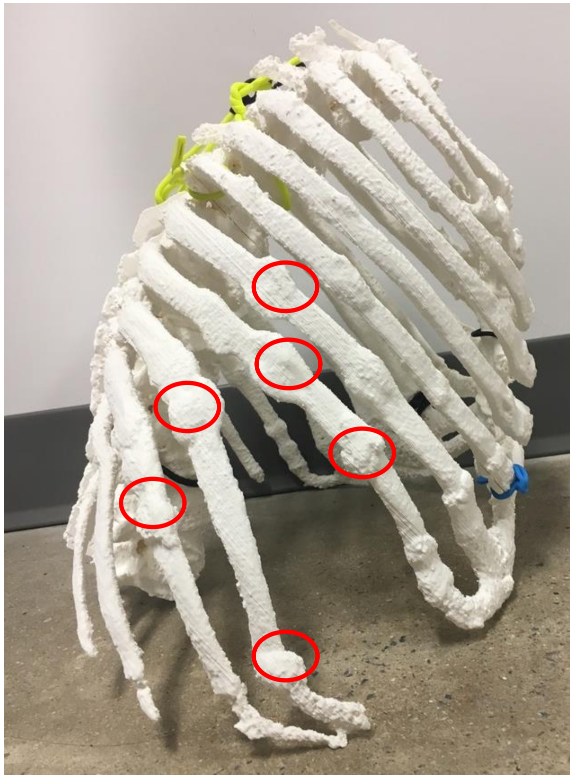
Medical Education

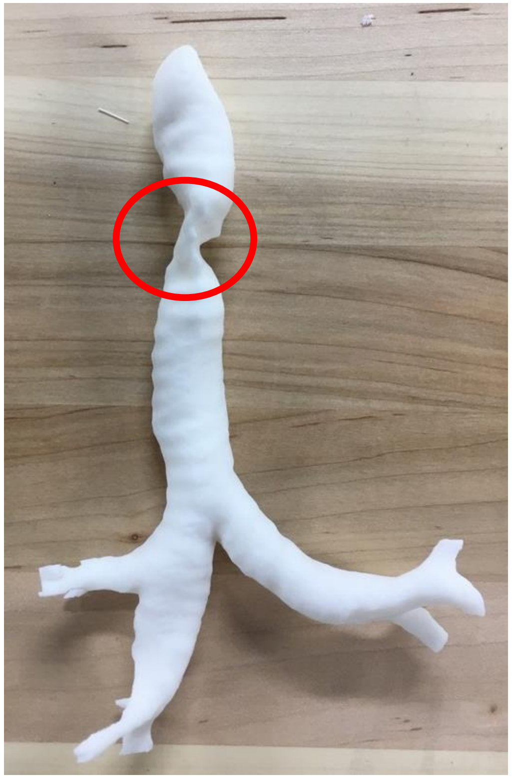
Surgical Planning

Patient Education

Future Directions for 3D Printing

Surgical Planning





Collaborators / Acknowledgements

Collaborators / Acknowledgements

Brody School of Medicine, East Carolina University	• Connor L. Pratson M3 → M4 • Connor J. Karr M4 → Intern
Department of Pathology and Laboratory Medicine, East Carolina University	• Philip J. Boyer, M.D., Ph.D. • Karen L. Kelly, M.D.
Department of Pathology, Duke University	• Andrea T. Deyrup, M.D., Ph.D.
Office of Student Development and Academic Counseling, Brody School of Medicine East Carolina University	• Terri N. Edwards
Department of Engineering, East Carolina University	• Kevin C. Nguyen • Joshua R. Butler
Innovation and Design Laboratory, East Carolina University	• William W. Godwin
E-Learning University Medical Center Groningen	• Anna Sieben

Need Models? Got Ideas?

Email: rayan16@students.ecu.edu