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

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Rationale / Need

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- 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
- 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**

Methods and Materials

Methods and Materials

- An **Index of Learning Styles survey** for the Classes of 2018-2020 was reviewed.
- Given an **interest in cardiology** by the medical student investigators, **cardiovascular pathology** was selected for a deep-dive into the pathology curriculum and teaching modalities.
- **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.

Methods and Materials

- Brody **learning objectives** were compared to those deployed at Duke and those cited in widely-used resources.
- **Second-year medical students** enrolled in the pathology course were **surveyed** regarding laboratory sessions.
- A new, optional **Congenital Heart Disease Laboratory** session was implemented based on the previous year's feedback
  - **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
    - **Potential role** of three dimensional **(3-D) printed models**. and specific diseases models could illustrate

Methods and Materials

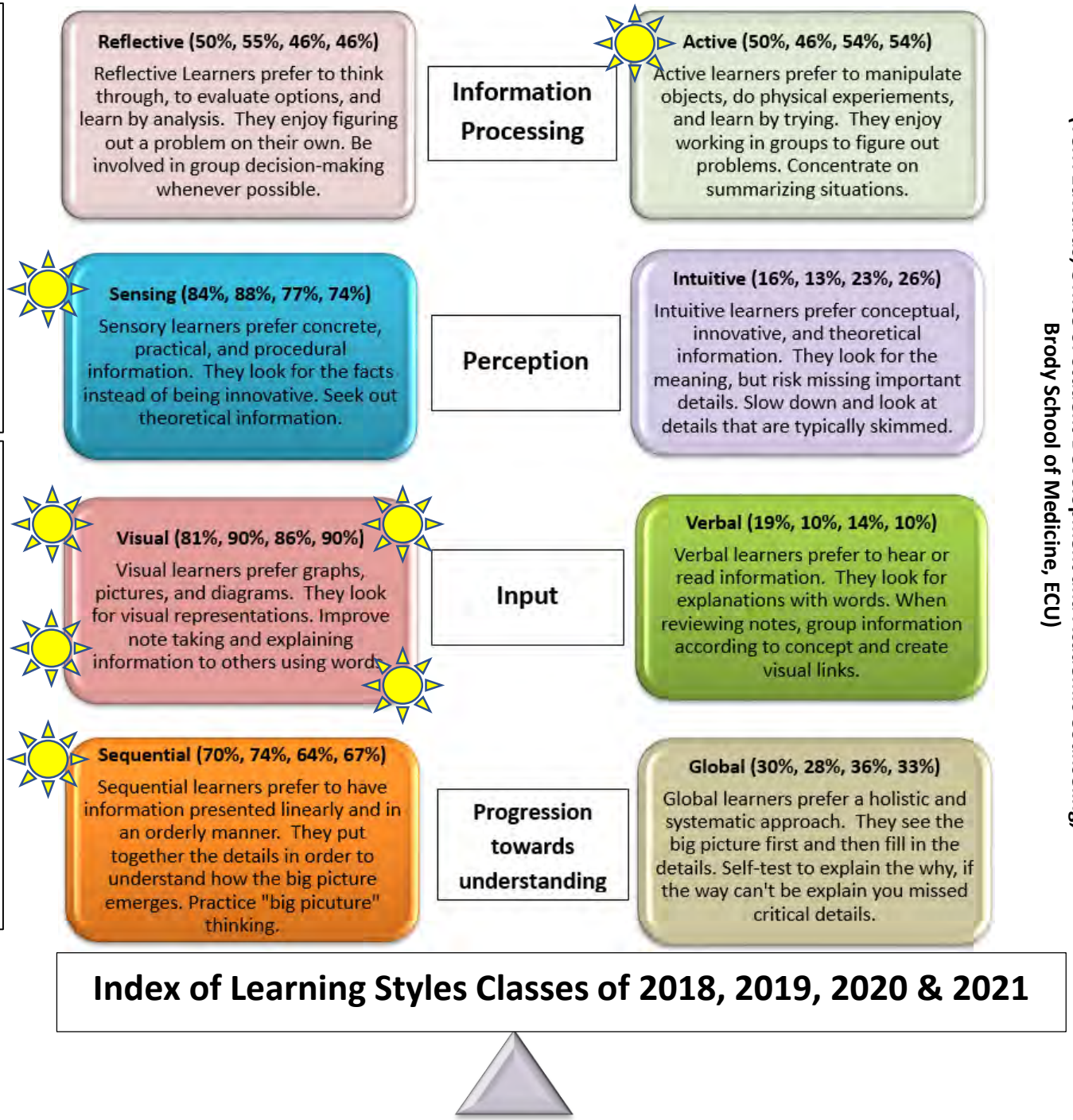
- **3-D model construct** was investigated for possible integration in 2018-2019 school year
  - Priority given to
    - Normal heart models
    - Diseases prioritized in survey

Preferred Learning Styles of Brody Medical Students

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)



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

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

What Should We Teach?

Curriculum Content

Pathology in Integrated Curriculum

Clinical Sciences

Basic Sciences

Block 3: Cell Injury & Death / Inflammation & Repair / Hemodynamics / Immune System / Nutrition / Environment / Neoplasia

Block 4.1: Cardiovascular / Renal & Urinary System

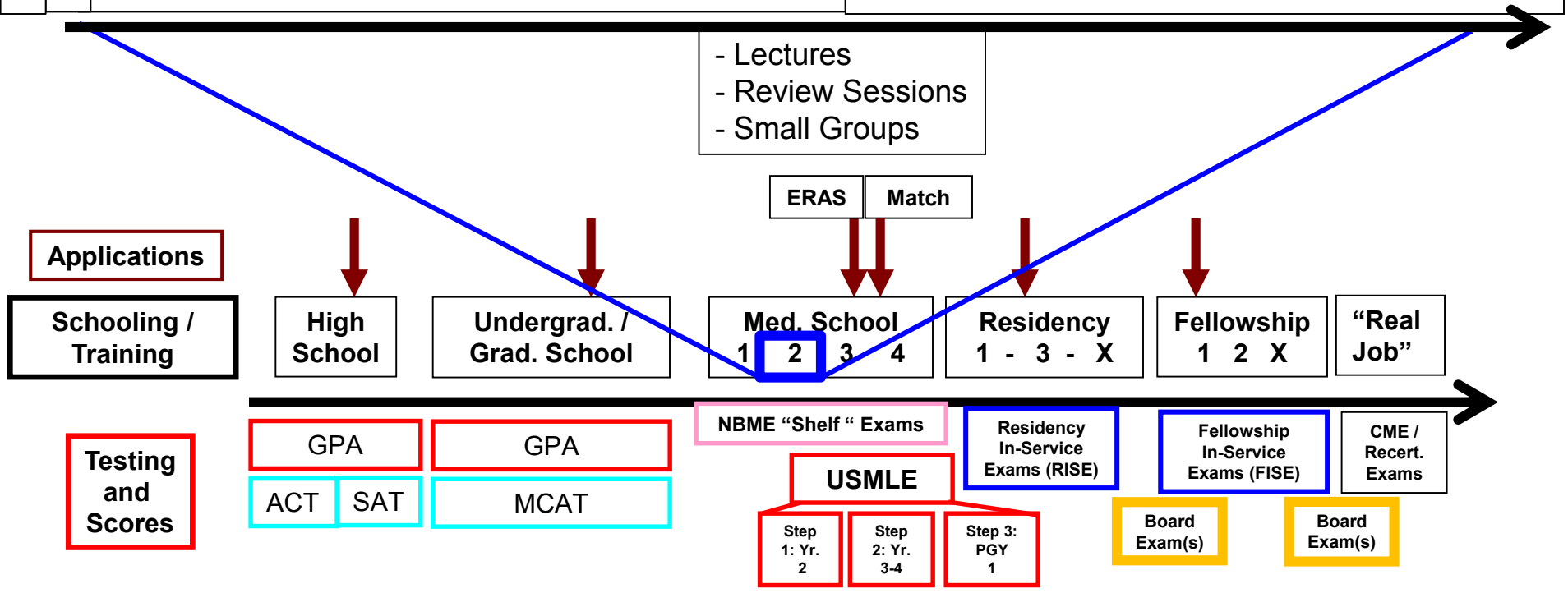
Block 4.2: Pulmonary / Rheumatology / Bone & Joint / Soft Tissue

Block 4.3: Central Nervous System; Nerve; NMJ; Muscle/ Infectious Disease

Block 4.4: Gastrointestinal / Liver & Gallbladder / Exocrine Pancreas / Pediatric Pathology

Block 4.5: Hematopathology; Hemostasis & Thrombosis /Transfusion Medicine / Skin / Eye

Block 4.6: Endocrine / Reproductive / Fetal-Maternal, Placenta / Laboratory Medicine



Cardiovascular Sections of Integrated Curriculum

SECTION 1 - CARDIO/RENAL 1 H Med, 15.75 H Pharm; Cardio: 11 H Path; 5 H Med, 1.5h CBS Renal: 11 H Path; 9 H Med, 1.5 H CBS

	Monday 08-13-18	Tuesday 08-14-18	Wednesday 08-15-18	Thursday 08-16-18	Friday 08-17-18
8:00	8:00-8:50 2S04 Pharm 4 Anti-Thrombotics 2	8:00-8:50 2S04 Pharm 5 Diuretics 1	8:00-8:50 2S04 Pharm 6 Diuretics 2	8:00-8:50 2S04 Pharm 7 Cardiac Ischemia-Angina	8:00-8:50 2S04 Pharm 8 Cardiac Ischemia-Infarct
8:30					
9:00	9:00-9:50 2S04 Path – Cardio 2	9:00-9:50 2S04 Path – Cardio 4	9:00-9:50 2S04 Path – Cardio 5	9:00-9:50 2S04 Path – Cardio 6	9:00-9:50 2S04 Med – Cardio 2
9:30	BVD; Vasculitis	Valvular Heart Disease	Atherosclerosis & Lipids	Coronary Artery Disease & Myocardial Infarct	Valve
10:00	10:00-10:50 2S04 Path – Cardio 3	10:00-11:20 2S04 Psych 4	10:00-11:30 6 rooms Ethics 10	10:00-10:50 2S04 Path – Cardio 7	10:00-10:50 2S04 Path – Cardio 9
10:30	BVD: Arterio- and Arteriolosclerosis, Dissection, Connective Tissue Disease, Aneurysm, Hypertension	Definitions/Classifications		Myocarditis; Cardiomyopathies	Heart Failure, Cardiac Neoplasms, Pericardial Disease
11:00	11:00-11:50 2S04 Psych 3			11:00-11:50 Labs Path – Cardio 8 **LAB 1**	11:00-11:50 2S04 Psych 5
11:30	Models & Mechanisms 2				Interviewing
12:00	LUNCH	LUNCH	LUNCH	Noon-12:50 FoM 2 LUNCH Career & Academic Development Small Groups	Student Organizations Fair
12:30					
1:00			1:00-5:00 Med – Cardio 1 Sim Lab 3 Rooms - (40 min per student group)	1:00-3:00 FoM PBL 1 Small Groups	
1:30		1:30-3:30 Doc2 2 Physical Diagnosis Rotation (PDR)			
2:00	2:00-5:00 Hold for Autopsy Experience				
2:30					
3:00					
3:30					
4:00					
4:30					

SECTION 1 - CARDIO/RENAL

	Monday 08-20-18	Tuesday 08-21-18	Wednesday 08-22-18	Thursday 08-23-18	Friday 08-24-18
8:00	**8:00-8:50 TC** **QUIZ 2** **(30 Questions Max)**	8:00-8:50 2S04 Pharm 9	8:00-8:50 2S04 Pharm 10	8:00-8:50 2S04 Pharm 11	8:00-8:50 2S04 Pharm 12
8:30		Congestive Heart Fail 1	Congestive Heart Fail 2	Hypertension 1	Hypertension 2
9:00	9:00-9:50 2S04 Path – Renal 1	9:00-9:50 2S04 Med – Cardio 3	9:00-9:50 2S04 Med – Cardio 4	9:00-9:50 2S04 Med – Renal 2	9:00-9:50 2S04 Med – Renal 4
9:30	Evaluation of Renal Disease	Coronary Artery Heart Disease	**CASES**	Diagnostic Approaches	Acid/Base
10:00	10:00-11:20 2S04 Psych 6	10:00-10:50 2S04 Path – Cardio 10	10:00-11:30 6 rooms Ethics 11	10:00-10:50 2S04 Med – Renal 3	10:00-10:50 2S04 Med – Renal 5
10:30	Mental Status Exam	Congenital Heart Disease		Fluids & Electrolytes	Acute Disease
11:00		11:00-11:50 2S04 Psych 7		11:00-11:50 2S04 Path – Renal 2	11:00-12:20 2S04 Psych 8
11:30	11:30-12:20 Labs Path – Cardio 11 **LAB** 2	Testing In PCP Setting Rating Scales		Histology & Mechanisms Of Renal Disease	Neurocognitive Disorders
12:00		LUNCH	LUNCH	LUNCH	
12:30	LUNCH				LUNCH
1:00				1:00-4:00 FoM PBL 2 Small Groups	
1:30		1:30-3:30 2S04 Doc2 3 PDR	**1:30-3:00** **Med** **Case-Based Study** **Cardiovascular**		
2:00					
2:30	2:30-5:00 Hold for Autopsy Experience				
3:00					
3:30					
4:00					
4:30					

Pathology **Pharmacology** **Medicine** **Psychiatry** **Doctoring** **Foundations of Medicine**

Topic Comparison

- No peer-reviewed publication was identified which summarized consensus cardiovascular pathology topics for medical students
- Key topics in legacy Pathology curriculum were compared to available topic sources relevant to teaching cardiovascular pathology:
  - Duke University Curriculum
  - USMLE Step 1 Content Description and General Information, 2013-2014
  - USMLE Step 2 Clinical Knowledge (CK) Content Description and General Information, 2014
  - Robbins Pathology
  - Group for Research in Pathology Education (GRIPE)

Duke Curriculum

Collaboration: Andrea T. Deyrup, M.D., Ph.D., Course Director

DukeMedicine

Pathology and Virtual Microscopy Resources
Duke University Medical School

	Duke Anatomy	Duke Embryology	Duke Histology	Duke Neuro	HOME
Normal Lab Values	PathologyPics	Pathopics	WebPath	UMich Basic Path	UMich Pathology

Duke Clinical Tools (Login to Duke VPN for full access)

Search this site | Jump to Another Topic

Pathology Topic

Week 1: Cell Injury	Feb 6 - 10
Week 2: Inflammation	Feb 13 - 17
Week 3: Circulatory Dysfunction	Feb 20 - 24
Week 4: Genetic Disorders	Feb 27 - March 3
Week 5: Immunopathology	Mar 6 - 10
Week 6: Neoplasia	Mar 14 - 17
Week 7: Environmental Pathology	Mar 20 - 24
SPRING BREAK	Mar 27 - 31
Week 8: Central Nervous System Part 1	Apr 3 - 7
Week 9: Central Nervous System Part 2	Apr 10 - 14
Week 10: Nerve, Muscle, & Eye	Apr 17 - 21
Week 11: Pulmonary System	Apr 24 - 28
Week 12: Cardiovascular System	May 1 - 5
Week 13: Hematologic Disease	May 8 - 12
Week 14: Renal & Bladder	May 15 - 19
Week 15: Endocrine & Male Genital	May 22 - 26
Week 16: Breast & Gynecologic Disease	May 29 – Jun 2
Week 17: Hepatobiliary & Pancreas	June 5 - 9
Week 18: Gastrointestinal Tract	June 12 - 16
Week 19: Musculoskeletal & Dematologic	June 19 - 23

COMPREHENSIVE LIST OF CASES & DIAGNOSES

COMPREHENSIVE LIST OF GROSS SPECIMEN VIDEOS

CARDIOVASCULAR PATHOLOGY Review Items

Key Vocabulary Terms (click here to search any additional terms on *Stedman's Online Medical Dictionary*)

anastomosis	marantic endocarditis
aneurysm	mitral valve prolapse
angina pectoris	myocardial infarct
arrhythmia	myocarditis
Aschoff body	necrosis
cardiac tamponade	pericarditis
cardiogenic shock	Prinzmetal angina
cardiomyopathy	reperfusion injury
congestive heart failure	rheumatic fever
contraction band	rheumatic heart disease
cor pulmonale	stenosis
dextrocardia	sudden cardiac death
diastole	systole
ductus arteriosus	tetralogy of Fallot
endocardial fibroelastosis	transposition of great vessels
endocarditis	truncus arteriosus
foramen ovale	unstable angina
heart failure	valvular insufficiency
hemopericardium	valvular regurgitation
hypertension	valvular stenosis
ischemic heart disease	vegetation
Libman-Sacks endocarditis	

LEARNING OBJECTIVES

Absolutely critical information you must know to practice medicine is in bold font.
Important information that will be needed for routine patient care is in regular font.
Information about less common diseases that you may encounter in clinical practice and that will probably appear on examinations is i italics

1. **List the most common forms of heart disease in the United States**

2. **Contrast and compare the clinical and pathologic features of the following:**
   - **congestive heart failure**
   - **high-output heart failure**
   - **left-sided heart failure**
   - **right-sided heart failure**
   - **cor pulmonale**

3. **Discuss cardiogenic shock in terms of:**
   - **etiologic factors**
   - **pathogenesis**
   - **morphology**
   - **stages**
   - **clinical manifestations**

4. Discuss congenital heart disease in terms of:
   - genetic and environmental factors
   - types which result in:
     - left-to-right vs. right-to-left shunts
     - cyanotic vs. acyanotic disease
   - types which come to medical attention in:
     - infancy
     - childhood
     - adulthood

5. Compare and contrast clinical and pathologic features of congenital heart disease:
   - atrial septal defect (ASD)
   - ostium primum
   - ostium secundum
   - venticular septal defect (VSD)
   - tetralogy of Fallot
   - endocardial cushion defects
   - hypoplastic left heart syndrome
   - patent ductus arteriosus (PDA)
   - transposition of the great vessels
   - coarctation of the aorta
   - preductal
   - postductal
   - anomalous pulmonary venous return

6. **Compare and contrast clinical and pathologic features of the following**
   - **endocarditis**
   - **myocarditis**
   - **pericarditis**
   - **pericardial effusion**
   - **cardiac tamponade**
   - **pancarditis**

7. Compare and contrast the clinical and pathologic features of the following
   - acute rheumatic fever.
   - chronic rheumatic heart disease

8. Compare and contrast the clinical and pathologic features of valvular heart disease
   - calcific aortic stenosis
   - aortic insufficiency
   - mitral stenosis/insufficiency
   - mitral valve prolapse
   - mitral annular calcification
   - tricuspid insufficiency
   - pulmonic insufficiency
   - infectious endocarditis

10. Compare and contrast the clinical and pathologic features of the following:
    - dilated (congestive) cardiomyopathy
    - hypertrophic cardiomyopathy (idiopathic hypertrophic subaortic stenosis (IHSS)
    - restrictive cardiomyopathy
    - endomyocardial fibrosis
    - eosinophilic (Loeffler) endomyocarditis
    - endocardial fibroelatosis

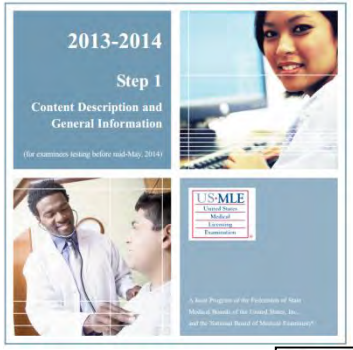
11. **Discuss coronary artery disease, in terms of:**
    - **epidemiology**
    - **risk factors**
    - **etiologic factors**
    - **pathogenesis**
    - **complications**

12. Develop an understanding of acute coronary syndrome, relationship to plaque rupture and thrombosis, develop an understanding of the role of interventional cardiology and bypass surgery and why these treatments are used.

13. **Discuss myocardial infarct, in terms of:**
    - **etiologic factors**
    - **risk factors**
    - **pathogenesis**
    - **morphology**
      - **evolution of morphologic changes with time**
      - **correlation of morphologic distribution of infarct with site of coronary artery disease**
    - **clinical, laboratory, and electrocardiography findings that change with time after the event**
    - **complications, including expected timing after the event**
    - **prognosis, and common causes of death with increasing time after the event**

14. **Discuss sudden cardiac death, in terms of:**
    - **causes**
    - **relationship to arrhythmias**
    - **cardiac morphology**

15. *Discuss the following cardiac tumors*
    - *myxoma*
    - *rhabdomyoma*
    - *lipoma*
    - *metastatic*



USMLE Step 1 Topic List

2013-2014

(www.usmle.org)

Cardiovascular System

Normal processes

- embryonic development, fetal maturation, and perinatal changes
- organ structure and function
  - chambers, valves
  - cardiac cycle, mechanics, heart sounds, cardiac conduction
  - hemodynamics, including systemic, pulmonary, coronary, and blood volume
  - circulation in specific vascular beds
- cell/tissue structure and function
  - heart muscle, metabolism, oxygen consumption, biochemistry, and secretory function
  - endothelium and secretory function, vascular smooth muscle, microcirculation, and lymph flow (including mechanisms of atherosclerosis)
  - neural and hormonal regulation of the heart, blood vessels, and blood volume, including responses to change in posture, exercise, and tissue metabolism
- repair, regeneration, and changes associated with stage of life

Abnormal processes

- infectious, inflammatory, and immunologic disorders
- traumatic and mechanical disorders
- neoplastic disorders
- metabolic and regulatory disorders (including dysrhythmias, systolic and diastolic dysfunction, low- and high-output heart failure, cor pulmonale, systemic hypertension, ischemic heart disease, myocardial infarction, systemic hypotension and shock, and dyslipidemias)
- vascular disorders
- systemic diseases affecting the cardiovascular system
- congenital and genetic disorders of the heart and central vessels
- idiopathic disorders
- drug-induced adverse effects on the cardiovascular system
- degenerative disorders

2014 USMLE United States Medical Licensing Examination

Step 2 CK
Content Description and General Information

(www.usmle.org)

USMLE Step 2 Topic List

2014

Cardiovascular Disorders

Health and Health Maintenance

- Arterial hypertension
- Atherosclerosis and coronary artery disease; hyperlipidemia
- Prevention of rheumatic heart disease, thromboembolic disease, pulmonary emboli, bacterial endocarditis

Mechanisms of Disease

- Cardiac output, resistance, central venous pressure
- Valvular stenosis, incompetence
- Congenital heart disease
- Regulation of blood pressure
- Disorders of the arteries and veins

Diagnosis

- Dysrhythmias; palpitations, syncope (eg, premature beats; paroxysmal tachycardias; atrial flutter and fibrillation; bradycardias; ventricular fibrillation; cardiac arrest)
- Heart failure (congestive, diastolic, systolic dysfunction), dyspnea, fatigue, peripheral edema of cardiac origin (eg, chronic heart failure; cor pulmonale)
- Ischemic heart disease; chest pain of cardiac origin (eg, angina pectoris; coronary insufficiency; myocardial infarction)
- Diseases of the myocardium (eg, hypertrophic; myocarditis)
- Diseases of the pericardium (eg, acute pericarditis; chronic constrictive pericardiopathy; pericardial effusion; pericardial tamponade)
- Valvular heart disease (eg, acute rheumatic fever; mitral and aortic valve disorders; infective endocarditis)
- Congenital cardiovascular disease (eg, patent ductus arteriosus; atrial septal defect; ventricular septal defect; endocardial cushion defect; tetralogy of Fallot; coarctation of the aorta)
- Systemic hypotension, hypovolemia, cardiogenic shock; cyanosis
- Arterial hypertension (eg, essential; secondary)
- Atherosclerosis - lipoproteins
- Disorders of the great vessels (eg, dissecting aortic aneurysm; ruptured aneurysm; aortoiliac disease)
- Peripheral arterial vascular diseases, vasculitis (eg, polyarteritis; temporal arteritis; arteriovenous fistula)
- Diseases of the veins, peripheral edema (eg, varicose veins; thrombophlebitis; deep venous thrombosis)
- Traumatic injury

Topic Comparison

Robbins and Cotran Topic List	USMLE Step 1 – 2013 Topic List	USMLE Step 2 – 2012-2013 Topic List
Vessel: Structure Arteriosclerosis Atherosclerosis Aneurysm and dissection Vasculitis Veins and lymphatics Vascular Tumors Pathology of vascular intervention	Infectious, Inflammatory, Immunologic disorder Traumatic and mechanical disorder Metabolic and regulatory disorder: • Dysrhythmia • Dysfunction • Heart failure • Cor Pulmonale • Systemic hypertension • Ischemic heart disease • Myocardial infarct • Hypotension and shock • Dyslipidemia Vascular disorders Systemic disease affecting CV system Congenital and genetic disorders Idiopathic disorders Drug induced adverse effects Degenerative disorders	**Diagnosis of:** Dysrhythmia, palpitation, syncope Heart failure Ischemic heart disease, Chest pain of cardiac origin Diseases of myocardium Diseases of pericardium Valvular heart disease Congenital cardiovascular disease Systemic hypotension, hypovolemia, cardiogenic shock; cyanosis Arterial hypertension Atherosclerosis Disorders of great vessels Peripheral arterial vascular diseases Vasculitis Diseases of the veins and peripheral edema Traumatic injury
Cardiac: Structure Aging Heart Failure Congenital Heart disease Ischemic Heart disease Cardiomyopathies Pericardial Disease Rheumatologic Disorder Tumors of Heart		

Topic Comparison

Conclusions from Analysis of Resources

- Content in **Brody legacy cardiovascular course** **follows** **Robbins** topic lists
- **Gap Analysis**: **No gaps identified**
  - Near perfect overlap with Duke curriculum learning objectives and key words
  - All USMLE Step 1 & 2 topics covered
  - All GRIPE topics covered: topics recapitulate listing from Robbins

How Do We Currently Teach Content?

Lecture and Laboratory

Cardiovascular Disease Pathology

2017

Philip Boyer, M.D., Ph.D.
Karen Kelly, M.D.
Peter Kragel, M.D.

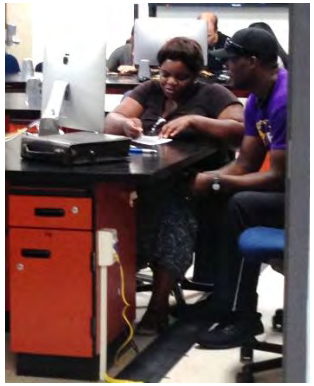
Fri- Aug 11	10:00-10:50	Cardiovascular 1 – Blood Vessel Disease (BVD): Congenital & Tumors	Boyer
Mon- Aug 14	10:00-10:50	Cardiovascular 2 - BVD: Vasculitis	Boyer
Tues- Aug 15	9:00-9:50	Cardiovascular 3 - BVD: Arterio- and Arteriolosclerosis, Dissection, Connective Tissue Disease, Aneurysm; Hypertension	Boyer
Wed- Aug 16	9:00-9:50	Cardiovascular 4 - Valvular Heart Disease	Kelly
Wed- Aug 16	10:00-10:50	Cardiovascular 5 - Atherosclerosis and Lipids	Boyer
Wed- Aug 16	11:00-11:50	Cardiovascular 6 - Coronary Artery Disease & Myocardial Infarct	Boyer
Thurs- Aug 17	10:00-10:50	Cardiovascular 7 - Myocarditis; Cardiomyopathies	Kelly
Thurs- Aug 17	11:00-11:50	**Cardiovascular 8 Laboratory - 7th Floor**	Boyer/Kragel
Fri- Aug 18	10:00-10:50	Cardiovascular 9 - Heart Failure, Cardiac Neoplasms, Pericardial Disease	Boyer
Mon- Aug 21		**No Path Scheduled**	
Tues- Aug 22	10:00-10:50	Cardiovascular 10 - Congenital Heart Disease	Kelly
Wed- Aug 23	11:00-11:50	**Cardiovascular 11 Laboratory - 7th Floor**	Boyer / Kragel

CV Session Construct: Current

- **Lecture Sessions: N = 9**
  - **Setting:** Traditional classroom
  - **Formative Assessment:** All sessions include case-based, poll-style questions (**TurningPoint**, TurningTechnologies.com)
    - Attendance is assessed via TurningPoint response
  - **Recordings:** Sessions are recorded (MediaSite, Sonicfoundry.com)
  - **Attendance**: Optional
    - Attendance Bonus Points: 70% attendance
      - 1 Point available for each section examination score with
      - 1 Point available for final course grade if criteria met for all Block 3 and Block 4 examinations
- **Small Group Discussion Sessions: N = 0**
  - Too few pathology faculty to allow for small group sessions

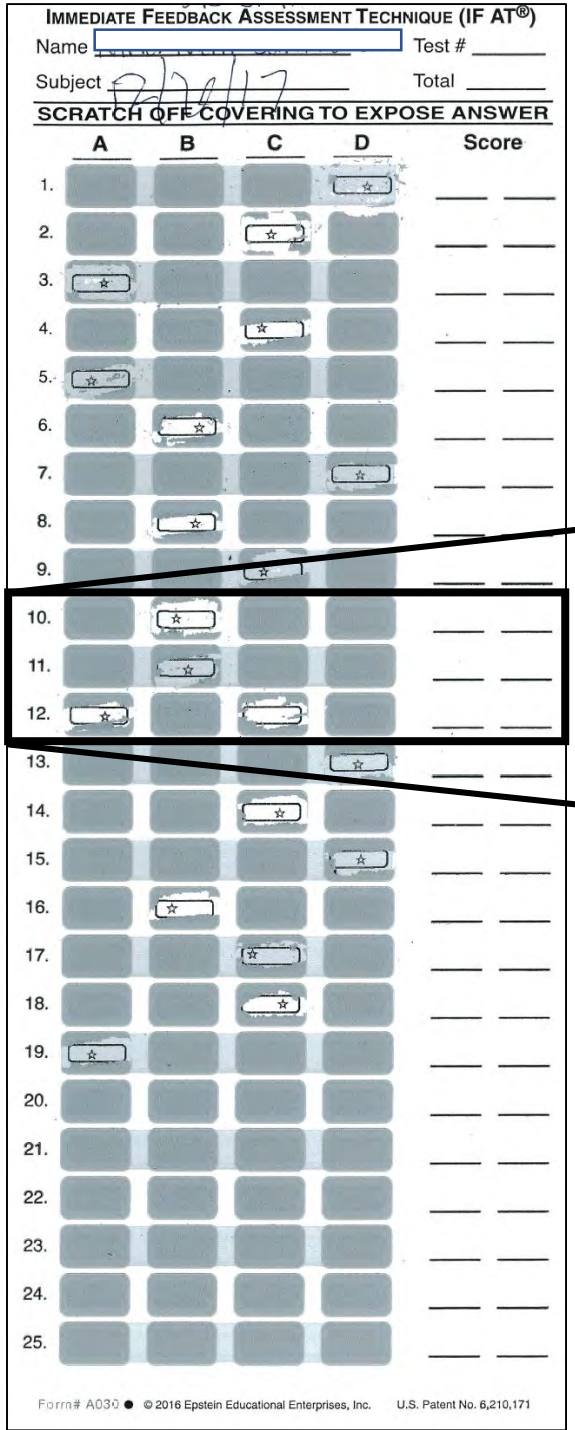
CV Session Construct: Current

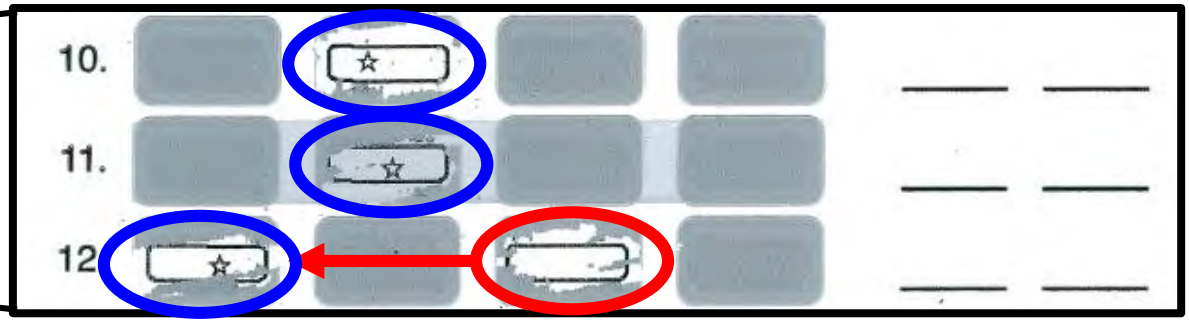
- **<u>Laboratory Sessions</u>:** N = 2
  - **Setting:** Laboratory space, 7th Floor of Brody Building


  - **Components:**
    - **<u>Small Groups of Students</u>:** Case-based PowerPoint content with questions reviewed; group responses to questions recorded on Immediate Feedback Assessment Technique scratch cards (Epstein Educational Enterprises)
    - **<u>Gross Organs - Normal and Abnormal</u>:** Demonstration and discussion of key pathologic entities
  - **Attendance**: Attendance at ≥ 50% of total sessions required
    - New for 2017-2018 school year

Immediate Feedback Assessment Technique (IFAT)





Congenital Cardiovascular Lab: 2017

- **Outlier**
  - **Congenital heart disease specimens had not been demonstrated in the past**
    - Time constraints
    - Small size of specimens
- **Details**
  - Held in PM
  - Date held: conflicts for some students
- **Sessions**
  - 2
- **Attendees**
  - 20

Surveys

2016-2017 Laboratory Survey:

- **Class of 2019 Survey:**
  - **33 Responses**
  - **Attendance**: at least 1 laboratory session during the year:
    - 100%
    - Attendance was entirely optional for this group of students
  - Attendance of both cardiovascular sessions
    - 75%

Parameter	All Laboratory Sessions	Cardiovascular Laboratory Sessions
Usefulness of Laboratory Sessions	4.44 / 5	4.35/5
Aided in Understanding Content	4.45/5	4.45/5

- **Interest in Optional Congenital Heart Disease Laboratory**
  - **100%**

2017-2018 Laboratory Survey:

- **Class of 2020 Survey:**
  - **33 Responses**
    - **100% Response from Cardiovascular Disease Lab Attendees**
      - **N = 20**
  - **Attendance**: 50% Attendance Required
    - Cardiovascular Laboratory 1: 100%
    - Cardiovascular Laboratory 2: 93.8%

Parameter	**CV Lab 1**	**CV Lab 2**	**Congenital Heart Disease Laboratory**
Usefulness of Laboratory Sessions	All Students: 4.4 / 5 CHD Attendees: 4.6 / 5	All Students: 4.3 / 5 CHD Attendees: 4.5 / 5	All Students: N/A CHD Attendees: 4.6 / 5

Course Survey: 2017

- **Most Useful Cardiovascular Laboratory Specimens:**

Specimen	All Students	CV Lab Attendees
Aortic Dissection	58.6% (n=17)	45% (n=9)
Valvular Disease	44.8% (n=13)	45% (n=9)
Atherosclerosis	37.9% (n=11)	25% (n=5)
Aneurism	34.5% (n=10)	30% (n=6)
Arteriosclerosis	31% (n=9)	45% (n=9)
Cardiomyopathy	31% (n=9)	30% (n=6)
Myocardial Infarction	27.6% (n=8)	20% (n=4)
Heart Failure	17.2% (n=5)	25% (n=5)
Myocarditis	6.9% (n=2)	10% (n=2)
Coronary Artery Disease	6.9% (n=2)	5% (n=1)
Pericardial Disease	6.9% (n=2)	5% (n=1)

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)

Comments

- (S)ince 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.

Course Survey: 2017

Which specimens would most benefit from a 3D model for demonstration and evaluation?

Responses: N = 7

- **Tetrology of Fallot** **7**
- **Transposition of Great Vessels** **3**
- **Truncus Arteriosus** **3**
- **Coarctation of Aorta** **1**

Comments

- 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.

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
- **Pediatric Resident congenital heart disease session**
  - 3D Models vs.
  - Photographs (2D)
- **Conclusion**:
  - 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.

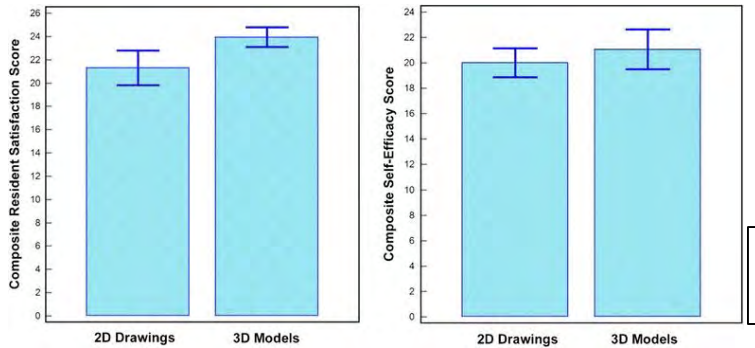
Methods: Pediatric residents rotating through an inpatient Cardiology rotation were recruited. The sessions were randomized into using either conventional 2D drawings of tetralogy of Fallot or physical 3D models printed from 3D cardiac imaging data sets (cardiac MR, CT, and 3D echocardiogram). Knowledge 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

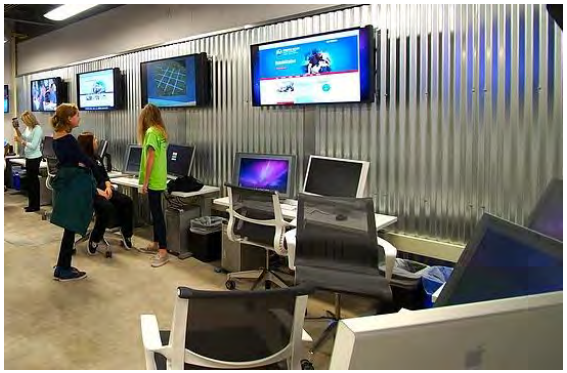
Not Statically Significant Difference

Innovation and Design Laboratory, East Carolina University

William W. Godwin: Director

Collaboration with ECU College of Engineering Students:

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



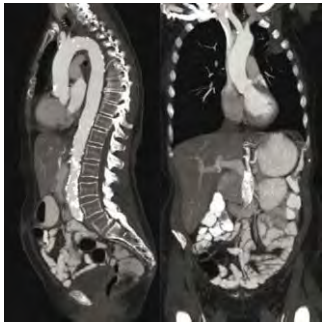
(bwarchitecture.info/about1-c12qf)

3D Printer: MakerBot Replicator - 5th Generation

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

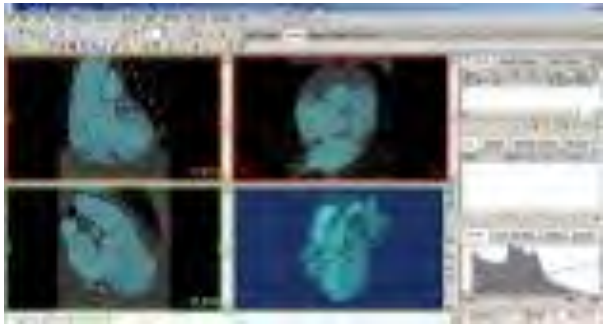
Overview: 3D Printing Process

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

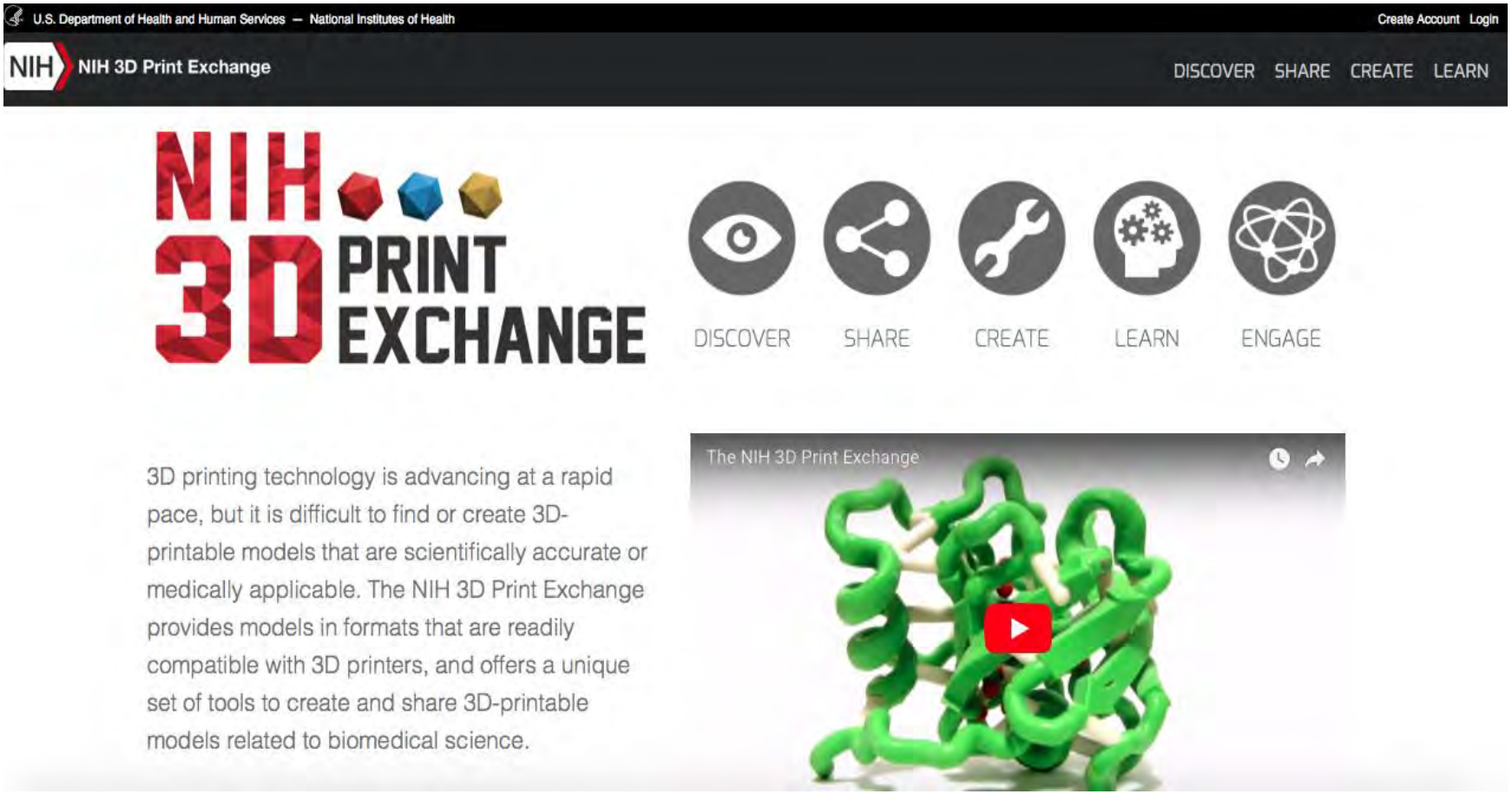
Step 4: Print Model

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

Simplified 3D Printing Process

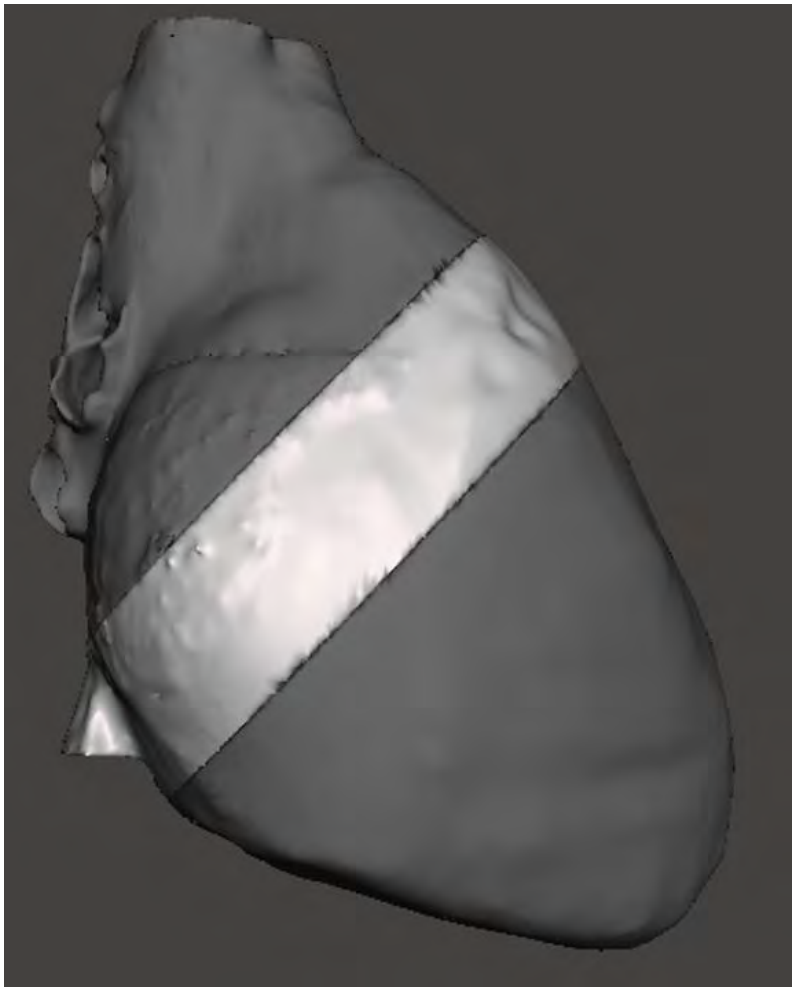
Step 1: Access NIH 3D Print Exchange

Step 2: Print Model

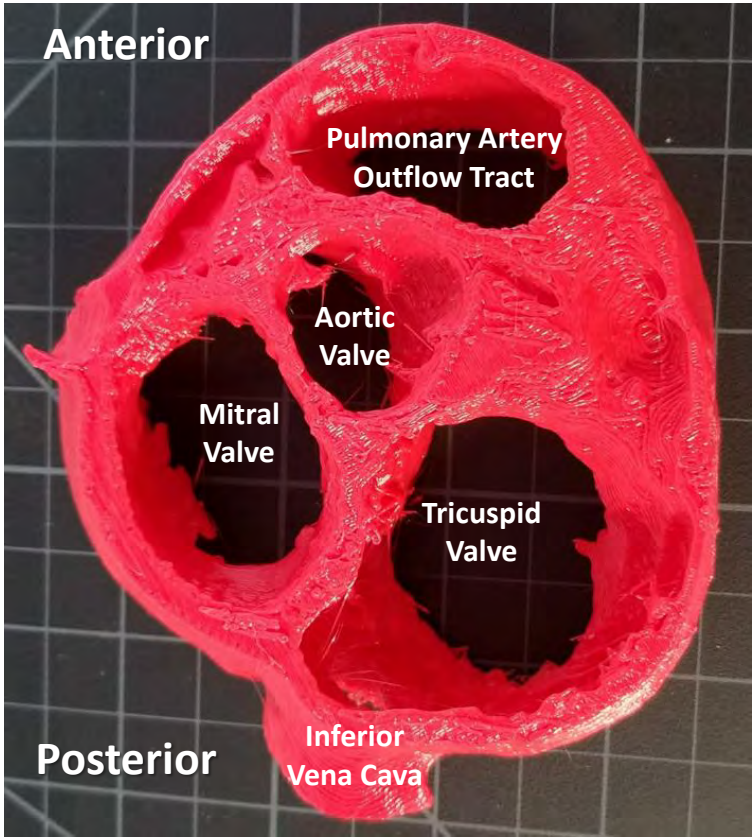


(3dprint.nih.gov)

Normal Heart: 17-Year-Old Woman, Diastole
Created Using 3D Reconstruction Software of CT Images

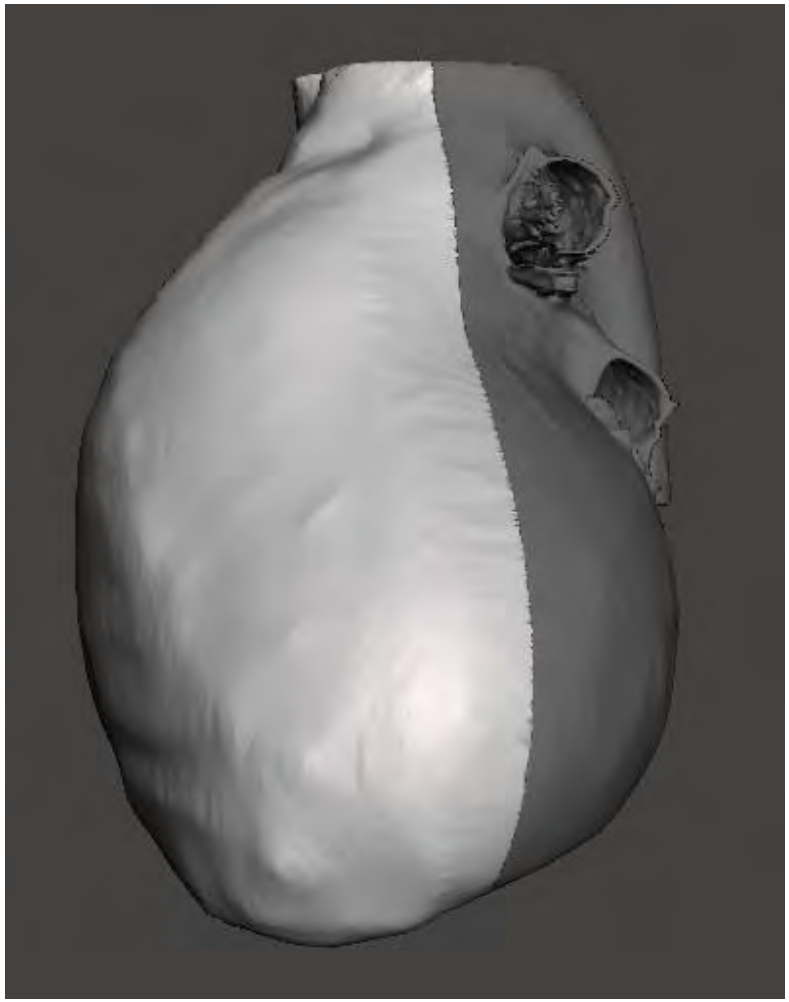


3D Printing Based on CT Imaging Data & 3D Reconstruction

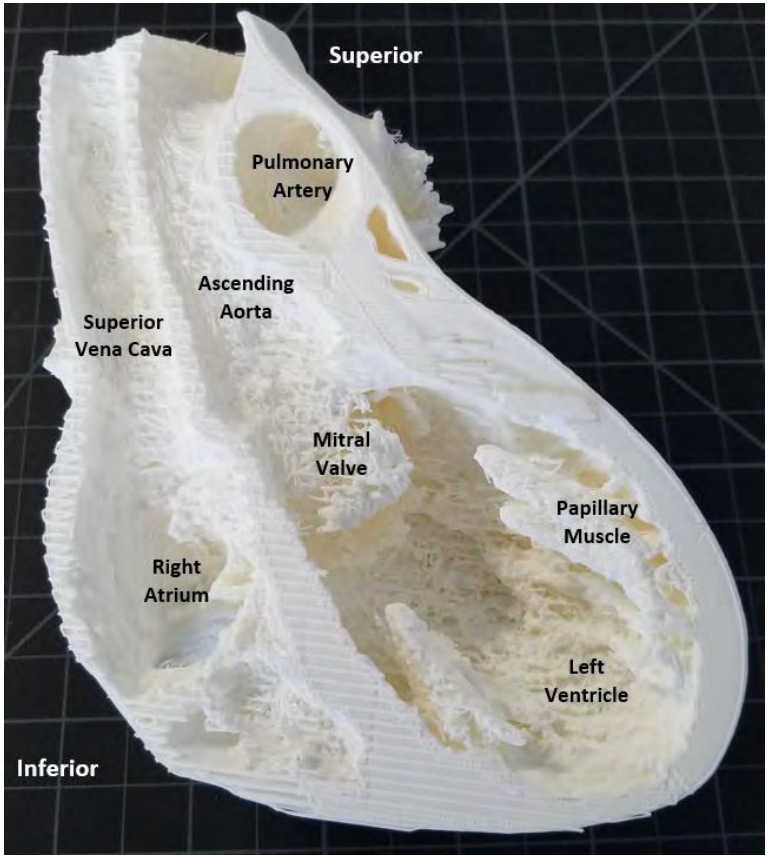


Data Source: 3dprint.nih.gov, Matthew Bramlet, Model ID: 3DPX-001684

Normal Heart: 17-Year-Old Woman, Diastole
Created Using 3D Reconstruction Software of CT Images

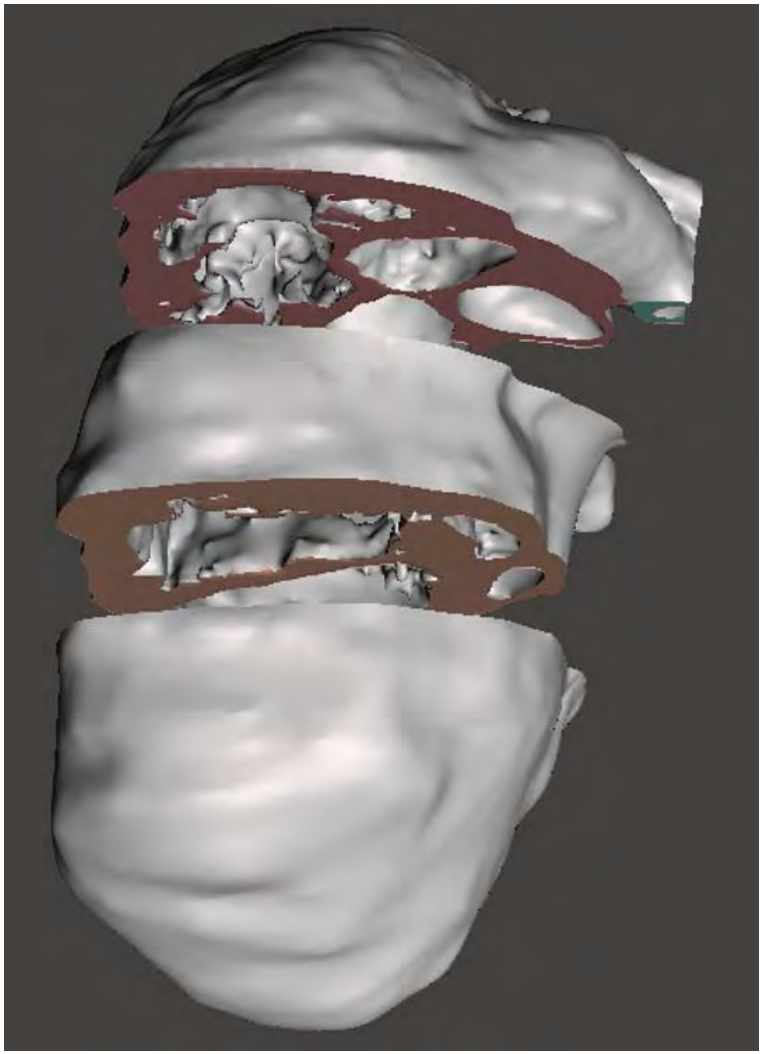


3D Printing Based on CT Imaging Data & 3D Reconstruction

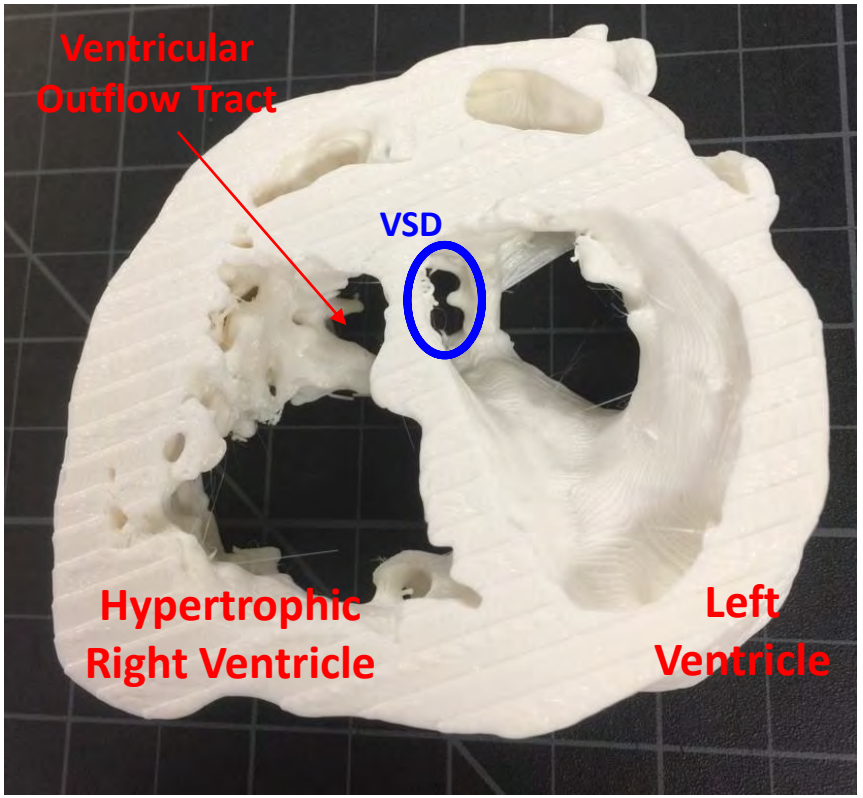


Data Source: 3dprint.nih.gov, slarochelle0769, Model ID: 3DPX-007207

Tetralogy of Fallot: "Boot-Shaped" Heart Created Using 3D Reconstruction Software of CT Images

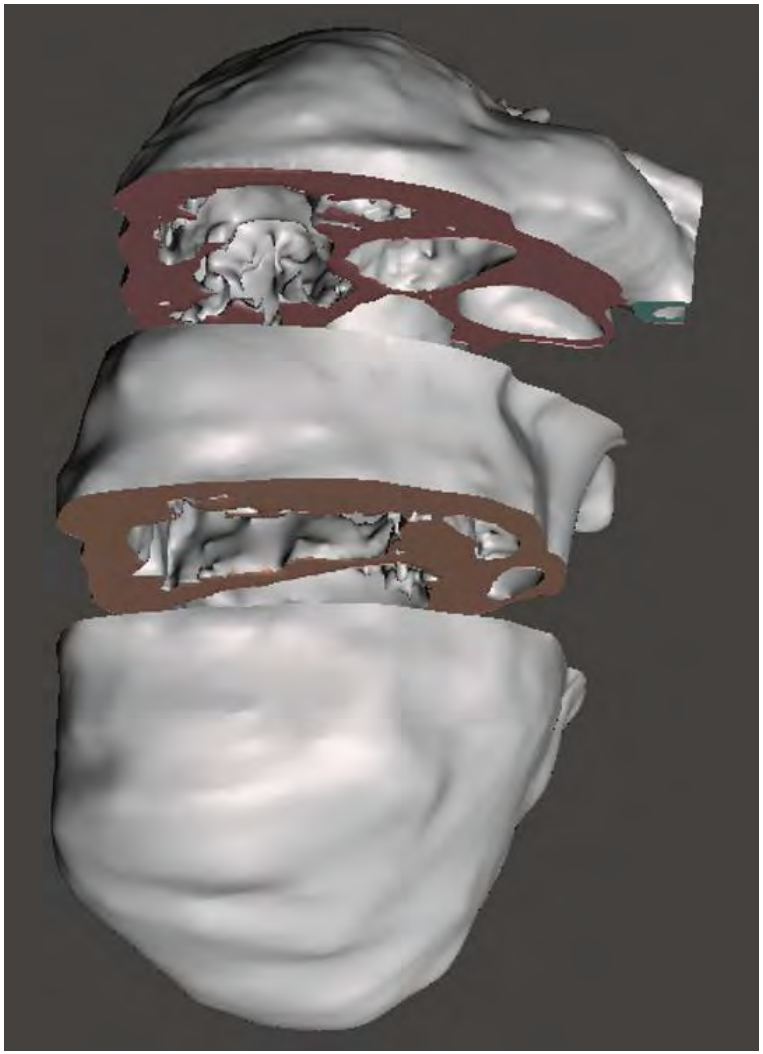


Tetralogy of Fallot: 4-Month-old Boy, Created Using 3D Printing Based on CT Imaging Data & 3D Reconstruction

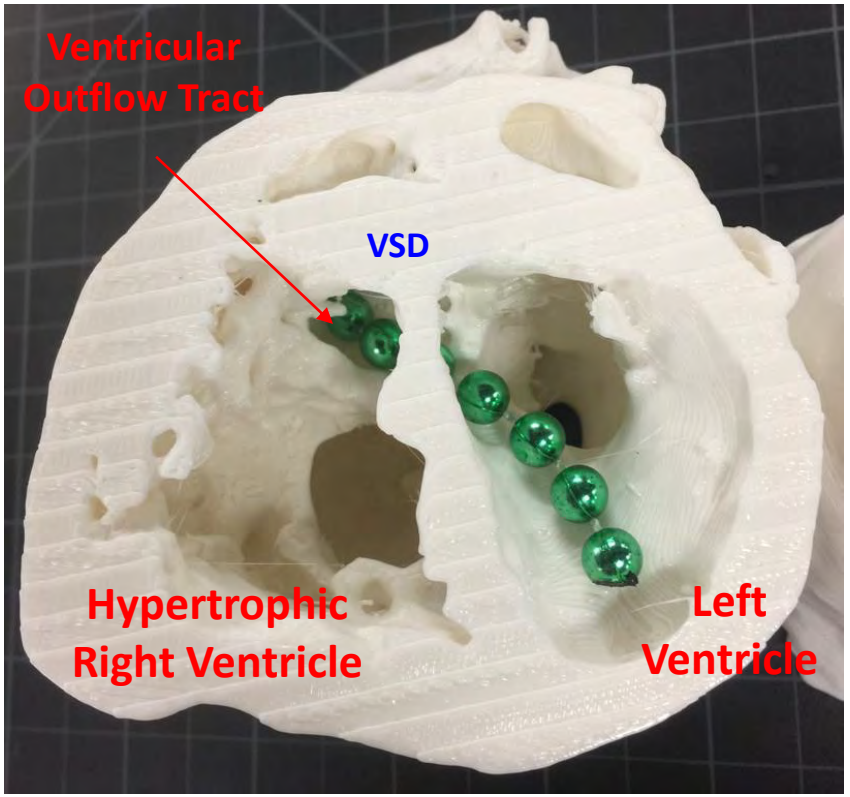


Data Source: 3dprint.nih.gov, Matthew Bramlet, Model ID: 3DPX-001684

Tetralogy of Fallot: "Boot-Shaped" Heart Created Using 3D Reconstruction Software of CT Images



Tetralogy of Fallot: 4-Month-old Boy, Created Using 3D Printing Based on CT Imaging Data & 3D Reconstruction

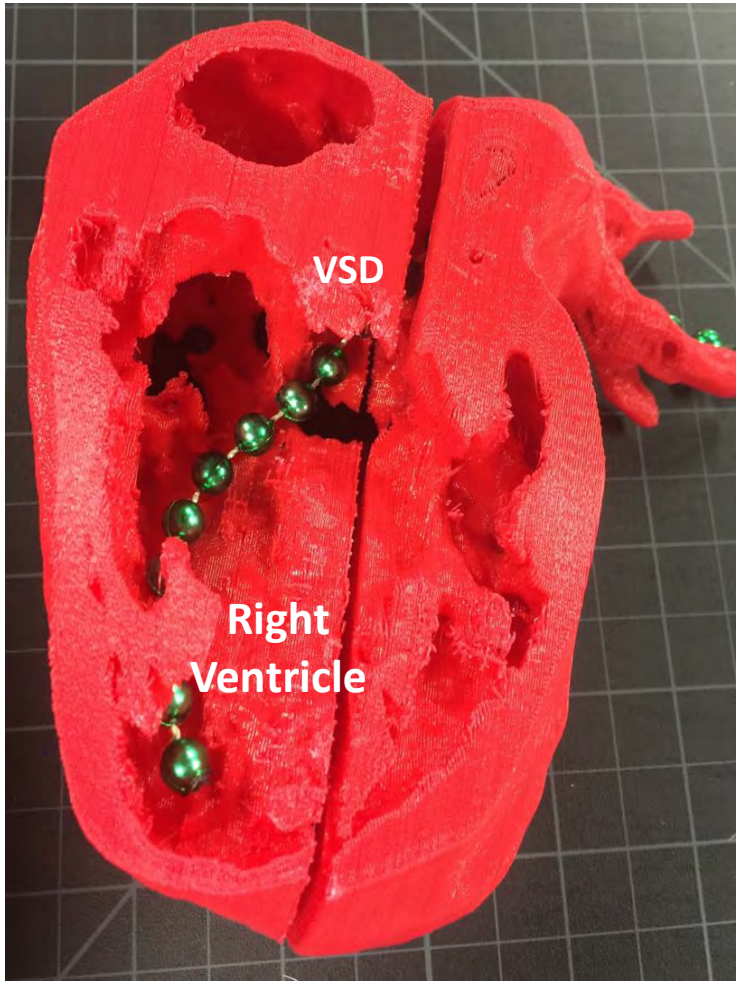


Data Source: 3dprint.nih.gov, Matthew Bramlet, Model ID: 3DPX-001684

Tetralogy of Fallot: 4-Month-old Boy:

3D Printing Based on CT Imaging Data & 3D Reconstruction

Demonstration of Defects - Longitudinal Section, Posterior View :
Green beads travel through right ventricle, across the VSD, and into the overriding aorta



Data Source: 3dprint.nih.gov, Matthew Bramlet, Model ID: 3DPX-001684

Conclusions
&
To-Do List

Conclusions

- Review **validates the content** covered in Brody's Pathology course against various resources including
  - Duke's cardiovascular curriculum
  - Step 1 and 2 outlines
  - Robins Pathology textbook and GRIP topic lists
- **Survey responses** suggest that cardiovascular **laboratory sessions** are considered to be an **effective education modality** based on
- **Optional congenital heart disease laboratory**
  - Well-received: will continue to offer this session
  - Groups limited to 10 students by sign-up list
  - Content will be supplemented with 3D models

To-Do List

- **3D Models for Congenital Heart Disease Laboratory**
  - Continue to optimize printing and areas of sectioning
  - Models will include
    - Normal heart
    - Tetrology of Fallot
    - Transposition of Great Vessels
    - Truncus Arteriosus
    - Coarctation of Aorta: Adult and pediatric variants

- **Survey**
  - Repeat survey for Class of 2021 after cardiovascular component

- **Cardiologist Collaboration**
  - Seek (1) Adult and (2) Pediatric cardiologist collaborator(s) to review and validate content being taught

Collaborators / Acknowledgements

Collaborators / Acknowledgements

Brody School of Medicine, East Carolina University	• Connor L. Pratson M2 → M3 • Andrew T. Ray M2 → M3 • Connor J. Karr M3 → M4
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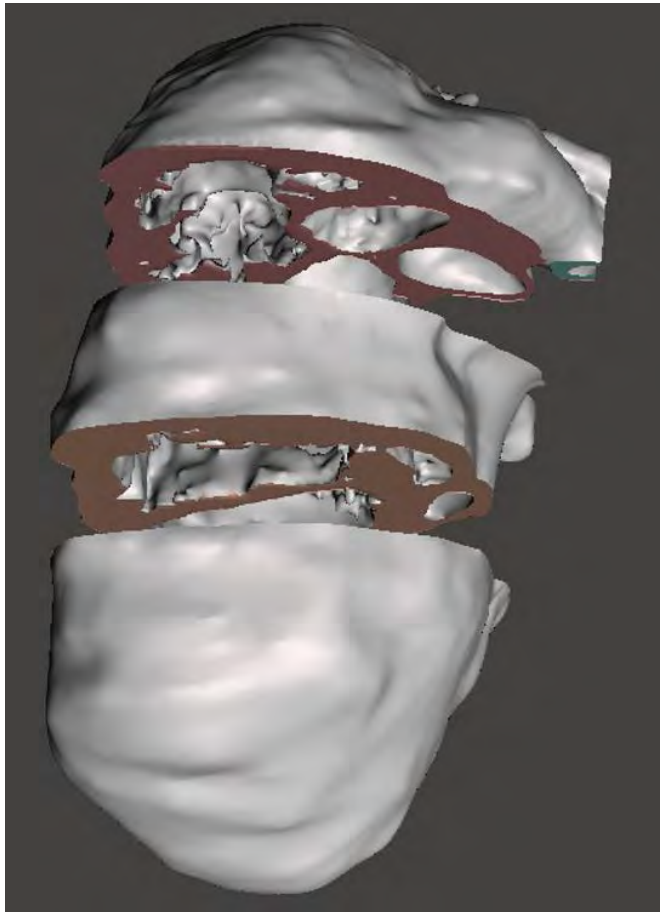
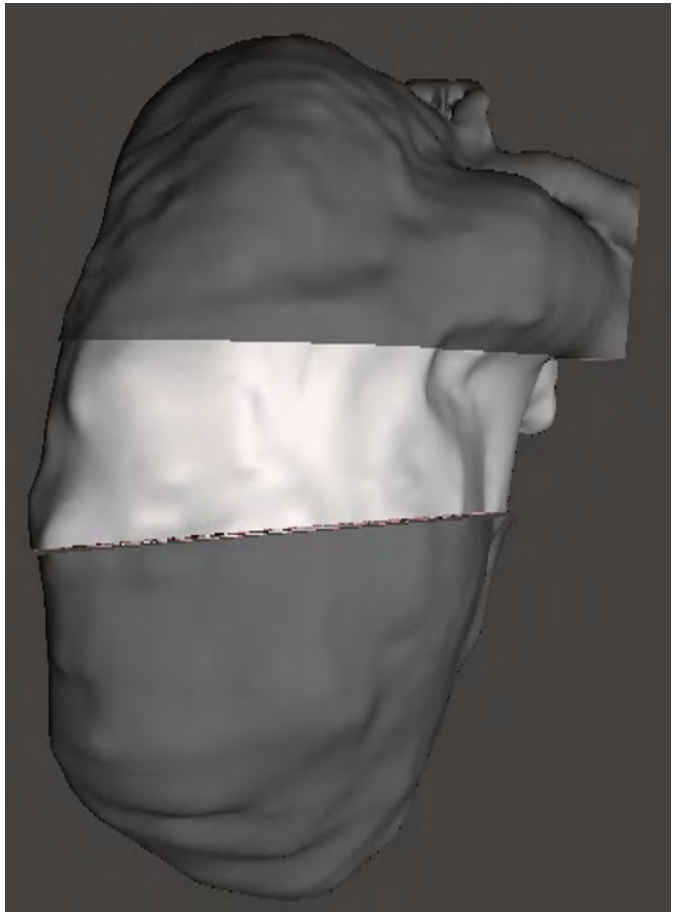
Department of Pathology, Duke University	• Andrea T. Deyrup, M.D., Ph.D.
Office of Student Development and Academic Counseling, Brody School of Medicine East Carolina University	• Terri N. Edwards
Department of Engineering, East Carolina University	• Kevin C. Nguyen • Joshua R. Butler
Innovation and Design Laboratory, East Carolina University	• William W. Godwin

Tetralogy of Fallot: "Boot-Shaped" Heart

Created Using 3D Reconstruction Software of CT Images





Data Source: 3dprint.nih.gov, Matthew Bramlet, Model ID: 3DPX-001684