Multidimensional imaging-based models for cardiovascular procedural skills training (BVP model)

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Problem Statement

Interventional cardiology is a rapidly expanding field in veterinary medicine. Pulmonary valve stenosis occurs when a dog is born with a malformed pulmonary valve, which restricts blood flow from the right heart to the lungs. Balloon valvuloplasty is a palliative procedure in which a balloon-tipped catheter is inserted into the jugular vein to the valve and is then inflated to help reduce the severity of the stenosis. Recently, the UW-Madison School of Veterinary Medicine has experienced a decrease in caseloads of canines with pulmonary valve stenosis, preventing the cardiology residents from being able to practice repairing this disorder. There is a need for a heart model to mimic pulmonary valve stenosis for residents to learn and practice repairing these valves.

This device, a model-based simulation program will be implemented to maintain the cardiologists' surgical skill set and to aid in cardiology resident training. Simulator training using multidimensional imaging-based models will augment the training already provided in the interventional lab and help protect against the ebb and flow of procedural caseload eroding skills. It also provides a more consistent experience for our residents and provides an objective method of assessing individual progress amongst our trainees.

The goal is to develop a silicone 3D model of canine pulmonary valve stenosis which can be used to learn/practice essential skills like handling of guidewires/catheters, balloon positioning and inflation, and communication between veterinary interventionists. Computed tomography angiography (CTA) of dogs with pulmonary valve stenosis will be used to create the 3D models, which will be secured in place. Lastly, a document camera will project an image of what the user is doing with their hands onto a screen. This provides a more realistic recreation of the interventional surgery, where the surgeon watches a fluoroscopy screen to monitor the movement of the interventional equipment inside the patient.

Brief Status Update

The team completed the preliminary design presentation and report. They have received material samples and gotten feedback from the client on the material choice. The team is now working on segmenting the CTA scan and developing the model for 3D printing.

Summary of Weekly Team Member Design Accomplishments

- Team:
  - Continued work with the CTA, translating it to a CAD model that can be 3-D printed.
  - Ordered Materials needed to 3-D print the model in the proper material that was chosen based on the design considerations.
  - Continued research and brainstorming on connecting the multiple components of the model together.
- Hunter Belting:
  - Began determining the material needs to ensure that what has been ordered will be adequate and that multiple iterations are possible.
  - Met with Jesse Darly in the TeamLab to understand the best way to go about printing the model as well as learning how to modify the model in the most efficient way.
- Anna Balstad:
  - Segmented the CTA and worked to make the STLs of the heart
  - Considered design ideas for connecting the heart components
- Rebecca Poor:
  - Met with Jesse Darly in the TeamLab to receive feedback on CAD model
  - Worked on STL files in SolidWorks to improve segmentation
  - Researched model fixturing
- Daisy Lang:
  - Researched jugular vein dimensions
  - Created 3D model for a jugular vein for printing and developed a fixture method to attach the jugular vein to the surface of the heart model
  - Received materials for printing from team labs

Weekly / Ongoing Difficulties

N/A

Upcoming Team and Individual Goals

- Team:
  - Generate design ideas for connection pieces
  - Begin editing STL files to add connection points
  - Practice printing the model using PLA or other cheaper material

- Hunter Belting:
    - Continue working with the STL heart model, as well as creating the jugular vein and annulus.
    - Begin printing components out of a different material to determine iterative changes that are still needed before using the actual materials.

- Anna Balstad:
    - Begin modifying the STL files by adding connection points
    - Determine how to separate the annulus in the STL

- Rebecca Poor:
    - Complete initial cardiac design
    - Print 3D model to prepare for show and tell
    - Begin researching stress tests for 3D printing

- Daisy Lang:
    - Print jugular vein model and consult maker space for consultation of dimensions
    - Discuss requirements for jugular vein access with client
    - Begin writing fabrication methods

Project Timeline

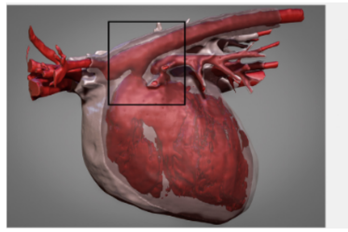
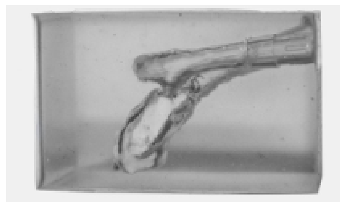
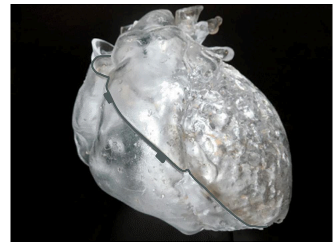
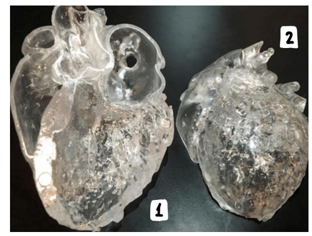
Project Goal	**Deadline**	**Team Assigned**	**Progress**	**Completed**
PDS	9/20	All	100%	x
Design Matrix	9/27	All	100%	x
Preliminary Presentations	10/4	All	100%	X
Preliminary Deliverables	10/9	All	100%	X
Show and Tell	11/1	All		
Poster Presentations	12/6	All		

Final Deliverables	12/11	All		

Expenses

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Component 1								
Component 2								
Component 3								
TOTAL:								**$0.00**

Overall Design Matrix

Design Criteria	3D Printed One Piece 		Molded One Piece  		3D Printed Four Piece  	
Anatomical Accuracy (25)	3/5	15	2/5	10	**4/5**	**20**
Ease of Fabrication (20)	**4/5**	**16**	1/5	4	3/5	12
Durability (15)	3/5	9	2/5	6	**4/5**	**12**
Modularity (15)	1/5	3	1/5	3	**5/5**	**15**
Ease of Use (10)	**4/5**	**8**	3/5	6	2/5	4
Cost (10)	3/5	3	**4/5**	**8**	2/5	4
Safety (5)	4/5	4	**5/5**	**5**	4/5	4
Total (100)	58/100		42/100		**71/100**	

Design Matrix - Jugular Vein and Annulus

Design Criteria	Elastic 50A Resin - Formlabs 		Flexible 80A - Formlabs 		NinjaFlex TPU - NinjaTek 	
Compliance (25)	**5/5**	**25**	2/5	10	1/5	5
Surface Finish (20)	2/5	8	3/5	12	**4/5**	**16**
Transparency (20)	**5/5**	**15**	4/5	12	1/5	3
Ease of Fabrication (15)	2/5	12	**4/5**	**12**	1/5	3
Cost (10)	3/5	6	3/5	6	**4/5**	**8**
Durability (5)	2/5	4	3/5	6	**4/5**	**8**
Resolution (5)	**4/5**	**4**	**4/5**	**4**	2/5	2
Total (100)	**68/100**		**62/100**		**45/100**	

Design Matrix - Heart Chambers

Design Criteria	Clear Resin V5 - Formlabs		Flexible 80A - Formlabs		PolyJet Photopolymer - Stratasys	
						
Compliance (25)	1/5	5	4/5	20	**5/5**	**25**
Surface Finish (25)	2/5	10	**4/5**	**20**	1/5	5
Transparency (20)	**5/5**	**20**	4/5	16	2/5	8
Ease of Fabrication (15)	**5/5**	**20**	4/5	16	1/5	4
Resolution (10)	4/5	**8**	4/5	8	**5/5**	**10**
Cost (5)	**5/5**	**5**	4/5	4	1/5	1
Total (100)	**68/100**		**84/100**		**53/100**	