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

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Date: January 31st to February 7th, 2025

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.

Summary of Weekly Team Member Design Accomplishments

- Team:
  - Finalized slides for preliminary presentation
  - Presented and received feedback on semester plan from advisor
- Hunter Belting:
  - Presented slides to our advisor
  - Printed off dog bones for mechanical testing
  - Researched some different options for a phone stand
- Anna Balstad:
  - Presented preliminary presentation to advisor
  - Made edits to the heart segmentation to increase area of ventricle and remove ridges
- Rebecca Poor:
  - Conducted further research on a peristaltic pump and what it is/how it works
  - Brainstormed ideas for pump design and connections into the heart model
  - Evaluated updates to heart chambers using OnShape
  - Finished slides and presented for preliminary presentation
- Daisy Lang:
  - Continued researching peristaltic pump and looked into various options to meet our design specs
  - Brainstormed ideas for pump design and made drawings of our preliminary ideas

Weekly / Ongoing Difficulties

N/A

Upcoming Team and Individual Goals

- Team:
  - Update timeline and plans based on feedback from advisor
  - Meet with client to evaluate progress and future plans for components of design

- Hunter Belting:
  - Order materials for a phone stand after deciding with team/client
  - Mechanical tensile test of the elastic 50A material

- Anna Balstad:
  - Continue editing the heart segmentation
  - Print a test model of the heart to visualize and possible test initial changes to the ventricles
  - Start creating new box for the heart model with an increased tolerance

- Rebecca Poor:
  - Order materials for pump after consultation with client
  - Research adequate tubing for fluid volume/speed

- Daisy Lang:
    - Place orders for pump, tubing, and phone stands
    - Update jugular vein design to to fit tubing and print in PLA to evaluate shape

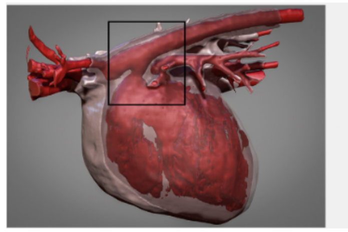
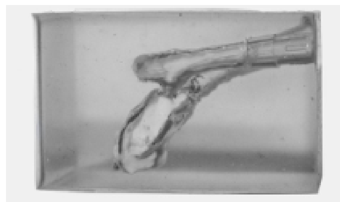
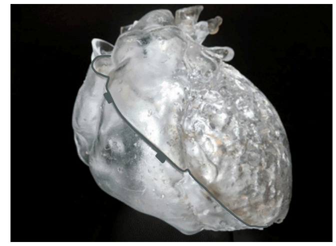
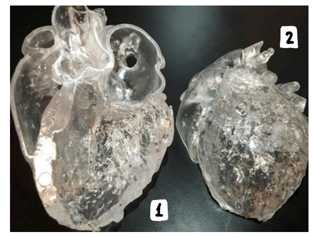
Project Timeline

Project Goal	**Deadline**	**Team Assigned**	**Progress**	**Completed**
Preliminary Presentation	2/7	All	100%	X
Preliminary Report	2/26	All		
Executive Summary	4/18	All		
Final Poster Presentation	4/25	All		
Final Deliverables	4/30	All		

Expenses

Item	Description	Manufacturer	Date	QTY	Cost Each	Total	Link
Category 1 3D Printed Material							
Elastic 50A Resin	Material for Jugular Vein and Annulus	Formlabs	10/14/24	1L	$208.57	$208.57	https://formlabs.com/store/materials/elastic-50a-resin-v2
Flexible 80A Resin	MAterial for Heart Chambers	Formlabs	10/14/24	1L	$208.57	$208.57	https://formlabs.com/store/materials/flexible-80a-resin
Category 2 Fabrication Materials							
Super Glue	Secure Jugular Veain to Heart	The Original Super Glue Coorporation	11/19/24	2 x 0.07 oz	$1.21	$2.42	https://supergluecorp.com/
Stand Print	Model Holder Stand	MakerSpace	11/20/24	2	$8.00	$16.00	N/A
					TOTAL:	**$435.56**	

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**	