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

This week we began working on the preliminary presentation and creating a plan for the semester. We also started conducting research on the new additions to our project and met with our client to determine goals for the final prototype.

Summary of Weekly Team Member Design Accomplishments

- Team:
  - Created a semester plan including prototype and testing plans
  - Started preliminary presentation
- Hunter Belting:
  - Worked on slides for preliminary presentation
  - Researched and tested what we could possibly use for videoing the procedure
  - Prepped questions to ask our client about scope of the display
- Anna Balstad:
  - Worked on slides for preliminary presentation
  - Attended client meeting to define goals for the semester
  - Conducted research on cardiac output values
- Rebecca Poor:
  - Conducted research on cardiac pumps for those currently on the market and cardiac output for a french bulldog
  - Worked on slides for preliminary presentation
- Daisy Lang:
  - Researched possible pumps to replicate heart pump water flow through model
  - Found literature values for design specs on pump
  - Worked on slide for preliminary presentation and made drawing for prototype updates

Weekly / Ongoing Difficulties

N/A

Upcoming Team and Individual Goals

- Team:
  - Finalize the preliminary slides as a team and practice the presentation
  - Continue development of the heart model
  - Either order or have an idea of what will be ordered for pumping

- Hunter Belting:
  - Finish slides for the preliminary presentation
  - Work with the client to determine which display/video method would work best at the clinic
  - Look into tripod systems that could be used in our application

- Anna Balstad:
  - Start updating the heart model STL to improve ventricles

    - Help with researching pumps to purchase
    - Finalize preliminary presentation

- Rebecca Poor:
    - Begin brainstorming ideas for pump design
    - Begin prototyping designs in CAD and consult makerspace for assistance
    - Finalize semester timeline and assignment submission dates

- Daisy Lang:
    - Work with Becca to come up with design ideas for pump and how to implement in our design
    - Begin looking for products to order for pump

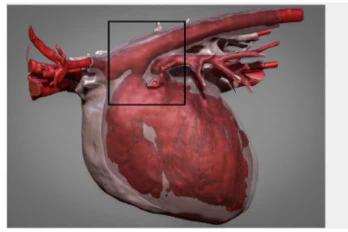
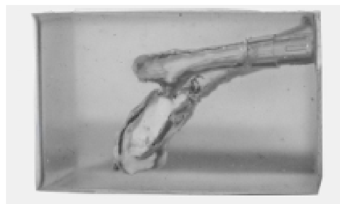
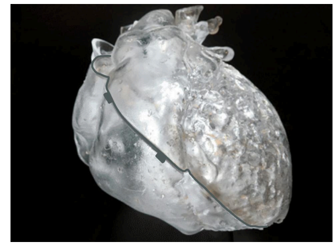
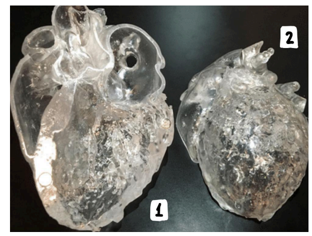
Project Timeline

Project Goal	**Deadline**	**Team Assigned**	**Progress**	**Completed**
Preliminary Presentation	2/7	All	25%	
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**	