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:
  - Finished segmentation for both the heart chambers and isolation of the annulus. This was then converted into an STL file.
  - The heart chambers were 3-d printed in a hard plastic material as a first look at how it would turn out.
  - The annulus was printed out of the elastic 50A material and was tested for durability and elasticity of the material.
  - A simplified version of the jugular vein was modeled and printed to give an idea on how the insertion of the catheter would happen.
- Hunter Belting:
  - Printed the heart chambers and annulus out of different materials.
  - Tested the durability of the annulus print by cycling a catheter through it 10 times and ensuring the model doesn’t break and is able to return back to its original state.
- Anna Balstad:
  - Segmented the heart and pulmonary valve.
  - Assisted with adding connectors to the heart.

- Rebecca Poor:
  - Worked on segmenting the heart and the valve.
  - Imported STL into OnShape and added connectors between heart halves.
  - Researched coefficient of friction testing strategies.

- Daisy Lang:
  - 3D-printed jugular vein
  - Researched artificial skin materials that we could purchase for covering the jugular vein

Weekly / Ongoing Difficulties

Upcoming Team and Individual Goals

- Team:
  - Continue iterative improvements for connection points and cleaning up the STL models.
  - Continue/Begin mechanical testing on the different printing materials as well as the “skin” that will be covering over the jugular vein.
  - Begin developing the stand that the model will sit in.

- Hunter Belting:
    - Improve the connections between the heart chambers and add a housing area within the heart for the annulus to lay.
    - Begin work on connecting the Jugular to the heart in the model.
    - Continue testing mechanical properties of the elastic 50A and start testing for the flexible 80A

- Anna Balstad:
    - Test coefficient of friction of 3D printed materials
    - Improve connector design
    - Begin designing stand for heart model

- Rebecca Poor:
    - Begin testing the coefficient of friction on the different 3D printed materials.
    - Update the connection points between the heart halves based on show and tell feedback.

- Daisy Lang:
    - Reprint the Jugular vein in the correct material
    - Redesign jugular vein with larger hole for catheter insertion
    - Purchase artificial skin materials for covering jugular vein

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	90%	
Poster Presentations	12/6	All		

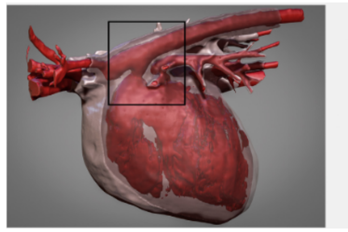
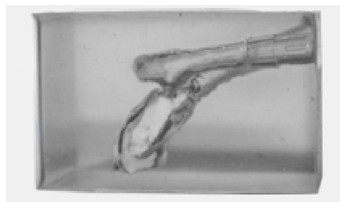
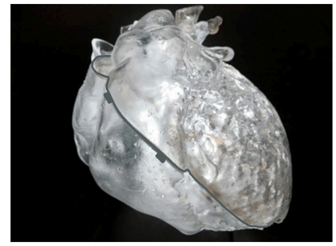
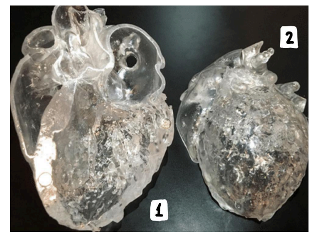
Final Deliverables	12/11	All		

Expenses

Item	Description	Manufacturer	Part #	Date	QTY	Cost Each	Total	Link
Component 1								
Elastic 50A Resin	Material for annulus and jugular vein	Formlabs	N/A	10/14/2024	1	$199.00	$199.00	https://formlabs.com/store/materials/elastic-50a-resin-v2/
Component 2								
Flexible 80A Resin	Material for Heart Chambers	Fromlabs	N/A	10/14/2024	1	$199.00	$199.00	https://formlabs.com/store/materials/flexible-80a-resin/

Component 3								
TOTAL:	**$417.14 ($19.14 shipping cost)**							

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**	