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 developing the model for 3D printing and creating testing procedures.

Summary of Weekly Team Member Design Accomplishments
- Team:
  - Continue working with the model to support the connections between each of the components.
  - Began studying how to test friction for the catheter to ensure that our material choices reflect that of the actual procedure.
  - Took feedback from the show and tell to help further guide our progress with the project.
- Hunter Belting:
  - Began cleaning up the heart chamber model so that there are no holes or gaps in wrong spaces.
- Anna Balstad:
  - Researched standards for coefficient of friction testing

- Rebecca Poor:
  - Continued research on coefficient of friction, consulted UW Madison Faculty for suggested testing plans
  - Began modeling the model supports/fixture in solidworks

- Daisy Lang:
  - Built the connection piece for the jugular vein and heart in solid works
  - Researched water proof adherents that we can use to secure the two pieces together

Weekly / Ongoing Difficulties

Upcoming Team and Individual Goals
- Team:
  - Begin friction testing on the two different materials to ensure they are comparable to natural tissue.
  - Continue working on connection points for the model, starting with smaller prints to test the different connections.
  - Continue working on the base support which will hold the model during the procedure.

- Hunter Belting:

    - Continue working on cleaning up the model so that there are no holes or gaps as well as normalizing the start of the heart chamber so there is an easy transition from jugular vein to the heart.
    - Print out more model components in the actual material choices to get a greater understanding of the material properties and connection points

- Anna Balstad:
    - Test coefficient of friction of jugular vein and heart materials selected
    - Begin creating final design poster
    - Perform wear testing on annulus

- Rebecca Poor:
    - Begin executing the coefficient of friction testing
    - Continue drafting the model for the heart supports
    - Print out of cheaper material to get initial feedback

- Daisy Lang:
    - Order adherent or any last-minute purchases for team needs
    - Prototype the connection between the jugular vein and heart chambers in cheap material at makerspace
    - Design how the manikin skin will be secured over the jugular

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	100%	x
Poster Presentations	12/6	All		

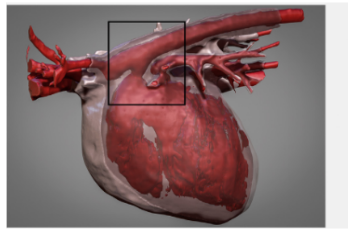
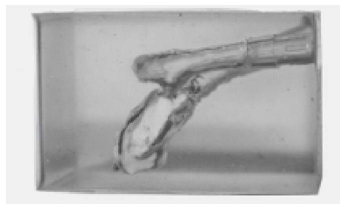
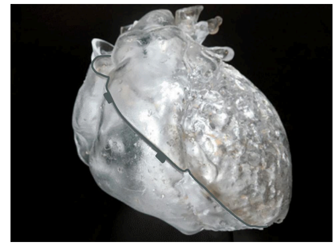
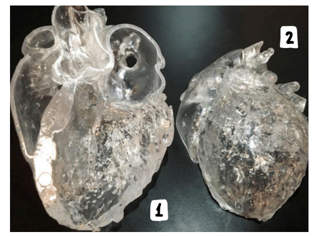
Final Deliverables	12/11	All		

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**	