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 the team focused on finalizing many aspects of the design – heart chambers connections, holes in the model, and the heart stand. We began testing and will continue doing other material property testing next week. We also met to create a schedule to complete all final deliverables on time.

Summary of Weekly Team Member Design Accomplishments
- Team:
  - Completed testing involved with the annulus/valve.
  - Made final changes to the heart model so that it is ready for printing and subsequent testing.
  - Began separating out final deliverables.
- Hunter Belting:
  - Printed connection components to test and see the best way to connect the two halves of the heart together.
  - Determine what can be used to test stress/strain of our components.
- Anna Balstad:
  - Wrote testing protocols
  - Performed fatigue testing on 3D printed valve leaflet
- Rebecca Poor:
  - Completed the CAD for the heart stand
  - Consulted client on initial design
- Daisy Lang:
  - Edited design for Jugular Vein to reduce stress concentrations
  - Researched procedure and wrote protocol for new stress/strain test for heart and jugular materials
  - Purchased adhesive for jugular connection

Weekly / Ongoing Difficulties
N/A

Upcoming Team and Individual Goals
- Team:
  - Finish fabrication of prototype
  - Wrap up testing
  - Start working on final deliverables

- Hunter Belting:
  - Finish printing off the different components.
  - Start on final deliverables
  - Help with any testing, and or protocols involved with testing

- Anna Balstad:
  - Begin writing final report and working on poster

    - Conduct final material properties testing

- Rebecca Poor:
    - Print heart stand at Makerspace
    - Draft test protocol for design feasibility testing
    - Begin working on final deliverables

- Daisy Lang:
    - Complete stress/strain curve testing
    - Updated preliminary report with edits from Dr. P
    - Begin working on final deliverables

Project Timeline

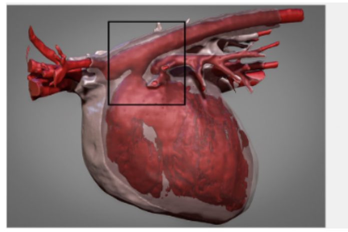
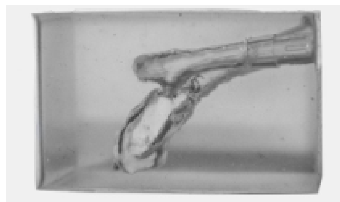
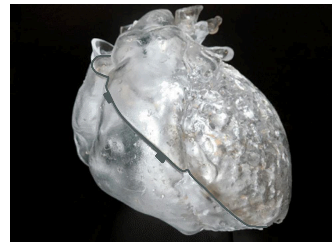
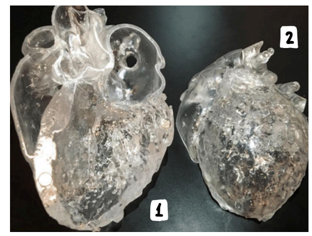
Project Goal	Deadline	Team Assigned	Progress	Completed
PDS	9/20	All	100%	x
Design Matrix	9/27	All	100%	x
Preliminary Presentations	10/4	All	100%	x
Preliminary Deliverables	10/9	All	100%	x
Show and Tell	11/1	All	100%	x
Poster Presentations	12/6	All	5%	
Final Deliverables	12/11	All	5%	

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**	