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

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Team: Hunter Belting, belting@wisc.edu (Team Leader)
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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

Friday we met with our client to learn more about balloon valvuloplasty and her goals for this project. She also supplied us with balloon catheters and other supplies. We were also able to see old heart models to get a better understanding of her likes and dislikes in those models. Individually we continued to research materials and manufacturing ideas. As a team, we brainstormed design ideas and filled out our design matrices. We then started our preliminary presentation.

Summary of Weekly Team Member Design Accomplishments

- Team:
    - Met with the client to learn about the procedure and get some equipment, including balloon catheters. This also allowed the client to send over the CTA scans that will be used to model the heart.
    - Team met to work through the design matrix and preliminary presentation slides.

- Hunter Belting:
    - Met with the client on Friday to discuss the procedure and gain a better understanding into how the model should feel.
    - Researched 3-D resins, specifically for formlabs to gain insight into the capabilities and possibilities of in house printing.
    - Worked with the team to create 3 design matrices and more specifically work on the heart portion of the design matrix. The preliminary presentation was also split up amongst team members.

- Anna Balstad:
    - Met with the client on Friday to learn more about balloon valvuloplasty.
    - Researched 3D printing resins and hard silicones used for molding.
    - Met with the team to discuss design ideas and create design matrices.
    - Wrote our details of a design matrix and created a draft of preliminary presentation slides.

- Rebecca Poor:
    - Researched materials to use for 3D printing the model and each of the components
    - Brainstormed design ideas for the model
    - Drafted slides for the preliminary presentation
    - Reviewed the protocol for the surgery that will be performed with the model
    - Wrote the summary of each design idea/material for design matrices

- Daisy Lang:
    - Researched possible materials for 3D printed hard exterior of our model
    - Wrote explanations for the Overall Design matrix
    - Drafted preliminary presentation slides

Weekly / Ongoing Difficulties
N/A

Upcoming Team and Individual Goals

- Team:
    - Meet with our advisor to discuss the preliminary presentation and design matrices and get feedback.
    - Gain samples of different 3-d printed models out of different resins.
    - Begin work on the CTA files to begin slicing the model into the 4 parts that will create the whole model.

- Hunter Belting:
    - Continue to refine and edit the preliminary presentation.
    - Continue ordering samples as needed or print samples from the makerspace as we continue to understand what materials best suit the models needs.
    - Understand how to transform the CTA scans into CAD, as well as segmenting it into the 4 different components in CAD

- Anna Balstad:
    - Edit preliminary design presentation and prepare for presentation next week Friday.
    - Sart segmenting the CT files provided by the client.
    - Continue researching 3D printing methods.

- Rebecca Poor:
    - Refine preliminary presentation slides
    - Begin drafting the CT scans into CAD model
    - Order samples of materials to consult client

- Daisy Lang:
    - Finish preliminary design presentation slides
    - Continue researching methods to develop CT model into CAD model
    - Research annulus and jugular vein properties

Project Timeline

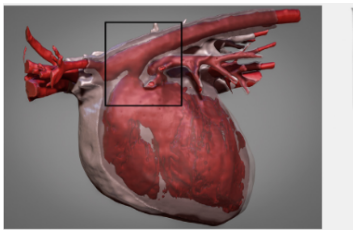
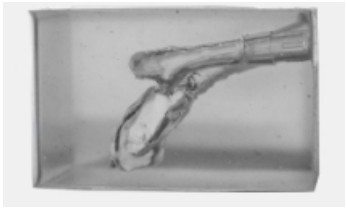
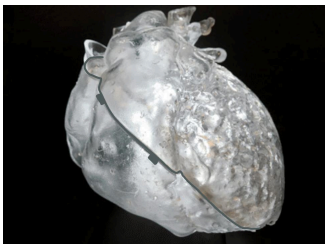
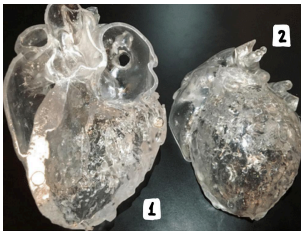
Project Goal	Deadline	Team Assigned	Progress	Completed
PDS	9/20	All	x	x
Design Matrix	9/27	All	x	x
Preliminary Presentations	10/4	All		
Preliminary Deliverables	10/9	All		
Show and Tell	11/1	All		
Poster Presentations	12/6	All		
Final Deliverables	12/11	All		

Expenses

Item	Description	Manufacturer	Part Number	Date	QTY	Cost Each	Total	Link
Component 1								
Component 2								
Component 3								

TOTAL:								**$0.00**

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**	