Preliminary Presentation

3D Printing Airway Trainers

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Client: Dr. Kristopher Schroeder

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Problem Statement

Client: Dr. Kristopher Schroeder

Problem #1: Most trainers do not replicate patient-specific pathology

Problem #2: Existing trainers are highly expensive

Figure 1: Ambu Airway Trainer [1]
https://www.ambu.com

Goal:

Create an affordable and patient-specific airway trainer.

Ilia

Background Material

- Airway management is a critical medical procedure
- 400,000 annual emergency intubations [2]
- 12.7% of intubations are initially unsuccessful [2]
- Procurement of trainers is inefficient
- 3D-printing is an alternative

Figure 2: Laerdal Trainer [3]
https://theemssuperstore.com

Ilia

Competing Designs

- Laerdal Airway Trainer [4]
  - Gold standard
    - Representative of standard anatomy
    - Durable
    - Multiple procedures possible
  - ~$3000
- Decent Simulators [5]
  - Adjustable difficulty, based on true anatomy
  - ~$1800
- TruCorp [6]
  - Difficult airway anatomy and some realistic pathology
  - Adjustable levels of edema and obstruction
  - ~$6000

Figure 3: Laerdal Trainer [4]
https://laerdal.com

Figure 4: Decent Simulators Trainer [5]
https://decentsimulators.com

Figure 5: AirSim Difficult Trainer [6]
https://trucorp.com

Jack

Product Design Specifications

- Imaging-based, patient specific difficult anatomy
    - Subglottic stenosis, Sublingual tonsils
  - Practice before operation, if possible
  - Serve as training after
- Resemble human airway biomechanics
  - Shore Hardness of 50 - 80A [7]
  - Young's Modulus of 16 MPa ∓ 8 MPa [8]
- Simulate variety of airway procedures
  - Top priority: Intubation
  - Oropharyngeal and Nasopharyngeal airways
- $750 budget

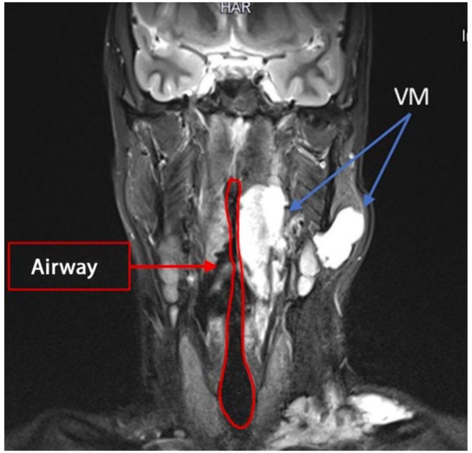


Figure 6: Coronal plane MRI of patient with venous malformation [9]
https://compva.com

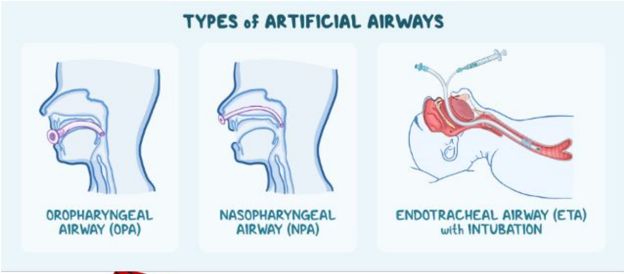


Figure 7: Example airway procedures [10]
https://moldeddevices.com

Jack

Method 1: Commercial Difficult Airway Trainers

Figure 8: TruCorp Airsim Difficult Airway Trainer [11]

https://trucorp.com

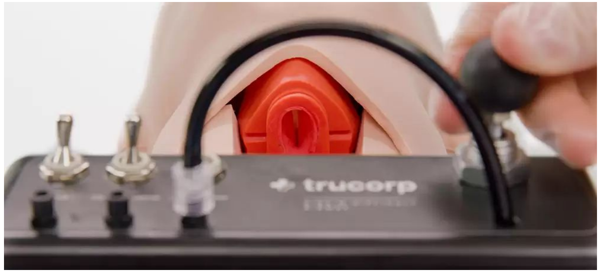


Figure 9: Simulated Laryngospasm, sudden closure of vocal cords [11]

https://trucorp.com

Advantages

- Range of difficult airway pathologies
- Airway simulations

Disadvantages

- Price $6000 [11]
- Lacks patient-specific pathology
- Made of latex

Elle

Method 2: Modification to TruCorp Airsim Airway Trainer

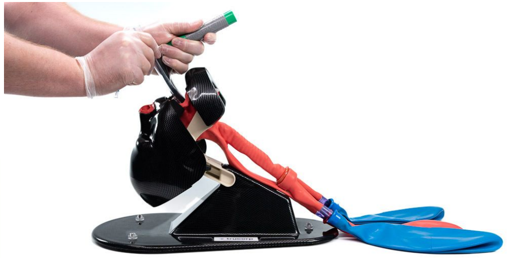


Figure 10: TruCorp Airsim Airway Trainer [12]
https://trucorp.com

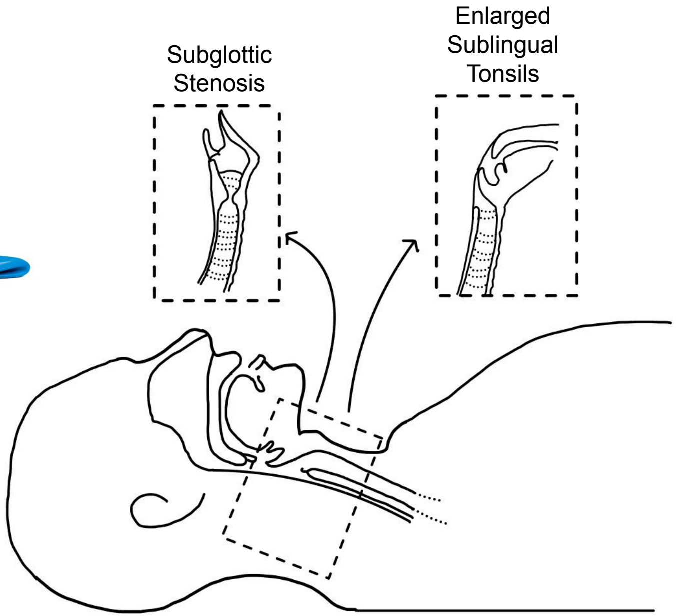


Figure 11: Modular airway trainer with replaceable difficult airways

Advantages

- Rotation of patient-specific pathologies
- Use of high-quality frame

Disadvantages

- Cost
- Lack of epiglottis mobility

Elle

Method 3: 3D Printed Modular Airway With Patient Specific Anatomy

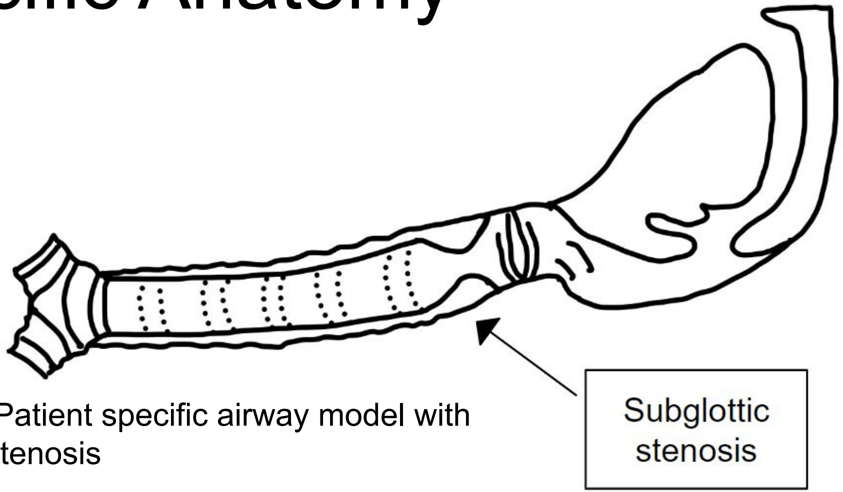


Figure 12: Patient specific airway model with subglottic stenosis

Main steps:

1. Segment patient-specific imaging
2. Refine .stl file
3. 3D print airway or mold
4. Design framework incorporating additional related anatomy

Advantages

- Low cost: $105 USD [13]
- Patient-specific pathology
- Possibility of pre-operative training

Disadvantages

- Imaging contains protected personal health information [14]
- Requires deidentified patient imaging
- Less procedural versatility

Maribel

Design Matrix: Methods

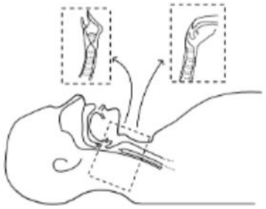
Design Criteria	Commercial Difficult Airway Trainers  Figure 8: TruCorp AirSim Difficult Airway [11]		Modifications to Existing Trainers  Figure 11: Modular airway trainer		3D Printed Modular Airway with Patient-Specific Anatomy  Figure 12: Patient specific airway	
Physiological Accuracy (25)	**4/5**	20	**3/5**	15	**5/5**	25
Complexity (20)	**4/5**	16	**2/5**	8	**3/5**	12
Cost (20)	**2/5**	8	**1/5**	4	**5/5**	20
Ease of Use (15)	**4/5**	12	**2/5**	6	**3/5**	9
Versatility (10)	**2/5**	4	**3/5**	6	**4/5**	8
Durability (10)	**4/5**	8	**2/5**	4	**3/5**	6
Total (100)	**70/100**		**41/100**		**80/100**	

Figure 13: Methods Design Matrix

Maribel

Design Matrix: Materials

Design Criteria	Material #1: Silicone 3D Printed Resin 60-75A, ~2 MPa		Material #2: Formlabs 80A Resin 80 A, ~4 MPa		Material #3: Liquid Silicone	
Biomechanical Properties (25)	**3/5**	15	**4/5**	20	**2/5**	10
Durability (20)	**3/5**	12	**3/5**	12	**2/5**	8
Ease of Fabrication (20)	**4/5**	16	**4/5**	16	**2/5**	8
Reliability (15)	**4/5**	12	**5/5**	15	**3/5**	9
Cost (10)	**4/5**	8	**2/5**	4	**3/5**	6
Compatibility with Training Materials (10)	**2/5**	4	**4/5**	8	**2/5**	4
Total (100)	**67/100**		**75/100**		**45/100**	

Figure 14: Materials Design Matrix

Nathan

Future Work

- Development
  - Material property testing
  - DICOM files
- Testing
  - Final design properties: Shore Hardness (50-80A) and Young's Modulus (16 MPa ∓ 8 MPa) [7,8]
  - Perform test procedures: Max 45 seconds [15]
  - Image vs model accuracy

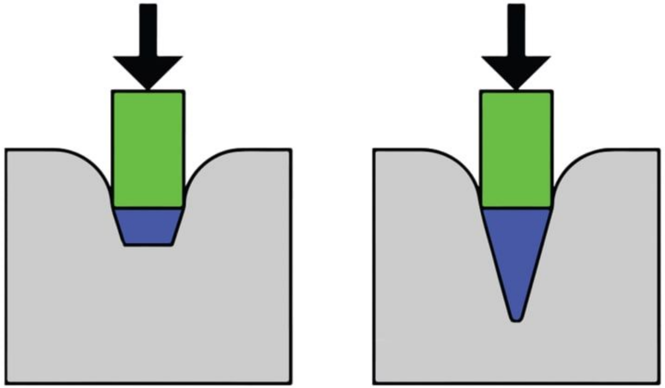


Figure 15: Shore Hardness Test (A on Left, D on Right) [16]

Maiwand

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Thank You! Questions?