Department of Biomedical Engineering
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3D Printing Airway Trainers

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Overview

Problem Statement

- Standard airway trainers are somewhat limited
- Abnormal airway practice improves patient outcomes
- No established method for printing airways
- Feasible to transform MRI to STL
- Transfer requires an advanced segmentation process
- Incorporate into a fully adjustable manikin

Background

- Dr. Kristopher Schroeder, Department of Anesthesiology
- Clinicians have 15-30 seconds before hypoxia [1]
- 12.7% of intubations fail on the first attempt [1]
- Training directly correlated to patient outcome [2]
- Trainers don’t simulate varied endotracheal environments [3]
- Personalized 3D printed airways aren’t used

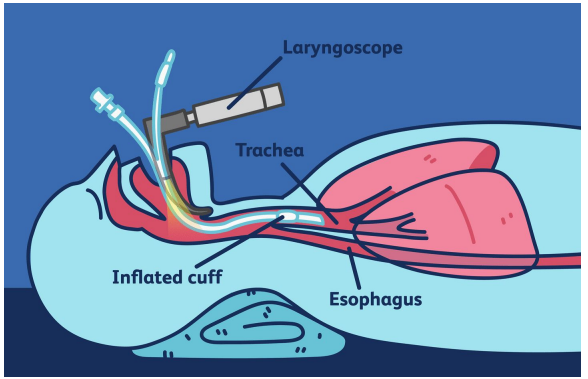


Figure 1: Intubation Diagram [4]

Competing Designs

- A variety of airway manikins exist
  - Babies
  - Swollen craniofacial structure
  - Burn victims
- Trainers often include just one feature of a difficult airway
  - Modular mandible
  - Adjustable neck
  - Inflatable tongue
  - Induced vomiting
  - Pressure sensitive teeth
- High end trainers can cost $1,700-3,000 [5]

Figure 2: Laerdal Airway Management Trainer [5]


Figure 3: Decent Simulators [6]

Process

MRI Scan → Segment → Convert → Print

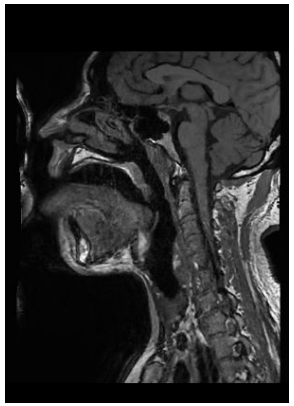


Figure 4: MRI

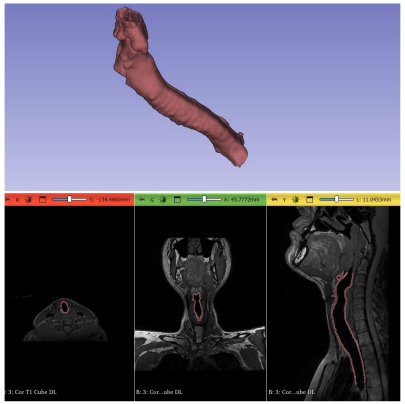


Figure 5: Segmentation

Figure 6: 3D Render

Figure 7: Solid Body

Figure 8: 3D Print

Product Design Specifications

- Physiological Accuracy & Material Properties
  - Maintain integrity following 20,000 intubation cycles [7]
  - Match human airway in look and texture
- Rapid adjustability of neck angle, tongue size, and mandible position
- Aim to minimize process cost for marketability
- Printing process should be repeatable in under 48 hours total

Design 1: Blocks

- 3D printed blocks of varying sizes to place under the manikin head
- Contoured to head shape
- Velcro to manikin base for stability
- Quickly swap blocks without tools

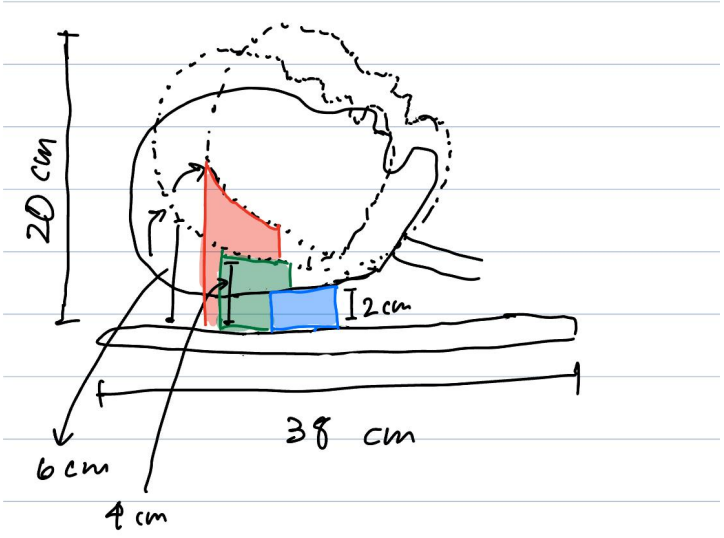


Figure 9: Sketch of Blocks Design

Design 2: Flexible Lamp Design

- Similar to a flexible lamp rod
- Adjustable in 3 DOF
- Threaded ends that screw into the top of the neck
- Implement design 1 for stability

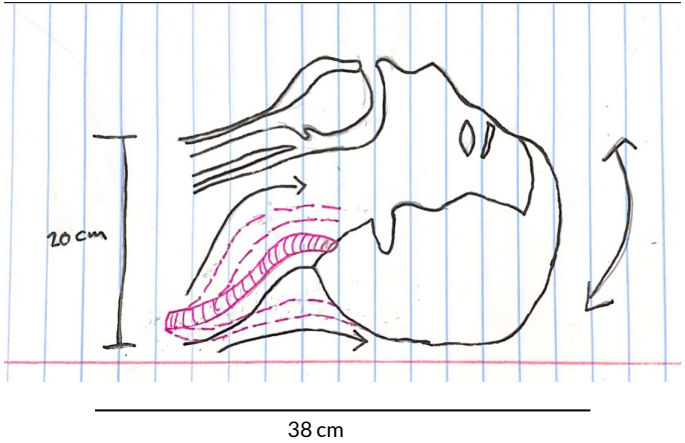


Figure 10: Sketch of Flexible Lamp Design

Design 3: Pin Design

- Hinge joint at manikin neck
- Aligned openings on manikin and base
- Only adjustable in the sagittal plane
- No mobility once pin is inserted

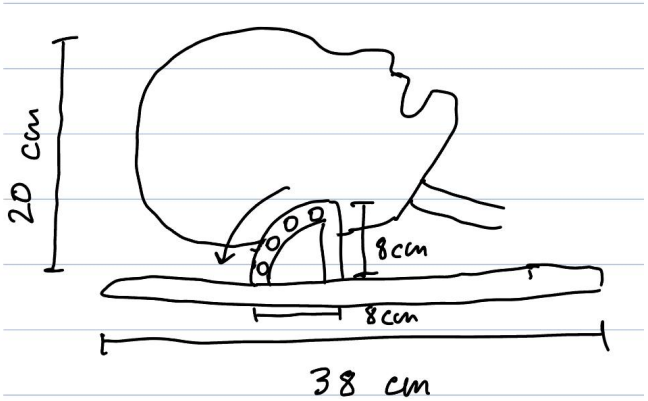


Figure 11: Sketch of Pin Design

Design Matrix

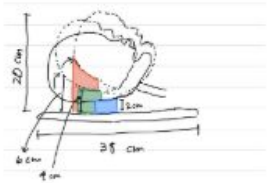
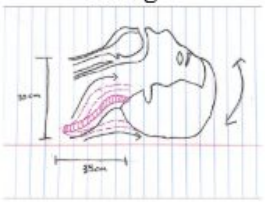
Design Criteria (Weight)	Design 1: Blocks 		Design 2: Flexible Lamp Design 		Design 3: Pin Design 	
Ease of Use (20)	4/5	16	5/5	20	4/5	16
Stability (20)	2/5	8	2/5	8	5/5	20
Durability (15)	5/5	15	3/5	9	5/5	15
Precision (15)	3/5	9	5/5	15	3/5	9
Ease of Fabrication (10)	5/5	10	4/5	8	3/5	6
Cost (10)	5/5	10	5/5	10	2/5	4
Safety (10)	5/5	10	5/5	10	4/5	8
Total Score (100)	**78**		**80**		**78**	

Table 1: Design Matrix

Testing

- Puncture resistance test
- Neck modulation durability test
- Time to adjust manikin
  - Swap airways
  - Adjust neck/mandible position
- Time for intubation with 3D printed airway
  - Compare professionals of varying abilities
  - Use existing models as a control group

Future Work

- Test software to optimize segmentation
- Make airway manikin modular/adjustable
  - Create manikin shell
  - Inflatable tongue, allowing for size variation
  - Adjustable mandible position (overbite, small mouth opening, etc.)
  - Pivoting neck
  - Allow for removal and replacement of 3D print

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References

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