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3D Printing Airway Trainers

2/21/25

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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
- Result should have >90% anatomical accuracy

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

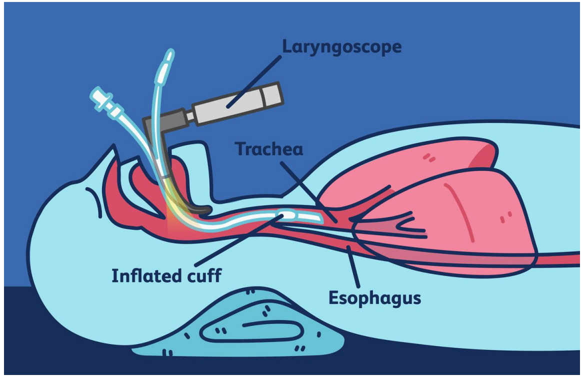

Figure 1: Intubation Diagram [4]

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 $2,000-3,000 [5]

Figure 2: Laerdal Airway Management Trainer [5]

Figure 3: TruCorp Trainer [6]

Figure 4: 7 Sigma Trainer [7]

Product Design Specifications

- Physiological Accuracy & Material Properties
  - Desired Young's Modulus of 2.3-23 MPa [8]
  - Preferred Shore A hardness of 59.6-91 A [9]
  - Maintain integrity following 20,000 intubation cycles [10]
  - Match human airway in look and texture
- $750 budget, should aim to minimize process cost
- Process should be repeatable in under 48 hours total

Process

MRI Scan → Segment → Print → Implement

Figure 5: MRI [11]

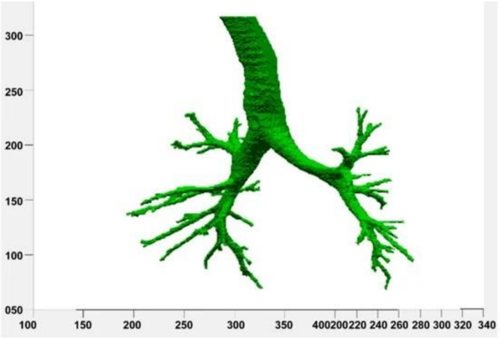

Figure 6: Segmentation [12]

Figure 7: 3D Printing [13]

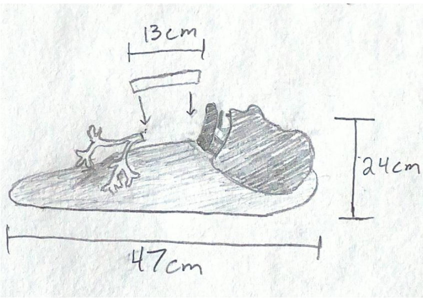

Figure 8: Hand Sketch of Finalized Airway Trainer

Material #1 - Formlabs Flexible Resin

- Stiff, flexible, and durable SLA filament
- Exclusively printable via Formlabs 3D-printers
- When cured, Young's Modulus of 8.9 MPa [14]
- Shore A hardness of 80.0 A [14]
- $0.29/g at UW Makerspace [15]

Figure 9: Formlabs Flexible Resin Sample [14]

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Material #2 - Silicone Casting With Ecoflex

- Print a mold, then cast in silicone
- Mold can be printed with any 3D printer
- Young’s Modulus of 82.7 kPa [16]
- Shore Hardness of 00-50 (~10 A) [17]
- $0.05/g silicone [18] + $0.05/g PLA [15]

Figure 10:
Silicone Cast [19]

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Material #3 - Thermoplastic Polyurethane

- Polyurethane plastic from thermoplastic elastomer family
- Flexible, very durable, and abrasion resistant
- Printable using any FDM 3D Printer
- Young's Modulus of 9.8 ± 0.7 MPa (X-Y) [20]
- 95A shore hardness [21]
- $0.05/g at UW Makerspace [15]

Figure 11: TPU Print [22]

Design Criteria (Weight)	**Design 1:** Formlabs 80A Resin [14] 		**Design 2:** Silicone Casting [19] 		**Design 3:** Thermoplastic Polyurethane (TPU) 95A [22] 	
Mechanical Properties (25)	5/5	25	2/5	10	4/5	20
Cost (20)	2/5	8	4/5	16	5/5	20
Ease of Fabrication (20)	4/5	16	1/5	4	3/5	12
Durability (15)	5/5	15	3/5	9	4/5	12
Resemblance to Trachea (10)	3/5	6	5/5	10	4/5	8
Printer Availability (10)	2/5	4	5/5	10	4/5	8
Total Score (100)	**74**		**59**		**80**	

Table 1: Design Matrix

Testing

- Measure and compare key anatomical measurements
  - Airway Volume - water displacement test
  - Airway Width
- Puncture resistance test
- Cyclical loading test
- Time for intubation with 3D printed airway
  - Compare professionals of varying abilities
  - Use existing models as a control group

Future Work

- Obtain MRI scans of subject in desired positions
- Meet with radiology to learn how to segment
- Make airway manikin modular/adjustable
  - 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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