3D Printing Airway Trainers

Dan Altschuler, Matt Sheridan, Lance Johnson, Cody Kryzer, Elle Thom
Client: Dr. Kristopher Schroeder Advisor: Dr. Paul Campagnola
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Problem Statement

- Airway management is an integral part of stabilizing a patient in many medical environments
- While training medical practitioners with simple airway trainers can improve patient outcomes, these trainers can cost upwards of $1700 [1]
- 3D printing patient imaging individualized airway manikins would assist medical professionals to practice airway management skills

Intubation & Airway Trainers

- Clinicians typically only have on average 15-30 seconds to secure an airway before possible onset of hypoxia and brain damage [2]
- 50% of intubations on difficult airways fail on the first attempt in emergency settings [2]
- The failure to successfully intubate a patient on the first attempt leads to a 33% increase in likelihood for patients to experience complications from lack of oxygen [2]
- The amount of clinician endotracheal intubation experience is directly correlated to patient outcomes [3]
- The process of 3D printing a mold to cast the patient's airway will reduce the chance of procedural complications during surgery by familiarizing the clinician with the difficult airway

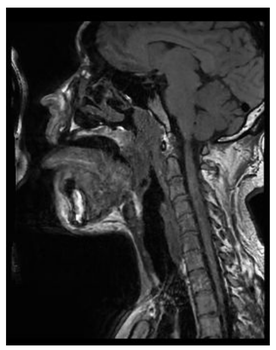

Figure 2: Volunteer Airway MRI

Figure 1: Decent Simulators Trainer [1]

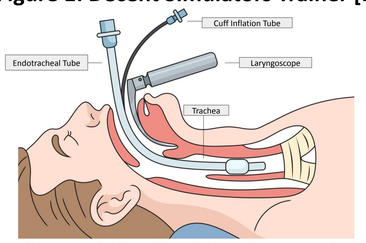

Figure 3: Tracheal Intubation [4]

Design Specifications

- The final airway should have >90% anatomical accuracy when compared to scans of the sample airway
- In order to be clinically effective, the process should be streamlined so that a printed airway can be made within 72 hours after the MRI
- The neck and the jaw should be fully modular to allow for variation in clinical scenarios for proper practice
- The airway trainer should withstand 20,000 intubation cycles to be comparable with other trainers on the market [5]
- Scans taken must be anonymized before being used on rendering software as to comply with the HIPAA protections on personal information [6]

Final Design

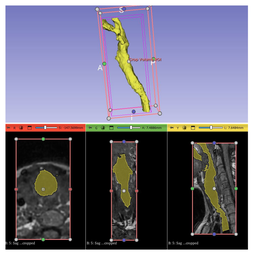

Figure 4: Segmentation

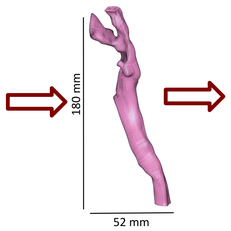

Figure 5: 3D Render

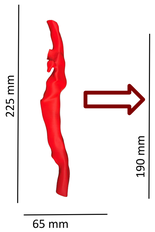

Figure 6: Scaled 3D Print

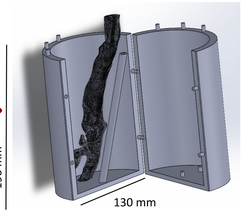

Figure 7: Mold

Figure 8: Silicone Mold Casting

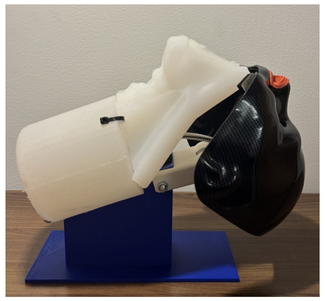

Figure 9: Airway Manikin Prototype

Testing

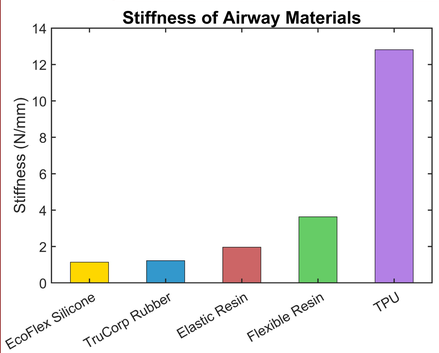

Figure 10: Stiffness of Materials During Compression Testing

Figure 11: Flexible Resin Before Compression

Figure 12: Flexible Resin After Compression

Durability Testing

- Each material was intubated until visible damage occurred, or until 50 iterations
- The rubber airway tested was part of a TruCorp manikin [7]
- EcoFlex 00-30 Silicone is the selected material for our manikin

Compression Testing

- Deformation of each material was measured under a compressive load of 24.6 N, a typical load experienced during intubation [8]
- Values were converted into stiffness to compare material properties

Material	EcoFlex Silicone	TruCorp Rubber	Elastic Resin	Flexible Resin	TPU
Intubations until damaged	>50 - Minimal Damage	>50 - No Damage	4	7	>50 - No Damage

Table 1: Durability Results For All Materials During Intubation

Results & Conclusions

- **MTS Compression Testing**
  - The elastic resin-printed airways had the most comparable material properties to biological airway tissue
  - Silicone and rubber provide the least resistance under intubation loads
- **Repeated Intubation Testing**
  - Both resin airways developed a small tear within the first 10 repetitions that continued to grow in the following few intubations
  - Tears were a result of the airway opening being too small; this issue has been temporarily remedied by scaling up the scanned airway
  - The silicone airway required lubricant to be effectively intubated on
- **Conclusions**
  - The material testing determined that ductile materials like silicone and elastic resin are more optimal choices for intubation trainers
  - Material properties under physiological conditions do not necessarily need to be replicated during intubation practice to achieve effective training
  - Casting a mold out of silicone is more functional for intubation than a printed airway, as a softer, thicker airway is more usable and durable compared to a thinner, stiffer material
  - It is ideal to have just one swappable part in the manikin; fewer total parts allows for more repeatable and accurate intubations.

Discussion & Future Work

- **Accomplishments**
  - Created a defined process for going from MRI to 3D print to silicone mold
  - Created a mold of an airway capable of attaching to an intubation manikin
- **Drawbacks of Current Design/Process**
  - MRI scans need to be scaled up in order to intubate properly
  - Silicone is expensive as a material
  - The current silicone airway has no failure mode (i.e. esophagus)
- **Moving Forward**
  - Work on solving the scaling issue when converting MRI to 3D print
  - Continue work on building our own manikin to attach our airways, improving the stand and facial features
  - Explore modulation of other trainer features including tongue size, mandible position, and integration of multiple materials
  - Create a mold that allows the mouth and airway to be cast as one piece

References

[1] "Airway Management Task Trainers | Decent Simulators," Decent Simulators, 2022. https://www.decentsimulators.com/airway-management-trainers
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