Comprehensive simulation, safer intubation

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What is **Fiberoptic Intubation**?

Fiberoptic intubation is an assistive breathing procedure that has become essential for difficult airway management in awake, sedated, and anesthetized patients.

Due to the lack of effective training methods, medical professionals are frequently tasked with creating their own intubation training models, using found materials like plastic tubing or toilet paper rolls. This lack of proper equipment puts an unnecessary burden on medical professionals to be innovative and takes them away from their core function of saving lives.

It is a perishable skill with large societal impacts, as 3 million intubations are performed in the US every year.

Of the three million intubations performed each year, 5.8% are classified as difficult to address. This leaves 174,000 intubations annually that medical professionals are currently unequipped to address using existing training methods.

$$3 \text{ Million} \times 5.8\% = 174,000$$

**Intubations performed annually**

**Classified as "difficult"**

**Difficult intubations**
About our product

In order to better prepare medical professionals for addressing difficult airways, ToobTek has created an anatomically relevant respiratory system mode utilizing emerging multi-material 3D printing technology and MRI DICOM data.

Our device is designed to have both the aesthetic and material properties of an actual human airway.

The model simulates the respiratory network from the larynx to the secondary bronchi and can be used for a variety of scenarios such as fiberoptic intubation, bronchoscopy, and laryngoscopy training.

Being a modular device, additional components can be added to model to simulate difficult airway features such as tumors or lesions and can also accommodate custom prints from MRI data.

The device is also lightweight and can be easily transported between different training sites with minimal setup and breakdown time.
Our project's **impact**

Our design is centered around the end user.

Our product is made to be cost accessible so it can be available to more medical professionals in a variety of settings. Current training models are either inaccessible in terms of cost or lacking in their anatomical relevance, a key feature needed for comprehensive training. These factors limit the quality of training medical professionals are currently receiving. **Toobtek’s mission** is to create a more comprehensive training experience so medical professionals can focus on their core function of saving lives. We plan to measure our success based on an increased level of confidence for medical professionals performing intubation.

Not only does our device benefit medical professionals, but also has the potential to save hospitals millions of dollars in litigation costs. Overall, we strive to help hospitals optimize patient care and enhance the future of medical simulation training.
Phase One: Developing requirements

Each of our team members visited with Murphy Anderson at Denver Health and engaged with his training model in-person.

From there, we identified deficiencies in the materials used in Murphy's model, namely the overall rigidity of the found materials did not reflect the properties of real human tissue, which is flexible in nature, and the tubing had sharp edges to it, preventing easy traversal of the respiratory model using a fiberoptic scope.

After interacting with Murphy's model, we built the first version of our product requirements and specifications focused on addressing these deficiencies through a new model produced using 3D printing methods. We also completed a Preliminary Design Review with our Project Director, where we identified changes to implement to the working model.
Phase Two: Prototyping

After Phase one, ToobTek began the process of modeling the respiratory components to be placed within the device and understanding what the device as a whole would look like. The team decided that each component would be connected with tubing and enclosed in a black box. This provides a replicable and simple way to train with very minimal setup time and cost.

In order to best match the respiratory system of a real human, we identified an MRI scan that could be used to model the larynx. This was the most challenging part to model, but it is one of the most foundational pieces of our device and shows that our device can be customizable in the long term. From there, we continued to model key respiratory components including the trachea and bronchial trees using Solidworks. This allowed us to create a working rendering of our initial design.

The team presented our design during the Critical Design Review and Manufacturing Review, finalizing the design and gaining useful feedback on the components themselves and the methods needed to manufacture them accurately and at high volumes. The team then updated the design documentation through the Critical Design Review Report and End of Term Report - illustrating the problem and solution, validating the market size for this product, proposing a plan for manufacturing and testing of the device, and calling out the key requirements and specifications.
Phase Three: Initial Prints and Testing

Our team performed intensive research on the materials needed for fabrication. The criterion used for this research were the material properties of human tissue, namely shore hardness and instantaneous elasticity. We consulted with biomechanics and medical device technology experts to help refine our research and material selection.

Finally, our team was ready to begin manufacturing our 3D printed, multi-material training device utilizing VeroVivid and Agilus30. We collaborated with Medtronic and Professor Robert MacCurdy’s Maclab, as partners to help print the initial tracheas for this device. This allowed us to avoid the long print times associated with printing the full model, as well as test our materials before finalizing them.

After two versions of the trachea were manufactured, the team conducted initial tests with CRNAs, anesthesiologists, and other medical professionals at Denver Health. This testing included an inspector survey regarding the look, feel, and overall design of each of the two trachea prototypes.
Phase Four: **Continued testing, iteration, prototyping**

From our initial test data, our team iterated on user feedback to produce a redesigned model, focusing on resolving user pain points. We were then able to manufacture our redesigned model through generous help from Medtronic and Professor Robert MacCurdy’s Maclab.

A second round of product testing was conducted with medical professionals at Denver Health. Through this round of testing, we saw improvement in the proficiency and overall satisfaction of medical professionals while using our device. A majority of the feedback surrounded the desire for more components, which the team plans to work after our Senior Design course. We are working on creating additional models that address cases of difficult airways as well as adding on to our base model to include a mouth and esophagus.

Test results from user testing with full model at Denver Health Medical Center.
Phase Five: Growth, Research & Development, Building a company

Our team has connected with several business mentors through the CU New Venture Challenge, including professionals with licensing experience and IP experts at Venture Partners. We are working on finalizing a provisional patent for our device to safeguard our IP from competitor infringement. In addition, we continue to research grants to fund additional printing materials and equipment to produce these models in a larger capacity. Lastly, we plan to further develop our relationships with both Stratasys and Medtronic.

Our team continues to focus on technological improvements through additional testing of the device for elastic deformation and resistance against frictional and normal force loads. We have added on additional valuable mentoring from doctors, CRNAs, and business experts in medical device technology to move our efforts forward.

Due to the need to prevent information disclosure while we are in the patent process, we have not included a final product photo.

Murphy Anderson using Toobtek’s product to train his students.
Challenges and Achievement

The Toobtek team persevered through the inherent challenges associated with remote learning.

Our team had to overcome barriers with communication, as we were unable to experience in-person interaction as a team during product development.

The team also overcame having little to no prior knowledge of the human anatomy or experience with medtech devices at the beginning of the course. Through our meetings with Murphy and extensive research, we were able to learn everything that we needed to in order to successfully complete this project.

Our team competed and advanced to CU NVC 14 Championships. Toobtek placed 3rd out of 150 competing teams and received a $16,000 prize.

We are proud of our expertise evolving. We have managed to complete valuable practice with developing a novel technology from the ground up. We are now well-versed in how to take this idea forward as a business and have a great understanding of how to form strategic partnerships and maintain them. We are also proud of our excellent understanding of how to communicate our ideas to key stakeholders and understanding of important business processes including: intellectual property development, pitching for investment, etc. that have stretched our experiences beyond just engineering.

We CAN save lives!
About our team

Our talented team of mechanical engineers brings expertise in all aspects of the engineering and design process.

Kathryn Kubacki is a senior studying Mechanical Engineering and minoring in Biomedical Engineering. She began this project in June 2020 before recruiting the rest of the team. Kathryn currently serves as the Project Manager for Toobtek and works closely with medical professionals at Denver Health Medical Center to ensure our product meets their training needs.

Kaushik Kannan is a senior studying Mechanical Engineering and Applied Mathematics. His experience in designing product strategy at both large companies and small startups helps him strategize how to drive Toobtek forward. He serves as the Logistics Manager for Toobtek, helping to create comprehensive design documentation of the product.

Rebecca Jacobs is studying Mechanical Engineering with minors in Computer Science and Engineering Management. Her experience in both mechanical design and technical sales makes her a valuable asset to the team when it comes to financial matters and business development. She strives to develop the Toobtek brand and help the company penetrate the medical simulation market.

Judson Martin is a senior studying Mechanical Engineering and minoring in Business at the University of Colorado Boulder. He is the CAD and Manufacturing Engineer for Toobtek and brings valuable expertise in design. He also works closely with the business development team in all stages of the company.

Jacob Haimes is a senior studying Mechanical Engineering and minoring in Computer Science Engineering at the University of Colorado Boulder. He is extremely knowledgable when it comes to data analysis and testing. He has specified requirements and designed tests to assess if our product meets our specified standards as the Systems and Test Engineer of Toobtek.

We are also joined by an incredible group of mentors, spanning the medical, engineering, and business development spaces.

Brian Rosenfeld, M.D.  Dan Riffell  Walter Wong  Dr. Virginia Ferguson  Jonathan Mischke