Emergency Cricothyroidotomy Device

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Abstract

Cricothyroidotomy is an emergency procedure used by EMS professionals to create an airway in patients with upper airway obstructions. The proposed design will be able to easily perform a cricothyroidotomy in instances EMS professionals aren't available.

Motivation

- > 4000 choking deaths per year in the US [1]
- Average EMS arrival time is 7 minutes [2]
- Heimlich maneuver is 86.5% successful [3]
- Permanent brain damage is likely after 4 minutes of choking [4]

Problem Statement

Current devices used to perform a cricothyroidotomy require multiple moving parts and specialized training. Time is everything in choking situations and victims lives rely on the response time of EMS. The device aims to be easy to use and incorporate multiple parts into one while also being adaptable to EMS tools.

Background Research

- No treatment other than Heimlich maneuver until EMS arrives
- Current market devices:
  - Require assembly
  - Not available to public
  - $30-$200 [5-7]
  - Requires training
- Cricothyroid membrane located under adam's apple

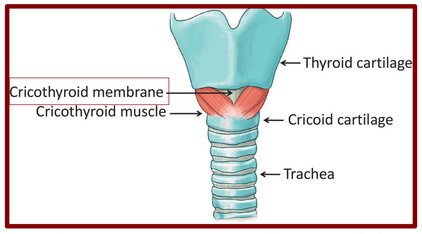

Figure 1: Anatomy of Larynx [8]

Design Specifications

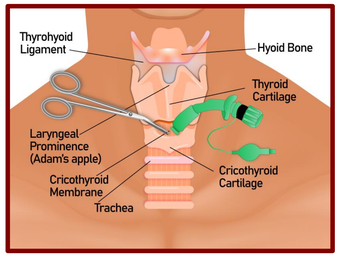

Figure 2: Cricothyroidotomy Procedure [9]

- Single use
- Sterile
- ≤ 8.2 cm in length
- Non-ferrous material
- Exchange 500 mL air every 3 seconds
- Singular component
- Puncture depth: 2.9 mm (female), 4.5 mm (male)
- Connects to bag valve mask

Final Design and Fabrication

- Aluminum chosen as material
  - Inexpensive, non-ferrous, lightweight
  - Strong, sharp edge
- Dimensions based on:
  - Anatomical considerations, competing devices, flow calculations
- Machining done in the TEAM Lab, using lathe and mill
  - Fabrication protocol established for replicability

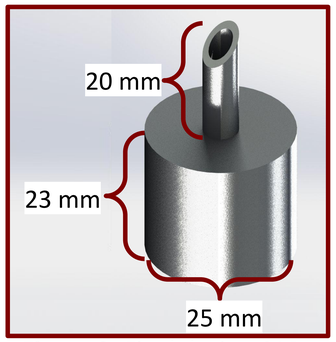

Figure 3: Final design CAD

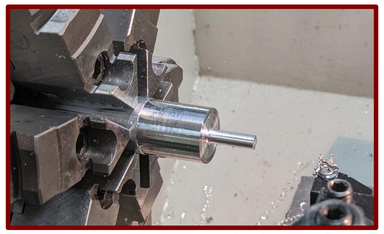

Figure 4: Turning on lathe to form overall shape and inner channel

Figure 5: Using mill to create sharp cutting tip and additional hole

Testing and Results

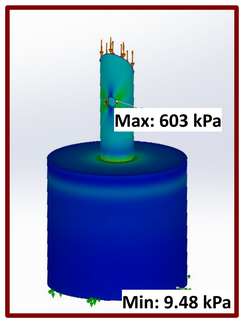

Figure 6: Aluminum Stress Testing using Solidworks

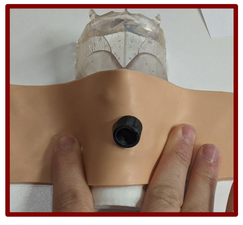

Figure 8: Upper airway manikin used during qualitative survey

- CAD simulation compression testing, to puncture skin
  - Aluminum: 603 kPa
  - PLA: 654 kPa
- Rudimentary functionality testing with skin mimic
  - 43.5 kPa to puncture skin
- Qualitative survey to gauge approachability
  - surveyed peers during show and tell
- MTS compression testing with a porcine larynx
  - Yielded no viable results
  - Porcine tissue not affixed properly

Figure 7: Skin puncture testing using force gauge

Figure 9: MTS testing of prototype with porcine larynx

Conclusions

Figure 10: Final prototype

- The final prototype is not sharp enough to consistently puncture tissue
  - Ensure precision and accuracy by machining a sharper edge
- Inconsistent testing methods between trials
  - Movement of trachea, larynx, and prototype created errors
  - Understand proper MTS load cell needed
  - Evaluate the physiological relevance of various testing methods
- Survey showed device to be approachable, unintimidating
  - Most people believe they can identify the cricothyroid membrane within 90 seconds
  - Lack of diverse population with survey
- Cannot run statistics because N=1 for CAD simulation

Future Work

- Formulate a reliable testing protocol and process
  - Consider ways to secure the trachea and larynx
  - Develop a procedurally relevant force application during testing
- Improve physiological representation of materials
  - Source animal skin to use during collection of puncture data
- Test ergonomics of the device for the user
  - Understand the extent of universality
  - Determine how to grip during use
- Measure airflow with BVM bag and air flowmeter to evaluate if air delivery rate matches 500mL/3 seconds
- Make design modifications based on testing data and considerations of gender anatomical differences
- Develop a manufacturing and marketing plan
  - Meet with the Wisconsin Alumni Research Foundation (WARF)

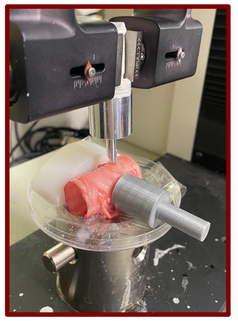

Figure 11: Testing stabilization method of the trachea on the MTS machine

Acknowledgements

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