Automated Endotracheal Intubation (AEI) Device

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Purpose

The purpose of our design is to facilitate endotracheal intubation with a hand-held electronically controlled device. This is possible using specialized actuators on the tip of our device and extruding motors. This platform allows for the seamless integration of artificial intelligence feeding and steering the placement of the endotracheal tube (ETT).

Clinical Background

Endotracheal intubation is often an emergency procedure performed on a patient having difficulty breathing if any path along the airway is blocked or damaged to maintain an open airway and helps prevent suffocation. A flexible plastic tube is placed into your trachea through your mouth quickly securing the airway to help you breathe. Around 13-20 million intubations performed each year in the US[1].

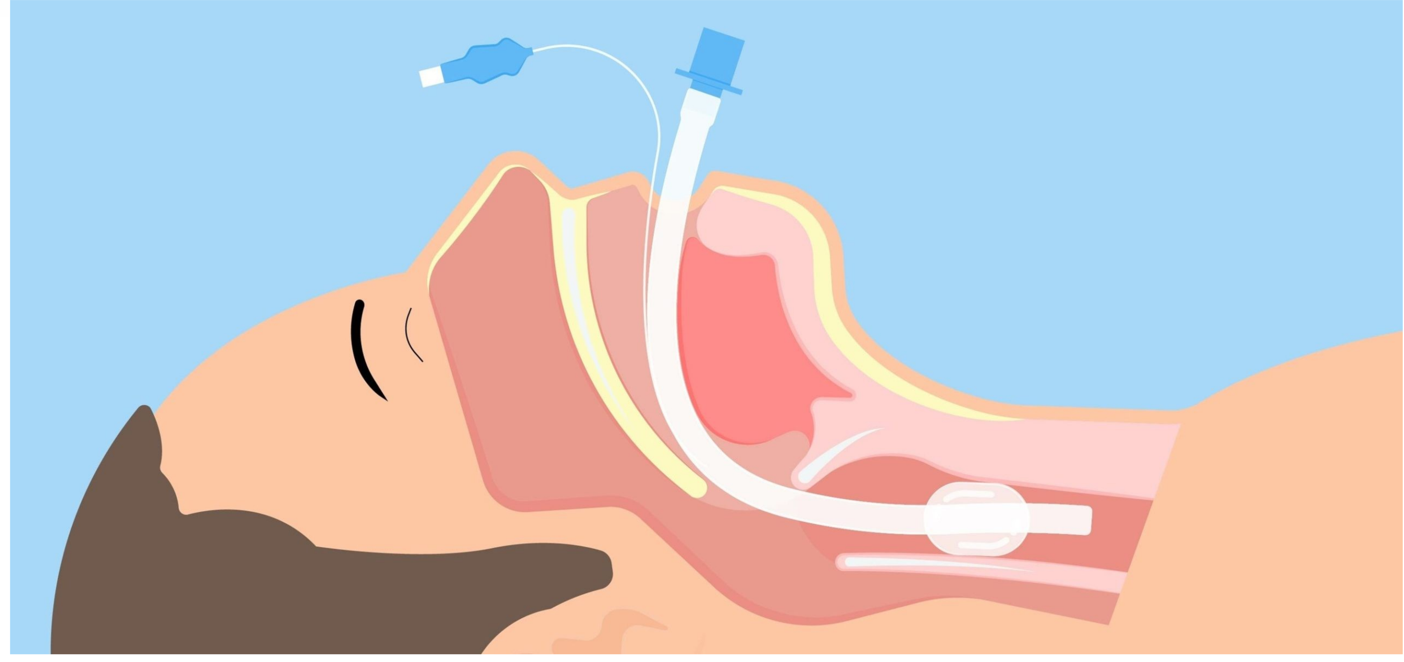

Figure 1: Intubation Tube Animation Mid-procedure

There are currently 3 standard devices for intubation as seen below.

Direct Laryngoscope	Video Laryngoscope	Flexible Intubation Scope
• Visualize ✗	• Visualize ✓	• Visualize ✓
• Navigate ✗	• Navigate ✗	• Navigate ✓
• Automation ✗	• Automation ✗	• Automation ✗

Figure 2: Current Intubation Tools and Their Pro/Cons

Problems with current treatment strategies:

- None of the current treatment strategies combine the best visualization of the airway, navigation of the ETT, and placement of the ETT via some form of automated movement.
- The flexible intubation scope is most promising but is difficult to learn and is still limited to being exclusively manually operated.

The Design Process

Using current literature on continuum robot actuation methods, intubation systems, and interviews with anesthesiologists, a ranking system for the characteristics of the desired device was created. These attributes were then given weights based on importance and used to select an actuation method that best suited the device needs. See Figure 3 below.

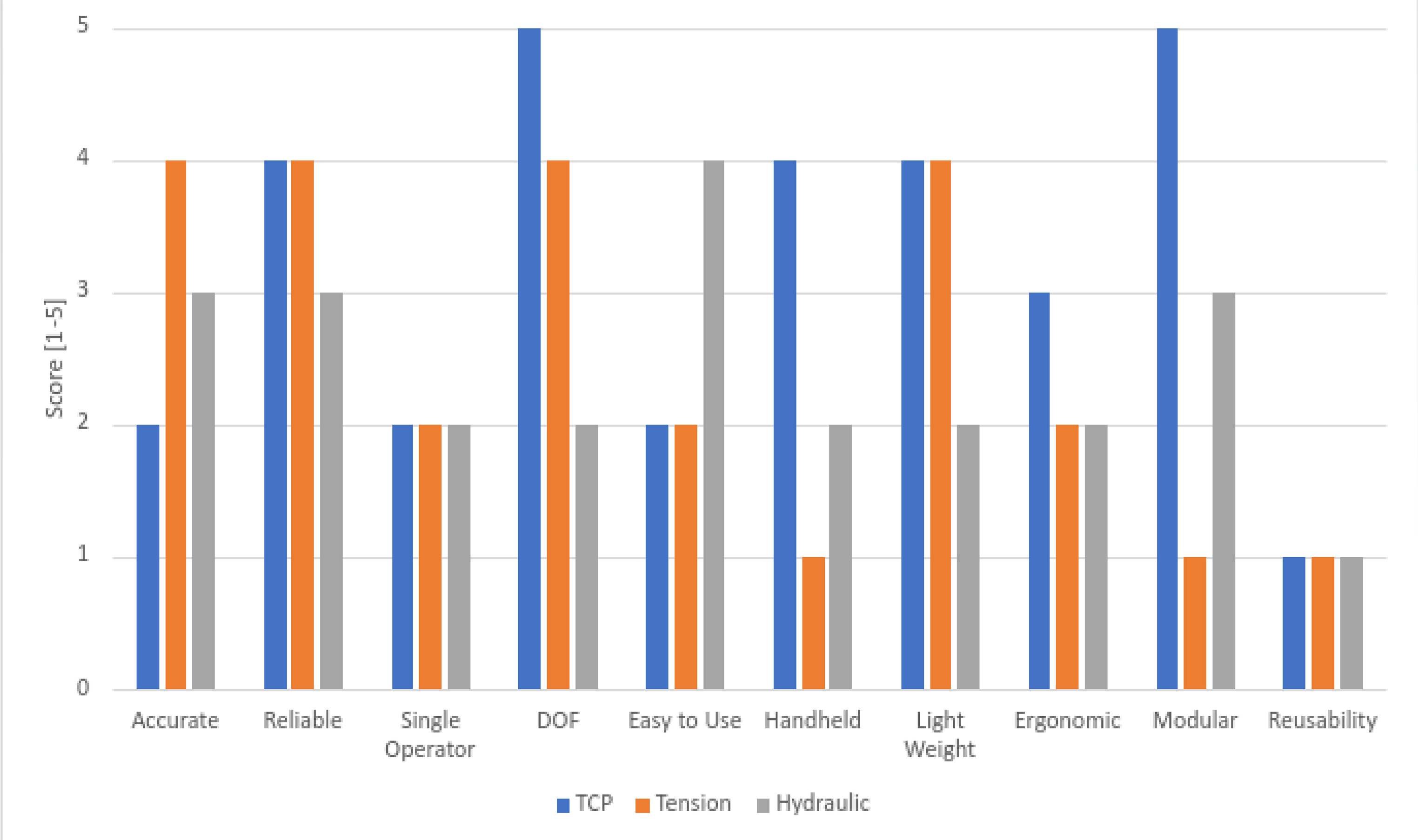

Figure 3: Actuation Characteristic Comparisons

As can be seen, the twisted and coiled polymer (TCP) method of actuation was the highest scoring method for the characteristics prioritized. It should be noted that, ideally, TCP is capable of being extruded from the main body. This feature sets it apart from all other current intubation methods and allows for the possibility of an intelligence driven system.

Component Design

Once the actuation method was chosen, the team began fabricating the TCP material to be used on the end effector, and initiated plans to create the housing unit as well as the control circuit. For these purposes we split into three teams that held the responsibility of completing each task.

Table 1: Device Component List with Responsibilities

Component Name	Description	Team Members
TCP	The end effector material. Made of twisted and coiled polymer (TCP) fiber.	MN, TS, CG, HM
Control Circuit	Circuit located in the housing module. Used to control current flow to the TCP.	MN
Housing Module	Containment unit for the circuit, and eventually stepper motor.	TS, CG

The TCP and Housing Module are shown in Figure 4.

Prototype Images

Figure 4: TCP End Effector and Assembled Prototype Respectively

Testing and Analysis

Analysis 1 – Movement

- Testing of the movement of the TCP in the x-y coordinate plane
- A pass would consist of free movement in the plane. Grading was completed with a qualitative percentage score.
- Score: 70% - Pass
  - This is primarily due to the lack of speed when changing directions.
  - Note: Current TCP adherence to the core tubing is not ideal, causing a lack of even tension between the opposing strings.

Analysis 2 – ISO/DIS 8600-4

- Maximal diameter of end effector/central tubing (8mm)
- Addressed in the team's device fabrication
  - 2 components (end effector & backing material)
    - End effector: TCA, core material, camera, circuit wiring
    - Central tubing: Core material, circuit wiring, outer sleeve
  - Physical resources: Silver coated nylon (TCP), hollow silicone tubing (core), circuit components, heat shrink wrap (outer sleeve)
- Test Result (Pass/Fail): Fail
  - Fix: Better adherence technique between TCP and core tubing.

Analysis 3 – Clinical

- Survey evaluation of intuitiveness of controls, visual display comfortability, confidence in device shape, speed of actuation, and future use of device
  - Each category was scored from 1 to 5
- Speed of actuation was the main detrimental factor
- Average score of 19.5/25 based on two mentor evaluations
- Test Result (Pass/Fail): Pass

References and Acknowledgements

1. Nadeem, A., Gazmuri, R. J., Waheed, I., Nadeem, R., Molnar, J., Mahmood, S., Dhillon, S. K., & Morgan, P. (2017). Adherence to Evidence-Base Endotracheal Intubation Practice Patterns by Intensivists and Emergency Department Physicians. *Journal of acute medicine, 7*(2), 47–53. https://doi.org/10.6705/j.jacme.2017.0702.001

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