Proceedings of the 2022 Design of Medical Devices Conference
DMD2022
April 11-14, 2022, Minneapolis, MN, USA

DMD2022-1024

MOTION BASED FEEDBACK TRAINING SYSTEM FOR ENDOTRACHEAL INTUBATION

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ABSTRACT

Endotracheal intubation is a common procedure that is performed for patients who are unable to adequately breathe. This procedure is often more successful when performed inside a hospital, but there are emergency situations that require out of hospital intubations. For both in-hospital and out of hospital, the statistics for flawed and failed intubation attempts are high. The primary risk associated with prolonged and failed intubation attempts are hypoxia leading to brain injury and death. To mitigate these risks, a motion-based feedback training system is proposed. Experimentation is performed to track the position of a laryngoscope during a manikin intubation. It was found that during intubation there was a significant range of motion in the x direction up to 120 and 114 mm. Also, it was found that for one trial the tortuosity value was significantly higher at 75. Overall results show that significant delicate movements are necessary, and that user movement varied between cases.

Keywords: Laryngoscope, Intubation, Medical Training

1. INTRODUCTION

Endotracheal intubation (ETI) is a vital procedure to maintain oxygen levels in patients that are unable to breathe voluntarily. Due to the diversity of the oropharyngeal anatomy, positioning a laryngoscope to align the laryngeal, pharyngeal, and oral axes can be a challenging task. If done improperly, negative impacts will result. The principal concern for failed intubation is the inability to provide oxygen to patient's tissues (hypoxia) which can precipitously lead to brain injury and death. Consciousness can be lost as fast as 15 seconds without oxygen, and brain damage occurs after about 4 minutes [1]. The second major concern is trauma to the oropharynx including teeth, lips, gums, tonsils, uvula and even esophagus [2]. The teeth and lips are particularly prone to being injured by inexperienced and under-experienced clinicians [3]. Soft tissue damage, while generally limited and benign, can, on rare occasions, become life threatening. In one study performed by Jacques Jougon, five cases of esophageal perforation were investigated. All of which required surgical intervention and two of which the patient died [4].

Currently there are no set standards for endotracheal intubation training. Each healthcare practice decides independently on the best way to evaluate ETI proficiency. Due to the lack of a set standard of evaluation, there is much variation within the practice. At some hospitals, it is required for a medical professional to perform at least 10 intubations per year to maintain their skill, others require periodic written exams on the subject, and others only require mannequin training [5].

The percentage of intubation failures are much higher when performed outside of the hospital which are performed in emergency situations. In one study, 108 field intubations were examined to reveal that misplacements occurred in 25% of intubation attempts [6]. Another study revealed that out of 1,953 patients the percentage of intubation with errors (tube misplacement, four or more intubation attempts, or failed attempt) was 22% [7]. These statistics are high, and without standardize training, it is challenging to improve the entire population's skill set.

There are many areas in which current endotracheal intubation practices are falling short. Some of these problems could be solved with more advanced intubation technology such as the routine use of video laryngoscopy, but these continue to have limitations: for instance, video laryngoscopy has been associated with increased risk of oropharyngeal trauma [8] and the failure rate may not be improved with inexperienced operators [9]. Hence, improved endotracheal intubation training is needed to reduce the current failure statistics. This paper discusses a concept for a training system that delivers critical motion-based feedback to help trainees develop specific areas that toned improvement to enhance their practice.

2. MATERIALS AND METHODS

The experiment was performed, and medical equipment sourced, from the Hershey Medical Center's Simulation Laboratory. The sensory equipment was provided by the Medical Instrumentation Design Lab at the Pennsylvania State University. To experimentally measure tool movement, a C-CAM Karl Storz laryngoscope was used with a magnetic sensor attached to the upper left side of the handle. Another magnetic sensor was thread through a Shiley 7.5 mm inner-diameter endotracheal tube. The sensorized laryngoscope setup can be seen in Figure 1. The sensors used were Northern Digital Inc. (Waterloo, ON) 3D Guidance TrakSTAR Model 800 and Model 90. This system has an accuracy of 1.4mm and 0.50°. While the intubations were being performed, the motion of the laryngoscope and tube were recorded. The data regarding the position and angle of the sensors was analyzed using MATLAB version R2020a (MathWorks, Natick, MA).

To understand the position of the laryngoscope, calipers were used to measure the dimensions of the ridged tool and the sensor's position relative to the top and center of the handle. The sensor was oriented to measure up/down motion in the x-direction, and forward/backwards in the y-direction, as shown in Figure 1. Five trials were performed on a Nasco Education Life/form "Airway Larry" Adult Airway Management Trainer with Stand.

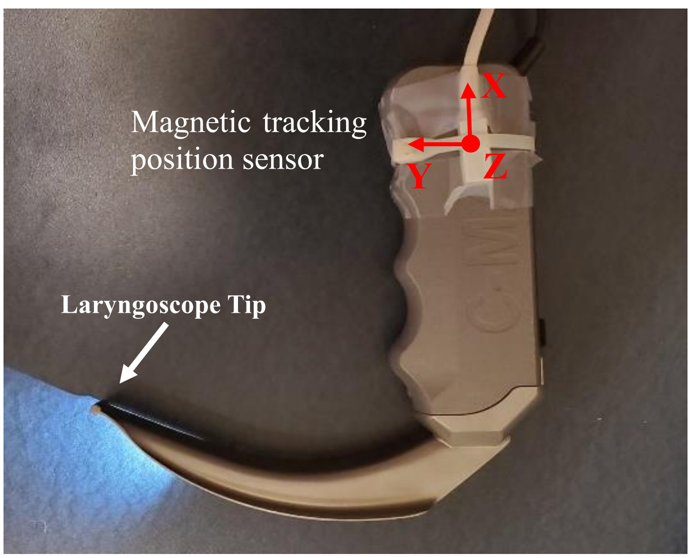

FIGURE 1: C-MAC LARYNGOSCOPE WITH MAGNETIC TRACKER ATTACHED ON THE UPPER LEFT SIDE OF THE HANDLE

For each ETI trial, an attending physician anesthesiologist, performed an oral intubation on the mannequin as shown in Figure 2. Five trials were recorded, using two different head positions: supported, where a blanket was placed under the head to achieve the "sniffing position" (trials 1-3) and unsupported (trials 4-5), with the head laying on the mannequin table. To maintain a consistent starting reference, the tube started at the right side of the head. The laryngoscope was oriented, so the tip of the blade was in contact with the right corner of the lip and the handle was angled slightly left. The starting position can be seen in Figure 2. Once the recording of the motion began, the materials were able to move from their original positioning.

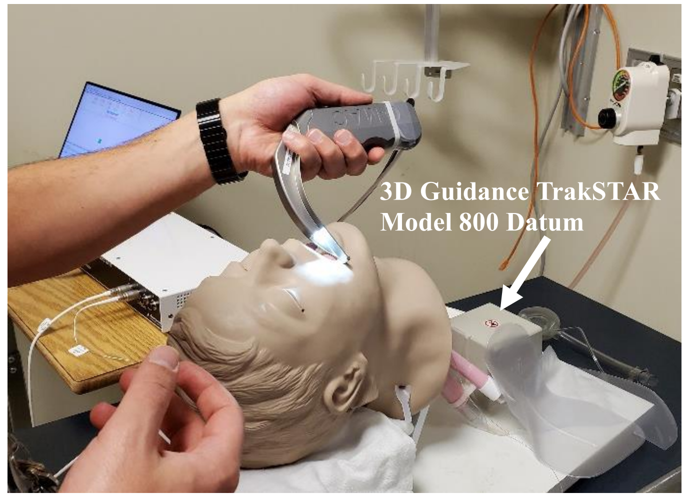

FIGURE 2: STARTING POSITIONING FOR ENDOTRACHEAL INTUBATION TRIALS

3. RESULTS AND DISCUSSION

The results for tip motion can be seen in Figure 3 and Table 1. Results indicate that substantial precise motion was required for positioning, with handle motion in the y direction as high as 120 mm. It was also found that levels of movement and tortuosity (ratio of the total path to the shortest path) varied significantly between trials. The smaller the tortuosity, the more efficient the intubation performed. For example, as seen in Table 1, the tortuosity for trial four was 75.42, which is a high ratio. In the video feedback from the intubation attempt, the tube overshot the trachea on the first two passes creating this high tortuosity value.

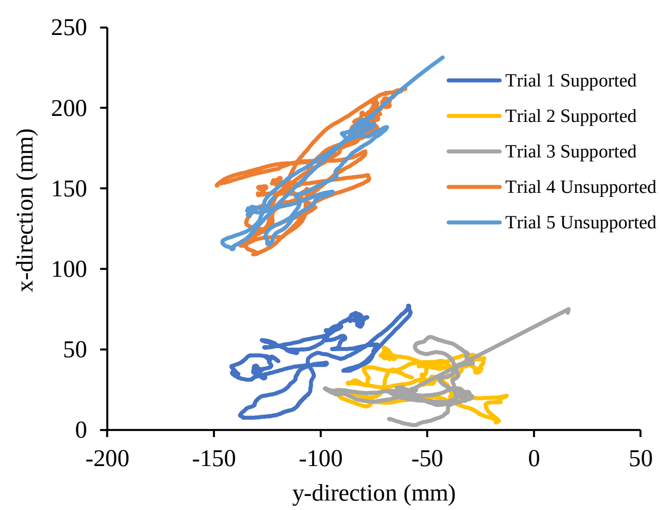

FIGURE 3: LARYNGOSCOPE TIP MOTION PLOTS FOR TRIALS ONE THROUGH FIVE

Head support was shown to impact the required movement in the x direction as shown in Table 1, where 120 and 102 mm of motion was required compared to 68, 39, and 68 mm. It is known that intubation with head support is generally easier procedure to perform compared to no head support. This is supported by the less motion required and the high tortuosity value of 75.42 in trial 4.

TABLE 1: TORTUOSITY AND MOVEMENT RANGE IN THE X AND Y DIRECTIONS FOR EACH TRIAL

		Movement Range (mm)			
		Handle		Tip	
Trial	Tortuosity	x	y	x	y
1	16	68	87	70	84
2	35	39	90	46	80
3	5	68	114	72	114
4	75	103	74	103	89
5	6	120	100	119	103

*Mannequin head was unsupported in trials 4 and 5.

In Figure 4 and Table 1, the motion for the tip and the handle can be seen. Generally, the motion and the range were very similar. For example, difference in the ranges between the tip and the handle for trial one is only 1.91 mm and 3.25 mm respectively. This indicates the laryngoscope was largely entered with little rotation.

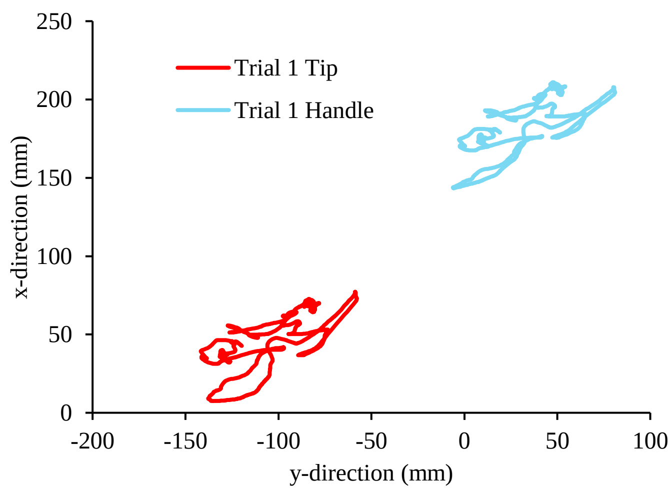

FIGURE 4: LARYNGOSCOPE HANDLE AND TIP MOTION PLOT FOR TRIAL ONE

4. CONCLUSION

Motion information for the endotracheal intubation process was collected. Trials for both supported and unsupported head positions were performed. From these results it is evident that there are significant delicate movements required and that movement can vary between cases. Having the ability to track and assess these movements will provide the trainee with useful feedback on their intubation technique. To reduce error in further testing, a rigid plastic laryngoscope will be used as to not interfere with the magnetic sensors. Future work will aim to collect more tracking information to understand the acceptable movement ranges, intubation durations, and develop an automated system that uses these measurements to provide effective feedback for continual learning.

ACKNOWLEDGEMENTS

This work presented was generously supported by the Shuman Scholarship at Pennsylvania State University.

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