Cross-over study of novice intubators performing endotracheal intubation in an upright versus supine position

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Preliminary data from this study was presented at the SAEM national meeting, San Diego, May 14, 2015

This is the author's manuscript of the article published in final edited form as:
Turner, J. S., Ellender, T. J., Okonkwo, E. R., Stepsis, T. M., Stevens, A. C., Eddy, C. S., … Cooper, D. D. (2016). Cross-over study of novice intubators performing endotracheal intubation in an upright versus supine position. Internal and Emergency Medicine, 1–6. https://doi.org/10.1007/s11739-016-1481-z

Abstract: There are a number of potential physical advantages to performing orotracheal intubation in an upright position. The objective of this study was to measure the success of intubation of a simulated patient in an upright versus supine position by novice intubators after brief training. This was a cross-over design study in which learners (medical students, physician assistant students, and paramedic students) intubated mannequins in both a supine (head of the bed at 0 degrees) and upright (head of bed elevated at 45 degrees) position. The primary outcome of interest was successful intubation of the trachea. Secondary outcomes included log time to intubation, Cormack-Lehane view obtained, Percent of Glottic Opening score, provider assessment of difficulty, and overall provider satisfaction with the position. There were a total of 126 participants: 34 medical students, 84 physician assistant students, and 8 paramedic students. Successful tracheal intubation was achieved in 114 supine attempts (90.5%) and 123 upright attempts (97.6%; $p = 0.283$). Upright positioning was associated with significantly faster log time to intubation, higher likelihood of achieving Grade I Cormack-Lehane view, higher Percent of Glottic Opening score, lower perceived difficulty, and higher provider satisfaction. A subset of 74 participants had no previous intubation training or experience. For these providers, there was a non-significant trend toward improved intubation success with upright positioning vs supine positioning (98.6% vs. 87.8%, $p = 0.283$). For all secondary outcomes in this group, upright positioning significantly outperformed supine positioning.

Key Words: intubation, airway management, education, simulation

INTRODUCTION

Orotracheal intubation is a procedural skill that is important for a variety of healthcare providers. Physicians commonly perform this procedure in multiple settings including the emergency department (ED), intensive care unit (ICU), and operating room (OR). Outside of the hospital, paramedics often use endotracheal intubation to care for unstable and critically ill patients. In addition, advanced practice providers such as physician assistants (PAs), are increasingly performing this procedure, with one recent study reporting 44-65% of PAs working in the ED had performed an intubation within the last year [1].

Proper positioning is important to facilitate successful orotracheal intubation. Levitan et al described the advantages of elevating a patient's head for achieving improved glottic visualization [2]. Studies in the anesthesia literature suggest that elevating the external auditory meatus to the level of the sternal notch, using pillows or positioning devices to achieve a "ramped" position or "head-elevated laryngoscopy position" ("HELP"), improve laryngoscopic views [3]-[5]. Other methods of head elevation include having the patient sit during intubation [6] or simply adjusting the bed to elevate the head [7], [8]. It is thought that such positioning improves lower cervical flexion and atlanto-occipital extension, providing better visualization angles. Head elevation may also have the advantage of decreasing the amount of force required for the intubator to lift the patient's tissues out of the way [4], [6], [7].

Despite the potential advantages of intubation in an upright position, there is a lack of data to support this technique in emergency medicine and medical education literature. We believe this technique may be particularly beneficial to students learning to intubate for the first time or to providers who infrequently intubate. Simulation has been demonstrated to be an effective modality for airway education [9] and allows for clinical recreation that can be offered to multiple learners. The objective of this study was to measure the success of intubation of a simulated patient in an upright versus supine position by novice intubators after brief training.

METHODS

Study Design

This was a cross-over design study conducted at the Simulation Center at Fairbanks Hall of Indiana University. The study was deemed exempt by the Indiana University Institutional Review Board. All study participants signed informed consent statements to participate.

Study Population

Novice intubators were chosen for this phase of study in order to limit pre-defined bias and influence of experience with patient position on measured outcomes. Study participants included third year physician assistant (PA) students, first and second year medical students, and first year paramedic students at Indiana University. PA students in consecutive classes had intubation training in July 2014 and July 2015 as part of their standard curriculum. All PA students undergoing this training were invited to participate in the study. First and second year medical students were recruited through a representative of the school's Emergency Medicine Student Interest Group, and volunteers attended one of two sessions in January 2015. Paramedic students were a convenience sample of volunteer first year students recruited by faculty and participated in a session in October 2014.

Study Protocol and Outcome Measures

Participants were sent a 20 minute instructional video on how to intubate one week prior to their scheduled session. Part of the video included a 2 minute description of intubating in an upright position, defined as the head of the bead raised at an angle of 45 degrees relative to the floor. On the date of the session, students were alternately assigned to Group A or Group B by time of arrival at the simulation center. On arrival to the session, students completed a survey containing basic demographic information including previous intubation experience. The first 15 minutes of the session included an overall review of intubation with faculty. Prior to the study independent investigators blindly confirmed airway anatomy and laryngeal view on each of two high-fidelity SimMan 3G mannequins (Laerdal – Stavanger, Norway)

in multiple positions (supine and head up) with 7.5 French endotracheal tubes using both curved (Macintosh Size 3) and straight (Miller Size 3) laryngoscope blades to ensure setup consistency. Student groups then spent 20 minutes per position practicing intubation on each mannequin with the all of the physical restrictions set to neutral. One mannequin was lying completely supine (zero degrees) and one had the head of the bed in the upright position (45 degrees). Group A practiced in the upright position first and group B practiced in the supine position first (Figure 1).

Following the practice sessions, each student attempted to intubate both upright and supine mannequins in the same sequence and simulated conditions in which they had practiced. The primary outcome of interest was successful orotracheal intubation. Placement of the tube in the trachea was confirmed by study investigators by direct visualization through a removable cricothyrotomy membrane. Throughout the study, mannequins and investigators had their positions alternated so that each participated in an equivalent number of supine and upright attempts.

Secondary outcomes of interest included time to intubation, provider assessment of difficulty, Cormack-Lehane (C-L) view, Percent of Glottic Opening (POGO) score, and overall provider satisfaction. For each attempt, the study investigator timed the intubation from the moment that the student touched the laryngoscope blade until they released the endotracheal tube. Following each intubation attempt, students were asked to record the level of difficulty on a 10 point Likert scale. Students were also asked to record a C-L view and POGO score for each attempt and indicate whether they were “not satisfied”, “somewhat satisfied”, or “very satisfied” with the positioning of the simulated patient for each attempt.

Data Analysis

Due to the crossover study design, we used a mixed effects regression model for analysis of continuous variables and mixed effects logistic regression for binary outcomes. Each model contained a random effect for student, a fixed effect for intubation position, order performed (first or second attempt), and a sequence effect. The mixed effect model with a random effect for student and fixed effect for

position is equivalent to a paired t-test. The addition of order performed to the model allows for testing of time independent of intubation position. The sequence effect tests whether the effect of intubation position differs by time. After testing the effect of intubation position overall, we performed an additional analysis that specifically looked at the effect of student's prior intubation experience by adding fixed effects for prior experience and the interaction of prior experience with intubation position to the mixed effects model. Due to the skewed nature of time to intubation, we used the log transformed time for all analyses. Since there were very few Grade III and Grade IV cases, CL view was analyzed as Grade I vs. Grades II, III, and IV. Similarly, satisfaction was tested using the dichotomy of very satisfied vs. somewhat and not satisfied. All analyses were performed using SAS v9.3.

RESULTS

A total of 128 students participated in the study. Two students did not fill out the data collection sheets, leaving 126 students (84 PA students, 34 medical students, and 8 paramedic students) for the final analysis. As our interest was primarily focused on novice intubators, for additional analysis students were divided into groups that had prior intubation experience (n = 52) and those with no prior intubation experience (n = 74). Students who had intubation experience prior to the session had a mean of 11 and median of 3 previous intubation attempts, with the majority of these attempts having been performed on mannequins.

Results from the overall sample are presented in Table 1. All sequence p-values were not significant indicating the effect of intubation position did not differ by order performed. The log time to intubation and difficulty were significantly lower for the upright position than the horizontal position. The POGO score, provider satisfaction, and Grade 1 view were significantly higher for the upright position. There was no significant difference in intubation success rates.

Results by prior experience are presented in Table 2. The effect of intubation position significantly differed by prior experience for two outcomes. For mean POGO score and log time to

intubation, the effect of intubation position significantly differed by prior experience. Upright intubation was significantly associated with lower log time to intubation and higher POGO score only for students with no prior experience. For mean difficulty, CL Grade 1 view, and provider satisfaction, upright statistically outperformed supine in both students with prior experience and students without prior experience. Overall, students with prior experience had significantly higher satisfaction (OR = 2.8 [1.3, 5.7]) and CL Grade I view (OR = 3.1 [1.5, 6.4]) than those without prior experience. Students with no prior experience had significantly higher difficulty scores than those with prior experience.

DISCUSSION

Upright positioning offers potential physical and anatomic advantages that may help facilitate successful orotracheal intubation. Various methods and degrees of head elevation have been described for intubating OR patients [3-5], [7-8], difficult ED patients [6], patients undergoing awake intubation [10], and even simulated patients in an ambulance setting [11]. Nevertheless, traditional supine intubation remains widespread and upright intubation remains underrepresented in research and in medical education. Venezia and colleagues reported a study of novice intubators using a face-to-face technique with simulated patients in an upright position [12]. To our knowledge, there are no other studies examining the success of teaching students to intubate in an upright position.

Students in our study performed well intubating in the upright position. While it did not reach statistical significance, in both groups a higher percentage of patients were successfully intubated in the upright position compared to the supine position. Larger studies could be conducted to determine if this trend toward increased success in the upright position represents a true difference. Regardless, even showing equivalence in success rates between the supine and upright positions is important, as there are likely other advantages to intubating in the upright position. In addition to potentially affecting intubation difficulty, some have suggested that an upright position might have other clinically important benefits, such as decreasing risk of aspiration [13]. A recent study of emergent intubations in the ward and ICU

settings found lower rates of complications, including aspiration, hypoxemia, and esophageal intubation, when intubating in the upright compared to the supine positions [14].

Secondary outcomes in this study generally favored the upright position. For students with no prior experience intubating, the upright position significantly outperformed the supine position in log time to intubation, likelihood of achieving Grade I C-L view, POGO score, provider assessment of difficulty, and overall provider satisfaction. Effects were less pronounced for providers with previous intubation experience, likely because they already had some level of comfort with the supine position. Nevertheless, among this group upright position was still associated with improved likelihood of achieving Grade I C-L view, provider assessment of difficulty, and overall provider satisfaction compared with supine positioning.

Our study adds to a growing body of literature that suggests that there may be advantages to a more upright position during intubation. Further research on the use of upright positioning in both medical education and in the clinical setting, as well as studies with providers having different levels of experience, would be beneficial.

Limitations

There are several limitations to our study. C-L view and POGO score were reported by the intubator who was not blind to position. This potentially could have biased the responses of the students, and video laryngoscopy recording of each intubation attempt with blinded review by a third party could reveal different results. Furthermore, there are questions about the reliability of these methods of assessing laryngeal view. Studies have suggested that C-L view has poor intra-observer and inter-observer reliability [15]-[17]. POGO may have better reliability, but this has not been specifically demonstrated in our study population [17]. It is also unclear if there is any important clinical benefit to small improvements in C-L and POGO scores. Nevertheless, we chose to look at these measures because they are well-known and widely used amongst airway educators, providing a standard for comparison. Additionally, faculty were not blinded to the mannequin position, which may have affected how the

procedure was taught to students. While we attempted to keep the training sessions as neutral as possible and did not reveal the objective of our research to students, it is possible that some students were aware that the upright position was being studied as an alternative to the more traditional supine approach, and this may have influenced their responses regarding satisfaction. Finally, the study was performed on mannequins. While simulation has been demonstrated to be an effective method for teaching airway skills [9], it is not clear how the performance of the upright position would translate to performance in actual patients. Live tissue in real patients is affected by gravity differently than mannequins. However, previous studies have suggested that head elevation may decrease the force of gravity on live tissues, indicating that the anatomic advantages of upright position would likely be important in live patients [4], [6], [7]. We did not specifically measure the anatomic changes or effects of force based on position in our study; future studies could help quantify this effect. Furthermore studies of upright positioning in live patients would be helpful to clarify differences in this effect between simulated models and live tissue.

Conclusions

Among novice intubators, upright positioning with the head of the bead at 45 degrees is associated with quicker log time to orotracheal intubation, improved views, decreased perceived difficulty, and higher provider satisfaction compare with supine positioning. There was no statistically significant difference in intubation success rates.

Compliance With Ethical Standards

Conflict of Interest: The authors declare that they have no conflict of interest

The authors have no financial disclosures. There is no financial support for this work to report.

The study was deemed exempt by the Indiana University Institutional Review Board. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards

Informed consent was obtained from all individual participants included in the study.

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Table 1. Summary Measures for Complete Sample

	Horizontal (n=126)	**Upright (n=126)**	**Position P-value**	**Time P-value**	**Sequence P-value**
Mean Time to Intubation, Seconds (SD)	24.0 (21.0)	19.6 (15.6)			
Median Time to Intubation, Seconds	17	16			
Mean Log Time to Intubation (SD)	3.0 (0.6)	2.8 (0.5)	0.003	0.018	0.178
Mean Difficulty (SD)	4.3 (2.2)	3.4 (1.9)	<0.001	0.083	0.303
Mean POGO (SD)	71.8 (25.8)	80.2 (22.5)	<0.001	0.020	0.851
N Successful (%)	114 (90.5)	123 (97.6)	0.283	0.976	0.497
CL View* (%)			0.011	0.046	0.844
Grade I	47 (38.2)	67 (54.0)			
Grade II	64 (52.0)	50 (40.3)			
Grade III	10 (8.1)	7 (5.7)			
Grade IV	2 (1.6)	0 (0.0)			
Satisfaction** (%)			<0.001	0.036	0.919
Not Satisfied	5 (4.1)	1 (0.8)			
Somewhat Satisfied	56 (45.5)	13 (10.5)			
Very Satisfied	62 (50.4)	110 (88.7)			

SD = Standard Deviation
POGO = Percent of Glottic Opening
CL = Cormack-Lehane
* CL view was tested as Grade 1 vs. Grade II, III, IV
** Satisfaction was tested as very satisfied vs. somewhat satisfied and not satisfied

Table 2. Comparison of Intubation Position by Experience

	Horizontal	Upright	Prior Exp P-value	Prior * Position P-value	Position P-value
Log Time to Intubation			0.018	<0.012	
No Prior Experience (n = 74)	3.2 (0.6)	2.9 (0.5)			<0.001
Prior Experience (n = 52)	2.7 (0.5)	2.7 (0.4)			0.968
Mean Difficulty			<0.001	0.200	
No Prior Experience	4.9 (2.3)	3.8 (2.1)			<0.001
Prior Experience	3.4 (3.0)	2.8 (3.0)			<0.001
Mean POGO			0.294	0.001	
No Prior Experience	65.0 (26.3)	78.2 (22.7)			<0.001
Prior Experience	81.7 (21.8)	83.0 (22.0)			0.765
N Successful (%)			0.622	0.409	
No Prior Experience	65 (87.8)	73 (98.6)			0.283
Prior Experience	49 (94.2)	50 (96.2)			0.283
CL View – Grade 1			0.002	0.367	
No Prior Experience	19 (26.4)	33 (45.8)			0.009
Prior Experience	28 (54.9)	34 (65.4)			0.009
Satisfaction – Very Satisfied			0.006	0.168	
No Prior Experience	27 (38.0)	63 (87.5)			<0.001
Prior Experience	35 (67.3)	47 (90.4)			

POGO = Percent of Glottic Opening
CL = Cormack-Lehane