



Evaluation of a Better Intubation Strategy When Only the Epiglottis is Visible: a Mannequin Study

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Abstract

Study Objective: Cormack-Lehane (C-L) grade III is considered as difficult airway where only the epiglottis is visualized under direct laryngoscopy and has a poor intubation success rate.

Objective: The purpose of the study is to investigate whether the endotracheal tube holding position, shapes and bend angles of endotracheal tube, stylet-assisted lifting of epiglottis can improve the success rate of intubation.

Methods: Thirty-two participants (26 physicians, 2 residents, and 4 nurse practitioners, average working length 12.09 ± 5.38 years in the emergency department with more than 150 annual intubation events) were enrolled in this randomized, cross-over mannequin study to investigate straight-to-cuff shape with 35° and 50° bend angles, banana shape, with longitudinal distance at 28 cm and 26 cm, holding the endotracheal tube on the top or middle, and their effects on intubation duration, success rate, and subjective difficulty. Lifting or not lifting of the epiglottis with stylets during intubation was also compared to investigate a better strategy in the management of C-L grade III.

Results: Two subgroups that performed lifting of the epiglottis with stylets had the shortest duration of intubation (23.75 ± 14.24 's and 20.72 ± 6.90 's in bend angles of 35° and 50°, Hazard ration 1.54 and 1.85 with confidence interval of 1.01 to 2.34 and 1.23 to 2.78, respectively) and 100% success rate of intubation. In survival analysis, only lifting of the epiglottis was significant ($p < 0.0001$, 95% CI 1.34 to 2.11).

Conclusions: The use of epiglottis lift as an adjunctive technique can facilitate and improve the intubation success rate in difficult airway graded as C-L III under direct laryngoscopy without increased difficulty.

Keywords: Difficult airways; Intubation technique; Stylet shapes; Lifting of epiglottis; Bend angles; Cormack-lehane grade

Introduction

Although the video laryngoscope has become a popular device among many emergency physicians, direct laryngoscopy remains a fundamental skill in intubation. The direct laryngoscope can visualize the direct path to the inlet of trachea (vocal cord), and visibility of the vocal cord is always the guarantee for successful intubation. Besides, direct laryngoscope is still the best device used when encountering patients with increased secretion, vomitus, or bloody discharge. Video laryngoscope can generally provide better glottic view based on its remote camera system, but it is vulnerable to misty vision.

Data in previous literature regarding the incidences of Cormack-Lehane (C-L) grading for

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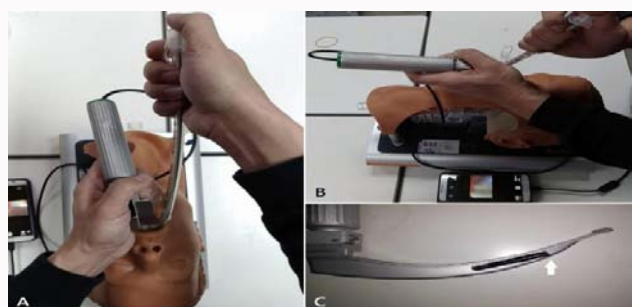


Figure 1: (A) Holding the top of the endotracheal tube and (B) bending the elbow to the chest right after the cuff passed through the incisors to elevate the tip of the tube with a larger torque. All the processes were recorded with a video camera. (C) The camera was attached to the blade for recording purposes. The participants used direct laryngoscope without watching the screen. White arrow indicated the location of the camera.

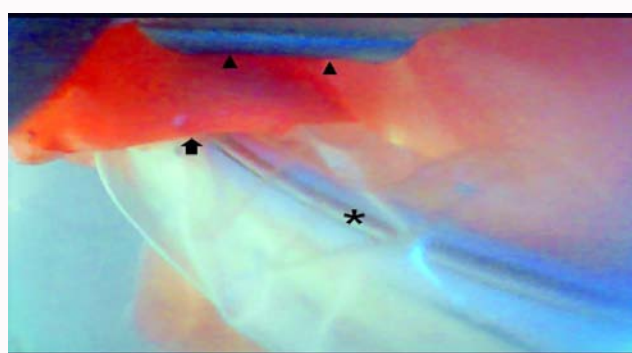


Figure 2: Elevating the epiglottis (black arrow) with the tip of the endotracheal tube with the right hand under direct laryngoscopy (black arrowheads). *indicated a stylet.

direct laryngoscopy were varied. The incidence of the occurrence of difficult airway IIb (only the arytenoids is visible) was 3.3% to 6.5%; III, 1.2% to 9.0% and 7.1% to 20.5% in the operating room and in the Emergency Department (ED) setting, respectively [1-11]. Casey et al. [11] reported that the intubation success rate on first attempt for C-L grade III was 44.7%. C-L grade IIb is similar to grades III and IV because the intubation success rate is much lower than grade IIa (lower part of the vocal cord visible). Difficult airway in the C-L grading system was defined as IIb-IV by Yantis et al. [1,2]. When the vocal cords are visible under laryngoscopy, such as in C-L grades I and IIa, successful intubation is always anticipated in skilled hands. However, in C-L grade IIb-IV, blind intubation (without seeing the endotracheal tube pass through the vocal cords) is more difficult because the distances among the tip of the endotracheal tube and epiglottis or other landmarks are obscured. Under such circumstances, if the performer can keep the tip of endotracheal tube moving along and just beneath the epiglottis closely (anterior part of the larynx), the endotracheal tube would slip from the windpipe of the larynx to the trachea. Compared with holding the middle part of the endotracheal tube and hooking the imaginary target of the trachea inlet out of the visual field, two techniques might help: 1. Manage the stylet as a Trachway intubating stylet (Biotronic Instrument Enterprise Ltd., Tai-Chung, Taiwan), by holding the top of the endotracheal tube with the right hand. Lever the endotracheal tube as a pry bar right after the cuff passing through the incisors with elbow bending to the chest. Such technique may provide a larger torque to hook and move the tip of the endotracheal tube beneath and parallel

to the epiglottis (Figure 1A and B). This technique was initially introduced by James Ducanto. 2. Lift the epiglottis with the tip of the stylet-equipped endotracheal tube. We always focus on our left hands to manipulate the laryngoscope for a better glottic view. When the glottic view is insufficient to perform intubation, we would adjust the tip of laryngoscope in vallecula and try to lift more. However, Wasa et al. [12] had reported a case that lifting the epiglottis with the stylet may also improve the glottic view directly.

Levitan et al. [13] had proved that the shapes and bend angles of the stylet affect the success of intubation. Although a hockey shape is widely used in emergency practice, how different shapes of the stylet and how curvature might affect intubation remained unclear. This study was designed to determine a better intubation strategy when managing difficult airway with a higher modified C-L grade, namely, IIb or III, while the inlet of the trachea is not visualized by the performer.

Study design and participants methods

This study was a randomized, cross-over study. The 32 participants were attending physicians, residents, and nurse practitioners (81.25%, 6.25%, and 12.50%, respectively), average working length 12.09 ± 5.38 years in the emergency department with more than 150 annual intubation events. They were recruited from multiple medical centers in north and south Taiwan (Taipei City Hospital, Shin Kong Wu Ho-Su Memorial Hospital, Dalin Tzu Chi Buddhist Hospital, Shuang Ho Hospital, Taipei Municipal Wanfang Hospital, Chang Gung Memorial Hospital) during an airway training course (CATLAB, Critical Airway Training Laboratory). This study was approved on October 31st, 2017, by the Institutional Review Board of Taipei City Hospital, Taiwan (approval number: TCHIRB-10610108-W, Chairman: Lee, Oscar Kuang-Sheng) and registered in the Clinical Trials Registry (Identifier NCT0366311). All participants were inexperienced in holding the top of the endotracheal tube nor lifting the epiglottis with a stylet while intubating. They were instructed to perform these two methods and to successfully intubate at least thrice on the AMBU Mannequin Intubation Airway (Ambu Enterprise Ltd., Ballerup, Denmark) before the study began. This mannequin provides an open view to verify successful intubation. Moreover, mouth opening was small; thus, the visualization of the vocal cord is limited.

Protocol

Direct laryngoscope (Macintosh #3 blade) was used in all the participants, and a conventional 7.0 mm internal diameter tracheal tube (Covidien, Mallinckrodt Pharmaceuticals Ltd., Surrey, United Kingdom) was used to intubate the mannequin without assistance. They were asked to lift the epiglottis with moderate strength to avoid visualization of the vocal cord and intubate under C-L grade III (only the epiglottis is visible). All intubation processes were recorded and reviewed latterly to ensure the intubation processes were under the view of C-L grade IIb to III.

Banana-shape curvature

The full length of the Covidien Cuffed Mallinckrodt endotracheal tube (7.0 mm internal diameter) from the tip to the adaptor was 32.5 cm. The estimated curvature with a longitudinal distance of 28 cm and 26 cm was $1/0.07$ ($p = 0.07$ m) and $1/0.08$ ($p = 0.08$ m), respectively. These curvatures were approximate to the bend angles of straight-to-cuff of 35° and 50° at the cuff level.

Part 1: When the performers had a proper glottic view under

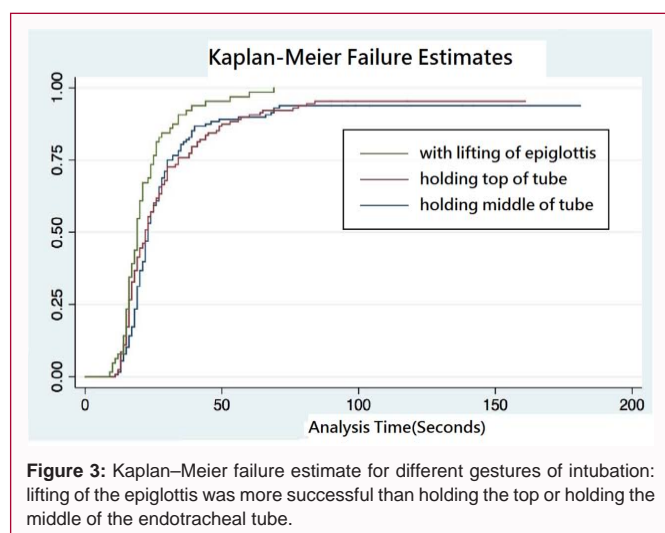


Table 1: Participant characteristics.

Variable	Mean		SD
Age (years-old)	38.56	±	5.19
Length of Service in ED (Years)	12.09	±	5.38
Total			32
· Attending			26
· Resident			2
· Nurse Practitioner			4
Height (cm)	169.69	±	6.47
Male : Female	27	:	5

Table 2: Results analysis.

Variable	HR	95% CI	p-Value
Shape of Stylet (banana Vs. Straight-to-cuff)	0.99	0.82-1.20	0.95
Lifting of epiglottis	1.68	1.34-2.11	<0.001
Holding level of tube (Middle Vs. Top)	1.04	0.86-1.26	0.675
Length of work	1	0.96-1.04	0.945
Height of performer	1.09	0.97-1.05	0.631

direct laryngoscopy, they would receive the endotracheal tube equipped with standardized stylet shapes and curvatures (straight-to-cuff 35° or 50°; banana shape in a longitudinal distance of 26 cm and 28 cm) and be instructed to hold the endotracheal tube on top or in the middle (Two different shapes with each shape of two different curvatures and two different holding positions formed 8 possible settings and were randomized with random.org before the study began). The participants only knew the shape at the time when the glottic view fulfilled the study setting and were asked to keep the shape and holding position during the intubation. Intubation time exceeding 90's would be considered as a failed attempt. A success intubation was defined as passing the tube through the vocal cords exceeding the vocal cords marker. After each intubation, they would provide a subjective 0 cm to 10 cm Visual Analog Scale (VAS) to assess difficulty (0: not difficult; 10: impossible to intubate). All the study processes were recorded by a video camera on the tip of blade (Figure 1C), and the time from inserting the laryngoscope to the mouth of the mannequin, the time of initial proper glottic view to initiate tracheal intubation, the time of withdrawal of the endotracheal tube, success or failure of intubation were all calculated retrospectively by the video

clips.

Part 2: At the end of the study, the participants would perform intubation with lifting the epiglottis by holding the middle part of the stylet-equipped endotracheal tube of a straight-to-cuff shape of 35° or 50° in a randomized order (two possible settings with random.org) (Figure 2). All performers intubated the mannequin totally 10 times: 8 times in part 1 and 2 times in part 2.

Measurements

The working duration in the ED, type of participants (attending, residents, or nurse practitioners), and height of the participants were all recorded (Table 1). The primary outcome in our study was the time interval of the intubation process (laryngoscope blade in and out of the mouth of the mannequin) and intubation success rate. The intervals between insertion and withdrawal of laryngoscope from the mannequin's mouth, success rate of intubation, and subjective difficulty scales were all reviewed and calculated based on recorded video clips and VAS records.

Statistical analysis

The characteristics of the participants, glottis views during intubation, duration of intubation, success rate of intubation, and VAS scores were summarized. We evaluated the time to successful intubation by plotting Kaplan-Meier survival curves to determine the trends. To cope with the correlated data from multiple intubation attempts by the same participants, we applied Cox regression models stratified by proportional hazard type in the evaluation of the different manipulations of the Hazard Ratios (HRs) of successful intubation after adjusting for relevant confounding factors, namely working year, sex, height, type of participant, and different shapes and bend angles of the stylet.

Linear regression was used to evaluate intubation time and VAS score, while logistic regression was applied to evaluate the odds ratio of the success rate by using the VAS scores after adjusting for the confounding factors. The generalized estimating equation method was adapted to account for the clustering of the participants.

SAS statistical package version 9.4 (SAS Institute, Inc., Cary, NC, USA) and STATA version 11.2 (Stata Corp, College Station, TX, USA) were used for data analysis. A two-tailed p value of <0.05 was considered statistically significant.

Outcomes

Table 1, Figure 3 shows the distribution of sex, class, height, and length of work of the 32 participants. Of the 32 participants, 81.25%, 6.25%, and 12.50% were attending physicians, residents, and nurse practitioners, respectively. After the video clips were reviewed, 96.87% of glottis view was C-L grade III, the rest was grade IIB (3.13%). The overall success rate of intubation was 95.63%. The duration of the intubation with the mean and standard deviation, success rate, VAS in different subgroups are shown in Figure 4.

A Kaplan-Meier plot illustrates the significant shorter time to successful intubation (Figure 3). The two subgroups that performed lifting of the epiglottis with stylets had the shortest duration of intubation (23.75 ± 14.24 's and 20.72 ± 6.90 s in bend angles of 35° and 50°, respectively) and 100% success rate of intubation. In Cox regression analysis, only lifting of the epiglottis was significant ($p < 0.0001$, Table 3).

For the evaluation of VAS and intubation, VAS is strongly related to intubation time. For each 1 cm increase in the VAS, the odds ratio

	Manipulation Holding part of tube	Shape	Longitudinal Distance(cm) Bend angles(degree)	Duration of Intubation			Success Rate(%)	VAS Score(cm)
				Mean±SD(seconds)	HR	95%CI		
1	Top	Banana	28 cm	33.63 ± 33.87	1.00	1.00	90.63%	4.24 ± 2.11
2	Top	Banana	26 cm	31.91 ± 31.82	1.05	0.60-1.83	93.75%	4.34 ± 2.33
3	Middle	Banana	28 cm	30.10 ± 18.73	1.01	0.63-1.62	96.88%	4.62 ± 1.94
4	Middle	Banana	26 cm	31.06 ± 24.59	1.04	0.68-1.59	93.75%	4.48 ± 2.12
5	Top	Straight-to-cuff	35 degrees	34.81 ± 27.70	0.87	0.55-1.37	93.75%	4.67 ± 2.30
6	Top	Straight-to-cuff	50 degrees	28.03 ± 16.36	1.11	0.68-1.82	96.88%	4.36 ± 2.32
7	Middle	Straight-to-cuff	35 degrees	34.10 ± 32.12	1.00	0.65-1.53	93.75%	4.29 ± 4.48
8	Middle	Straight-to-cuff	50 degrees	27.53 ± 16.31	1.15	0.74-1.78	96.88%	3.90 ± 2.12
9	Lifting of epiglottis	Straight-to-cuff	35 degrees	23.75 ± 14.24	1.54	1.01-2.34	100%	4.15 ± 2.22
10	Lifting of epiglottis	Straight-to-cuff	50 degrees	20.72 ± 6.90	1.85	1.23-2.78	100%	3.97 ± 2.13

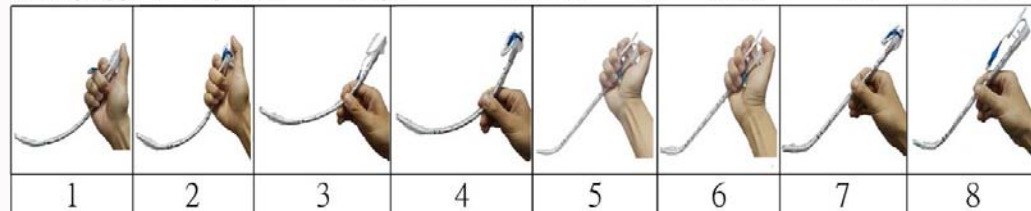


Figure 4: Ten different subgroup settings and the results of intubation duration, success rate and visual analog difficulty score.

of success is 0.55, and the intubation time will increase 3.77 s. (Figure 4 and Table 2) respectively.

Discussions

The Cormack-Lehane (C-L) grading system had been initially described by Cormack and Lehane under direct laryngoscopy in obstetrics patients in 1984 and was widely used in airway classification [14]. Yentis et al. [1] had modified this grading system and classified class IIa, where only the vocal cord was partially seen; IIb, where only posterior extremities of the glottis or arytenoids cartilage was seen. Class IIb was considered as a true difficult airway in this article. However, the incidence of C-L grading difficult airway (class III and IV in the original grading system or class IIb, III, and IV in modified grading system) in the studies in the operating room setting (1.2% to 9%) is lower than that in the Emergency Department (ED) setting (7.1% to 20.5%) [1-11]. One of the reasonable explanations is managing difficult airway in the ED setting might be more time-limited and more stressful. In addition to inadequate positioning, patient's C-spine limitation after trauma, radiation therapy, congenital or acquired diseases, sufficient advanced preparation might be very difficult in some chaotic conditions, such as in the ED.

Levitan et al. [13] had found that the bend angles beyond 35° with straight-to-cuff endotracheal tubes can jeopardize the success rate of tracheal intubation and increase the difficulty of passing tubes. However, with regard to difficult airway, such as C-L III, larger angulations might have some advantage. In our study, with regard to shape of straight-to-cuff and bend angles at 50° had a trend of shorter intubation time and better success rate compared with bend angles at 35° despite holding parts of the endotracheal tube (97.92% versus 95.83%, 25.43 ± 14.17 versus 30.89 ± 26.05's, $p = 0.0859$, 95% CI 0.97 to 1.61, respectively). Participants also felt that intubation was easier if larger angulations were used (4.08 ± 2.18 versus 4.37 ± 2.20 cm). In contrary, banana shape with larger angulations (longitudinal distance of 26 cm versus 28 cm) did not show any difference on the success rate, intubation time, and VAS (equally 93.75%, 31.48 ± 28.21 versus 31.86 ± 27.21's, 4.41 ± 2.21 versus 4.43 ± 2.02 cm, respectively).

The banana shape might cross the visual axis twice if the tube axis is parallel to the visual axis; thus, it is believed to be an unfavored way for intubation. Our results, however, showed no difference between straight-to-cuff and banana shape despite bend angles and holding parts of the tube on success rate, intubation time, and subjective difficulty scoring (96.88% versus 93.75%, 28.16 ± 21.10 versus 31.67 ± 27.60 s, 4.22 ± 2.19 versus 4.42 ± 2.11 cm, respectively).

Holding the top of the endotracheal tube and flexing the elbow to the chest, whereas the cuff passing the incisors will provide a larger torque and might be useful in managing difficult airway. To the best of our knowledge, this technique was initially introduced by James Ducanto. Compared with holding the middle part of the endotracheal tube, the tilting angle of endotracheal tip is larger during intubation when holding the top and starting up by the elbow instead of the wrist. However, no significant difference was found between holding the top or holding the middle of the endotracheal tube during intubation, success rate, or VAS score despite bend angles and shapes (32.09 ± 28.04 versus 27.88 ± 20.66 s; 93.75% versus 96.88%; 4.40 ± 2.25 versus 4.23 ± 2.10 cm, respectively). The participants in our study were all inexperienced in holding the endotracheal tube on the top before our study. Such condition may lead to a higher failure rate. However, our study showed no evidence that the holding position can improve the outcome of the management of difficult airway.

When only the epiglottis is visible under laryngoscopy (C-L grade III), the endotracheal tube passing between the vocal cord and trachea cannot be visualized directly and is considered as blinded intubation. The success rate in the first attempt of intubation in C-L grade III is only 44.7% under direct laryngoscopy in one report in an ED setting [11]. When the intubation attempt fails, the performer usually will reposition the patient and focus on the left hand go deeper to the vallecula or lift harder to obtain a better glottic view. However, we often neglect our right hand that is directly lifting the epiglottis with stylets, which can improve the glottic view, and focus only on the left hand. Moreover, nestling the tip of the endotracheal tube under the epiglottis and move along the anterior larynx will lead to the trachea inlet. Ueda et al. [12] reported a case that lifting of the epiglottis

with stylets might help improve the glottic view. In our study, the success rate of intubation with stylet-assisted epiglottis lifting is 100% in contrary to that without (94.53%). Lifting of the epiglottis also facilitated the mean duration of intubation than without (22.23 ± 11.20 versus 31.39 ± 25.86 s, respectively). In the survival analysis, lifting of the epiglottis is a strong factor to improve intubation (Figure 3, $p < 0.0001$). On top of that, lifting of the epiglottis with stylets was not considered more difficult compared with that without (4.06 ± 2.16 cm versus 4.36 ± 2.16 cm, $p = 0.137$, 95% CI - 0.80 to 0.11). Lifting of the epiglottis can accelerate intubation and improve success rate in difficult intubation without increasing difficulty. Among the different conditions with C-L grade III in our study, holding the top of the endotracheal tube with straight-to-cuff in bend angles of 35° was considered to be the most difficult intubation performed, followed by holding the middle with the smaller curvature of the banana shape (longitudinal distance = 28 cm). In contrast, holding the middle of the endotracheal tube with straight-to-cuff in bend angles of 50° was the easiest. The VAS scale was directly related to intubation time (odds ratio = 0.55). Namely, the higher the VAS scores, the longer the intubation duration will be.

Limitations

First, this is a mannequin study, and the results of this study need further investigation on human objects. Besides, during the intubation, the participants were asked to avoid better glottic visualization and keep intubating the C-L defined difficult airway. Such condition might not be very natural. However, to simulate a difficult airway without seeing the epiglottis after a good positioning, we recorded all the intubation process with video clips and reviewed for precise time intervals and correct C-L grades just before intubation. Moreover, some participants applied lifting of the epiglottis subconsciously. Although the participants intubated without being instructed to lift the epiglottis in the first part of the study, total avoidance without lifting was almost impossible. We found that the participants tended to lift the epiglottis unintentionally, particularly when they repeatedly failed to pass the endotracheal tube. However, to simulate the clinical setting, prohibition of contact to the epiglottis is not natural. Besides, although the study was designed to investigate C-L grade III where only the epiglottis was visible, some of the glottic views reviewed by video clips were grade IIb (3.13%), namely, where the lower part of the vocal cord might be seen. Moreover, the inexperience of the participants in "holding the top" of the endotracheal tube technique might have reduced the significance of this group. Finally, to focus on the lifting of the epiglottis, the two groups were arranged randomly at the last two rounds.

Conclusions

The use of lifting of the epiglottic with stylets as an adjunctive technique can facilitate and improve the success rate of intubation in difficult airway grading, such as C-L III under direct laryngoscopy without increasing difficulty. Our study suggests that based on a proper laryngoscope management, using the tip of the stylet-equipped endotracheal tube to lift the epiglottis and following the anterior part of larynx can significantly help in tracheal intubation where only the epiglottis is seen.

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