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ORIGINAL RESEARCH

Comparison of direct and video laryngoscopes in charcoal ingestion setting: a randomized cross-over simulation study

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Abstract

Choosing the right intubation method to increase the success rate and performing it quickly is very important in a difficult airway situation. We aimed to compare the endotracheal intubation success rates and completion time when using direct laryngoscopes (DL) and GlideScope video laryngoscopes (GVL) in an activated charcoal ingestion manikin simulation. This study was designed as a randomized cross over study in an activated charcoal ingestion simulated model. Physicians who had >30 successful endotracheal intubation (ETI) experiences participated in this study. The end points were successful ETI and the duration of ETI completion. In order to compare the degree of intubation difficulty, the participants rated the visual analog scale (VAS). A total of 38 people participated in this study. The success rate of the first attempt was 28/38 (73.7%) for DL and 37/38 (97.4%) for GVL ($p < 0.01$). The estimated duration to successful ETI were 45.5 s (26–69) for DL and 28 s (23–35) for GVL, respectively ($p < 0.01$). VAS score for the difficulty of intubation was lower in GVL than DL ($p < 0.01$). Using GVL had higher first pass success rate and was faster and easier than DL when intubating patients with activated charcoal ingestion in a simulated situation.

Keywords

Intubation; Charcoal; Simulation; Direct laryngoscope; Video laryngoscope

1. Introduction

Airway management is a fundamental and important element in emergency situations. Emergency physicians (EPs) should quickly and safely secure the airway and perform tracheal intubation in critical patients. Otherwise, significant morbidity or mortality can occur [1]. In addition, attempting tracheal intubation several times in a patient is associated with increasing adverse events [2]. Therefore, it is necessary to anticipate and prepare suitable equipment to manage difficult airway management situations. Also, tracheal intubation should be performed quickly and accurately.

Difficult airways are encountered in patients with cervical immobility, facial or neck trauma, large tongue, restricted mouth opening, blood or vomitus in the airway, and obesity [3]. Video laryngoscope (VL) equipment that was developed to help in these situations is being increasingly used for difficult airway management in anesthesia, intensive care units, and emergency departments (EDs) [4]. Since the introduction of VL, many studies have shown that it has helped in increasing the success rate in difficult airway situations [2, 4–6].

Activated charcoal is used as a decontamination therapy in poisoned patients [7]. However, vomiting occurs frequently when activated charcoal is used. Therefore, airway protection should be performed before the use of activated charcoal. Chemical pneumonitis caused by direct charcoal-induced aspiration is a fatal complication with poor prognosis [8, 9].

If activated charcoal therapy causes vomiting and aspiration occurs in a non-intubated patient, intubation may be required. In this situation, charcoal can potentially impede visualization of the airway, which can reduce the likelihood of a successful first attempt. Activated charcoal absorbs light, so it can block the field of your vision, in particular, when performing endoscopy [10]. Although there have been many studies on hematemesis and vomiting, there have been limited studies on the use of VL and direct laryngoscope (DL) in difficult airway situations caused by activated charcoal [3, 11].

The use of VL has been shown to improve endotracheal intubation (ETI) success rates in difficult airway situations. The GlideScope (Verathon Inc., Bothell, WA) is a commonly used video laryngoscopes in the ED [12]. However, because of the presence of a micro video camera on the undersurface of its blade, the GlideScope may get easily contaminated, thus performing less effectively than DL in the activated charcoal ingestion setting.

Therefore, this study aimed is to compare the ETI success rates and duration to successful attempt using the DL and

GlideScope video laryngoscope (GVL) in an activated charcoal ingestion simulation.

2. Materials and Methods

2.1 Study population and data collection

This was a simulation study with a prospective, randomized cross-over design. Thirty-eight physicians with at least 4 years of experience and >30 successful ETIs, including difficult airway situations, were recruited from several academic ED hospitals. After we explained the study objective, the participants provided their informed written consent to participate. We provided instructions and practical training before proceeding with the study. Due to the possibility of different success rate in using the DL or GVL in manikin models of the simulation setting without activating charcoal, all participants continued to practice until they were satisfied with their success rate. After these training, the participants participated in the study.

For randomization, thirty eight sequences were generated using the random number generator at www.random.org and placed in sealed envelopes. After each intubation attempt, they were allowed to rest and recover for up to 1 day (Fig. 1).

We used the Airway Trainer (Laerdal, Stavanger, Norway) for simulation and tracheal intubation. We dissolved 50 g of charcoal powder in 200 mL of sorbitol to simulate charcoal ingestion. The contents were poured into the pharynx to the level of covering the epiglottis (Fig. 2). We clamped the lower esophagus and bronchi of the manikin to keep the liquids in the pharynx. After each trial, the clamped lower esophagus was released, the remaining charcoal was discarded, and 50 g of fresh charcoal powder in 200 mL of sorbitol was poured into the pharynx.

All intubation procedures were performed using a 7.5-mm cuffed tracheal tube (Mallinckrodt Medical, Athlone, Ireland). For intubation attempts using the Macintosh laryngoscope, a malleable stylet was inserted into the endotracheal tube and molded to follow the inherent anterior curvature of the tracheal tube. A GlideRite® Rigid Stylet, supplied by the manufacturer, was used for intubation attempts using the GVL. For the Macintosh laryngoscope, the manikin's head and neck were placed in a sniffing position with an 8-cm pillow placed under the occipital area of the manikin's head. The manikin's head and neck were placed in a neutral position for the GlideScope. Maneuvers, such as BURP, were allowed if the participant required any.

Successful intubation was defined as tracheal intubation within 120 s [13, 14]. After intubation, a visible chest rise in the manikin was confirmed during bag-valve mask ventilation. Failed intubation was defined as esophageal intubation or tracheal intubation that required ≥120 s. Multiple attempts within 120 s were allowed until successful intubation. Within this time limit, if any, the number of esophageal intubations were counted. The manikin was designed to generate a "click" sound when significant pressure was applied to the upper incisors. We counted the number of "click" sounds during the given time.

2.2 Outcomes

The primary outcome was successful ETI on the first attempt, and the secondary outcome was the duration of completing the ETI. Duration was defined as the time taken between the start of the participant touching the selected scope device to complete intubation by removing the stylet after tube placement in the trachea and ending with ventilation using bag-valve mask. The number of attempts to achieve successful ETI was counted.

The visual analog scale (VAS) was used to measure the difficulty of successful ETI on the first attempt before and after activated charcoal ingestion settings. The VAS score ranged from 0 mm (extremely easy) to 100 mm (extremely difficult). Open comments of the participants were also recorded.

2.3 Statistical analysis

The sample size was calculated based on a previous hematemesis study on the success rate of intubation with the DL and VL [11]. In a previous study, the success rate of the control group was 88%, while that of the experimental group was 59%. Using an α error of 0.05 and a β error of 0.2, we estimated that 33 participants would be adequate for each group [15]. Therefore, we planned to recruit 38 participants in each group to adjust for missing data.

Categorical variables are presented as frequencies with percentages, and continuous variables are expressed as mean with standard deviation or median with interquartile range (IQR), according to normality testing. For comparisons between two groups, a generalized estimating equations was used, which considered the carryover and period effects as fixed effects and the subject effect as the random effect [16]. Kaplan-Meier analysis was used to compare the intubation success time between the laryngoscopes to overcome censored attempts (failed intubation). Data were analyzed using SPSS Statistics for Windows (version 26, IBM Corporation, Armonk, NY). Statistical significance was set at $p < 0.05$.

3. Results

In total, 38 individuals participated in this study with no drop outs. Among them, 23 were men (60.5%), and the mean age was 34.9 ± 5.2 years. There was significant difference in the rate of successful ETI at first attempt between the two devices in the activated charcoal ingestion setting (Table 1). The success rate of tracheal intubation in the first trial was 28 (73.7%) with the DL and 37 (97.4%) with the GVL (p = 0.01). One participant in GVL group failed due to severe lens contamination.

The total duration until successful intubation was different between the two groups. Using the DL, it took a median of 45.5 s (IQR, 26–69 s), while the GVL took a median of 28 s (IQR, 23–35 s), showing that the DL took longer duration ($p <$ 0.01). On comparing the median duration time till successful intubation of only those who succeeded on the first attempt, there was no significant difference between the two groups—30 s (IQR, 25–52) in the DL group and 28 s (IQR, 23–35) in the GVL group (p = 0.69). The number of esophageal intubations was 10 (26.3%) in the DL and 0 in the GVL groups.

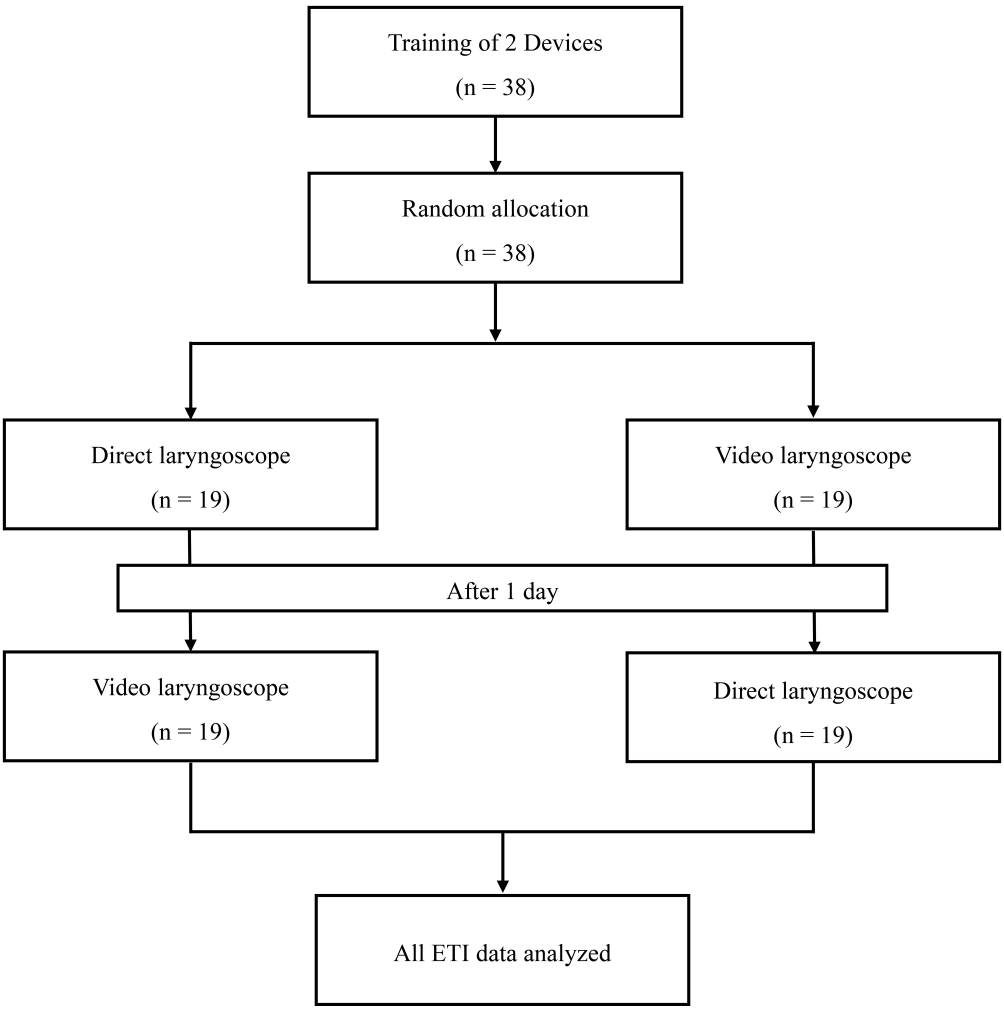

FIGURE 1. Flow diagram of the study. ETI: endotracheal intubation.

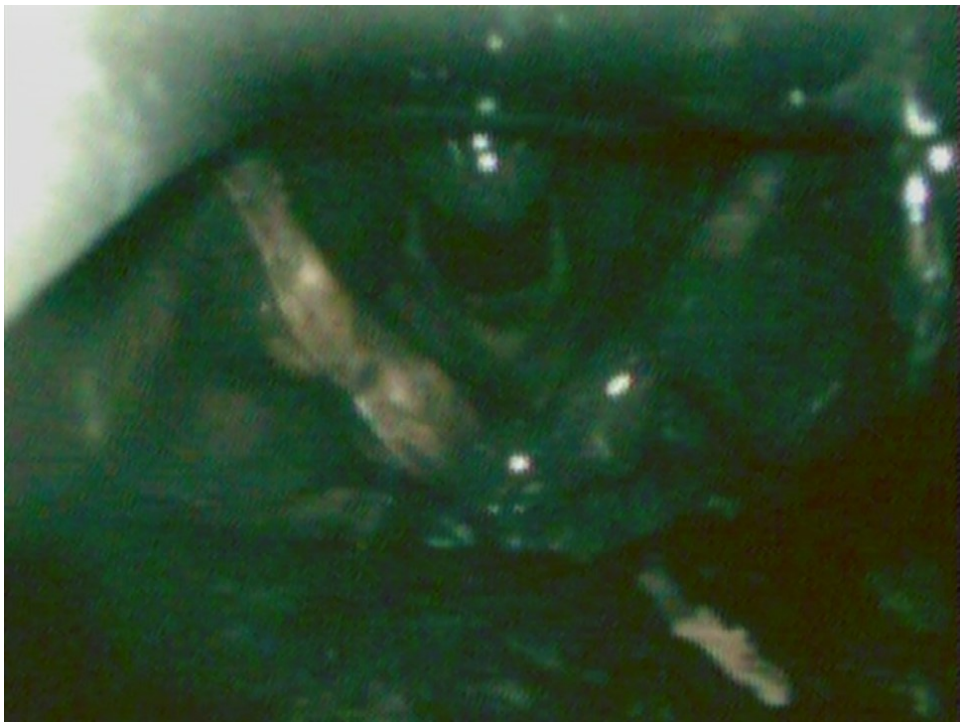

FIGURE 2. View of the activated charcoal simulated airway.

TABLE 1. Data for endotracheal intubation with different devices and related complications.

	Direct laryngoscopy (n = 38)	GlideScope video laryngoscopy (n = 38)	*p*
Successful ETI at first attempt	28 (73.7)	37 (97.4)	0.01
Total duration of successful ETI (s)	45.5 (26–69)	28 (23–35)	<0.01
Duration of successful ETI at first attempt (s)	30 (25–52)	28 (23–35)	0.69
Esophageal intubation	10 (26.3)	0 (0)	NA
Pressure to teeth	8 (21.1)	2 (5.3)	0.02

Values are presented as number and percentage, median and interquartile range. ETI, endotracheal intubation; NA: not available.

TABLE 2. Difficulty visual analog scale in before and after activated charcoal setting.

	Direct laryngoscopy (n = 38)	GlideScope video laryngoscopy (n = 38)	*p*
VAS in before activated charcoal setting	10 (0–10)	10 (0–10)	0.58
VAS in after activated charcoal setting	70 (70–80)	30 (22.5–40)	<0.01

Values are presented as median and interquartile range. VAS, Visual analog scale.

Among cases in which the first tracheal intubation attempt was unsuccessful, most of them succeeded on the second attempt. Only one case of DL intubation was unsuccessful because it exceeded 120 s. The occurrence of pressure on the upper incisors was determined by counting the number of clicking sounds during intubation. It occurred 8 (21.1%) and 2 (5.3%) times in the DL and GVL groups, respectively ($p = 0.02$).

There was a statistically significant difference between the groups in terms of the cumulative success rate of ETI within 120 s ($p < 0.01$, Fig. 3).

The VAS score was not significantly different between the GVL and DL groups before activated charcoal ingestion setting. In the activated charcoal ingestion setting, the VAS score increased in both the groups. It was significantly higher in the DL group than in the GVL group in the activated charcoal ingestion setting ($p < 0.01$, Table 2).

4. Discussion

In our study, when intubation using the DL and GVL was performed under the activated charcoal ingestion setting, using GVL had a higher first attempt success rate and was faster and easier than using DL. Pressure on the upper incisors, which is a complication when performing intubation, was more common in the DL group.

Blood, secretions, and active vomiting are predictors of difficult intubation [17–19]. In difficult airway situations, it is important to perform airway protection quickly and accurately. Methods to increase intubation success rate on the first attempt are being studied in difficult airway situations, and many studies support the effectiveness of the VL in these situations.

In a meta-analysis comparing the DL and several types of the VL, including the GVL, the rate of failed intubation was low when VL was used in difficult airway situations [20]. Other studies have also reported similar results. Sakles *et al.* [1] showed that first-pass successful intubation was higher when VL was used and recommended using VL when a difficult airway was expected. For soiled airways, such as vomitus and hematemesis, the GVL success rate was 93.8%, which was higher than that of the DL (79.9%) [3]. In retrospective analysis study from a multicenter ED registry involving patients with gastrointestinal bleeding, the success rate with VL was higher than that of DL (93.3% *vs.* 88.5%) [21].

Many studies have reported the superiority of GVL in various difficult airway situations. However, limited studies have shown its advantages in activated charcoal aspiration. Charcoal ingestion situation is an uncommon difficult airway situation, but it can still occur in the ED. Charcoal-induced aspiration is a fatal complication associated with poor prognosis. Tracheal intubation should be performed to protect the airways of poisoned patients with reduced consciousness and depressed gag reflex. In alert poisoned patients, intubation is not necessarily performed, and activated charcoal is administered orally. However, after administration of activated charcoal, a patient may experience emesis resulting from activated charcoal or due to the overdose. This can lead to a difficult airway situation requiring intubation different from normal vomiting.

Activated charcoal can deteriorate the glottic view which is similar to hematemesis, but unlike blood, it absorbs light and can worsen the view [10]. Activated charcoal occasionally blocks the field of vision when performing endoscopy [10]. Therefore, a study is necessary to determine whether the GVL is more effective than the DL in activated charcoal aspiration.

In our study, when intubation using the DL and GVL was performed under the activated charcoal ingestion situation, using GVL had a higher first attempt success rate and was faster and easier than using DL. Moreover, the cumulative success rate using Kaplan-Meier analysis was also high in the GVL group.

To the best of our knowledge, this study is the first to show that the GVL is better than other laryngoscopes under activated charcoal ingestion conditions. Although our study did not evaluate the retention of skills or real-world clinical outcomes, previous research suggests that simulation is an excellent method for teaching procedural competence. Simulation provides better instruction in skill acquisition and retention

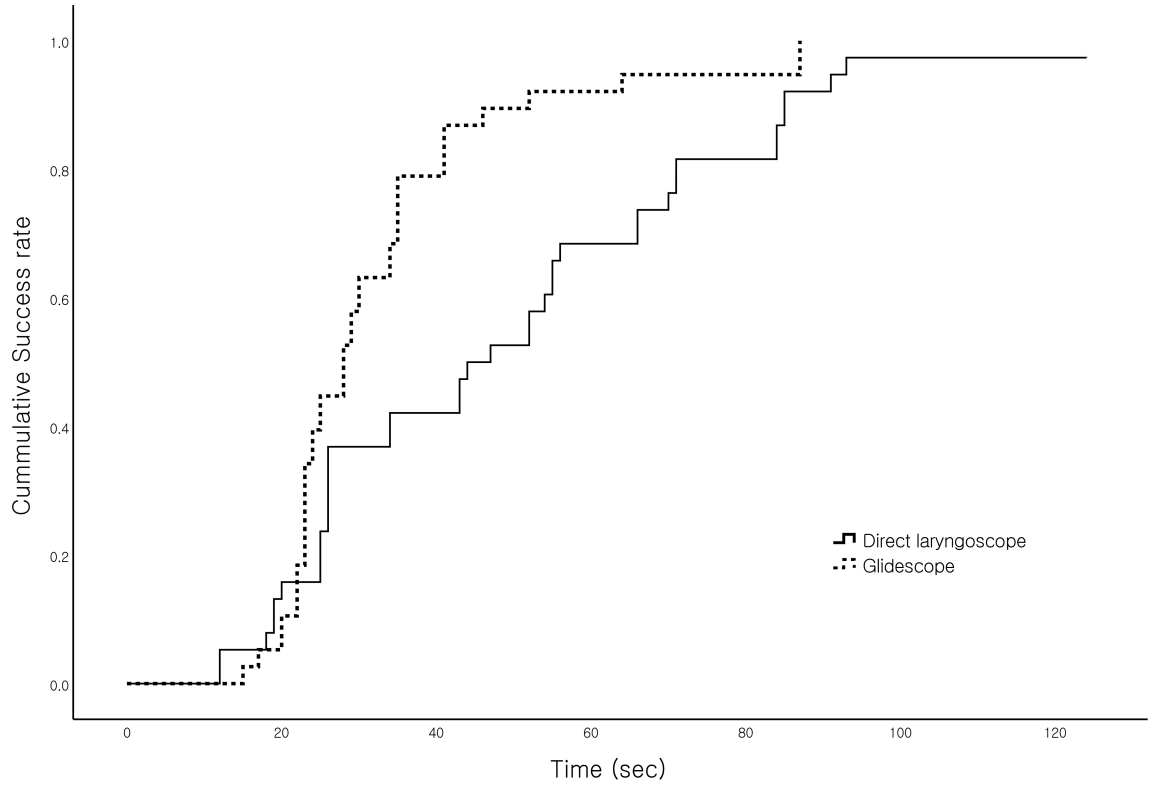

FIGURE 3. Kaplan-Meier analysis of cumulative endotracheal intubation success rate using direct laryngoscopy and GlideScope (Log rank test, $p < 0.01$).

than non-simulation methods [22]. Moreover, in a simulation study, learners feel stress similar to the real-world resuscitations [23].

This study has some limitations. First, the airway intervention time for intubation may be shorter than that required for actual patients because it was performed on a manikin. Second, our study used the GVL among VLs, which makes it difficult to generalize the results to other VLs. Third, warm air was not respired by the manikin; thus, our study is not adequate to comment on fogging or contamination of the lens in such an environment. Activated charcoal contamination may be different in a manikin than that in a real-world patient. Lens contamination is likely to occur when the VL is used in unclean airway among difficult airways. In a study comparing the GVL and DL in pre-hospital settings, the main problems suggested when using the GVL were impaired sight due to a fogged camera and impaired monitor visibility [24]. It is necessary to always consider the difficulty in securing the view when using the VL because of these problems; therefore, management and supervision are needed. If this problem occurs frequently, it may lead to hesitation in the use of VL. However, according to one study, severe lens contamination of the GVL in actual soiling of the airway was as low as 1.3% [3]. In our study, only one participant in the GVL group did not succeed on the first attempt due to lens contamination. The light source attached to the blade in the DL can also contaminate and deteriorate the glottic view. However, despite these limitations, this study is significant as a simulation study of activated charcoal contamination.

5. Conclusions

GVL had a higher first attempt success rate and cumulative success rate and was faster and easier than the DL in an activated charcoal ingestion simulation.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

YHL—responsible for the conception and the writing of the study and had full access to all of the data with YSC, YHL—take responsibility for the integrity of the data and the accuracy of the data analysis. YSC—contributed substantially to the study design, data analysis and interpretation. All authors contributed and have approved the final article.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the institutional review board of Soonchunhyang University Seoul hospital (No. 2021-01-020-002), and written informed consent was obtained before the study.

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Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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