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Educational suitability of new channel-type video-laryngoscope with AI-based glottis guidance system for novices wearing personal-protective-equipment

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Abstract

The aim of this study was to determine which of 4 laryngoscopes, including A-LRYNGO, a newly developed channel-type video-laryngoscope with an embedded artificial intelligence-based glottis guidance system, is appropriate for tracheal intubation training in novice medical students wearing personal protective equipment (PPE).

Thirty healthy senior medical school student volunteers were recruited. The participants underwent 2 tests with 4 laryngoscopes: Macintosh, McGrath, Pentax Airway-Scope and A-LRYNGO. The first test was conducted just after a lecture without any hands-on workshop. The second test was conducted after a one-on-one hands-on workshop. In each test, we measured the time required for tracheal intubation, intubation success rate, etc, and asked all participants to complete a short questionnaire.

The time to completely insert the endotracheal tube with the Macintosh laryngoscope did not change significantly ($P = .177$), but the remaining outcomes significantly improved after the hands-on workshop (all $P < .05$). Despite being novice practitioners with no intubation experience and wearing PPE, the, 2 channel-type video-laryngoscopes were associated with good intubation-related performance before the hands-on workshop (all $P < .001$). A-LRYNGO's artificial intelligence-based glottis guidance system showed 93.1% accuracy, but 20.7% of trials were guided by the vocal folds.

To prepare to manage the airway of critically ill patients during the coronavirus disease 2019 pandemic, a channel-type video-laryngoscope is appropriate for tracheal intubation training for novice practitioners wearing PPE.

Abbreviations: AWS = pentax airway scope, C-L grade = cormack-lehane grade, COVID-19 = coronavirus disease 2019, IVT = the interval from the blade of each laryngoscope passing the incisor to visualization of the glottis, PPE = personal protective equipment, VFT = the interval from visualization of the glottis to endotracheal tube insertion completion with removal of the laryngoscope.

Keywords: artificial intelligence, education, novice practitioner, personal protective equipment, tracheal intubation

1. Introduction

Tracheal intubation is an essential method of providing adequate oxygenation and ventilation assistance for emergency center patients with poor oxygenation and/or failure to maintain and protect airway patency.

Before the coronavirus disease 2019 (COVID-19) pandemic, direct laryngoscopy was the basic approach used in tracheal intubation; however, according to the literature, it is very difficult to use direct laryngoscopy for intubation, and the initial success rate is only 51% to 61%.[1–3] For this reason, well-trained and experienced medical staff are responsible for performing tracheal

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intubation in the emergency department.[4] Nevertheless, the COVID-19 pandemic is changing emergency airway management in the emergency department and intubation training for novice practitioners.

Although wearing personal protective equipment (PPE) can be a factor that makes rapid, safe and successful intubation difficult, since the start of the COVID-19 pandemic, medical staff have been forced to intubate critically ill patients who require intubation while wearing PPE. However, it is very difficult to achieve successful intubation using direct laryngoscopy while wearing PPE. Over time, wearing PPE because of the COVID-19 pandemic has led to a greater preference for video laryngoscopy over direct laryngoscopy among emergency physicians.[5–7]

Due to the COVID-19 pandemic, pre-emptive screening and isolation rooms are used in all emergency centers, making it difficult to accommodate critically ill patients. In addition, since it is necessary to perform tracheal intubation while wearing PPE, there is a high possibility that delayed intubation and intubation failure will occur, and experienced physicians often perform the intubations. As a result, the chances of being satisfied with the intubation experience when an inexperienced physician is involved have diminished.[5–7]

In other words, the factor that guarantees skill level in airway management is the level of experience with successful intubation[8]; however, the COVID-19 pandemic makes it difficult to provide an adequate number of intubation experiences for novice practitioners.

Therefore, airway management training for novice practitioners in video laryngoscopy and direct laryngoscopy is of great importance for these situations. Video laryngoscopy was developed and implemented to increase the intubation success rate; nevertheless, due to the variety of types and different characteristics of video-laryngoscopes, a lack of understanding of the specific characteristics of a given video-laryngoscope can make intubation more difficult than with direct laryngoscopy.[9–13]

In this study, 4 types of laryngoscopes, including the A-LRYNGO (Fig. 1), a channel-type video-laryngoscope embedded with an artificial intelligence-based glottis guidance system developed in preparation for an infectious disease pandemic, were used. We tried to determine which laryngoscope is appropriate for tracheal intubation training for novice medical students wearing PPE and which laryngoscope is suitable for novice practitioners performing intubations during an infectious disease pandemic situation.

2. Methods

2.1. Study design

We conducted a randomized simulated manikin study of intubation with 4 laryngoscopes at the Kangnam Sacred Heart Hospital in March 2021. The Institutional Review Board of Kangnam Sacred Heart Hospital approved this study in June 2020 (IRB No. HKS NON2020-002).

2.2. Equipment and materials

All participants performed intubations using 4 laryngoscopes: a direct laryngoscope (Macintosh, Macintosh #4 blade), 1

Figure 1. A-LRYNGO, a newly developed channel-type video-laryngoscope. The white arrow indicates the embedded artificial intelligence-based glottis guidance system.

Figure 2. Personal protective equipment. Goggles, Respirator with a rating of N95, Disposable apron, Gloves.

non-channel-type video-laryngoscope and 2 channel-type video-laryngoscopes.

An endotracheal tube with an inner diameter of 7.5 mm (Portex, St. Paul, MN, USA) was used in this study. A bag-valve mask (BVM; Ambu Mark IV - Reusable Resuscitator, Ballerup, Denmark) was used in this study.

The non-channel-type video-laryngoscope used was the McGrath MAC Video Laryngoscope (McGrath; Medtronic plc, Dublin, Ireland). One of the channel-type video-laryngoscopes used was the Pentax Airway Scope (AWS; PENTAX Corporation, Tokyo, Japan). The other channel-type video-laryngoscope was the A-LRYNGO (A-LRYNGO; AIMD Corporation, Seoul, Republic of Korea).

We used a high-fidelity airway management manikin (BT-CSIE, BT Inc., Gyeonggi-do, Republic of Korea) for the simulated intubations. The manikin was set with a normal airway.

2.3. Participants

We recruited 30 healthy volunteers who were senior medical school students at the College of Medicine in Hallym University in March 2021. We excluded people who had fever, respiratory symptoms, wrist and low back diseases. All participants signed a written consent form before recruitment.

The sample size was calculated based on the results of a pilot study. The mean and standard deviation time from blade insertion to first ventilation after intubation was 24.27 ± 20.79 with AWS and 12.75 ± 9.87 with A-LRYNGO in a pilot study. To detect a 33% difference in intubation time with a power of 0.95, we estimated that 28 participants would be adequate for each device, assuming a 20% drop-out rate.

2.4. Interventions

We provided participants with a one-hour lecture on emergency airway management, the characteristics of each device and how to use the laryngoscopes examined in this study. We conducted 2 tests on the participants in this study. During the 2 tests, the participants wore PPE (Fig. 2). The PPE worn by the participants consisted of gloves, a disposable apron, a respirator with a rating of N95 and goggles.[14] To minimize the learning effect between devices, the devices were presented in a random order, and we used "http://www.random.org/" for random sequence generation. For the same purpose, the participants were not informed of the labeled number of any device, and in the test, each device was prepared by changing the labeled number. After the lecture, all participants performed intubation on the manikin with the 4 devices in a random order as a first test. After the first test, a one-on-one hands-on workshop with an emergency physician was conducted regarding the 4 laryngoscopes; each participant's workshop lasted 30 minutes. Then, for the second test, the participants performed intubations on the manikin with the 4 devices in a new random order. Finally, the participants completed a simple questionnaire.

During each test, the A-LRYNGO screen was recorded as a video file using A-LRYNGO's recording function to evaluate the performance of the artificial intelligence-based glottis guidance.

2.5. Outcomes

The primary endpoints were the intubation time interval and the intubation success rate. The intubation time was divided into 3 intervals and recorded by a recorder. The recorder was informed about how to assess the intubation time interval and was blinded to all authors of the present study. The first time interval was from the time when each device's blade tip passed the incisor to the time when the participant looked at the glottis and stated, "I can see the glottis, Cormack-Lehane grade (C-L grade) I ~ IV". The second time interval was from the time when the participant stated "I can see the glottis" to the time when endotracheal tube insertion was complete and the laryngoscope was removed. The third time interval was from the time when endotracheal tube insertion was complete to the time when the participant performed the first manual ventilation using a Bag-valve mask. The interval from the blade of each laryngoscope passing the incisor to visualization of the glottis (IVT) was the first interval. The interval from visualization of the glottis to endotracheal tube

insertion completion with removal of the laryngoscope (VFT) was the second interval. The interval from endotracheal tube insertion to first manual ventilation was the third interval. We defined intubation failure as follows: esophageal intubation or IVT + VFT for 90 seconds or more.

Secondary endpoints were the glottis view using the C-L grade and A-LRYNGO's artificial intelligence-based glottis guidance performance.

2.6. Statistical analysis

The raw data were compiled using a standard spreadsheet application (Excel, Microsoft, Redmond, WA, USA) and were analyzed using the Statistical Package for the Social Sciences 26.0 KO for Windows (SPSS Inc., Chicago, IL). We generated descriptive statistics and presented them as frequencies and percentages for categorical data and medians with interquartile ranges for continuous data because the data were not normally distributed. To compare each time interval by type of laryngoscope, the Kruskal–Wallis test was used for continuous variables. A x^2 test was used to compare categorical variables, such as the intubation success rate. To compare each time interval by type of device before and after the hands-on workshop, the Wilcoxon signed rank test was used for continuous variables. For all data, $P < .05$ was considered statistically significant. However, a post hoc analysis was conducted with the Mann–Whitney test using a Bonferroni correction, and $P < .0083$ was considered significant. Kaplan–Meier analysis was performed to analyze the cumulative success rate in terms of the total intubation time.

3. Results

3.1. Participants' characteristics (Fig. 3, Table 1)

The total number of participants was 29. One participant had cough, sputum and fever on the day before participation and was not able to participate after being tested for COVID-19 (Fig. 3). The baseline characteristics of all participants are shown in Table 1. There were 16 men (55.2%) and 13 women (44.8%), and the average age was 25.5 ± 1.01 for men and 24.92 ± 0.62 for women. All participants were medical students at the College of Medicine at Hallym University, had little experience with direct laryngoscopy on airway manikins in the last year and were all novices to video-laryngoscopes.

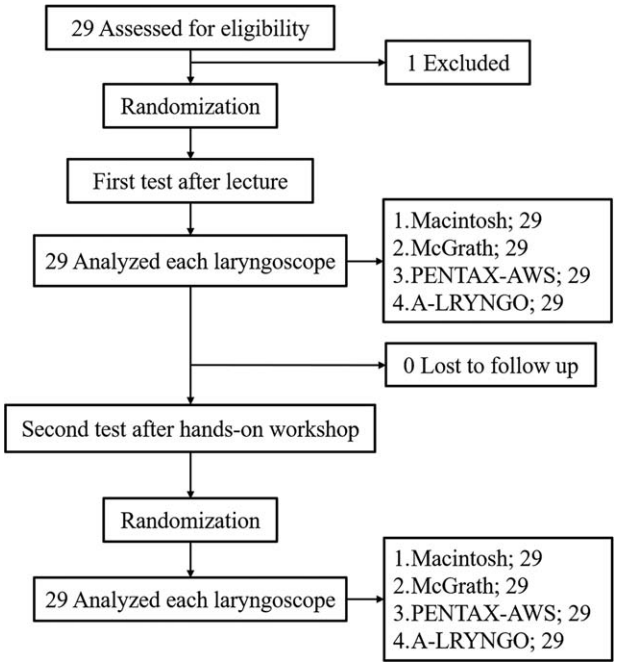

Figure 3. Flow diagram.

Table 1

Participants' characteristics.

	Male	Female
Number, n (%)	16 (55.2)	13 (44.8)
Age, Mean ± SD	25.5 ± 1.01	24.92 ± 0.62
Experience with Video Laryngoscope Intubation	None	None

SD = standard deviation.

3.2. Intubation performance with the 4 laryngoscopes after the lecture (Table 2)

After the lecture, there was no significant difference among the 4 laryngoscopes in the time it took to find the vocal cord, which was the result of using 4 laryngoscopes (IVT: Macintosh; 9.56 ± 8.33, McGrath; 9.96 ± 8.74, AWS; 6.67 ± 4.92, A-LRYNGO; 8.07 ± 4.68, $P = .345$). However, there was a statistically significant difference among the 4 laryngoscopes in the time it took to insert an endotracheal tube into the trachea (VFT: Macintosh; 10.10 ± 5.37, McGrath; 16.02 ± 19.72, AWS; 9.41 ± 12.49, A-LRYNGO; 9.52 ± 6.39, $P = .01$). There was no significant difference in the time to first ventilation from the time of completion of endotracheal tube insertion (VFT: Macintosh; 7.13 ± 0.9, McGrath; 7.14 ± 0.69, AWS; 7.36 ± 0.66, A-LRYNGO; 7.51 ± 1.19, $P = .286$).

The intubation success rate was 51.7% for Macintosh, 75.9% for McGrath, 82.8% for AWS, and 89.7% for A-LRYNGO ($P = .006$). Among the 4 laryngoscopes, A-LRYNGO had the highest frequency of C-L grade I at 89.7%. There were no significant differences among the laryngoscopes in the time taken to find the vocal cord. However, the time taken to insert the endotracheal tube into the trachea was significantly longer for McGrath (VFT: 16.02 ± 19.72) than for Macintosh (VFT: 10.10 ± 5.37; $P = .004$) and A-LRYNGO (VFT: 9.52 ± 6.39; $P = .002$). Although not statistically significant, the time for McGrath was also longer than that for AWS (VFT: 9.41 ± 12.49; $P = .025$).

3.3. Intubation performance with the four laryngoscopes after the one-on-one hands-on workshop (Table 3)

After the hands-on workshop, there were significant differences among the 4 laryngoscopes in the time it took to find the vocal cord (IVT: Macintosh; 7.28 ± 4.39, McGrath; 4.49 ± 2.59, AWS; 4.49 ± 2.48, A-LRYNGO; 4.85 ± 1.67, $P < .001$) and in the time it took to insert an endotracheal tube into the trachea (VFT: Macintosh; 9.19 ± 3.87, McGrath; 9.71 ± 3.07, AWS; 5.77 ± 2.83, A-LRYNGO; 6.70 ± 2.36, $P < .001$). However, there was no significant difference in the time to first ventilation from the time of completion of endotracheal tube insertion (VFT: Macintosh; 6.97 ± 1.00, McGrath; 7.15 ± 0.78, AWS; 6.96 ± 0.92, A-LRYNGO; 7.32 ± 1.02, $P = .627$).

The intubation success rate was 100% for all 4 laryngoscopes. Among the 4 laryngoscopes, A-LRYNGO had the highest

Table 2

Comparison of intubation performance with the 4 laryngoscopes after the lecture.

Devices	IVT	VFT	FVT	Success rate, %	C-L grade, n (%)			
					I	II	III	IV
Macintosh	9.56 ± 8.33	10.10 ± 5.37	7.13 ± 0.90	51.7	2 (6.9)	14 (48.3)	4 (13.8)	9 (31.0)
McGrath	9.96 ± 8.74	16.02 ± 19.72	7.14 ± 0.69	75.9	7 (24.1)	15 (51.7)	1 (3.4)	6 (20.7)
AWS	6.67 ± 4.92	9.41 ± 12.49	7.36 ± 0.66	82.8	14 (48.3)	11 (37.9)	0 (0)	4 (13.8)
A-LRYNGO	8.07 ± 4.68	9.52 ± 6.39	7.51 ± 1.19	89.7	26 (89.7)	2 (6.9)	0 (0)	1 (3.4)
P value	.345	.010	.286	.006	NA	NA	NA	NA

Post hoc analysis			*P* value*			
Macintosh	vs	McGrath	0.761	0.004	.553	0.058
Macintosh	vs	AWS	0.093	0.846	.191	0.013
Macintosh	vs	A-LRYNGO	0.440	0.747	.116	0.002
McGrath	vs	AWS	0.291	0.025	.276	0.520
McGrath	vs	A-LRYNGO	0.664	0.002	.214	0.168
A-LRYNGO	vs	AWS	0.174	0.786	.534	0.450

Continuous variables are given as the median ± interquartile range. The *P* value was calculated by the Kruskal–Wallis test, and $P < .05$ was considered significant.
Categorical variables (success rate) are given as percentiles. The *P* value was calculated by the χ^2 test, and $P < .05$ was considered significant.
AWS = PENTAX-Airway scope, C-L grade = Cormack-Lehane grade, FVT = from endotracheal tube insertion to first manual ventilation, IVT = from the blade of each laryngoscope passing the incisor to visualization of the glottis, VFT = from visualization of the glottis to completion of endotracheal tube insertion and removing the laryngoscope.
* Calculated by Kruskal–Wallis test with Bonferroni correction in post hoc analysis. $P < .0083$ was considered significant.

frequency of C-L grade I at 100%. There were significant differences between Macintosh and the other 3 laryngoscopes in the time taken to find the vocal cord (Macintosh vs McGrath; $P = .003$, Macintosh vs AWS; $P < .001$, Macintosh vs A-LRYNGO; $P < .001$). However, there were no significant differences among the video-laryngoscopes in the time taken to find the vocal cord (McGrath vs AWS; $P = .592$, McGrath vs A-LRYNGO; $P = .994$, A-LRYNGO vs AWS; $P = .963$). There were significant differences between the non-channel-type laryngoscopes (Macintosh, McGrath) and the channel-type laryngoscopes (AWS, A-LRYGNO) in the time taken to insert the endotracheal tube into the trachea ($P < .001$ in every match). However, regarding the time taken to insert the endotracheal tube into the trachea, there were no significant differences between non-channel-type laryngoscopes (Macintosh vs McGrath; $P = .509$) or between channel-type video-laryngoscopes (AWS vs A-LRYNGO; $P = .437$).

3.4. Educational effect according to the difference in performance before and after the workshop (Table 4 & Table 5)

In terms of the time taken to find the vocal cord, there were significant improvements for all 4 laryngoscopes (Macintosh, $P = .011$; McGrath, AWS and A-LRYNGO, $P < .001$). There was significant improvement for all 3 video-laryngoscopes in the time to insert the endotracheal tube into the trachea (McGrath; $P = .005$, AWS; $P = .002$, A-LRYNGO; $P = .001$). In the time to ventilation from the time of insertion of the endotracheal tube, there were statistically significant improvements for the 2 channel-type video-laryngoscopes (AWS; $P = .003$, A-LRYNGO; $P = .007$). For the non-channel-type laryngoscopes, there was a significant improvement in the success rate (Macintosh; $P < .001$, McGrath; $P < .016$). For the channel-type video-laryngoscopes, there was no significant

Table 3

Comparison of intubation performance with the 4 laryngoscopes after the one-on-one hands-on workshop.

Devices	IVT	VFT	FVT	Success rate, %	C-L grade, n (%)			
					I	II	III	IV
Macintosh	7.28 ± 4.39	9.19 ± 3.87	6.97 ± 1.00	100	6 (20.7)	23 (79.3)	0 (0)	0 (0)
McGrath	4.49 ± 2.59	9.71 ± 3.07	7.15 ± 0.78	100	21 (72.4)	8 (27.6)	0 (0)	0 (0)
AWS	4.49 ± 2.48	5.77 ± 2.83	6.96 ± 0.92	100	25 (86.2)	4 (13.8)	0 (0)	0 (0)
A-LRYNGO	4.85 ± 1.67	6.70 ± 2.36	7.32 ± 1.02	100	29 (100)	0 (0)	0 (0)	0 (0)
P value	<.001	<.001	.627	NA	NA	NA	NA	NA

Post hoc analysis			*P* value*		
Macintosh	vs	McGrath	0.003	.509	0.774
Macintosh	vs	AWS	< 0.001	<.001	0.335
Macintosh	vs	A-LRYNGO	< 0.001	<.001	0.913
McGrath	vs	AWS	0.592	<.001	0.253
McGrath	vs	A-LRYNGO	0.994	<.001	0.750
A-LRYNGO	vs	AWS	0.963	.437	0.287

Continuous variables are given as the median ± interquartile range. The *P* value was calculated by the Kruskal–Wallis test, and $P < .05$ was considered significant.
AWS = PENTAX-Airway scope, C-L grade = Cormack-Lehane grade, FVT = from endotracheal tube insertion to first manual ventilation, IVT = from the blade of each laryngoscope passing the incisor to visualization of the glottis, VFT = from visualization of the glottis to completion of endotracheal tube insertion and removing the laryngoscope.
* Calculated by Kruskal–Wallis test with Bonferroni correction in post hoc analysis. $P < .0083$ is considered significant.

Table 4

Educational effect on performance before and after the workshop.

Devices	IVT			VFT			FVT		
	Before workshop	After workshop	*P* value	Before workshop	After workshop	*P* value	Before workshop	After workshop	*P* value
Macintosh	9.56 ± 8.33	7.28 ± 4.39	.011†	10.10 ± 5.37	9.19 ± 3.87	.177	7.13 ± 0.90	6.97 ± 1.00	.272
McGrath	9.96 ± 8.74	4.49 ± 2.59	<.001†	16.02 ± 19.72	9.71 ± 3.07	.005†	7.14 ± 0.69	7.15 ± 0.78	.527
AWS	6.67 ± 4.92	4.49 ± 2.48	<.001†	9.41 ± 12.49	5.77 ± 2.83	.002†	7.36 ± 0.66	6.96 ± 0.92	.003†
A-LRYNGO	8.07 ± 4.68	4.85 ± 1.67	<.001†	9.52 ± 6.39	6.70 ± 2.36	.001†	7.51 ± 1.19	7.32 ± 1.02	.007†

Continuous variables are given as the median ± interquartile range. The *P* value was calculated by the Wilcoxon signed rank test, and $P < .05$ was considered significant.
AWS = PENTAX-Airway scope, FVT = from endotracheal tube insertion to first manual ventilation, IVT = from the blade of each laryngoscope passing the incisor to visualization of the glottis, VFT = from visualization of the glottis to completion of endotracheal tube insertion and removing the laryngoscope.

improvement in the success rate (AWS; $P = .063$, A-LRYNGO; $P = .250$),.

3.5. Lifting point of the blade tip during intubation with the 2 channel-type video-laryngoscopes (Table 6)

Among 58 trials, the blade tip lifted the epiglottis in 72.4%, and when using AWS, the vallecular tip was lifted in 27.6%. On the other hand, out of a total of 58 trials, the blade tip lifted the vallecular in 91.4%, and when using the A-LRYNGO, the epiglottis was lifted in only 5%.

3.6. Cumulative success rate with the 4 laryngoscopes in terms of total intubation time (Fig. 4)

There was no statistically significant difference among the laryngoscopes in the first test, conducted after the lecture. Macintosh, which all participants had experienced at least a little, seemed to be better than the other three video-laryngoscopes (Fig. 4A, $P = .087$). However, in the second test, conducted after the one-on-one hands-on workshop, the 2 channel-type video-laryngoscopes showed significantly better results than the 2 non-channel-type laryngoscopes (Fig. 4B, $P < .001$).

Table 5

Educational effect on success rate before and after the workshop.

Devices	Numbers of successful intubations, n (%)		
	Before workshop	After workshop	*P* value
Macintosh	15 (51.7)	29 (100)	<.001†
McGrath	22 (75.9)	29 (100)	.016†
AWS	24 (82.8)	29 (100)	.063
A-LRYNGO	26 (89.7)	29 (100)	.250

Categorical variables are given as percentiles.
The *P* value was calculated by McNemar's test, and $P < .05$ was considered significant.
AWS = PENTAX-Airway scope.

Table 6

The lifting point of the blade tip during intubation in the two-channel-type video laryngoscopes.

Channel-type devices	Vallecular, n (%)	Epiglottis, n (%)
AWS	16 (27.6)	42 (72.4)
A-LRYNGO	53 (91.4)	5 (8.6)

AWS = PENTAX-Airway scope.

3.7. Artificial intelligence-based glottis guidance with A-LRYNGO (Fig. 5)

In terms of the performance of A-LRYNGO's artificial intelligence-based glottis guidance, out of a total of 29 trials, 72.4% provided accurate guidance through the trachea, and 20.7% identified the vocal fold position; thus, 93.1% provided appropriate guidance through the glottis. It was found that 6.9% were guided by the vestibular folds. There were no other cases of guidance through the esophagus or epiglottis.

3.8. Results of the short questionnaire for all participants (Table 7)

All participants responded that the workshop was effective. They also indicated that after this process, they had gained confidence in intubation. Participants reported that the effort required for learning the 2 channel-type video-laryngoscopes and the ease of intubation with these 2 devices were similar. In terms of equipment preference, AWS and A-LRYNGO were preferred. Among the 4 devices, Macintosh and McGrath were selected as the most difficult devices to learn, and AWS and A-LRYNGO were selected as the easiest devices to learn.

4. Discussion

Due to the unprecedented COVID-19 pandemic, the number of infection cases among healthcare workers has begun to increase, and many changes and challenges in the medical field have resulted. Healthcare workers have accounted for 21% of infected people worldwide during the COVID-19 pandemic,[15] and the most at-risk healthcare workers are those involved in procedures at high risk of aerosol formation.[16] In fact, approximately 10% of healthcare workers who performed tracheal intubation for patients with suspected or confirmed COVID-19 were found to be infected with COVID-19.[17]

For this reason, many changes have occurred in the field of emergency airway management. Wearing PPE has become a prerequisite to participating in all procedures for patients with suspected or confirmed COVID-19 infection. In addition, video-laryngoscopes are recommended rather than direct laryngoscopy to reduce intubation failure due to PPE worn to prevent exposure to infection sources.[5–7] Eventually, for this reason, there is a high possibility that education on video laryngoscopy will be emphasized in airway management education in the future.

However, it is difficult to find a simulation study using 2 or more channel-type video-laryngoscopes with novice practitioners participating in tracheal intubation training wearing PPE considering the pandemic situation. Although not a study using

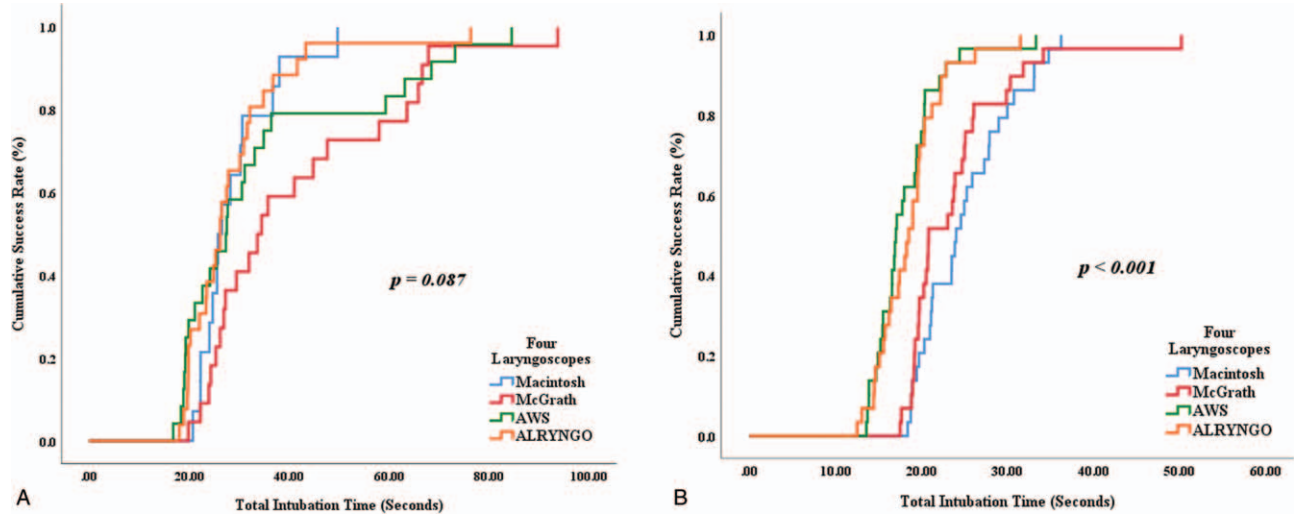

Figure 4. Cumulative success rate of the 4 laryngoscopes in terms of total intubation time. Calculated by log-rank test. $P < .05$ is considered significant. (A) Cumulative success rate in the first test after the lecture. (B) Cumulative success rate in the second test after the hands-on workshop.

a channel-type video-laryngoscope, Michael et al conducted a simulation study of paramedic students using a Macintosh laryngoscope and a Macintosh video-laryngoscope in 2009. As a result, it was reported that the Macintosh video-laryngoscope can improve the laryngeal view and that the intubation success rate is higher than that with the Macintosh laryngoscope.[18] In the same year, Muhammad A. Malik et al conducted a study comparing Macintosh laryngoscopy, GlideScope, and AWS for medical students. At the conclusion of the study, they suggested AWS was an easier device for novice practitioners to use to acquire tracheal intubation skills.[19] In 2011, Hayashi et al of Japan compared the channel-type video-laryngoscopes AWS and Airtraq with Macintosh laryngoscopes and Miller laryngoscopes for medical students. They proposed that AWS allows novice practitioners to intubate patients more safely with a better laryngeal view, even with minimal instruction.[20] In 2012, Yamada et al conducted a manikin study of novice laryngoscopists using a GlideScope, AWS and a Macintosh laryngoscope. GlideScope and AWS offered better laryngeal visibility and device operability than Macintosh.[21] In a study comparing Macintosh laryngoscopy and AWS in 2018, Kyu et al reported to novice doctors that AWS provides a better laryngeal view faster and more easily and proposed including a video-laryngoscope in future intubation education.[22] In 2020, Kyong et al compared McGrath, AWS and Macintosh laryngoscopes for nurses with no intubation experience and found that McGrath and AWS appeared to be suitable equipment for novices to use compared to Macintosh laryngoscopes.[23] In 2021, Yuryo et al conducted a simulation study in novice doctors using Macintosh, McGrath, and AWS. They reported that McGrath and AWS were better equipment options for novice doctors than Macintosh in terms of laryngeal view and intubation success.[24]

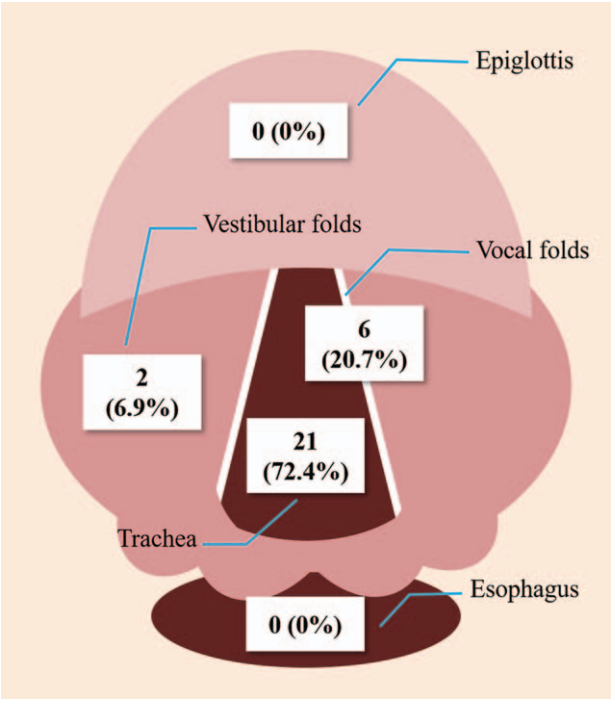

Figure 5. A-LRYNGO artificial intelligence-based glottis guidance performance.

Although PPE was not worn, most studies have suggested that video laryngoscopy provides a safer and faster laryngeal view than direct laryngoscopy and is an appropriate laryngoscope for novices.

In addition, the studies conducted while wearing PPE were not about novice education, and most of them were conducted for emergency physicians with sufficient intubation experience. These studies reported that the effect of PPE on intubation was not significant for emergency physicians with sufficient tracheal intubation experience.[25–27] However, in a study on emergency medicine residents, wearing PPE affected the intubation time and success rate, and it was reported that the subjects preferred video-laryngoscopes over direct laryngoscopes.[28]

In this study, participants wore PPE and were first-time video-laryngoscope users, although they had exposure to direct laryngoscopy once 1 year prior. Nevertheless, in the first test, when using 2 channel-type video-laryngoscopes without any

Table 7

Results of the short questionnaire for all participants.

Question	5-point Likert Scale, n (%)				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Was the hands-on workshop effective?	0 (0)	0 (0)	0 (0)	4 (13.8)	25 (86.2)
Was the effort to improve skills related to the two laryngoscopes, AWS and A-LRYNGO, similar?	0 (0)	1 (3.4)	1 (3.4)	5 (17.1)	22 (75.9)
Was the ease of intubation with the two laryngoscopes, AWS and A-LRYNGO, similar?	0 (0)	0 (0)	1 (3.4)	3 (10.3)	25 (86.3)
Have you gained confidence in tracheal intubation?	0 (0)	0 (0)	0 (0)	7 (24.1)	22 (75.9)

Question	Laryngoscopes, n (%)			
	Macintosh	McGrath	AWS	A-LRYNGO
Which laryngoscope do you prefer?	0 (0)	0 (0)	19 (65.5)	10 (34.5)
Which laryngoscope was the most difficult to learn?	11 (37.9)	18 (62.1)	0 (0)	0 (0)
Which laryngoscope was the easiest to learn?	0 (0)	0 (0)	18 (62.1)	11 (37.9)

AWS = PENTAX-Airway scope.

hands-on training, a better laryngeal view was obtained, and the intubation success rate was very high. Although not statistically significant, it was found that A-LRYNGO embedded with an artificial intelligence-based glottis guidance system was superior to AWS in C-L grade and intubation success rate. In the first test, McGrath, a non-channel-type video-laryngoscope, showed a higher intubation success rate than Macintosh, but the intubation time was rather slow compared to Macintosh. The participants did not have enough experience, though they had direct experience with the laryngoscope a year prior. Therefore, these differences can be interpreted as participants with no experience with video-laryngoscopes being unfamiliar with inserting the endotracheal tube while viewing the display. Considering the ratio of C-L grades I and II for each laryngoscope, the largest factor affecting the success of intubation in novices can be explained by the level of laryngeal view.

In the second test, conducted after the one-on-one hands-on workshop, all participants successfully performed intubations, and the laryngeal view was also improved compared to the first test, so there was no C-L Grade III or V for any of the 4 laryngoscopes. The time taken to obtain a laryngeal view was significantly faster with all 3 video-laryngoscopes than with the Macintosh laryngoscope. Additionally, 2 channel-type video-laryngoscopes without Stylet were significantly faster in terms of the time to complete intubation than the Macintosh and McGrath laryngoscopes using Stylet.

In terms of the effectiveness of education, the time to complete insertion of the endotracheal tube for Macintosh did not change significantly, but the rest of the times improved after a hands-on workshop. Despite being novice practitioners with no intubation experience and wearing PPE, the 2 channel-type video-laryngoscopes showed good intubation-related performance before the hands-on workshop. As a result, it seemed that the educational effect was not large after the hands-on workshop was implemented.

Compared to that of AWS, the blade tip of A-LRYNGO has an acute angle, and the blade tip tends toward the vallecular direction. This is thought to reflect the characteristics of a blade with an acute angle. A-LRYNGO's artificial intelligence-based glottis guidance system showed 93.1% accuracy, but 20.7% of trials were guided by the vocal folds. In addition, proper glottis guidance was not provided in 6.9% of trials, so it is thought that the performance of embedded artificial intelligence systems should be improved by collecting more data in the future. In a short questionnaire, the participants of this study evaluated that the degree of effort required to acquire the skills needed for AWS and A-LRYNGO and the ease of intubation were almost equal. They chose 2 channel-type video-laryngoscopes as the preferred and most easy-to-learn laryngoscope for novice practitioners.

This study has the following limitations. First, the short-term effect of the one-on-one hands-on workshop, but not the long-term effect, was confirmed. It seems that further study of the long-term effect on the same participants will be needed in the future. Second, with only the results for McGrath, it cannot be concluded that the non-channel-type video-laryngoscope is not as good as the channel-type video-laryngoscope for educating novice practitioners wearing PPE. Therefore, an additional simulation study is needed on education and training for other non-channel-type video-laryngoscopes. Third, this study was conducted only in normal airways. Difficult airway or chest compression situations were not considered, so further research is needed in this field. Therefore, further studies on various situations related to tracheal intubation education are needed in the future.

5. Conclusion

To prepare for an airway management of critically ill patients during the COVID-19 pandemic, a channel-type video-laryngoscope is appropriate for tracheal intubation training for novice practitioners wearing PPE. If the performance of the A-LRYNGO artificial intelligence glottis guidance system, a channel-type video-laryngoscope, is improved, it is thought that it can be recommended along with AWS as a device for novice practitioners.

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