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Different fit factors for the N95 respirator during endotracheal intubation: Comparing video laryngoscopy and direct laryngoscopy

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Abstract

Endotracheal tube (ET) intubation is a high-risk procedure for healthcare workers (HCWs) because of exposure to aerosolized disease particles. The effectiveness of (N95) respirators may be decreased by movements due to leakage, especially during ET intubation by direct laryngoscopy (DL). A randomized crossover study was conducted to compare the fit factor of a duckbill-shaped N95 between video laryngoscopy (VL), DL, and ET intubation. Physicians (n=34) were enrolled and randomized to each study arm. A quantitative fit test machine measured the fit factor during ET intubation (primary outcome) using VL vs. DL. The lowest fit factor with VL was higher than with DL (168 vs. 88, p=0.048). An acceptable fit for an N95 during ET intubation (secondary outcome) with VL was 88.2% compared to 67.6% with DL, albeit the difference was not statistically significant (p=0.065). In addition, the angle of head-up and hip bending with VL were lower than with DL (0° vs. 10°, p<0.001, 0° vs. 32°, p <0.001). In conclusion, VL can achieve a superior N95 fit during ET intubation over against DL because the need for physician movement is decreased. HCWs should consider performing ET intubation with VL instead of DL for a more stable N95 fit.

Keywords: N95 respirator, Endotracheal tube, Video laryngoscopy, Direct laryngoscopy

1. Introduction

Airborne diseases are transmitted via aerosol particles, typically 1-10 μm, which quickly spread in the air and are difficult to control [1]. SARS-CoV-2 (COVID-19) can also be transmitted via the airborne route, particularly in areas of poor ventilation and/or where aerosol-generating procedures (AGP) are being performed [2]. The WHO declared the COVID-19 outbreak a global pandemic on March 11, 2020 [3]. Some patients with severe symptoms require endotracheal tube (ET) intubation for ventilation support [4]. Healthcare workers (HCWs) that perform ET intubations are at high risk of exposure to aerosolized particles. ET intubation is an AGP as it stimulates spasmodic coughing in the patient during the intubation process. In addition, HCWs must be close to the patient's mouth (source of the aerosolized particles) to perform this procedure, especially when using a direct laryngoscope. It is thus valuable to measure their infectious controls. The N95 respirator (N95) is a standard respirator for HCWs, protecting them from airborne diseases [5]. However, Grinshpun et al [6] reported that leakage could be significant, as particles can slip passed the face seal 7 to 20 times more than that can pass through the filter media. Crucially, movement during ET intubation-such as bending at the hip with the head looking upward-tends to break the N95 seal [7-10]. This tendency makes ET intubation a high-risk procedure for HCWs, as well as being an AGP near the patient's mouth.

Video laryngoscopy (VL) was suggested as a replacement for direct laryngoscopy (DL) during the COVID-19 pandemic [11,12]. VL does not require the HCW to be near the patient's mouth to verify its position vis-à-vis the endotrachea. VL may also decrease the need for flexing and craning movements of HCWs during ET intubation, so it decreases the risk of potential N95 leakage. Notwithstanding, several factors can interfere with the fit, such as experience using VL, experience using the N95, facial dimensions, and the N95 model [13-16]. Only one study in South Korea compared laryngoscopic devices vis-à-vis the N95 fit [17], but since Thai facial dimensions and N95 models differ from that study, there is a limitation to applying the results to our setting. Since there has been no report on the duckbill-shaped N95, we conducted a study to compare the fit factor of the duckbill-shape N95 between VL and DL during ET intubation in Thailand. We were the first to report other factors such as the angle of physician movement, fit test results before ET intubation, and physician opinion vis-à-vis N95 use.

We aimed to compare VL and DL for the lowest fit factor value of N95 during ET intubation with manikin, compare VL and DL for the number of acceptable N95 fits (lowest fit factor value ≥ 100) during ET intubation with manikin, and ask for physicians' opinions about the safety & comfort of N95 and laryngoscope device they chose for airborne disease patients.

2. Materials and methods

2.1 Study design

We conducted the same experimental unit study for controlling the wearer factor (facial dimension and skill) to be the same in two interventions (VL vs. DL). Since these are the main factors affecting leakage of the N95 respirator. Although there were some weak points of the same experimental unit study-such as the carry-over effect and sequence effect-a balance and uniform crossover study design was used to compensate for these effects.

2.2 Setting

The experimental study was conducted at the Faculty of Medicine, Khon Kaen University, Thailand, between July and August 2021.

2.3 Participating physicians and sampling

The number of subjects was calculated using the G-power program [18] (alpha error 0.05 and power 0.8). Based on the mean fit factor from a previous study, 26 physicians were needed (i.e., mean fit factor/standard division (SD) of VL=170.27/39.25, mean fit factor/SD of VL=128.71/41.07) [17]. We randomized 35 (130% of 26) of 143 residents from three departments (Internal Medicine, Emergency Medicine, and Anesthesiology). Participants were required to meet the inclusion criteria: Thai ethnicity. In addition, the participants were to withdraw if they 1) could not pass the medical evaluation for safe respirator use; 2) had facial hair or facial anatomy that interfered with fitting the N95; 3) smoked within 24 h before the study; 4) could not pass the fit test for the N95 Pasture F550CS model; or, 5) had difficulty breathing or experienced dizziness during the study, as per the withdraw criteria (Figure 1).

2.4 Equipment and materials

A National Institute for Occupational Safety and Health (NIOSH) approved particulate filtering facepiece respirator in the N95 class (N95) [19]-the Pasture F550CS model-was used in this study (Figure 2A). The mask had a duckbill shape, and the head strap was adjustable [20].

A quantitative fit test machine-TSI PORTACOUNT PLUS 8048 model-was used to conduct the fit test and measure the fit factor during ET intubation. The fit factor is a parameter that quantifies how well the N95 fits the user's face: it is calculated from the ratio of particle concentration outside the N95 compared to the particle concentration leaked inside the N95 mask [21]. The quantitative fit test machine measures the fit factor between 1 and 200. Therefore, if the fit factor value was more than 200, the monitor still just presented 200 as the preset maximum.

VL and DL were the standard Macintosh curved blade size 3. VL was a C-MAC Karl Storz 8403 AXC model designed to have a display separate from the blade holder (Figure 2B). The ET was size 8 with a balloon cuff. The manikin was a full-body standard size laid in a medical bed that could be height adjusted from 35 to 70 cm.

The researchers recorded the study results on paper data record forms. Digital calipers were used to measure the facial dimensions in millimeters. A video camera was used to record physician movements.

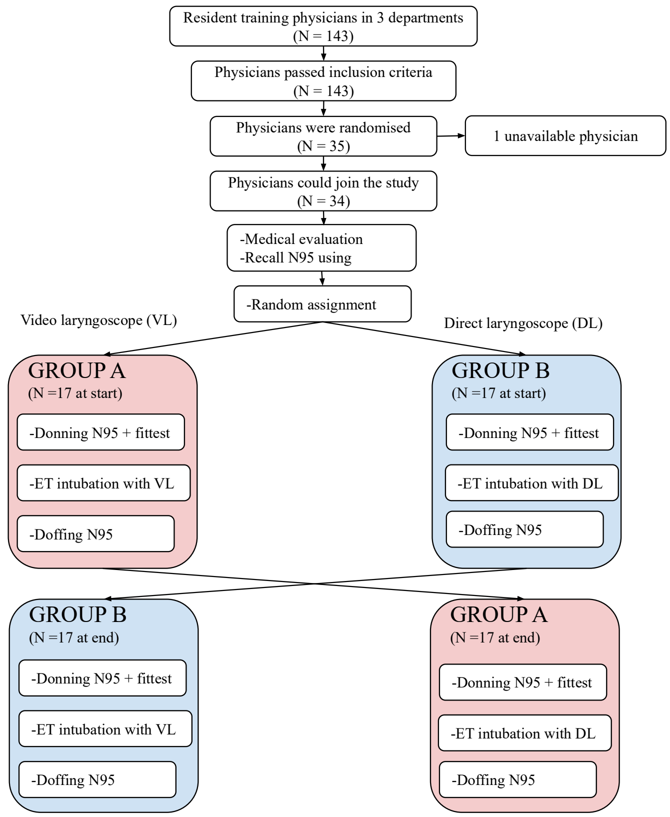

Figure 1 Experimental procedure.

Figure 2 N95 respirator and video laryngoscopy: (A) Duckbill-shaped N95 Pasture F550 CS model. (B) C-MAC Karl storz 8403 AXC model.

2.5 Intervention

2.5.1 Demographic data collection phase

The physicians received recall training on wearing the N95 properly as per the manufacturer's recommendations, including a self-fit check [22]. In addition, demographic data were collected, including age, sex, weight, height, experience in N95, and experience in ET intubation. The researcher measured the following parameters: facial dimensions (A. Biectoorbitale breadth, B. Bizygomatic breadth (Face width), C. Bigonial breadth, D. Menton-nasal length (Face length), E. Nose protrusion, F. Lip length/Lip width, and G. Tragion-Menton arch) (Figure 3A). According to the NIOSH bivariate panel, faces were categorized into three sizes (Figure 3B) [23]. After demographic data collection, participants were randomized into 2 study groups (group A performed the fit test with VL. First, group B performed the fit test with DL first), then each performed ET intubation with both VL and DL (Figure 1). The outcomes collection is as follow:

1) Main objective: The primary outcome was the lowest fit factor of an N95 during ET intubation using VL and DL. The secondary outcome was the number of acceptable fits of the N95 (the lowest fit factor value ≥ 100 [24]) during ET intubation with VL and DL. The lowest fit factor was the lowest value of fit factor during the intubation procedure.

2) Pre-ET intubation control factors were recorded: donning and fit test results, including the fit factor during the fit test, the re-fit test, and the strap adjustment of the N95 (Figure 3C).

3) During the ET intubation: The time taken for intubation was recorded-from picking up to placing the laryngoscope. Inappropriate N95 *positions* (i.e., slipping of mask or strap and obvious leakage) and physician movement during ET intubation were recorded by a video camera. The angle of head up and hip bending of the physicians were measured using the Kinovea program (Figure 3D) [25]. The success rate was also recorded.

4) Physician opinion: After finishing the test, physicians were asked to score their N95 safety and comfort (1-10) and choose whether they prefer the VL and DL for patients with the airborne disease.

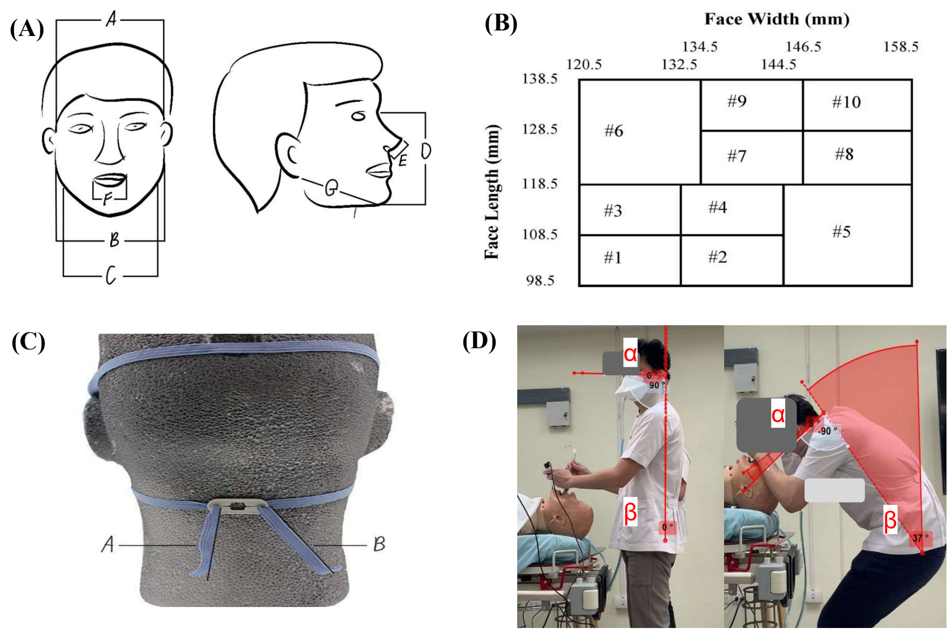

Figure 3 Measurement: (A) Facial dimensions: A. Biectoorbitale breadth, B. Bizygomatic breadth (Face width), C. Bigonial breadth, D. Menton-nasal length (Face length), E. Nose protrusion, F. Lip length/Lip width, G. Tragion-menton arch. (B) NIOSH bivariate panel: #1, #2, #3=small size, #4, #5, #6, #7=medium size, #8, #9, #10=large size. (C) Strap adjustment of N95: A + B (cm). (D) Measured angle of head up (α) and hip bending (β) of the physician's movement were measured by the Kinovea program.

2.5.2 Quantitative fit test phase

The physicians were required to pass quantitative fit testing to ensure that the N95 was not leaking because of facial characteristics or improper donning before ET intubation using VL and DL. The physicians would wear an N95 used for the quantitative fit test machine and did exercises as per the Occupational Safety and Health Administration (OSHA)-accepted fit test protocols (viz., modified ambient aerosol condensation nuclei counter quantitative fit testing protocol for filtering facepiece respirators) [21], including 1) hip bending for 50 sec; 2) talking for 30 sec; 3) head side-to-side for 30 sec; and 4) head up and down for 40 sec (Figure 4A). The test result constituted the fit factor determined during the test. The physicians could pass the fit test if they achieved a fit factor value ≥ 100. The physicians could redo the test once, but they were excluded from the study if they did not pass the second attempt.

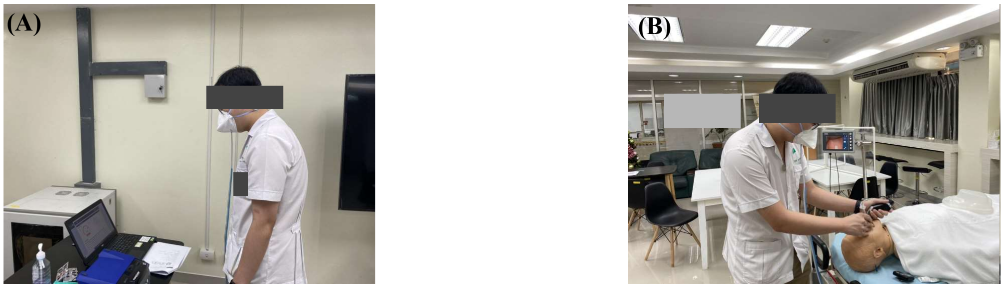

Figure 4 Fit testing and endotracheal intubation procedure: (A) Quantitative fit testing. (B) Measuring a fit factor during the ET intubation.

2.5.3 Endotracheal tube intubation phase

Room temperature was set at 25°C because sweat could lose the seal [26]. Physicians could adjust bed height and manikin position as needed. After passing the fit test, the physicians performed an ET intubation while wearing the N95 connected to the quantitative fit test machine in order to measure the ongoing fit factor value during intubation (Figure 4B). The ET intubation process included: 1) picking up a laryngoscope; 2) inserting the laryngoscope into the manikin's mouth; 3) looking for the best anatomical position of the larynx and vocal cord; 4) inserting the ET through the vocal cord; and 5) taking out and placing the laryngoscope. First, the researcher would confirm the correct ET position (a balloon passed the vocal cord). Then, the physician took off the N95 and retested with another laryngoscope (viz., redon the N95, fit test, and ET intubation).

2.6 Statistical analysis

Data was transferred from the paper data record forms to a Microsoft Excel spreadsheet using double data entry. The SPSS program (IBM SPSS Statistics for Macintosh, Version 28.0. Armonk, NY: IBM Corp) was used to analyze the data. The descriptive data were presented as frequencies with percentages for ordinal and nominal scaling, medians with Interquartile ranges (IQR) for the N95 fit factor value during ET intubation (non-normal distribution ratio scale), and the means with SD for the normally distributed ratio scale. The Wilcoxon sign-rank test was used to compare the lowest N95 fit factor between VL and DL (primary outcome). The sign test was used to compare the number of acceptable N95 fits between VL and DL (secondary outcome). The significance level was set at $p < 0.05$. Finally, the subgroup analysis was performed comparing the fit factor value during ET intubation between VL and DL in each department, training year, and face size.

3. Results

3.1 Demographics data

There were 34 physicians (from 35 randomized physicians) who met the inclusion criteria and joined the study. All of them completed the study. The median age was 27.5 years. Participants had worked as doctors for an average of 3.5 years. They had performed an average of 7 cases of ET intubation per month and used the N95 10 times per month. Face size was usually small (79%), followed by medium (21%). No one had a large face size (Table 1).

Due to limitations in measurement, 14 of 34 physicians had an equally lowest fit factor value (200) for both VL and DL during ET intubation. The actual fit factor might have been greater than 200 and not equal between VL and DL. Only 20 physicians had a within range fit factor measurement during ET intubation (range, 1-199). The data for these 20 physicians were analyzed and presented as a separate data set (actual fit factor physicians). Their demographic data revealed that almost all of them (90%) had a small face size (Table 1).

Table 1 Demographics of participant physicians.

Variables	All-physicians (n = 34)	Actual fit factor physicians (n = 20)
Study group: n (%)		
Group A (start with VL then DL)	17 (50%)	11 (55%)
Group B (start with DL then VL)	17 (50%)	9 (45%)
Sex: n (%)		
Male	20 (59%)	10 (50%)
Female	14 (41%)	10 (50%)
Facial size group: n (%)		
Small	27 (79%)	18 (90%)
Medium	7 (21%)	2 (10%)
Large	0	0
Department: n (%)		
Emergency medicine	15 (44.1%)	8 (40%)
Anesthesiology	11 (32.4%)	7 (35%)
Medicine	8 (23.5%)	5 (25%)
Year of resident training: n (%)		
1st year	6 (17.6%)	3 (15%)
2nd year	15 (44.1%)	10 (50%)
3rd year	13 (38.2%)	7 (35%)
Age (year): median, Q1-Q3	27.5, 27-29	28.0, 27-29
Experience: median, Q1-Q3		
Working year as a doctor (year)	3.5, 3-5	4.5, 2.5-5
Frequency of ET Intubation (cases per	7, 2-30	10, 2-30
month)	5, 4-9	5.5, 3.5-10
Emergency medicine	40, 35-47.5	40, 30-45
Anesthesiology	2, 1.5-3.5	2, 1-2
Medicine	10, 2-20	8.5, 2-20
Frequency of N95 using (times per month)	20, 12.5-20	20, 17.5-20
Emergency medicine	5, 2.5-7.5	5, 3.5-7.5
Anesthesiology	1.5, 1-4.5	1, 1-2
Medicine		
Facial dimensions (mm): mean, SD		
- A. Biectoorbitale breadth	141.0, 8.4	138.8, 8.8
- B. Bizygomatic breadth (Face width)	129.5, 125-136*	127.5, 123.5-133.5*
- C. Bigonial breadth	117.2, 8.4	112.0, 108.5-117.5*
- D. Menton-nasal length (Face length)	106.2, 7.4	106.6, 5.9
- E. Nose protrusion	23.4, 4.5	23.9, 4.7
- F. Lip length/Lip width	54.3, 4.8	53.9, 4.8
- G. Tragion-menton arch	129, 8.3	126.9, 8.8
Height (cm): median, Q1-Q3	168, 163.0-174.0	166.5, 160-172.5
Weight (kg): median, Q1-Q3	60, 54.0-71.0	59, 51-65

Actual fit factor: Lowest fit factor during the ET intubation ranged between 1 and 199
*Median, Q1-Q3

3.2 Comparing the lowest fit factor and acceptable N95 fit between VL and DL

The lowest fit factor value of the N95 during ET intubation (primary outcome) was different between VL and DL (p=0.048). There were 15 positive difference cases (fit factor value for VL > DL) and 5 negative difference cases (fit factor value for VL < DL) for both the all-physicians group and the actual fit factor physicians' group. The median of the lowest fit factor value during ET intubation with VL and DL were equal in the all-physicians group (200), but VL was higher than DL in the actual fit factor physician group (168.5 vs. 88) (Table 2.). The number of physicians with an acceptable N95 fit during the ET intubation (secondary outcome) was not statistically different between VL and DL (p=0.065). Among the all-physicians group, the number of physicians who had an acceptable fit with VL numbered 30 (88.2%) vs. 23 with DL (67.6%). While in the actual fit factor physicians' group, the number of physicians who had an acceptable fit with VL was 16 (80%) vs. 9 with DL (45%) (Table 2.).

3.3 Pre-ET intubation controlling factor, during ET intubation results, physician opinion

Donning and fit test results (strap adjustment, fit factor during fit test, and number of physicians who did a re-test) were not different between the VL and DL devices. The results during ET intubation revealed that physician movement with VL was lower than with DL in both the all-physicians group (0° vs. 10°, p <0.001 for head up, 0° vs. 32°, p <0.001 for hip bending) and the actual fit factor physician group (0° vs. 10°, p=0.04 for head up, 0° vs. 31°, p<0.001 for hip bending). Other results during ET intubation-including intubation time, intubation success rate, and inappropriate N95 position during the ET intubation-were not different between devices. As for physician opinion, all 34 would choose VL if they had to perform an ET intubation for patients with airborne disease. Trust in N95 safety was 8/10. The N95 comfort score was about 6/10 (Table 2).

Table 2 Comparing the lowest fit factor and acceptable fit of the N95 between VL and DL, Pre-ET intubation control factor, during ET intubation results, physician opinion.

Variable	All-physicians (n=34)			Actual fit factor physicians (n=20)		
	VL	DL	*p*-value	VL	DL	*p*-value
Primary and secondary outcome						
The lowest fit factor during ET intubation: median, Q_1-Q_3	200, 162-200	200, 85-200	0.048* (+) case: 15 (-) case: 5	168.5, 129-199	88, 57.5-178.5	0.048* (+) case: 15 (-) case: 5
Acceptable fit of N95 during ET intubation: n (%)	30 (88.2%)	23 (67.6%)	0.065 (+) case: 9 (-) case: 2	16 (80.0%)	9 (45.0%)	0.065 (+) case: 9 (-) case: 2
Donning and Fit test result (Pre-ET intubation controlling factor)						
Strap adjustment (cm): mean, SD	26.45, 7.4	26.49, 8.7	0.969	26.44, 8.6	26.40, 9.2	0.765
Fit factor during the fit test: median, Q_1-Q_3	200, 190-200	200,172-200	0.193	198, 178-200	189.5,128.5-200	0.211
Re-fit test: n (%)	8 (24%)	7 (21%)	1.00	4 (20%)	4 (20%)	1.00
During ET intubation result						
Intubation time (second): median, Q_1-Q_3	17.5, 13-22	16.0, 13-24	0.634	17.5, 13.5-22.5	16.5, 13-25	0.850
Physician's movement (degree)						
- Angle of head-up: median, Q_1-Q_3	0°, 0-0	10°, 0-18	<0.001*	0°, 0-0	10°, 0-15.5	0.004*
- Angle of hip bending: median, Q_1-Q_3	0°, 0-0	32°, 22-45	<0.001*	0°, 0-0	31°, 18.5-45	<0.001*
Intubation success in one attempt: n (%)	34 (100%)	34 (100%)	1.00	20 (100%)	20 (100%)	1.00
Not appropriate N95 position: n (%)	2 (5.88%)	1(2.94%)	1.00	1 (5%)	1 (5%)	1.00
Physician's opinion						
Laryngoscope device for ET intubation with an airborne disease	All 34 physicians chose VL			All 20 physicians chose VL		
N95 safety score (1 - 10): median, Q_1-Q_3	8, 8-8			8.0, 8-8.5		
N95 comfortable score (1 - 10): mean, SD	5.91, 1.7			5.85, 1.8		

* Significant, VL: video laryngoscope, DL: direct laryngoscope, n: number.
Actual fit factor: Lowest fit factor during the ET intubation ranged between 1 and 199.
(+) case: fit factor VL > DL, acceptable fit for VL but non-acceptable fit for DL.
(-) case: fit factor VL < DL, acceptable fit for DL but non-acceptable fit for VL.

3.4 Comparing fit factor between VL and DL in each department, training year, and face size

The internal medicine residents' subgroup had the lowest fit factor during ET intubation (VL 200 vs. DL 123.5 n=8 of the all-physicians group, p=0.042: VL 199 vs. DL 90 n=5 of the actual fit group, p=0.042). While the lowest fit factor during ET intubation between DL and VL was not different in emergency medicine, anesthesiology, each year of training, and each face size subgroup (Table 3). The internal medicine residents averaged only 2 ET intubation cases per month and only 1.5 N95 uses per month. By comparison, emergency medicine and anesthesiology residents had a respective 5 and 20 ET intubations per month and 20 and 5 N95 uses per month (Table 1).

4. Discussion

The finding of our study showed that 1) the lowest fit factor value of the N95 during ET intubation (primary outcome) was different between VL and DL (p= 0.048); 2) The number of physicians that had an acceptable N95 fit during the ET intubation (secondary outcome) was not statistically different between VL and DL (p= 0.065); and 3) physician movement with VL was lower than with DL in both the all-physicians group.

N95 is a standard respirator for HCWs that protects them from airborne diseases. For effective protection, the N95 must fit and seal to the user's face when they are exposed to airborne disease-causing particles [27]. Movement by HCWs while performing ET intubation-viz., bending at the hips and raising the head for a better viewing angle-tends to break the seal on the face [6-8]. VL may decrease the risk of N95 leakage during ET intubation because less movement is needed by the HCW; however, several factors might interfere with this assumption. The current study was designed to control for confounding factors that affect the N95 fit. ET intubation with VL and DL were performed by the same physicians (same experimental unit) to control the experience and facial dimension factors. A randomized uniform crossover design was used to minimize any period or sequencing effect [28]. After taking it off and re-donning, a quantitative fit test was done to ensure the N95 did not leak before performing an ET intubation: this was done to control any carry-over effects. The donning and fit test results were not different between the VL and DL groups, indicating that these factors were well-controlled before the ET intubation (Table 2).

The lowest N95 fit factor value during the ET intubation (the primary outcome) was higher using VL than DL (168.5 vs. 88 in the actual fit factor physician group, p=0.048) (Table 2). Physician movement during ET intubation can affect the N95 seal [10], particularly bending at the hip and raising the head [6,14].

Since ET intubation with VL visualizes the larynx using a display monitor, physicians do not need to adjust their body position to look at the larynx in contrast to DL. We found the incidence of upward angle of the head (0° vs. 10°) and bending at the hips (0° vs. 32°) was lower with VL than with DL (Table 2). This observation explains why the fit factor value differed between VL and DL. Our findings were consistent with a previous study conducted in South Korea in which VL had a higher fit factor value than DL when using a cup-shaped N95 model (200 vs. 166, $p< 0.001$, respectively). By contrast, the same study reported that for the folding N95 model, the fit factor value was not different between VL and DL (200 vs. 200, $p= 1$) [17]. The result was different for each N95 model because several factors vis-à-vis the N95 design affected the fit (i.e., shape, size, sealing material, nose clip, and adjustable strap) [16,20,29,30]. The study in South Korea might have faced similar limitations regarding the fit factor value measurement (maximum 200), resulting in their not observing any difference in the folding N95 model. Our secondary outcome also showed that the acceptable fit of the N95 during ET intubation with VL was 80-88.2%, compared to 45-67.6% with DL, even though there was no statistical difference ($p= 0.065$) (Table 2). Notably, the data were sufficient to conclude that ET intubation with DL could influence the seal of the N95 and that using VL could reduce this risk by reducing the need for movement of HCWs. HCWs should thus perform ET intubation with VL instead of DL for the most effective N95 seal. By way of corroboration, physician opinions concurred as they all chose VL for ET intubation when working with patients with airborne disease.

The finding vis-à-vis VL was expected to encourage policymakers to fully support an expensive VL tool in some instituteions. However, future studies may be required because there are many factors in actual clinical practice that differ from manikin laboratory settings (i.e., patients' airway anatomical variation, cooperation of patients, emergency conditions, and other PPE of physicians interfering with ET intubation). For example, N95 leakage in DL should be higher in emergency situations than in VL because of more movement. However, if the urgent situation requires equal movement for both VL and DL, the N95 leakage may not differ between the two approaches. In addition, there are a variety of VL models in each hospital, such as the position of the display, blade shape, material, and a low budget DIY VL that may affect the result. Future studies will help clarify this issue and how to apply it to clinical practice where resources are limited.

In the subgroup analysis, internal medicine residents had a significantly different result between VL and DL during the ET intubation (viz., fit factor value 200 vs. 123.5 in all medicine physicians, p=0.042, 199 vs. 90 in the actual fit factor medicine physician group, p=0.042, respectively) (Table 3).

Table 3 Comparing the fit factor between VL and DL in each department, training year, and face size.

Subgroup	Lowest fit factor during the ET intubation: median, Q_1-Q_3							
	All-physicians (n=34)				Actual fit factor physicians (n=20)			
	n	VL	DL	p-value**	n	VL	DL	p-value**
Department								
- Emergency medicine	15	200, 158-200	200, 85-200	0.674	8	158, 56-199	85, 49-199	0.674
- Anesthesiology	11	200, 148.5-200	200, 105.5-200	0.499	7	167, 129-199	140, 65.5-178.5	0.499
- Medicine	8	200, 181-200	123.5, 88-200	0.042*	5	199, 162-199	90, 86-119	0.042*
Year of training								
- 1st	6	200, 200-200	142, 55-200	0.109	3	199, n/a	55, n/a	0.109
- 2nd	15	200, 146-200	57, 85.5-200	0.241	10	181, 90-200	88, 71-107	0.241
- 3rd	13	200, 167-200	200, 128-200	0.352	7	167, 50-185	128, 89.5-199	0.352
Facial size								
- Medium	7	200, 200-200	200, 164-200	0.180	2	199, n/a	107, n/a	0.180
- Small	27	200, 150-200	200, 78-200	0.107	18	164.5, 28-199	87.5, 55-199	0.107

*Significant. VL: video laryngoscope, DL: direct laryngoscope, n: number, n/a: not applicable.
** (VL vs. DL).
Actual fit factor: Lowest fit factor during the ET intubation ranged between 1 and 199.

This is perhaps because internal medicine residents perform fewer ET Intubations with N95 per month than other residents (Table 1). Experience with ET intubation can improve facility and reduce movements during the procedure [13,31]. Practice using N95 can also affect fit [14], which might account for the difference between the value achieved using VL and DL among internal medicine residents. So, VL should probably replace DL, especially for those HCWs with less experience. HCWs performing ET intubation with patients having an airborne disease should be highly experienced with ET intubation and N95 use [12,13]. Therefore, training in ET intubation and N95 use should be done regularly [32-34]. Too few physicians in the subgroup analysis might explain why we did not find any difference in the fit factor value between VL and DL.

The study limitation was mainly due to the quantitative fit test machine itself, as the maximum measurable fit factor value for the N95 was 200. Unfortunately, fit factor values greater than 200 were still reported as just 200, making it difficult to interpret results at or above 200. So, the outcome of the current study was asymmetrical as only 20 of the 34 physicians had a fit factor value within the range of the test machine. We believe that the difference in fit factor value between VL and DL in all 34 physicians would be more apparent if we could measure fit factor values above 200. A second limitation was the lack of physicians with a large face, limiting the generalizability of the results. Finally, the results regarding subgroup analysis may be difficult to conclude since the sample size was relatively small and unequal among residents in each department.

5. Conclusion

The present study revealed that the fit factor value of the duckbill shaped N95 during ET intubation with VL was greater than with DL. Furthermore, physician movement during the procedure with VL was also lower than with DL, suggesting that VL can provide a better N95 fit during ET intubation than DL because of lower physician movement. HCWs should thus perform ET intubation with VL over against DL for optimized N95 safety. The subgroup analysis revealed that physicians with limited experience achieved a poorer fit factor value between VL and DL, so VL should replace DL, especially among these HCWs.

6. Ethical approval

The study was approved by the Center for Ethics in Human Research, Khon Kaen University (project number: HE641016). Each participating physician signed informed consent before starting the study.

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