



Predictors of difficult intubation when using a videolaryngoscope with an intermediate-angled blade during the first attempt: a prospective observational study

Hye Jin Kim¹ · Hye Rim Kim² · So Yeon Kim¹ · Ha Yan Kim² · Wyun Kon Park¹ · Min Ho Lee¹ · Hyun Joo Kim¹ 

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Abstract

The curvature of a videolaryngoscope blade has been diversified from the standard macintosh-type to the hyperacute-angle-type, resulting in different performances. We aimed to determine the intubation success rate and identify predictors of difficult intubation when using an intermediate-angled videolaryngoscope in the first attempt of intubation under routine anaesthesia settings. We enrolled 808 patients between 19 and 79 years of age, scheduled for elective surgeries under general anaesthesia with orotracheal intubation from July 2017 to November 2018; patients who were candidates for awake intubation were excluded. We obtained patient demographic data and performed airway evaluation before induction of anaesthesia for elective surgeries. We used the UEScope for tracheal intubation with a hockey stick-shaped malleable stylet. The intubation time was defined as the total duration from the entry of the blade into the oropharynx to the detection of first end-tidal carbon dioxide capnogram; this duration was recorded along with the number of intubation attempts. Difficult intubation was defined as either > 60 s duration for tracheal intubation, or > 1 intubation attempt. The use of the UEScope demonstrated a 99.4% success rate for intubation; however, increased difficulties were observed in patients who were male, obese, had a short thyromental distance, limited mouth opening, and high upper-lip-bite test class. Despite the high intubation success rate using an intermediate-angled videolaryngoscope, we recommend preparing backup plans, considering the increased difficulty in patients with certain preoperative features.

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Keywords Airway assessment · Predictor difficult intubation · Videolaryngoscope · Time factors

1 Introduction

Difficult intubation (DI) may lead to complications such as death and brain damage [1]; therefore, preventing DI is an important task for anaesthesiologists. Despite advancements in medical technology, DI continues to occur [2]. Human factors, such as lack of preoperative airway assessments,

improper preplanning, or inadequate tool selection, are known to be the major causes of DI [1].

Using a videolaryngoscope (VL) during the first intubation attempt is increasingly becoming standard [3, 4] because of the higher intubation success rates, fewer intubation difficulties, and lower number of laryngeal/airway trauma cases compared to when using a direct laryngoscope (DL) [2]. The angle of view in VLs is usually wider (~ 60 degrees), compared with the 15-degree angle of view in DL [5, 6]. Moreover, the blade curvature in a VL has been diversified from a standard Macintosh-type (~ 30 degrees) and intermediate-type (between 30 and 60 degrees) to hyperacute-angle types (~ 60 degrees), with various thicknesses and shapes that result in different performances [2, 7, 8]. Therefore, to select a suitable laryngoscope and establish a strategy for successful intubation, knowledge of the type of laryngoscope that is best suited for patients with specific airway features is required.

✉ Hyun Joo Kim
jjollong@gmail.com

¹ Department of Anesthesiology and Pain Medicine, Yonsei University College of Medicine, Anesthesia and Pain Research Institute, 50-1, Yonsei-ro, Seodaemun-gu, Seoul 03722, Republic of Korea

² Biostatistics Collaboration Unit, Department of Biomedical Systems Informatics, Yonsei University College of Medicine, Seoul, Republic of Korea

The advantages of using a VL with an acute angulation of 60 degrees in difficult airways are obvious; however, the feasibility of using an acute-angled VL during the first attempt of intubation in normal airways has been questioned [9]. The hyperacute-angle blade may result in impingement of the tube tip against the cricoid ring due to the acute angle of the tube path [10]; moreover, the gap between the camera and tube-insertion angle requires intricate eye coordination, which could negatively affect tube guidance, increase in intubation time [11], and cause intubation failure [9].

In contrast, the Macintosh-type VL, with a gently curved blade, allows smoother tube advancement, and the intubation process can be viewed both on the screen and directly with the naked eye [12]. This results in a reduced or comparable intubation time with less dependency on the stylet, compared to an acute-angled VL in a normal airway. However, it is difficult to clearly distinguish between difficult and normal airways, [13] and if intubation fails, the glottis view would need to be improved by replacing the Macintosh-type VL with a more curved blade [6]. Thus, VLs with intermediate-angled blades rather than blades with acute or Macintosh-type angles may be more suitable for both glottis view and tube advancement and may be optimal for use during an initial intubation attempt in general cases. The upward angle of the UEScope (UE Medical Devices, Inc. 831 Beacon Street, Suite 136 Newton, MA 02459, USA) blade used in this study was ~45 degrees, i.e. of intermediate curvature; slightly higher than that of the Macintosh-type and lesser than that of the acute-angled VL (Fig. 1) [4, 14, 15]. Reduced acute angulation and proper location of the camera eliminates concerns around blind spots and ensures easy tube guidance; thus, enhancing intubation performance in both normal and difficult airways [4]. Consequently, other predictors for DI can be identified using the UEScope.

However, few studies have evaluated the performance of intermediate-angled VLs during initial intubation attempts, and no studies have investigated the risk factors for DI when using intermediate-angled VLs. Therefore, we aimed to determine the intubation success rate and identify specific demographic or structural features that can predict DI when an intermediate-angled VL is used during an initial intubation attempt.

2 Material and methods

2.1 Study population

This prospective observational study was performed at Severance Hospital, Yonsei University Health System, Seoul, Korea, in accordance with the Declaration of Helsinki. The study protocol was approved by the institutional review board of Severance Hospital (chairperson: Myoung

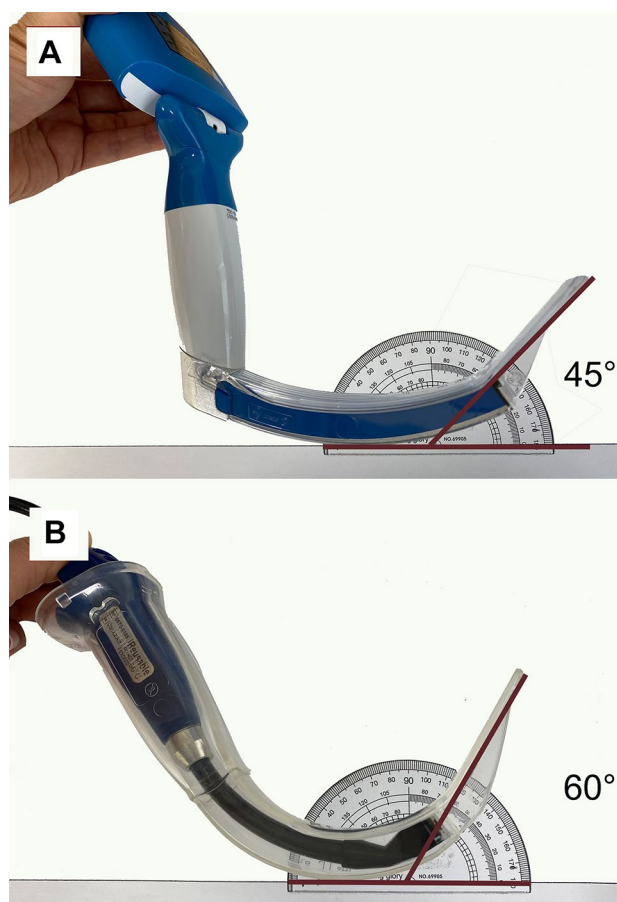


Fig. 1 Laryngoscopes with intermediate and hyperacute blade angles **A** The UEScope with an ~45-degree intermediate-angled blade; and **B** the GlideScope videolaryngoscope with a 60-degree hyperacute-angled blade

Soo Kim, IRB No. 1-2017-0035) on 5 July 2017, and registered with the World Health Organization International Clinical Trials Registry Platform (NCT03215823, Principal investigator: Hyun Joo Kim, Date of registration: 12 July). This manuscript adheres to the applicable Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. Written informed consent was obtained from all patients. We enrolled patients between 19 and 79 years of age who were scheduled for elective otorhinolaryngology surgery under general anaesthesia with orotracheal intubation between July 2017 and November 2018. We excluded patients who were candidates for awake intubation (base of tongue tumours > 4 cm, severely limited neck extension due to ankylosing spondylitis, and severe deformation and atrophy of the anatomical structure of the head and neck after free-flap reconstruction); were pregnant; had a tracheostomy tube; wore a neck collar due to cervical fracture; or were unable to read the consent form due to illiteracy or language barriers.

2.2 Anaesthetic management and measurements

Difficult airway is defined as a clinical situation in which a conventionally trained anaesthesiologist experiences difficulty with facemask ventilation of the upper airway, tracheal intubation, or both [16]. Potential risk factors for a difficult airway are evaluated through medical history and preoperative physical examination. Baseline patient demographic data, including age, sex, weight, height, body mass index (BMI), and history of rheumatoid arthritis (RA), head and neck cancer, or snoring, were obtained. Preoperative airway evaluation included the modified-Mallampati classification [17], upper lip bite test (ULBT) [18], measurements of inter-incisor distance, thyromental distance, sterno-mental distance, teeth-thyroid distance, neck circumference at the thyroid cartilage level (perpendicular to the longitudinal axis of the neck), testing of cervical spine mobility (normal vs. limited vs. severely limited), and assessment of the appearance of the head and neck (micrognathia and dentition, including loose teeth and the prominence of the maxillary teeth). All lengths were assessed using a pair of compasses and a ruler. Inter-incisor distance was measured when the mouth was maximally open.

In the fully extended neck position with the mouth closed, the straight distances from the upper border of the thyroid cartilage to mentum (thyromental distance) and from the suprasternal notch to mentum (sterno-mental distance) were measured. The distance between the tip of the lower incisor and the thyroid cartilage was measured with the mouth open and neck extended (teeth-thyroid distance).

Upon a patient's arrival to the operating room, standard monitors, including a pulse oximeter, 3-lead electrocardiography monitor, and non-invasive blood pressure monitor, were attached to the patient in a supine position with a pillow under the patient's head. Anaesthesia and tracheal intubation were performed by attending anaesthetists or senior resident doctors, all with at least 2 and 3 years of experience, using a UEScope and DL, respectively. Anaesthesia was induced using 1 and 2 mg/kg propofol (Fresofol 1% MCT; Fresenius Kabi Austria GmbH, Graz, Austria) and 0.1–0.2 $\mu\text{g}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ of remifentanyl (Ultian; Hanlim Pharm Co., Ltd., Seoul, Korea).

To induce muscle relaxation, 0.6–1.2 mg/kg rocuronium bromide was administered. No response to 50-Hz train-of-four stimulation on the ulnar nerve at the adductor pollicis muscle using a peripheral nerve stimulator (Innervator 252; Fisher & Paykel Healthcare, Auckland, New Zealand) was regarded as adequate muscle relaxation. If difficulty was encountered in mask ventilation, chin lift or jaw thrust were attempted, and an oral airway was inserted in the patient's mouth with a 4-handed technique, according to the guidelines set forth by the Difficult Airway Society in 2015 [19].

After sufficient muscle relaxation was confirmed, tracheal intubation was performed using a UEScope with a hockey stick-shaped, malleable, 60-degree angled stylet, while the patient's neck was extended. A size 4 disposable angulated blade sheath was used in all cases and was introduced into the mouth along the midline. Ramped or 25-degree head-up positioning was used for patients with a BMI $\geq 30\text{ kg/m}^2$. Backward, upward, and rightward pressure on the larynx manoeuvre and jaw thrust by the assistant were performed as needed and recorded as the airway opening manoeuvre. A failed VL view before and after the airway opening manoeuvre was defined as a glottis view of Cormack-Lehane grade 3 or 4. If the laryngoscope was removed from the patient's mouth without successful intubation and reinserted, it was recorded as an additional intubation attempt. At this time, the patient's head or UEScope's blade was repositioned and/or the distal end of the stylet was reshaped with more angulation at the discretion of the operator. The UEScope was used during the second attempt without any time limit, and the hyperacute-angled VL was used for the third attempt. If intubation failed after 3 attempts, 'VL failure' was recorded, and intubation was attempted with other types of tools, such as laryngeal masks or fiberoptic bronchoscopes, or awake intubation was performed in accordance with the Difficult Airway Society's 2015 guidelines for management of unanticipated DI in adults [19].

The intubation time was defined as the total time from the entry of the blade into the oropharynx to the time the first end-tidal carbon dioxide capnogram was obtained; this duration was recorded along with the number of intubation attempts. We also recorded complications that occurred during intubation.

2.3 Study endpoints

Primary endpoints were the predictors of DI, which were defined as either $> 60\text{ s}$ needed for tracheal intubation or more than 1 intubation attempt [20]. The secondary endpoint was intubation success within 2 attempts using a UEScope.

2.4 Statistical analysis

Continuous variables were analysed using independent *t*-test or Mann–Whitney U-test according to the results of the Shapiro–Wilk test. Categorical variables were analysed using the Chi-square test or Fisher's exact test. Binary data are presented as numbers (%), whereas continuous data are presented as the mean (standard deviation [SD]) if normally distributed, or as median (interquartile range [IQR] [range]) if non-normally distributed.

Model building was done using a (randomly chosen) training data set containing 71% of the data. Using the training set, variables with P-values < 0.1 in the univariable

analysis were entered into a multivariable logistic model through forward stepwise variable selection for assessment of their impact on the prediction of DI after confirming multicollinearity. The model with the lowest Akaike information criterion value was chosen and validated using the remaining 29% of the data (test data set). The area under the receiver operating characteristic (AUROC) curve was calculated, goodness-of-fit was determined using the Hosmer–Lemeshow test, and the calibration plot was drawn using bootstrap resampling 1000 times to evaluate the predictability of the model. Statistical significance was set at $P < 0.05$.

The occurrence of DI and failed VL view before and after the airway opening manoeuvre was analysed using the Chi-square test; we also specifically assessed the role of poor glottis view and tube delivery as a cause of DI.

All analyses were performed using Statistical Package for the Social Sciences 25 (IBM Corp., Armonk, NY, USA), R 3.4.3 (The R Foundation for Statistical Computing, Vienna, Austria), and SAS 9.4 (SAS Inc., Cary, NC, USA).

2.5 Sample number calculation

This was a prospective observational study to identify the predictors of DI in routine clinical practice; therefore, we did not set an exact target number of participants. This was approved by the Statistical Support Team of the School of Medicine, Yonsei University, Seoul, Korea. Assuming that the number of predictors is 3 or 4 based on logistic regression analysis, the number of DIs should be at least between 30 and 40 according to the event-per-variable rule [21].

The incidence of DI is reportedly about 5.8–10.3% [9, 18]. To target 45–90 DI cases, 800–900 tracheal intubation attempts would be needed. Thus, we planned to enrol 800–900 patients for an expected duration of 2 years.

3 Results

We screened 1042 patients and enrolled 808 patients. There were 7 dropouts, and 801 patients completed the study (Fig. 2). One case with missing data in the case report form was excluded from the analysis.

DI occurred in 146 patients (18.2%) within the total data set; 100 patients (17.7%) in the training data set ($n = 565$), and 46 patients (19.6%) in the test data set ($n = 235$). Among the patients with DI ($n = 146$), the number of attempts for achieving successful intubation were 1, 2, and 3 in 79 (54.1%), 62 (42.5%), and 4 (2.7%) patients, respectively; 1 patient with VL failure required awake intubation during the fourth attempt (0.7%). In the total study population ($n = 800$), the number of attempts for achieving successful intubation were 1, 2, 3 and 4 (VL failure) in 733 (91.6%), 62 (7.8%), 4 (0.5%) and 1 (0.1%) patient, respectively.

In 5 patients, the intubation failed despite 2 attempts using intermediate-angled VL (Table 1). Among them, 4 patients had Cormack-Lehane grade 3 after the airway opening manoeuvre; successful intubation was achieved using the McGRATH X-Blade (McGRATH™ MAC X-Blade size 3 VL; Medtronic, Minneapolis, MN, USA) in 1 patient and the GlideScope VL (Verathon, Bothell, WA, USA) in 2 patients.

Fig. 2 Flow chart of patient enrolment. Among the 1042 patients who were scheduled for elective surgery from July 2017 to November 2018 at our institution, 234 patients were excluded. Among the remaining 808 patients, anaesthesia plans for 4 patients changed to nasotracheal intubation in the operation room, while failure in time measurements occurred in 2 patients, and 1 patient withdrew his/her consent to participate. Ultimately, 801 patients completed the study, and 1 patient with missing data in the case report form was excluded from analysis

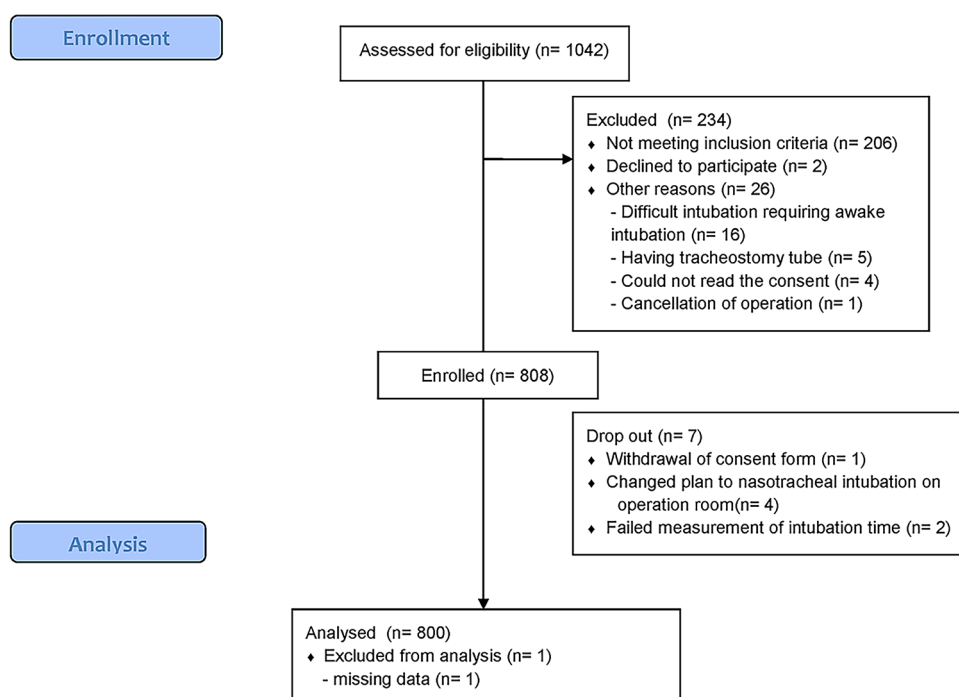


Table 1 Profile of patients with intubation failure after second attempt using the UEScope and rescue techniques

Number of patients	Age, sex, underlying history	CL Grade at first attempt of UEScope	CL Grade at second attempt of UEScope	Reason for difficult intubation	Rescue technique	Complication
1	51, M, snoring	2	2	Tube delivery ^a	Acute-angle VL (GlideScope)	Dental damage
2	44, M, none	3	3	Poor glottis view	Acute-angle VL (GlideScope)	None
3	59, M, none	3	3	Poor glottis view	Acute-angle VL (McGrath Mac X blade)	None
4	48, F, none	3	3	Poor glottis view	Acute-angle VL (GlideScope)	None
5	58, M, none	3	3	Poor glottis view	Awake fiberoptic intubation after failure with acute-angle VL (GlideScope)	None

CL grade cormack-lehane grade; VL videolaryngoscope

^aDespite a fair glottis view, an almost 90-degree-angled stylet was needed to guide the tube. The almost right-angled stylet facilitated tube insertion after switching to the GlideScope in this patient, who had a marginally narrow inter-incisor distance

One patient required awake intubation after a failed third attempt using the GlideScope due to poor glottis view. The remaining patient had difficulty in tube delivery despite a Cormack-Lehane grade of 2, and intubation was performed successfully using the GlideScope with a 90-degree angled stylet.

Baseline patient characteristics are shown in Table 2. Table 3 shows the results of the univariable logistic regression analysis using the training data set. In the univariable analysis of the training data set, increased weight, height, and BMI, longer inter-incisor distance, thicker neck circumference, male sex, loose teeth, micrognathia, and ULBT class 3 were positively associated with the occurrence of DI. Age, history of head and neck cancer, RA, or snoring, thyromental distance, and modified-mallampati classification ≥ 3 were additionally included in the multivariable analysis as potential factors with a P-value < 0.1 in the univariable analysis.

In the final multivariable logistic regression model, higher BMI (odds ratio [OR] 1.08, 95% confidence interval [CI] 1.01, 1.16), shorter thyromental distance (OR 0.69, 95% CI [0.53, 0.90]), reduced inter-incisor distance (OR 0.61, 95% CI [0.39, 0.95]), male sex (OR 3.86, 95% CI [2.26, 6.62]), and ULBT class 3 (OR 5.77, 95% CI [1.60, 20.81]) were independently associated with the occurrence of DI (Table 4). A calibration plot for the training data set is shown in Fig. 3. The AUROC curve of the model was 0.713 (95% CI 0.660–0.766) in the training data set and 0.686 (95% CI 0.608–0.763) in the test data set with no significant difference between them ($P=0.567$) (Fig. 4). The Hosmer–Lemeshow statistic indicated a good fit of the model in both the training and test data sets ($P=0.448$ and $P=0.707$, respectively).

The incidence of failed VL view before the airway opening manoeuvre was higher in the patients with DI than in those without DI (72.6% and 13.1%, respectively; $P < 0.001$).

When the additional airway opening manoeuvre was performed, the incidence of failed VL view improved in both groups, despite maintaining a higher incidence in patients with DI than in the rest (22.6% and 3.7%, respectively, $P < 0.001$). For the latter 3.7% of patients, delicate epiglottis lifts by the tube allowed easy intubation. Among the patients with DI, 77.4% who did not have failed VL view under the airway opening manoeuvre had problems with tube delivery.

4 Discussion

In this study, we showed a high intubation success rate of 99.4% with a maximum of 2 attempts when using an intermediate-angled VL, and we observed more cases of DI in patients who were male, obese, had a short thyromental distance, limited mouth opening, or a high ULBT class. This study covered normal and difficult airways under routine clinical practice, unless it was clearly evident that awake intubation was necessary.

The intubation success rate in this study was 91.6% on the first attempt, which improved to 99.4% on the second attempt. This result is comparable to the previously reported 99.7% success rate on a third attempt using a GlideScope in 400 patients who underwent elective surgery with or without difficult airways [18]. The DI incidence in this study was 18.3% ($n = 146$). The enrolment of patients who underwent an otorhinolaryngology surgery and the broad DI definition may have contributed to this higher incidence, compared with the previously reported incidences [13, 22]. When using a DL, securing the view usually guarantees tube delivery. However, with VLs, larger anterior views can be secured through the camera, though tube delivery remains a problem. When the airway opening manoeuvre was used, the possibility of a failed VL view was significantly reduced to less than a third; though the remaining 77% DIs occurred

Table 2 Demographic characteristics and preoperative airway parameters of patients intubated using the UEScope for elective surgeries

Parameter	Total (n = 800)
Age (years)	50.5 ± 15.0
Sex, male	438 (54.8)
Height (cm)/weight (kg)	165.6 ± 8.9 / 66.4 ± 12.9
BMI (kg/m ²)	24.1 ± 3.5
Co-medical history	
Rheumatoid arthritis	4 (0.5)
Head and neck cancer	68 (8.5)
Snoring	397 (49.6)
Airway parameter	
Modified-mallampati classification score ≥ 3	371 (46.4)
Upper-lip-bite test class of 3 ^a	13 (1.6)
Inter-incisor distance (cm)	4.0 [3.6, 4.4]
Thyromental distance (cm)	6.5 [6.0, 7.2]
Sterno-mental distance (cm)	14.8 ± 2.1
Neck circumference (cm)	37.8 [34.6, 41.0]
Normal/limited/severely limited cervical mobility	727 (90.1) / 72 (9.0) / 1 (0.1)
Micrognathia	42 (5.3)
Loose tooth/protruded maxillary teeth	230 (28.7) / 18 (2.3)
Intubating provider	
Attending anaesthetist/senior resident doctor	424 (53) / 376 (47)
Number of intubation attempts 1/2/3/4 for achieving successful intubation	733 (91.6) / 62 (7.8) / 4 (0.5) / 1 (0.1)
Complications	12 (1.5)
Gum damage	2 (0.3)
Dental damage	1 (0.1)
Lip damage	9 (1.1)

Values are presented as mean ± standard deviation, median (interquartile range), or number of patients (%)
 BMI, Body mass index

^aUpper lip bite test class of 3: the lower incisors cannot bite the upper lip

due to tube delivery. Similar to our research, Cooper et al. reported an incidence of 76.9% failed intubations, despite achieving a fair view using a GlideScope [23]. With the use of UEScope in our study, despite a nontrivial percentage of failed first attempts or long intubation times due to tube delivery difficulty, endotracheal intubation was successful with proper eye, hand, tube, and VL coordination within 2 attempts in most patients.

The DI predictors in our study differed from those reported with a DL or other types of VL. In our study, a high modified-Mallampati score, limited neck extension, RA, and head and neck cancer were not independently associated with DI when using an intermediate-angled VL. The Mallampati score reflects the ratio of tongue size to mouth space [13] that might block the direct line of sight to the vocal cord, and it does not have a significant effect on VLs compared to DLs. It seems that VLs are superior to DLs as they provide improved laryngeal views in cases of RA, limited neck extension, and high modified-Mallampati score [24]. Moreover, as the temporomandibular joint is rarely the

first joint to be affected by RA, the ULBT class and amount of mouth opening [25] seem to predict DI better than a history of RA alone. Furthermore, we excluded patients with severely altered head and neck pathologies as indications for awake intubation, which may explain the reduced impact of head and neck cancer on DI in our study.

Conversely, a short thyromental distance, limited mouth opening, and a ULBT class 3, which are well known to be associated with DI with use of a DL [26, 27], corresponded well with the use of a VL in this study. A ULBT class 3 suggests a decrease in temporomandibular joint function and prognathic ability [17, 26], and thyromental distance is an indicator of mandibular space [13], resulting in a small amount of room for upward disposition of the epiglottis. These factors result in a lack of room for vocal cord exposure, even with a VL. Additionally, a shorter thyromental distance implies anterior disposition of the larynx [17], making tube advancement more difficult. A previous study reported that a short thyromental distance is a predictor of intubation failure when using a GlideScope

Table 3 Univariable logistic regression analysis for prediction of difficult intubation in the training set (n = 565) comprising patients intubated using the UEScope

Parameter	Odds ratio (95% confidence interval)	P-value
Age (years)	1.014 (0.999, 1.030)	0.066
Sex	3.126 (1.908, 5.121)	<0.001
Height (cm)	1.036 (1.010, 1.062)	0.002
Weight (kg)	1.028 (1.011, 1.046)	0.001
BMI (kg/m ²)	1.079 (1.012, 1.151)	0.020
Co-medical history		
Rheumatoid arthritis	9.469 (0.850, 105.466)	0.068
Head and neck cancer	1.883 (0.976, 3.633)	0.059
Snoring	1.486 (0.960, 2.299)	0.076
Airway parameter		
Modified-Mallampati classification score ≥ 3	1.523 (0.987, 2.352)	0.058
Upper-lip-bite test class of 3 ^a	5.870 (1.755, 19.633)	0.004
Inter-incisor distance	0.642 (0.422, 0.978)	0.039
Thyromental distance	0.802 (0.641, 1.003)	0.053
Sterno-mental distance	0.990 (0.890, 1.100)	0.850
Neck circumference	1.149 (1.085, 1.216)	<0.001
Limited cervical spine mobility	0.812 (0.370, 1.780)	0.602
Micrognathia	2.322 (1.018, 5.295)	0.045
Loose tooth	1.582 (1.001, 2.500)	0.050
Protruded maxillary teeth	0.929 (0.200, 4.305)	0.925

BMI body mass index

^aUpper lip bite test class of 3: the lower incisors cannot bite the upper lip

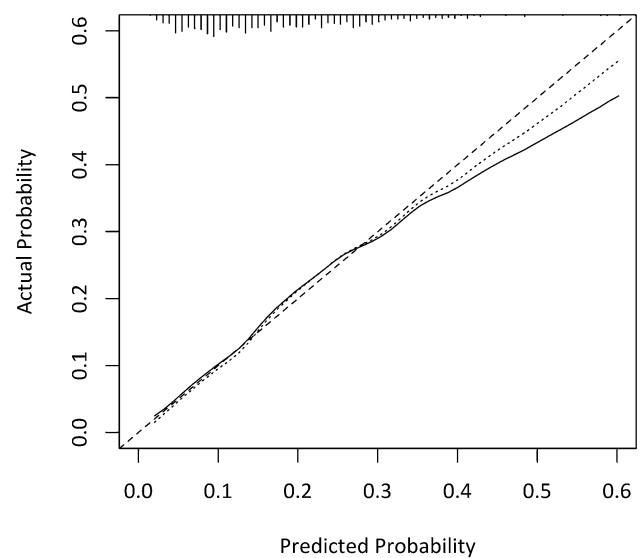
Table 4 Multivariable logistic regression analysis for prediction of difficult intubation in the training set (n = 565, consisting of 71% of the entire data set) comprising patients intubated using the UEScope

Parameter	Odds ratio (95% confidence interval)	P-value
Sex	3.864 (2.256, 6.619)	<0.001
BMI (kg/m ²)	1.082 (1.006, 1.164)	0.033
Upper-lip-bite test class of 3 ^a	5.774 (1.602, 20.807)	0.007
Inter-incisor distance	0.606 (0.386, 0.952)	0.030
Thyromental distance	0.687 (0.525, 0.901)	0.007

BMI body mass index

^aUpper lip bite test class of 3: the lower incisors cannot bite the upper lip

[28]. Traditionally, an inter-incisor distance of ≤ 3 cm suggests DI with use of a DL. VLs have reduced the minimum required mouth opening for intubation [17]. However, there are inconsistent reports on whether reduced inter-incisor distance is independently associated with DI with use of a VL [18, 20]. Different blade thicknesses for each VL may be the reason for contradictory results. Thin blades enable

**Fig. 3** Calibration plot of the model for the prediction of difficult intubation in the training set. In this plot, the comparison between predicted probabilities (x-axis) of difficult intubation derived from the final multivariable model and actual probabilities (y-axis) of difficult intubation in the training set are observed. The dotted and thin lines represent the apparent and bias-corrected curves, respectively, that predict the performance of the training set. A closer fit to the diagonal dashed line indicates a better prediction

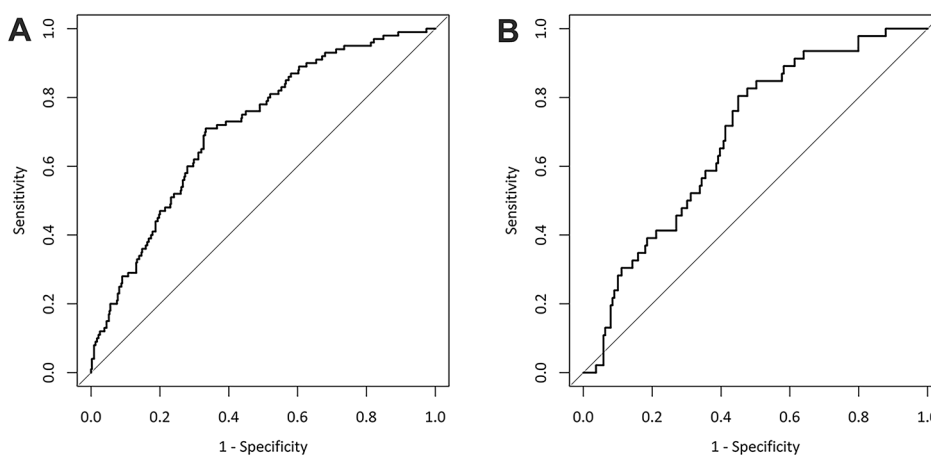
relatively easy introduction and manipulation in small oral cavities; thus, they are beneficial for patients with limited mouth openings [7].

It is controversial whether a higher BMI is an independent predictor of DI using a DL. However, several studies have shown that DI is more likely to occur in obese individuals [13, 29]. Increased weight is positively associated with excessive upper airway soft tissue volume [30], consequently reducing the room available for tube delivery. A DL flips the tongue to the left, widening the pathway for tube insertion. Despite the advantage of a better glottis view with an intermediate-angled VL compared to a DL, a blade placed on the midline of the tongue might result in less room for tube insertion [31], interfering with tube advancement. Interestingly, male sex was identified as a predictor of DI. Male sex has previously been reported as a predictor of difficult mask ventilation [32] and DI in studies using DLs [27] and airway scopes [33].

Intubation-related complications occurred in 1.5% of patients in our study, which is comparable or even superior to those in previous studies using an acute-angle [34] or Macintosh-type VL [35] in patients without difficult airways.

Our study has several limitations. First, it was conducted only using VL with intermediate-angled blade. Further studies comparing intermediate-angled VLs with VLs of different angles (Macintosh or more acute-angled types) is needed. Second, the explanatory power of individual

Fig. 4 Receiver operating characteristic curves of the model for the prediction of difficult intubation in both the training and validation data sets. The area under the curve of the prediction model for difficult intubation was 0.713 (95% confidence interval [CI] 0.660–0.766) in the training data set (left) and 0.686 (95% CI 0.608–0.763) in the test data set. The diagonal line indicates 50% discrimination and is provided to show how much each model improves on random assignment of risk



variables is low, and even when all these factors are considered, the AUROC curve for predicting DI was ~ 0.7 , implying low predictability. However, this result was similar to those of previous studies, which have shown that preoperative airway assessments using GlideScopes [28] have lower predictive values, as with DLs [36]. Nevertheless, considering that DI may lead to devastating complications [1], preoperative airway assessment is essential and must be performed for tracheal intubation. Third, the predictors of DI become less relevant, given the high ultimate success rate. However, considering the hazardous effect of multiple intubation attempts compared to a single attempt [37], predicting DI and creating optimal intubating conditions are required.

In our study, intermediate-angled VL showed a high success rate within 2 intubation attempts and a low complication rate in normal and difficult airway cases. Nevertheless, we recommend preparing a backup plan, such as that with an acute-angled VL, considering the increased difficulty in patients with certain preoperative airway assessment results.

Further evaluations are needed to compare the intubation times, success rates, incidence rates of a change to other devices, and complication rates between intermediate-angled VLs and VLs with blades of different angles.

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Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

Ethical approval The study protocol was approved by the institutional review board of Severance Hospital (IRB No. 1-2017-0035) on 5 July 2017. The study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

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

References

1. Cook TM, Woodall N, Frerk C, Fourth National Audit P. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1: anaesthesia. *Br J Anaesth.* 2011;106(5):617–31. <https://doi.org/10.1093/bja/aer058>.
2. Lewis SR, Butler AR, Parker J, Cook TM, Schofield-Robinson OJ, Smith AF. Videolaryngoscopy versus direct laryngoscopy for adult patients requiring tracheal intubation: a cochrane systematic review. *Br J Anaesth.* 2017;119(3):369–83. <https://doi.org/10.1093/bja/aex228>.
3. Zaouter C, Calderon J, Hemmerling TM. Videolaryngoscopy as a new standard of care. *Br J Anaesth.* 2015;114(2):181–3. <https://doi.org/10.1093/bja/aeu266>.
4. Xue FS, Yang BQ, Liu YY, Li HX, Yang GZ. Current evidences for the use of UEScope in airway management. *Chin Med J.* 2017;130(15):1867–75. <https://doi.org/10.4103/0366-6999.211536>.
5. van Zundert A, Pieters B, Doerges V, Gatt S. Videolaryngoscopy allows a better view of the pharynx and larynx than classic laryngoscopy. *Br J Anaesth.* 2012;109(6):1014–5. <https://doi.org/10.1093/bja/aes418>.
6. Cavus E, Kieckhaefer J, Doerges V, Moeller T, Thee C, Wagner K. The C-MAC videolaryngoscope: first experiences with a new device for videolaryngoscopy-guided intubation. *Anesth Analg.* 2010;110(2):473–7. <https://doi.org/10.1213/ANE.0b013e3181c5bce5>.
7. Kleine-Brueggeney M, Greif R, Schoettker P, Savoldelli GL, Nabecker S, Theiler LG. Evaluation of six videolaryngoscopes in 720 patients with a simulated difficult airway: a multicentre randomized controlled trial. *Br J Anaesth.* 2016;116(5):670–9. <https://doi.org/10.1093/bja/aew058>.

8. Downey AW, Duggan LV, Adam Law J. A systematic review of meta-analyses comparing direct laryngoscopy with videolaryngoscopy. *Can J Anaesth.* 2021;68(5):706–14. <https://doi.org/10.1007/s12630-021-01921-7>.
9. Sharma DMDDM. Is glidescope® the best way to intubate? *Anesthesiology.* 2010;113(1):258–9. <https://doi.org/10.1097/ALN.0b013e3181e0ef5c>.
10. Karalapillai D, Darvall J, Mandeville J, Ellard L, Graham J, Weinberg L. A review of video laryngoscopes relevant to the intensive care unit. *Indian J Crit Care Med.* 2014;18(7):442–52. <https://doi.org/10.4103/0972-5229.136073>.
11. Higgs A, McGrath BA, Goddard C, Rangasami J, Suntharalingam G, Gale R, Cook TM. Guidelines for the management of tracheal intubation in critically ill adults. *Br J Anaesth.* 2018;120(2):323–52. <https://doi.org/10.1016/j.bja.2017.10.021>.
12. Noppens RR, Geimer S, Eisel N, David M, Piepho T. Endotracheal intubation using the C-MAC(R) video laryngoscope or the macintosh laryngoscope: a prospective, comparative study in the ICU. *Crit Care.* 2012;16(3):R103. <https://doi.org/10.1186/cc11384>.
13. Shiga T, Wajima Z, Inoue T, Sakamoto A. Predicting difficult intubation in apparently normal patients: a meta-analysis of bedside screening test performance. *Anesthesiology.* 2005;103(2):429–37.
14. Szarpak L, Madziala A, Czekajlo M, Smereka J, Kaserer A, Dabrowski M, Madziala M, Yakubtsevich R, Ladny JR, Ruetzler K. Comparison of the UEScope videolaryngoscope with the macintosh laryngoscope during simulated cardiopulmonary resuscitation: a randomized, cross-over, multi-center manikin study. *Medicine.* 2018;97(36):e12085. <https://doi.org/10.1097/md.00000000000012085>.
15. Liu YY, Xue FS, Yang GZ, Li HX. Pediatric videolaryngoscopy. *Pediatr Crit Care Med.* 2017;18(8):820. <https://doi.org/10.1097/PCC.0000000000001216>.
16. UbtCo S, Parameters P, Apfelbaum JL, Hagberg CA, Caplan RA, Blitt CD, Connis RT, Nickinovich DG, Hagberg CA, Caplan RA, Benumof JL, Berry FA, Blitt CD, Bode RH, Cheney FW, Connis RT, Guidry OF, Nickinovich DG, Ovassapian A, Management TpuwdbtASoATFoDA. Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists task force on management of the difficult airway. *Anesthesiology.* 2013;118(2):251–70. <https://doi.org/10.1097/ALN.0b013e31827773b2>.
17. Crawley SM, Dalton AJ. Predicting the difficult airway. *BJA Education.* 2014;15(5):253–7. <https://doi.org/10.1093/bjaceaccp/mku047>.
18. Tremblay MH, Williams S, Robitaille A, Drolet P. Poor visualization during direct laryngoscopy and high upper lip bite test score are predictors of difficult intubation with the glidescope videolaryngoscope. *Anesth Analg.* 2008;106(5):1495–500. <https://doi.org/10.1213/ane.0b013e318168b38f>.
19. Frerk C, Mitchell VS, McNarry AF, Mendonca C, Bhagrath R, Patel A, O'Sullivan EP, Woodall NM, Ahmad I, Difficult Airway Society intubation guidelines working g. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. *Br J Anaesth.* 2015;115(6):827–48. <https://doi.org/10.1093/bja/aev371>.
20. Aziz MF, Bayman EO, Van Tienderen MM, Todd MM, St AGEIG, Brambrink AM. Predictors of difficult videolaryngoscopy with glidescope(R) or C-MAC(R) with D-blade: secondary analysis from a large comparative videolaryngoscopy trial. *Br J Anaesth.* 2016;117(1):118–23. <https://doi.org/10.1093/bja/aew128>.
21. Peduzzi P, Concato J, Kemper E, Holford TR, Feinstein AR. A simulation study of the number of events per variable in logistic regression analysis. *J Clin Epidemiol.* 1996;49(12):1373–9. [https://doi.org/10.1016/s0895-4356\(96\)00236-3](https://doi.org/10.1016/s0895-4356(96)00236-3).
22. Martin LD, Mhyre JM, Shanks AM, Tremper KK, Kheterpal S. 3423 emergency tracheal intubations at a university hospital: airway outcomes and complications. *Anesthesiology.* 2011;114(1):42–8. <https://doi.org/10.1097/ALN.0b013e318201c415>.
23. Cooper RM, Pacey JA, Bishop MJ, McCluskey SA. Early clinical experience with a new videolaryngoscope (GlideScope) in 728 patients. *Can J Anaesth.* 2005;52(2):191–8. <https://doi.org/10.1007/bf03027728>.
24. Stroumpoulis K, Pagoulatou A, Violari M, Ikonomou I, Kalantzi N, Kastrinaki K, Xanthos T, Michaloliakou C. Videolaryngoscopy in the management of the difficult airway: a comparison with the macintosh blade. *Eur J Anaesthesiol.* 2009;26(3):218–22. <https://doi.org/10.1097/EJA.0b013e3182831c84d1>.
25. Samanta R, Shoukrey K, Griffiths R. Rheumatoid arthritis and anaesthesia. *Anaesthesia.* 2011;66(12):1146–59. <https://doi.org/10.1111/j.1365-2044.2011.06890.x>.
26. Khan ZH, Mohammadi M, Rasouli MR, Farrokhnia F, Khan RH. The diagnostic value of the upper lip bite test combined with sternal distance, thyromental distance, and interincisor distance for prediction of easy laryngoscopy and intubation: a prospective study. *Anesth Analg.* 2009;109(3):822–4. <https://doi.org/10.1213/ane.0b013e3181af7f0d>.
27. Wang B, Zheng C, Yao W, Guo L, Peng H, Yang F, Wang M, Jin X. Predictors of difficult airway in a Chinese surgical population: the gender effect. *Minerva Anesthesiol.* 2019;85(5):478–86. <https://doi.org/10.23736/s0375-9393.18.12605-8>.
28. Aziz MF, Healy D, Kheterpal S, Fu RF, Dillman D, Brambrink AM. Routine clinical practice effectiveness of the glidescope in difficult airway management: an analysis of 2004 glidescope intubations, complications, and failures from two institutions. *Anesthesiology.* 2011;114(1):34–41. <https://doi.org/10.1097/ALN.0b013e3182023eb7>.
29. Rose DK, Cohen MM. The airway: problems and predictions in 18,500 patients. *Can J Anaesth.* 1994;41(5 Pt 1):372–83. <https://doi.org/10.1007/bf03009858>.
30. Ferguson KA, Ono T, Lowe AA, Ryan CF, Fleetham JA. The relationship between obesity and craniofacial structure in obstructive sleep apnea. *Chest.* 1995;108(2):375–81. <https://doi.org/10.1378/chest.108.2.375>.
31. van Zundert A, Maassen R, Lee R, Willems R, Timmerman M, Siemonsma M, Buise M, Wiepking M. A macintosh laryngoscope blade for videolaryngoscopy reduces stylet use in patients with normal airways. *Anesth Analg.* 2009;109(3):825–31. <https://doi.org/10.1213/ane.0b013e3181ae39db>.
32. Riad W, Vaez MN, Raveendran R, Tam AD, Quereshy FA, Chung F, Wong DT. Neck circumference as a predictor of difficult intubation and difficult mask ventilation in morbidly obese patients: a prospective observational study. *Eur J Anaesthesiol.* 2016;33(4):244–9. <https://doi.org/10.1097/eja.00000000000000324>.
33. Ono K, Goto T, Nakai D, Ueki S, Takenaka S, Moriya T. Incidence and predictors of difficult nasotracheal intubation with airway scope. *J Anesth.* 2014;28(5):650–4. <https://doi.org/10.1007/s00540-013-1778-2>.
34. Teoh WH, Shah MK, Sia AT. Randomised comparison of pentax airwayscope and glidescope for tracheal intubation in patients with normal airway anatomy. *Anaesthesia.* 2009;64(10):1125–9. <https://doi.org/10.1111/j.1365-2044.2009.06032.x>.
35. Teoh WH, Saxena S, Shah MK, Sia AT. Comparison of three videolaryngoscopes: pentax airway scope, C-MAC, glidescope vs the macintosh laryngoscope for tracheal intubation. *Anaesthesia.* 2010;65(11):1126–32. <https://doi.org/10.1111/j.1365-2044.2010.06513.x>.
36. Eberhart LH, Arndt C, Cierpka T, Schwaneckamp J, Wulf H, Putzke C. The reliability and validity of the upper lip bite test

compared with the mallampati classification to predict difficult laryngoscopy: an external prospective evaluation. *Anesth Analg.* 2005;101(1):284–9. <https://doi.org/10.1213/01.Ane.0000154535.33429.36>.

37. Sakles JC, Chiu S, Mosier J, Walker C, Stolz U. The importance of first pass success when performing orotracheal intubation in the emergency department. *Acad Emerg Med.* 2013;20(1):71–8. <https://doi.org/10.1111/acem.12055>.

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