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REPORTS OF ORIGINAL INVESTIGATIONS

Laryngoscope manipulation by experienced *versus* novice laryngoscopists

Manipulation du laryngoscope, comparaison entre novices et laryngoscopistes expérimentés

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Abstract

Purpose *During endotracheal intubation using a Macintosh laryngoscope blade, it has been recommended by some that the best laryngeal view is achieved with a laryngoscope handle angle of 45° from horizontal; however, this may be unnecessary. Novices are rarely taught specifically how or where to grip the laryngoscope handle. This study compared the angle and grip of the laryngoscope handle by experienced vs novice laryngoscopists to determine whether basic differences could be identified that might aid in teaching the nuances of skillful laryngoscope manipulation.*

Methods *Laryngoscopists were photographed performing tracheal intubation for elective surgical patients (22 experienced laryngoscopists) and an airway trainer mannequin (22 experienced and 21 novice layngoscopists). The photographs were analyzed for laryngoscope handle angle from horizontal, eye-scope distance, and eye-scope angle. Airway trainer photographs were also assessed for hand rotational angle and distance from the laryngoscope base.*

Results *The average laryngoscope handle angle for patient tracheal intubations was 23.7° (95% confidence interval [CI]: 21.1 to 26.2), significantly less than 45° ($P < 0.001$). Compared with novices, experts gripped the laryngoscope handle closer to the hinge at rest and at best laryngeal view ($P = 0.001$ and $P = 0.003$, respectively), held the laryngoscope in their fingers vs the palm of their hand ($P = 0.005$), and used greater eye-scope distances ($P = 0.005$) for airway trainer intubations. Expert technique was unchanged with patient vs airway trainer laryngoscopy.*

Conclusion *Experienced laryngoscopists used laryngoscope handle angles less than 45° from horizontal for routine intubations. Compared with novices, experts gripped the laryngoscope closer to the hinge and held the laryngoscope more in their fingers vs the palm of their hand. Sharing these important points with novices early in their instruction may improve technique and skill acquisition.*

Author contributions *Jorge E. Zamora* was involved in the study conception and design and manuscript preparation. *Bryan J. Weber* and *Annie R. Langley* recruited participants. *Jorge E. Zamora, Bryan J. Weber,* and *Annie R. Langley* collected data. *Andrew G. Day* was involved in data analysis. *Andrew G. Day* and *Jorge E. Zamora* were involved in data interpretation. *Jorge E. Zamora, Bryan J. Weber, Annie R. Langley,* and *Andrew G. Day* were involved in manuscript revision.

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Résumé

Objectif *Au cours de l'intubation endotrachéale à l'aide d'un laryngoscope doté d'une lame Macintosh, certains ont recommandé de maintenir le manche à un angle de 45° par rapport à l'horizontale pour obtenir la meilleure vue laryngée; toutefois, cela n'est peut-être pas nécessaire. Il est rare d'enseigner aux novices spécifiquement où et*

comment tenir le manche du laryngoscope. Cette étude a comparé l'angle et la prise du manche du laryngoscope par des novices et des laryngoscopistes expérimentés pour déterminer si des différences fondamentales pouvaient être identifiées qui aideraient potentiellement au raffinement de l'habileté de la manipulation du laryngoscope.

Méthodes *Des laryngoscopistes ont été photographiés en train de réaliser une intubation trachéale chez des patients subissant une chirurgie programmée (22 laryngoscopistes expérimentés) et sur un mannequin pour la formation à l'intubation des voies respiratoires (22 laryngoscopistes expérimentés et 21 laryngoscopistes débutants). L'angle formé entre le manche du laryngoscope et l'horizontale, la distance et l'angle œil-laryngoscope ont été analysés sur les photographies. L'angle de rotation de la main et sa distance par rapport à la base du laryngoscope ont également été évalués sur les photographies de formation à l'intubation.*

Résultats *L'angle moyen du manche du laryngoscope pour les intubations trachéales des patients était de 23,7° (intervalle de confiance [IC] à 95 % : 21,1 à 26,2), significativement inférieur à 45° ($P < 0{,}001$). Comparativement aux novices, les experts ont empoigné le manche du laryngoscope plus près de sa charnière au repos et pour la meilleure vue laryngée (respectivement, $P = 0{,}001$ et $P = 0{,}003$), ont tenu le laryngoscope entre leurs doigts plutôt que dans leur paume ($P = 0{,}005$), et utilisaient des distances œil-laryngoscope plus importantes ($P = 0{,}005$) pour les intubations sur le mannequin de formation. La technique des experts était la même pour la laryngoscopie sur patient et sur mannequin de formation.*

Conclusion *Des laryngoscopistes expérimentés ont utilisés des angles de manche du laryngoscope inférieurs à 45° par rapport à l'horizontale pour les intubations de routine. Comparativement aux novices, les experts tenaient le laryngoscope plus près de la charnière et davantage entre les doigts qu'avec la paume de la main. La transmission de ces éléments importants à des débutants au cours de leur formation pourrait potentiellement améliorer l'acquisition de la technique et de l'habileté.*

Endotracheal intubation using direct laryngoscopy is a complex skill that requires extensive training and practice. Almost fifty intubation attempts in the clinical setting are required to achieve a 90% probability of successful intubation.[1] With the exception of anesthesia trainees, novices usually have access to a limited number of clinical encounters during which they can refine and reinforce their newly acquired skills in an elective controlled setting.[2]

Patient safety issues and time constraints often prevent novices from testing and exploring different laryngoscope manipulation techniques. Proper insertion and lifting of the laryngoscope have been identified as crucial for the competent performance of laryngoscopic tracheal intubation. Few recommendations exist regarding fundamental aspects of laryngoscope handling.[3] To achieve best laryngeal view when using a Macintosh laryngoscope blade, novices are often taught to lift the laryngoscope at an angle of 45° from horizontal in the direction of the laryngoscope handle.[2-6] This can sometimes be interpreted as a laryngoscope handle angle of 45° from horizontal being optimal for achieving best laryngeal view. In addition, novices are often not taught specifically how or where to grip the laryngoscope handle other than being instructed to grip the laryngoscope in their left hand.[3-5]

This study was designed to examine two easily taught elements of laryngoscope manipulation: 1) laryngoscope handle angle from horizontal for best laryngeal view during routine intubation and 2) laryngoscope grip. Our primary hypothesis is that the laryngoscope handle angle from horizontal used by experienced laryngoscopists to achieve best laryngeal view during routine intubation is significantly less than 45° when using a Macintosh laryngoscope blade. Our secondary hypothesis is that the laryngoscope grip used by experienced laryngoscopists differs from that used by novices.

Methods

Study population

Following Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board approval (Reference ANAE-131-07, 08 January 2007) and signed informed consent, experienced and novice laryngoscopists were recruited from Kingston General Hospital (KGH) and Queen's University School of Medicine from May 2007 to September 2007. KGH is a 450-bed full-service tertiary care teaching hospital affiliated with Queen's University. All laryngoscopists were blinded to the study parameters. Patients presenting to KGH for elective surgery requiring endotracheal intubation were recruited for the "Patient Setting" phase of the study. Patients provided informed written consent and release for photographic materials. All postgraduate year level four or higher resident anesthesiologists or any attending anesthesiologist were eligible for study participation as experienced laryngoscopists (n = 22). Medical students beginning core anesthesia rotations at the time of data

collection were eligible for study participation as novice laryngoscopists (n = 21). Students were recruited at the beginning of their anesthesia rotations and were excluded if they had any previous tracheal intubation experience in patients. Prior to beginning their anesthesia rotations and immediately prior to participation in this study, all students participated in a training session that included a didactic and mannequin-based hands-on session on laryngoscopy and intubation. All laryngoscopies were performed with Macintosh laryngoscope blades (Penlon, Abingdon, UK). Laryngoscopists were instructed to adjust the operating table to their preferred height and to make no modifications to their laryngoscopy technique.

Patient setting

Each experienced laryngoscopist was photographed during direct laryngoscopy and tracheal intubation of elective surgical patients. All photographs were taken in a standardized manner using a digital single-lens reflex camera and zoom lens with focal length of 18 mm (Nikon D70 camera and 18-200 mm lens, Nikon Corp., Tokyo, Japan). The camera was supported on a tripod and positioned 1.2 m to the left of the operating table. The camera, tripod head with dual axis levelling bubbles (Manfrotto model 808RC4, Bassano del Grappo, Italy), and operating table were all levelled to horizontal prior to patient entry into the operating room (OR). Photographs were taken during endotracheal tube insertion at best view of the vocal cords.

Photographs were excluded from analysis if the airway intervention met the following criteria for non-routine laryngoscopy or intubation: modified Cormack & Lehane[7] laryngoscopy grades of 2B or greater, the use of laryngoscope blades other than Macintosh size 3 or 4, the use of two or more airway adjuncts (laryngeal manipulation, malleable stylet, or gum elastic bougie) or any indirect laryngoscopy technique, the use of operating table angles other than horizontal, or failed intubation. Data collection continued until each experienced laryngoscopist was photographed during five routine intubations.

Airway trainer setting

Due to ethical concerns and practical limitations, laryngoscope grip was assessed among experienced and novice laryngoscopists at rest and during direct laryngoscopy of a Laerdal® Airway Management Trainer (Laerdal Medical Corp., Wappingers Falls, NY, USA). A standardized sniffing position was obtained by positioning the airway mannequin on an OR table with its occiput on a 5-cm headrest (Emergo, The Hague, Netherlands). Laryngoscopists were photographed from the right and left side of the operating table with the camera positioned as previously described. Laryngoscopists were also photographed from the foot of the operating table with a view directed at the bottom of the laryngoscope handle in order to assess laryngoscope grip. Photographs were taken at rest and at best view of the mannequin vocal cords.

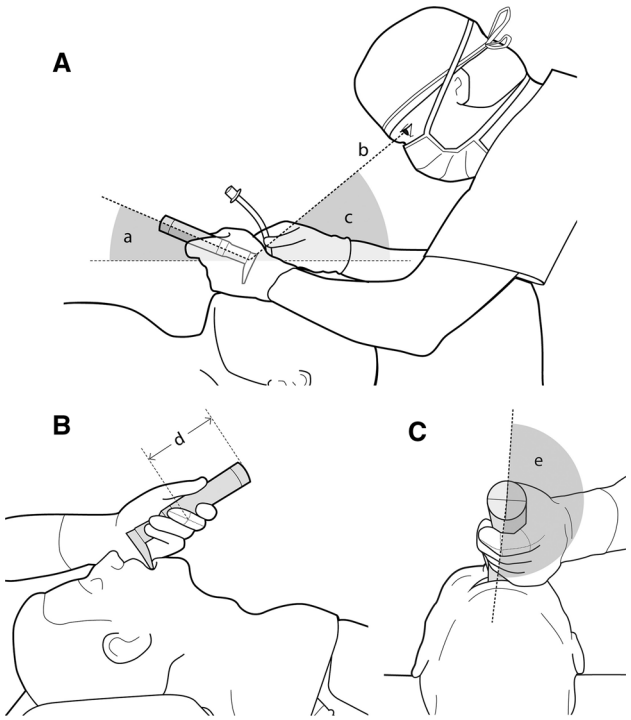

Fig. 1 A (*top center*): Reference points used for the measurement of laryngoscope handle angle (a), eye-scope distance (b), and eye-scope angle (c) B (*bottom left*): Reference points used for the measurement of middle finger distal interphalangeal (DIP) to scope base distance (d) C (*bottom right*): Reference points used for the measurement of the index finger distal interphalangeal (DIP) angle (e) (Figure courtesy of Jenna Rebelo)

Laryngoscopy assessment

Photographs were analyzed using Adobe Photoshop (Adobe Systems Inc., San Jose, CA, USA) software. Photographs from the patient and airway trainer settings were analyzed (B.J.W. and A.R.L. – not blinded to laryngoscopist level of experience) for laryngoscope handle angle (measured as the angle of the laryngoscope handle relative to horizontal), eye-scope distance (measured as the distance from the laryngoscopist's eye to the laryngoscope handle tip), and the eye-scope angle (measured as the angle formed between the eye-scope distance line and the horizontal plane) (Fig. 1A).

Photographs from the airway trainer setting were also assessed for measurements of laryngoscope grip. To facilitate assessment of laryngoscope grip, laryngoscopists wore a fitted surgical glove on their left hand with markings

on the distal interphalangeal (DIP) joints of the index and middle fingers. Hand position along the laryngoscope handle was measured as the distance from the base of the laryngoscope handle to the laryngoscopist's middle finger DIP joint (Fig. 1B).

To facilitate measurement of rotational hand position, the laryngoscope base was labelled with markings at 3, 6, 9, and 12 o'clock. The intersection of a line drawn from the 12 to 6 o'clock marking and a second line drawn from the 3 to 9 o'clock marking indicated the centre of the laryngoscope base and served as the vertex for angle measurement. A line from the 12 o'clock mark to the vertex served as the zero degree reference line. Using photographs taken from the foot of the operating table directed down the long axis of the laryngoscope blade, the angle of the laryngoscopist's index finger DIP joint relative to the zero degree reference indicated rotational hand position on the laryngoscope handle (Fig. 1C).

Statistical analysis

A priori, we considered a difference of 10° from a laryngoscope handle angle of 45° to be minimally clinically important, and we conservatively assumed that the between laryngoscopist standard deviation would be no more than 13°. The study was designed under these assumptions, which required data from 20 experienced laryngoscopists to achieve 90% power to test the primary study hypothesis at a two-sided alpha = 0.05.

Since, in the patient setting, multiple intubations were measured for each experienced laryngoscopist, we used a random effects model with laryngoscopist as the random effect to estimate the overall mean and variance measures (handle angle, eye-scope distance, and eye-scope angle) with correct confidence intervals and to test if the mean handle angle was significantly different from 45°. The random effects model partitioned the total variance into between and within laryngoscopist variance components, which allowed us to estimate the intraclass correlation coefficient (ICC), defined as the between laryngoscopist variance divided by the total (between+within) variance. We used a likelihood ratio test to assess if the ICC was greater than zero, which would indicate that true heterogeneity existed between laryngoscopists.

Pearson's correlation coefficients were calculated to assess linear associations among laryngoscopy measures and to assess correlations between these measures and patient-related variables (height, weight, and body mass index [BMI]). Since there were multiple measures per laryngoscopist, we present both between and within laryngoscopists correlation. Between laryngoscopists correlation is the correlation of each laryngoscopist's average values.[8] Within laryngoscopist correlation is the partial correlation obtained by correlating the values after correcting for the laryngoscopist specific averages.[9] Between subject correlation measures if subjects with high average X tend to have high (or low) average Y, while within subject correlation measures if high X values for a subject tend to be associated with high (or low) Y values for that subject.

Fisher's exact test was used to determine if the following criteria differed significantly amongst laryngoscopists: frequency of the modified Cormack & Lehane[7] laryngoscopy grade observed during intubation (1 *vs* 2A), Macintosh laryngoscope blade size used (3 *vs* 4), and the use of cricoid pressure or intubation adjuncts (laryngeal manipulation, malleable stylet, gum elastic bougie). Blade size and intubation adjunct used were also assessed for their influence on the laryngoscopy measures by using a linear mixed-effects model with these variables as fixed effects and the laryngoscopist as a random effect.

For the airway trainer setting, differences between experienced and novice laryngoscopists were assessed for each measure by the independent Student's *t* test. Welch's *t* test was used when variances were significantly different between groups according to the folded F-test ($P < 0.1$).

The measures of experienced laryngoscopists in the patient and airway trainer settings were compared using the linear mixed-effects model with laryngoscopist as a random effect and setting as a fixed effect. The mixed effects modelling was estimated by restricted maximum likelihood using the MIXED procedure of SAS/STAT® version 9.2 (Copyright© 2008 by SAS Institute Inc., Cary, NC, USA).[10,11] All reported *P* values are two sided without correction for multiplicity.

Results

Patient setting

One hundred sixty-five patients provided release and consent for photographic materials. Due to overlapping surgical start times, data were collected from one hundred twenty-eight intubations. Twenty intubations were not analyzed because they met exclusion criteria. One hundred eight intubations were analyzed from 22 experienced laryngoscopists, 17 attending anesthesiologists (average of 17 years' experience), and five resident anesthesiologists (average of 4.6 years' experience). Five photographs were analyzed for each laryngoscopist, except for one laryngoscopist who was photographed only three times due to scheduling errors. Figure 2 displays the observed measures and raw averages of the laryngoscope handle angle for each laryngoscopist. Table 1 summarizes the averages and variances across the 22 laryngoscopists. The

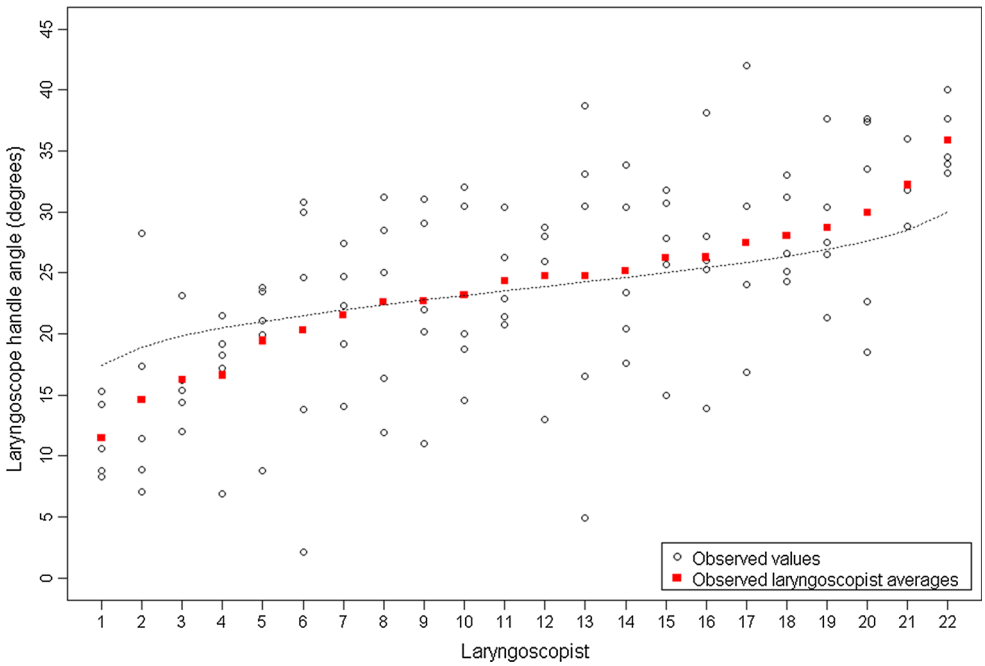

Fig. 2 The observed measures of the laryngoscope handle angle for each experienced laryngoscopist in the patient setting arranged in increasing magnitude of average laryngoscope handle angle. For each laryngoscopist, the average is superimposed as a square. The dotted line is the expected range of observed average laryngoscope handle angle in the absence of laryngoscopist heterogeneity

Table 1 Patient setting measurements

Measurement	Overall average (95% CI)*	Between laryngoscopist variance† (SD)*	Within laryngoscopist variance† (SD)*	ICC
Laryngoscope handle angle (degrees)	23.7 (21.1 to 26.2)	21.9 (4.7)	55.1 (7.4)	0.28
Eye-scope angle (degrees)	45.6 (42.7 to 48.4)	34.1 (5.8)	39.6 (6.3)	0.46
Eye-scope distance (cm)	29.7 (26.9 to 32.4)	34.7 (5.9)	20.8 (4.6)	0.63

* Based on linear mixed-effect model with laryngoscopist as a random effect to account for the repeated measures per laryngoscopist

† Unit of measure for variance is the original unit of measure squared

CI = confidence interval of mean

SD = standard deviation is the square root of the variance component. Unit of measure for SD is the original unit of measure

ICC = intraclass correlation coefficient is the between laryngoscopist variance divided by the total (between+within) laryngoscopist variance. For all outcomes, the ICC is significantly greater than zero (all $P < 0.001$), indicating there is significant heterogeneity between laryngoscopists

estimated overall average laryngoscope handle angle of 23.7° (95% confidence interval [CI] 21.1 to 26.2) is significantly lower than 45° ($P < 0.001$). The handle angle was less than 45° in all 108 intubations (range 2.1-42.0°). The total variance in handle angle was 77.0 (between laryngoscopist variance = 21.9 + within laryngoscopist variance = 55.1). Of the total variance, 28% (ICC = 0.28) was attributable to between laryngoscopist variance, which represented a statistically significant degree of heterogeneity ($P < 0.001$). Between laryngoscopist heterogeneity was even greater for eye-scope angle (ICC = 0.46) and eye-scope distance (ICC = 0.63).

By correlating the 22 laryngoscopists' averages to examine between laryngoscopist correlation, we found that laryngoscopists with larger average handle angles had smaller average eye-scope angles (r = -0.78; $P < 0.001$). Within laryngoscopist correlation revealed that intubations where the laryngoscopist used a larger than usual handle angle were correlated with smaller than usual eye-scope angles (partial r = -0.53; $P < 0.001$). However, there was not a significant within laryngoscopist correlation between handle angle and eye-scope distances (partial r = -0.10; $P = 0.34$).

Patient height correlated with both laryngoscope handle angle (partial r = 0.30; $P = 0.005$) and eye-scope angle (partial r = -0.31; $P = 0.003$). Patient weight correlated only with laryngoscope handle angle (partial r = 0.31; $P = 0.004$), and BMI was not significantly correlated with either measure.

A significant differential use of Macintosh laryngoscope blade size (3 *vs* 4) and other intubation adjuncts (laryngeal manipulation, malleable stylet, or gum elastic bougie) was observed across laryngoscopists according to the Fisher's

Table 2 Airway trainer setting measurements

Measurement	At rest or Best view	Experienced mean (SD)	Novice mean (SD)	Experienced-Novice mean (95% CI)	Means *P* value (Student's *t* test)*	Variance *P* value(F-test)†
Laryngoscope manipulation and body posture						
Laryngoscope handle angle (degrees)	Best view	26.3 (4.9)	31.0 (9.3)	−4.6 (−9.2 to 0.1)	0.052	0.005
Eye-scope angle (degrees)	Best view	44.9 (6.6)	40.3 (13.1)	4.7 (−1.7 to 11.0)	0.152	0.003
Eye-scope distance (cm)	Best view	32.2 (8.1)	24.3 (9.2)	7.9 (2.5 to 13.2)	0.005	0.564
Laryngoscope grip						
Middle finger DIP to scope base distance (cm)	At rest	8.8 (2.4)	6.4 (2.1)	2.4 (1.0 to 3.8)	0.001	0.649
	Best view	8.3 (2.2)	6.4 (2.1)	1.9 (0.7 to 3.1)	0.003	0.333
Index finger DIP angle (degrees)	At rest	176.6 (29.6)	202.3 (27.4)	−25.7 (−43.3 to −8.1)	0.005	0.728
	Best view	176.2 (29.6)	194.3 (36.1)	−18.1 (−36.8 to 0.6)	0.061‡	0.058

* Comparison of means by independent Student's *t* test; Welch's *t* test for unequal variance reported when folded F-test $P < 0.1$

† Comparison of variance by folded F-test

‡ The difference in the DIP index angle at best view becomes statistically significant if the single outlying laryngoscopist value angle of 265° is removed ($P = 0.013$)

CI = confidence interval; DIP = distal interphalangeal; SD = standard deviation

exact test ($P = 0.003$ and $P < 0.001$, respectively). The use of cricoid pressure and best laryngeal view obtained did not differ significantly between laryngoscopists (both $P > 0.05$). In both unadjusted and adjusted multivariable analysis, none of these variables were found to be associated with laryngoscope handle angle.

Airway trainer setting

Table 2 and Fig. 2 present measures taken from 22 experienced and 21 novice laryngoscopists in the airway trainer setting. Experienced laryngoscopists used a greater mean eye-scope distance ($P = 0.005$) (Fig. 4A). They also demonstrated less variance in laryngoscope handle angle ($P = 0.005$) and eye-scope angle ($P = 0.003$) during laryngoscopy.

Experts used a greater mean distance between their middle finger DIP and the base of the laryngoscope both at rest ($P = 0.001$) and at best laryngeal view ($P = 0.003$) (Fig. 4B), indicating a tendency to grip the laryngoscope handle closer to the hinge. They also used a lower mean angle between their index finger DIP and the 12 o'clock marking on the base of the laryngoscope handle at rest ($P = 0.005$) (Fig. 4C). This shows a tendency for experts to grip the laryngoscope handle in their fingers rather than in the palm of their hand, as demonstrated in Fig. 3.

Setting comparison

For experienced laryngoscopists, the mean laryngoscope handle angle (23.7° *vs* 26.3°; $P = 0.11$), eye-scope angle (45.5° *vs* 44.9°; $P = 0.68$), and eye-scope distance (29.7 cm *vs* 32.2 cm; $P = 0.051$) did not vary significantly between the patient and airway trainer settings.

Discussion

Our study demonstrates that the mean laryngoscope handle angle of experienced laryngoscopists using a Macintosh laryngoscope blade is significantly lower than 45° in patients with Cormack & Lehane grade 1 or 2A views.

Large laryngoscope handle angles may render novices more prone to lever the laryngoscope. Levering the laryngoscope has been associated with increased patient complications such as damage to teeth.[12,13] The Laerdal Airway Management Trainer provides audible feedback when excessive pressure is exerted on the upper teeth by the laryngoscope blade. Experience with this mannequin both prior to and during this study might explain why novices also used laryngoscope handle angles less than 45°. Large laryngoscope handle angles may also make intubation more difficult by altering the sight lines between the laryngoscopist's eye and the patient's glottis.[14] Conversely, an excessively low laryngoscope handle angle might also lead to difficulty visualizing the larynx due to a sight line directed towards the posterior pharynx instead of the glottis.

Our results differ slightly from those of Walker and Horton *et al.* who found that experienced laryngoscopists use a laryngoscope handle angle of 30-35° when intubating airway training mannequins or patients.[14,15] This difference could be due to several factors, including differences in measurement criteria, differences in patient or mannequin positioning, the degree of head extension at best laryngeal view, patient exclusion criteria, or the use of intubation adjuncts.

The average laryngoscope handle angles used by experts did not vary significantly between the patient and airway trainer settings. Although greater initial force may be

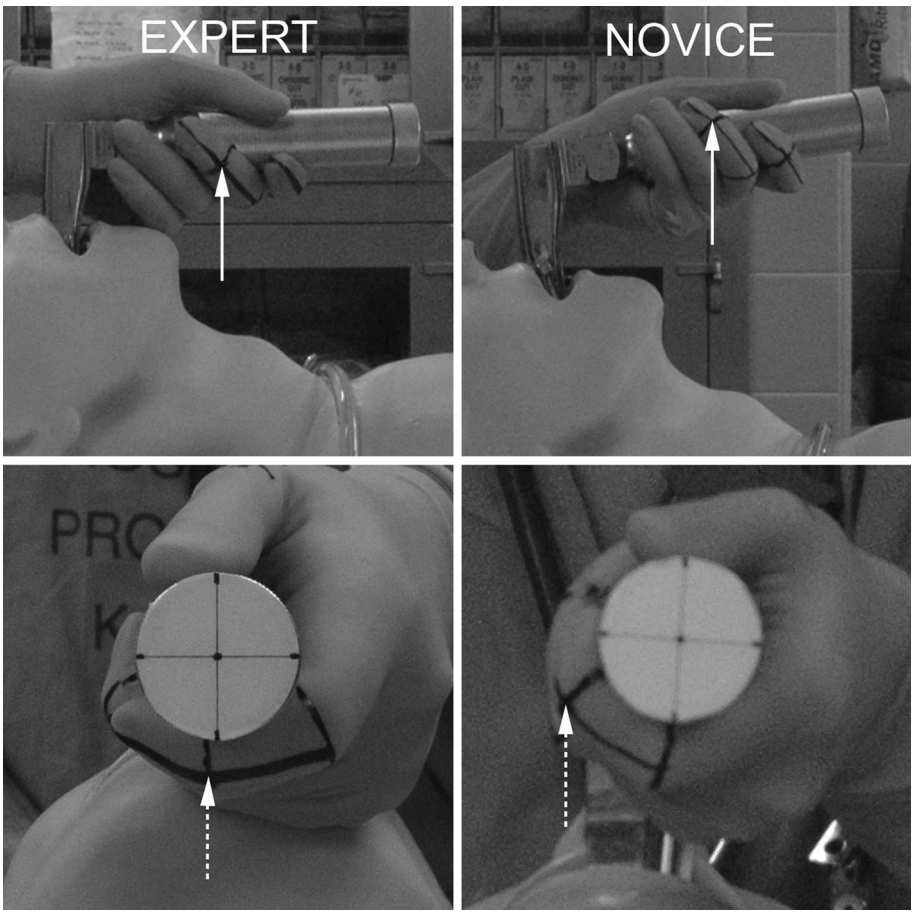

Fig. 3 Photographs of representative study participants showing typical laryngoscope grip at rest seen in an experienced (left) and a novice (right) laryngoscopist. Upper photographs show measurement points (solid arrow) for middle finger distal interphalangeal (DIP) to scope base distance. Lower photographs show measurement points (dashed arrow) for index finger DIP angle

required to displace the plastic of the airway trainer when compared with a patient,[16] our results suggest that laryngoscope handle angle does not require adjustment when using the Laerdal Airway Management Trainer. Multivariate analysis also suggests that the use of intubation adjuncts did not significantly affect laryngoscope handle angle in the patient setting.

We suspect that the observed "within laryngoscopist" variances (Table 1) may be largely due to differences in patient characteristics encountered by each laryngoscopist during their five recorded intubation attempts. The "between laryngoscopists" variance and heterogeneity are most likely due to inherent differences in individual laryngoscopist's intubation technique. Despite these variances, all recorded laryngoscope handle angles were less than 45°.

In the airway trainer setting, smaller eye-scope distances ($P = 0.005$) were observed with novices. Our observations are consistent with previous reports demonstrating that novices stood closer to the airway mannequin[14] and adopted a more crouched body position during laryngoscopy.[17]

Experts grip the laryngoscope closer to the hinge and grip with their fingers rather than the palm of the hand. The grip used by experts has been referred to as a "pincer grip" or "blade grip" by some authors.[17,18] This grip has been associated with less force applied during intubation, may discourage levering the laryngoscope blade on the upper teeth, and may allow for more precise manipulation of the laryngoscope. This grip might also result in fewer awkward wrist and forearm postures during laryngoscopy.[19] The failed intubations in the study by Waddington *et al*. were observed in novices who did not use a pincer-style grip.[18]

We suspect these differences in laryngoscope grip can be partially explained by novices assuming that the standard laryngoscope handle is designed to be gripped forcefully along the majority of its length. Prior experience using an airway trainer might reinforce this assumption due to the greater initial force required to displace the plastic of the mannequin. With sufficient experience with tracheal intubation in patients, laryngoscopists eventually learn to modify their grip to one where optimal laryngeal view is obtained by adjusting the position of the laryngoscope blade using fine movements of the wrist and fingers.

Several studies have investigated posture, force and torque,[16,18] and position of the laryngoscope blade tip[20] during direct laryngoscopy. We extended previous findings by obtaining objective and reproducible measurements of

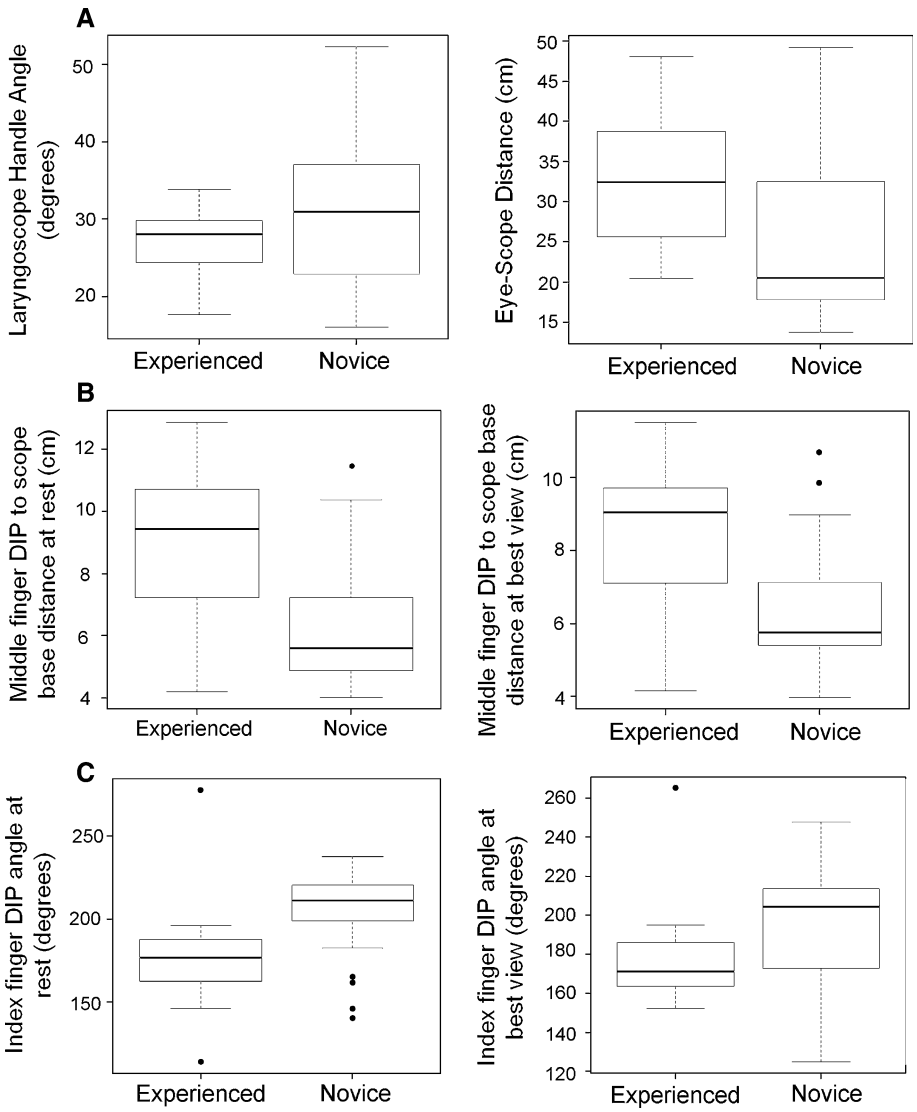

Fig. 4 Boxplots showing measures from experienced and novice laryngoscopists in the airway trainer setting. A) Laryngoscope handle angle from horizontal and eye-scope distance at best view. B) Middle finger distal interphalangeal (DIP) to scope base distance at rest and at best laryngeal view. C) Index finger DIP angle at rest and at best laryngeal view. The box represents the interquartile (middle 50%) of the data. The bold line in the box depicts the median. The outer bars represent the range of the data up to 1.5 times the width of interquartile range beyond the box (i.e., beyond the 1st or 3rd quartiles). Values beyond this range are often considered outliers and are depicted by isolated dots

laryngoscope handle angle from horizontal and laryngoscope grip. Intraclass correlation coefficients (and 95% CI) between two raters for our methods of measurement of laryngoscope handle angle, middle finger DIP to scope base distance, and index finger DIP angle were 0.990 (95% CI 0.973 to 0.997), 0.939 (95% CI 0.86 to 0.974), and 0.998 (95% CI 0.995 to 0.999), respectively.

The current investigation is not without limitations. Due to the variables being measured, it was impossible to blind those analyzing the photographs to the laryngoscopist level of experience. Despite attempts to standardize camera position during data acquisition, differences between the plane of the photograph and the alignment of the laryngoscope, the alignment of the patient on the OR table, or the position of the camera relative to the laryngoscope, may have introduced sources of measurement error. Eye-scope distance was recorded as an indicator of laryngoscopist posture; however, not unlike several other studies comparing laryngoscope manipulation and posture during laryngoscopy in novices *vs* experts, laryngoscopist height and position relative to the operating table was not recorded.[14,15,17,21] The airway trainer phase of the study was designed to detect whether novices and experts used different laryngoscope grips regardless of intubation success rate; therefore, as with other studies, success rate was not recorded during this phase of the study. [14,17]

Intubation using direct laryngoscopy is still the standard method used for establishing a secure airway. Despite success with airway trainer mannequins, many novices still experience difficulty performing tracheal intubation in patients. The current investigation suggests that novices should be informed that experts use a laryngoscope handle angle of roughly 25° from horizontal during routine laryngoscopies with a Macintosh laryngoscope blade. Current recommendations to lift the laryngoscope at a

45° angle from horizontal may need to be re-examined or clarified. Novices should also be taught to grip the laryngoscope handle closer to the hinge with their fingers as opposed to the palm of the hand. Historically, these subtleties in technique would be acquired in an *ad hoc* manner or possibly never learned at all. Further investigation will determine if teaching appropriate laryngoscope handle angle from horizontal and optimal laryngoscope grip will result in increased success during direct laryngoscopy.

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