

Video Laryngoscopy vs Direct Laryngoscopy on Successful First-Pass Orotracheal Intubation Among ICU Patients

A Randomized Clinical Trial

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IMPORTANCE In the intensive care unit (ICU), orotracheal intubation can be associated with increased risk of complications because the patient may be acutely unstable, requiring prompt intervention, often by a practitioner with nonexpert skills. Video laryngoscopy may decrease this risk by improving glottis visualization.

OBJECTIVE To determine whether video laryngoscopy increases the frequency of successful first-pass orotracheal intubation compared with direct laryngoscopy in ICU patients.

DESIGN, SETTING, AND PARTICIPANTS Randomized clinical trial of 371 adults requiring intubation while being treated at 7 ICUs in France between May 2015 and January 2016; there was 28 days of follow-up.

INTERVENTIONS Intubation using a video laryngoscope (n = 186) or direct laryngoscopy (n = 185). All patients received general anesthesia.





MAIN OUTCOMES AND MEASURES The primary outcome was the proportion of patients with successful first-pass intubation. The secondary outcomes included time to successful intubation and mild to moderate and severe life-threatening complications.

RESULTS Among 371 randomized patients (mean [SD] age, 62.8 [15.8] years; 136 [36.7%] women), 371 completed the trial. The proportion of patients with successful first-pass intubation did not differ significantly between the video laryngoscopy and direct laryngoscopy groups (67.7% vs 70.3%; absolute difference, -2.5% [95% CI, -11.9% to 6.9%]; $P = .60$). The proportion of first-attempt intubations performed by nonexperts (primarily residents, n = 290) did not differ between the groups (84.4% with video laryngoscopy vs 83.2% with direct laryngoscopy; absolute difference 1.2% [95% CI, -6.3% to 8.6%]; $P = .76$). The median time to successful intubation was 3 minutes (range, 2 to 4 minutes) for both video laryngoscopy and direct laryngoscopy (absolute difference, 0 [95% CI, 0 to 0]; $P = .95$). Video laryngoscopy was not associated with life-threatening complications (24/180 [13.3%] vs 17/179 [9.5%] for direct laryngoscopy; absolute difference, 3.8% [95% CI, -2.7% to 10.4%]; $P = .25$). In post hoc analysis, video laryngoscopy was associated with severe life-threatening complications (17/179 [9.5%] vs 5/179 [2.8%] for direct laryngoscopy; absolute difference, 6.7% [95% CI, 1.8% to 11.6%]; $P = .01$) but not with mild to moderate life-threatening complications (10/181 [5.4%] vs 14/181 [7.7%]; absolute difference, -2.3% [95% CI, -7.4% to 2.8%]; $P = .37$).

CONCLUSIONS AND RELEVANCE Among patients in the ICU requiring intubation, video laryngoscopy compared with direct laryngoscopy did not improve first-pass orotracheal intubation rates and was associated with higher rates of severe life-threatening complications. Further studies are needed to assess the comparative effectiveness of these 2 strategies in different clinical settings and among operators with diverse skill levels.

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Intubation of patients in the intensive care unit (ICU) carries a risk of potentially severe complications, including cardiac arrest.¹ Hypoxemia is common in patients in the ICU requiring intubation, which must be performed rapidly to avoid aspiration because the patient is usually not in a fasted state.² Studies have assessed interventions such as routine neuromuscular blockade that are designed to improve intubation success rates.³ Care bundles⁴ combined with training on simulators have improved the safety of intubation. Nevertheless, intubation in the ICU still carries higher morbidity and mortality rates compared with intubation in the operating room.⁵

For the past half century, orotracheal intubation has been performed using the Macintosh laryngoscope for direct laryngoscopy. The video laryngoscope is a recently developed device that provides indirect visualization of the glottis via a camera. Video laryngoscopes have been extensively studied for intubation in the operating room and may facilitate orotracheal intubation compared with direct laryngoscopy.⁶ Video laryngoscopes have either a curved blade similar to the Macintosh laryngoscope or a tube channel.

In the ICU, observational studies and small randomized studies support the use of video laryngoscopy for orotracheal intubation,⁷ regardless of the predicted difficulty of intubation. Some of these studies also recorded adverse effects such as longer duration of the orotracheal intubation procedure⁸ and higher mortality.⁹ Therefore, whether use of video laryngoscopes in ICUs¹⁰ is of greater benefit to patients deserves investigation.

The objective of this study was to test the hypothesis that routine use of the video laryngoscope for orotracheal intubation of patients in the ICU increased the frequency of successful first-pass intubation¹¹ compared with use of the Macintosh direct laryngoscope.

Methods

Study Design and Setting

The McGrath Mac Videolaryngoscope Versus Macintosh Laryngoscope for Orotracheal Intubation in the Critical Care Unit (MACMAN) trial was an institutionally sponsored, non-blinded, multicenter, open-label, 2 parallel-group randomized clinical trial (RCT) conducted at 7 ICUs in France. The protocol¹² (appears in [Supplement 1](#)) was approved by the appropriate ethics committee (Comité de Protection des Personnes Ouest 2, #2014-A00674-43). According to French law, because the strategies used in both groups were considered components of standard care, consent was not required; however, it was mandatory that certain information be provided to the patient or next of kin.

If no next of kin was available, patients without decision-making competence were included in compliance with French law. Patients were informed as soon as they regained competence and were asked whether they wanted to remain in the trial. Data from patients who requested full withdrawal were to be excluded from the analysis in accordance with French law.

Key Points

Question Should video laryngoscopy be used for orotracheal intubation in the intensive care unit (ICU) despite conflicting evidence that it improves the first-pass success rate?

Findings Video laryngoscopy for orotracheal intubation in the ICU did not improve the first-pass success rate compared with conventional direct laryngoscopy (67.7% vs 70.3%, respectively).

Meaning Video laryngoscopy did not improve the frequency of successful first-pass intubation in the ICU.

In addition to electronic database monitoring, onsite monitoring was performed by a study nurse at each ICU to ensure the good quality and completeness of the study data. All investigators attended a meeting about the trial before inclusion of the first patient.

Patients were recruited between May and December 2015. Patient follow-up was 28 days. The follow-up period ended in January 2016.

Participants

Inclusion criteria were ICU admission and need for orotracheal intubation to allow mechanical ventilation. Exclusion criteria were (1) contraindications to orotracheal intubation (eg, unstable spinal lesion), (2) insufficient time to include and randomize the patient (eg, because of cardiac arrest), (3) age younger than 18 years, (4) currently pregnant or breastfeeding, (5) correctional facility inmate, (6) under guardianship, (7) without health insurance, (8) refusal by patient or next of kin, and (9) previous enrollment in an RCT with intubation as the primary end point (including previous inclusion in the present trial).

Randomization, Allocation Concealment, and Follow-up

The randomization sequence was generated by a statistician at the clinical research unit (Centre Hospitalier Département de la Vendée) who had no role in patient recruitment. Randomization was performed in blocks of 4. The randomization scheme was balanced and stratified by center and expert or nonexpert status of the individual performing intubation.¹³ An *expert* was defined as a physician who had either worked at ICUs for at least 5 years or worked at ICUs for at least 1 year after receiving at least 2 years of anesthesiology training. Physicians who did not meet these criteria were classified as *nonexperts*.

The software used to collect the data from the electronic report form automatically allocated the patients, thereby ensuring concealment. Included patients were followed up until day 28 after randomization.

Intervention and Control Intubation Methods

All physicians working at the participating ICUs received hands-on training in the use of the video laryngoscope and conventional (direct) laryngoscope. Specific equipment was provided to each participating center for the training sessions (eg, size 3 and 4 blades of each laryngoscope type and manikins for intubation training). Orotracheal intubation per-

formed by a nonexpert was always supervised by an expert. Orotracheal intubation was performed in both groups according to the following protocol:

1. Preoxygenation was achieved using the device chosen by the bedside physician according to the standard ICU protocol. Options included a bag valve mask delivering oxygen at a flow of 15 L/min or greater for at least 3 minutes; a nonbreathing (high concentration) mask delivering oxygen at a flow of 15 L/min or greater for at least 3 minutes; a ventilator in noninvasive mode providing 100% fraction of inspired oxygen (FiO_2) for at least 3 minutes¹⁴; or a high-flow nasal oxygen device (eg, Optiflow) delivering oxygen at a flow of 60 L/min or greater with 100% FiO_2 for at least 3 minutes.¹⁵
2. General anesthesia was then induced by injecting a hypnotic agent and a neuromuscular blocking agent. The choice of agent and dosage were chosen by the individual performing the intubation. In agreement with the guidelines,¹⁶ 2 principles were applied: (1) the preferred neuromuscular blocking agent in the absence of contraindications (eg, hyperkalemia, burn injury >24 hours earlier, spinal lesion, or allergy) was 1 mg/kg of succinylcholine and the alternative was 1 mg/kg of rocuronium provided the antidote sugammadex (16 mg/kg) was available; and (2) the preferred hypnotic agent was either 0.2 to 0.3 mg/kg of etomidate or 1 to 2 mg/kg of ketamine.
3. Laryngoscopy was performed using the device allocated at random (ie, either a video laryngoscope with a requirement to obtain indirect glottis visualization via the camera for the first pass, or the Macintosh direct laryngoscope). The McGrath MAC video laryngoscope (Medtronic) was chosen for the intervention group because the intubation technique with this device is similar to that with the Macintosh laryngoscope (in particular, the blade curve is not specifically designed for difficult intubation), a previous study suggests benefits for ICU intubation,¹⁷ the small size of the device enabled bedside use, and the cost was low compared with other video laryngoscopes. As recommended by French guidelines,¹⁸ no stylet was used for the first-pass intubation attempt.
4. Intratracheal tube position was confirmed by analyzing the capnography curve over 4 breaths or more. After tube insertion, the cuff was inflated and the tube was connected to the ventilator. Use of the Sellick maneuver was at the discretion of the individual performing intubation and was recorded on the electronic case report form.
5. If the first-pass intubation attempt failed, the individual performing intubation chose between repeat laryngoscopy and an alternative intubation technique in accordance with French guidelines.¹⁸ During repeat laryngoscopies, the video laryngoscope could be used with either indirect or direct glottis visualization. Each introduction of the laryngoscope into the oral cavity was considered a separate laryngoscopy attempt.

Study Outcomes

The primary outcome measure was the proportion of patients with successful first-pass orotracheal intubation, which

was defined based on a normal-appearing waveform of the partial pressure of end-tidal exhaled carbon dioxide curve over 4 or more breathing cycles.

The secondary outcomes included (1) the proportion of patients with successful orotracheal intubation at any attempt, (2) total time to successful orotracheal intubation (time from anesthesia induction initiation to confirmation of good tube position based on partial pressure of end-tidal exhaled carbon dioxide), (3) Cormack-Lehane grade of glottis visibility, (4) Percentage of Glottic Opening scale score,¹⁹ (5) proportion of patients with difficult intubation, (6) proportion of patients intubated using alternative techniques (gum elastic bougie, laryngeal mask airway [eg, Fastrach], video laryngoscope proven helpful in difficult orotracheal intubation [Airtraq or GlideScope], fiber optic endoscopy, or rescue percutaneous or surgical transtracheal oxygenation), (6) complications (death, cardiac arrest, severe cardiovascular collapse [systolic blood pressure <90 mm Hg], hypoxemia [oxygen saturation by pulse oximeter $\{\text{SpO}_2\}$ <90%] or severe hypoxemia [SpO_2 <80%], esophageal intubation, aspiration, arrhythmia [ventricular tachycardia, ventricular fibrillation, salvo of ventricular premature beats], and dental injury), (7) duration of mechanical ventilation, (8) ICU length of stay, (9) hospital length of stay, (10) ICU mortality, and (11) 28-day mortality. Previously described¹⁷ severe life-threatening complications included death, cardiac arrest, severe cardiovascular collapse, and severe hypoxemia and mild to moderate life-threatening complications included esophageal intubation, aspiration, arrhythmia, and dental injury.

Sample Size

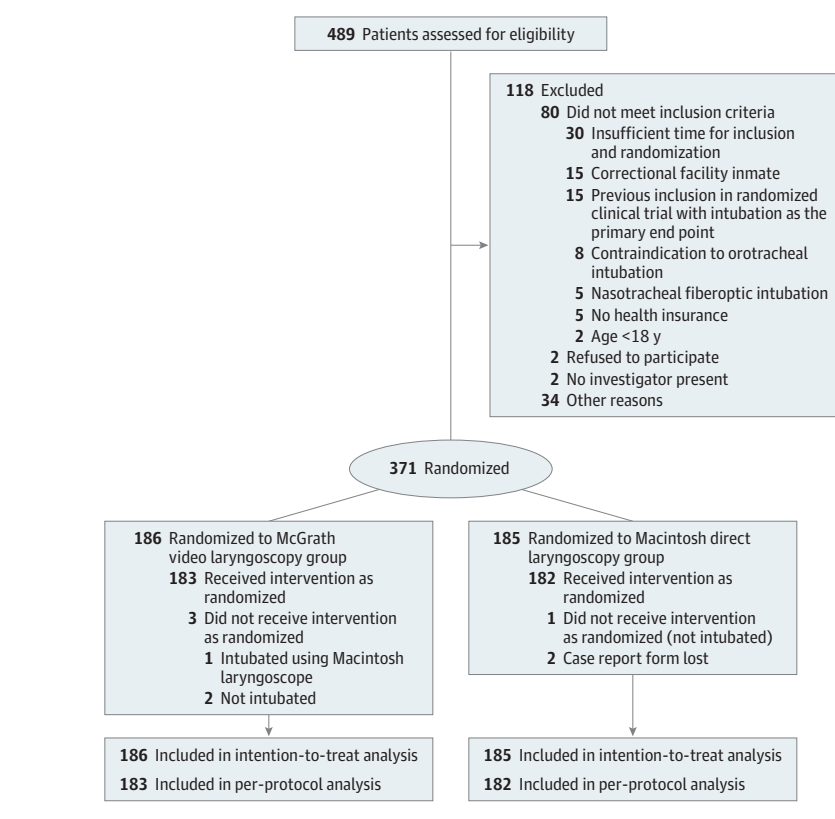
Based on previous data,^{17,20,21} the expected rate of successful first-pass orotracheal intubation was 65% for patients in the direct laryngoscopy group. Assuming that video laryngoscopy would increase this proportion to 80%,¹⁷ with type I error set at 5% and type II error set at 10%, 185 patients were needed in each group (ie, 370 patients total).

Statistical Analysis

Baseline features were described as number (percentage) for categorical variables and mean (standard deviation) and quartiles for quantitative variables. Proportions of patients with successful first-pass orotracheal intubation were compared between groups using a mixed-effects logistic model to account for stratification factors. The model included center as a random effect and group and operator experience as fixed effects. The intention-to-treat principle was followed. A per-protocol analysis also was performed and excluded the patients who (1) did not meet inclusion or exclusion criteria, (2) did not receive invasive mechanical ventilation, or (3) had medical reasons for study withdrawal.

Patients without data for the primary outcome were classified as experiencing intubation failure. A sensitivity analysis based on the MACOCHA score (which is made up of a Mallampati score of 3 or 4, apnea syndrome [obstructive], cervical spine limitation, opening mouth <3 cm, coma, hypoxemia, and operator not being an anesthesiologist) for predicting difficult intubation was performed; when at least

Figure 1. Flow of Patients Through the McGrath Mac Videolaryngoscope Versus Macintosh Laryngoscope for Orotracheal Intubation in the Critical Care Unit (MACMAN) Randomized Clinical Trial



1 component of the score was missing (161 patients), multiple imputation (100 imputations) based on randomization group, operator experience, and center was used.

Comparisons of the secondary outcomes were performed using the χ^2 or Fisher exact test for qualitative data and the t test or the Wilcoxon rank sum test for quantitative data as appropriate. Intubation procedure duration was assessed using Kaplan-Meier curves and the log-rank test. Post hoc subgroup analyses were conducted using repeated-measures mixed models in patients with (1) a ratio of PaO_2 to FiO_2 of less than 200 mm Hg or (2) of less than 150 mm Hg at enrollment²² to assess whether the severity of hypoxemia was related to low saturation during intubation.

All tests were 2-tailed. P values of less than .05 were considered significant. Multiple imputations were performed for missing data. Stata statistical software version 13 (StataCorp) was used. No adjustments were made for the multiple comparisons; therefore, the results for the secondary outcomes should be interpreted as exploratory.

Results

Of 489 patients assessed for eligibility, 371 were randomized and included in the intention-to-treat analysis (mean [SD] age, 62.8 [15.8] years; 136 [36.7%] women) and 365 were included in the per-protocol analysis (Figure 1 and eTable 1 in Supplement 2).

Baseline features were evenly balanced between groups (Table 1). The first orotracheal intubation attempt was performed by nonexperts in 83.8% of patients and by experts in 16.2% of patients.

Primary Outcome: Successful First-Pass Intubation

Data on the primary outcome were unavailable for 5 patients, who were classified as experiencing first-pass orotracheal intubation failure in the intention-to-treat analysis. The 366 remaining patients were successfully intubated. The proportion of patients experiencing successful first-pass orotracheal intubation was not significantly different between the video laryngoscopy group (126 of 186 patients [67.7%]) and the direct laryngoscopy group (130 of 185 patients [70.3%]) (absolute difference, -2.5% [95% CI, -11.9% to 6.9%]; $P = .60$).

The frequency of first-attempt orotracheal intubation failure was not significantly different with video laryngoscopy (odds ratio [OR], 1.12 [95% CI, 0.71-1.78]; $P = .63$) both after adjustment for operator expertise (randomization stratification factor) and after adjustment for the MACOCHA score (OR, 1.10 [95% CI, 0.69-1.75]; $P = .69$). The main reason for patients to experience first-pass intubation failure was because the glottis was not visualized during direct laryngoscopy. For patients in the video laryngoscopy group, first-pass intubation failure was due to failure of tracheal catheterization (Table 2). Second-attempt laryngoscopy and total number of attempts

Table 1. Patient Baseline Data

	Video Laryngoscopy (n = 186)	Direct Laryngoscopy (n = 185)
Demographics^a		
Age, mean (SD), y	62.7 (15.3)	62.8 (16.3)
Male sex, No. (%)	122 (65.6)	113 (61.1)
BMI, mean (SD) ^b	26.2 (6.7)	26.6 (7.2)
Simplified Acute Physiologic Score II, mean (SD) ^c	58.0 (21.0)	57.7 (21.8)
Activity level (Knaus chronic health status score), No. (%)		
Normal health status	24 (12.9)	22 (11.9)
Moderate activity limitation	90 (48.3)	103 (55.7)
Severe activity limitation due to chronic disease	70 (37.6)	56 (30.3)
Bedridden	2 (1.1)	4 (2.2)
Charlson comorbidity index, mean (SD) ^d	2.9 (2.1)	3.0 (2.1)
Diagnosis at admission to the intensive care unit, No. (%)		
Acute circulatory failure	32 (17.2)	22 (11.9)
Acute neurological failure	46 (24.7)	40 (21.6)
Acute respiratory failure	73 (39.2)	86 (46.5)
Trauma	35 (18.8)	37 (20.0)
Other ^e	45 (24.2)	44 (23.8)
Reason for intubation, No. (%)		
Neurological failure	71 (38.2)	76 (41.1)
Respiratory failure	52 (28.0)	51 (27.6)
Circulatory failure	3 (1.6)	4 (2.2)
Other	13 (7.0)	9 (4.9)
At time of enrollment		
Sequential Organ Failure Assessment score, mean (SD) ^f	7 (4)	7 (3)
Glasgow Coma Scale score, mean (SD) ^g	12 (4)	12 (4)
Heart rate, mean (SD)	107 (28)	101 (25)
Arterial systolic pressure, mean (SD), mm Hg	129 (32)	126 (30)
Peripheral oxygen saturation, mean (SD), %	95 (6)	95 (6)
Ratio of PaO ₂ to FiO ₂ , median (IQR)	95 (71-191)	91 (71-145)
Serum lactic acid, mean (SD), mmol/L	3.1 (3.1)	3.0 (3.3)
Criteria for difficult facial mask ventilation, No./total (%)		
Age >55 y	134/185 (72.4)	133/185 (71.9)
Edentulous	41/183 (22.4)	45/181 (24.9)
Snoring	28/171 (16.4)	35/173 (20.2)
Has beard	22/184 (12.0)	22/181 (12.2)
Limited mandibular protrusion	5/147 (3.4)	12/135 (8.9)
BMI >26	77/177 (43.5)	88/179 (49.2)
Criteria for difficult intubation		
History of difficult intubation, No. (%)	3 (1.6)	2 (1.1)
Mallampati score, No./total (%)^h		
1	25/111 (22.5)	32/107 (29.9)
2	45/111 (40.5)	44/107 (41.1)
3	30/111 (27.0)	26/107 (24.3)
4	11/111 (9.9)	5/107 (4.7)
Thyromental distance <65 mm, No./total (%)	19/182 (10.4)	26/177 (14.7)
Mouth opening <35 mm, No./total (%)	27/181 (14.9)	26/178 (14.6)
Limited cervical mobility, No./total (%)	12/183 (6.6)	13/179 (7.3)
Sleep apnea, No./total (%)	11/182 (6.0)	10/180 (5.6)
BMI >35, No./total (%)	13/177 (7.3)	20/179 (11.2)
MACOCHA score, mean (SD) ⁱ	3 (3)	3 (3)

Abbreviations: BMI, body mass index; FiO₂, fraction of inspired oxygen; IQR, interquartile range.

^a Recorded at study inclusion.

^b Calculated as weight in kilograms divided by height in meters squared.

^c Score range: 0 (lowest level of critical illness) to 163 (most severe level of critical illness with 100% predicted mortality). A score of 50 predicts a risk of death at 46.1%. The score was calculated 24 hours after admission to the intensive care unit.

^d Categorizes the comorbidity burden. Each comorbidity category was weighted from 1 to 6, depending on the adjusted risk of mortality or resource use. The sum of all the weights produces a single comorbidity score for the patient. A score of zero indicates that no comorbidities were found. Higher scores predict a higher risk of mortality and greater resource use.

^e Included acute metabolic disorders, acute kidney insufficiency, and upper gastrointestinal bleeding.

^f Score range: 0 (no organ failure) to 24 (most severe level of multiorgan failure).

^g Score reflects the level of consciousness. Score range: 3 (comatose) to 15 (awake).

^h Predicts glottis visibility. Score range: 1 (fully visible) to 4 (not seen).

ⁱ Predicts ease of intubation. Score range: 0 (easy) to 12 (very difficult). This index is made up of a Mallampati score of 3 or 4, apnea syndrome (obstructive), cervical spine limitation, opening mouth less than 3 cm, coma, hypoxemia, and operator not being an anesthesiologist.

Table 2. Intubation Characteristics and Outcomes of Patients

	No./Total (%) of Patients ^a		Absolute Difference (95% CI), %	P Value
	Video Laryngoscopy	Direct Laryngoscopy		
Primary Outcome: Successful First-Pass Intubation				
Intention-to-treat analysis	126/186 (67.7)	130/185 (70.3)	-2.5 (-11.9 to 6.9)	.60
Per-protocol analysis	126/183 (68.9)	130/182 (71.4)	-2.5 (-12.3 to 6.4)	.54
Secondary Outcomes				
Cormack-Lehane grade ^b				
1	133/176 (75.6)	93/177 (52.5)	23.1 (13.3 to 32.7)	<.001
2	25/176 (14.2)	51/177 (28.8)	-14.6 (-23.0 to -6.2)	
3	10/176 (5.7)	20/177 (11.3)	-5.6 (-11.4 to 0.2)	
4	8/176 (4.5)	13/177 (7.3)	-2.8 (-7.7 to 2.1)	
Percentage of glottic opening score, median (IQR) ^c	100 (80 to 100)	80 (50 to 100)	20 (0 to 20)	<.001
Maneuvers during first-attempt laryngoscopy				
Head elevation	38/183 (20.8)	46/181 (25.4)	-4.6 (-13.3 to 4.0)	.29
BURP maneuver ^d	26/183 (14.2)	28/181 (15.5)	-1.3 (-8.6 to 6.0)	.73
Sellick maneuver ^e	28/184 (15.2)	38/181 (21.0)	-5.8 (-13.6 to 2.1)	.15
Reason for intubation failure ^f				
Glottis not seen	13/58 (22.4)	36/51 (70.6)	-48.2 (-64.6 to -31.7)	<.001
Failure of tracheal catheterization	41/58 (70.7)	12/51 (23.5)	47.2 (30.6 to 63.7)	
Adverse event ^g	1/58 (1.7)	2/51 (3.9)	-2.2 (-8.5 to 4.1)	
Laryngeal obstruction	1/58 (1.7)	1/51 (2.0)	-0.3 (-5.3 to 4.8)	
Technical failure (battery, other)	2/58 (3.4)	0	3.4 (-1.2 to 8.1)	
No. of intubation attempts, median (range)	1 (1 to 4)	1 (1 to 5)	0 (0 to 0)	.68
Difficult intubation ^h	14/186 (7.5)	14/185 (7.6)	-0.1 (-5.5 to 5.4)	.99
Duration of intubation, median (IQR), min	3 (2 to 4)	3 (2 to 4)	0 (0 to 0)	.95
Need for facial mask ventilation after first-attempt laryngoscopy	16/73 (21.9)	15/66 (22.7)	-0.8 (-30.1 to 28.5)	.91
Need for gum elastic bougie	49/257 (19.1)	34/247 (13.8)	5.3 (2.2 to 25.4)	.11
After first-attempt laryngoscopy	22/184 (12.0)	10/181 (5.5)	6.5 (0.7 to 12.2)	.03
After second- to fifth-attempt laryngoscopy	27/73 (37.0)	24/66 (36.4)	0.6 (-25.9 to 27.1)	.94
Type of complication				
Death	1/184 (0.5)	0/181	0.5 (-0.5 to 1.6)	.99
Cardiac arrest	4/184 (2.2)	0/181	2.2 (0.07 to 4.3)	.12
Arrhythmia	3/184 (1.6)	4/181 (2.2)	-0.6 (-3.4 to 2.2)	.69
Esophageal intubation	3/184 (1.6)	6/181 (3.3)	-1.7 (-4.9 to 1.5)	.33
Aspiration	4/184 (2.2)	4/181 (2.2)	0 (-3.0 to 3.0)	.99
Tooth injury	0/184	1/181 (0.6)	-0.6 (-1.6 to 0.5)	.50
Hypoxemia ⁱ	14/173 (8.1)	19/174 (10.9)	-2.8 (-9.0 to 3.3)	.37
Severe hypoxemia ^j	6/176 (3.4)	1/181 (0.5)	2.9 (-0.03 to 5.7)	.06
Hypotension ^k	8/180 (4.4)	4/179 (2.2)	2.2 (-1.5 to 5.9)	.24
≥1 Life-threatening complication	24/180 (13.3)	17/179 (9.5)	3.8 (-2.7 to 10.4)	.25
Type of life-threatening complication ^l				
Mild to moderate ^m	10/181 (5.4)	14/181 (7.7)	-2.3 (-7.4 to 2.8)	.37
Severe ⁿ	17/179 (9.5)	5/179 (2.8)	6.7 (1.8 to 11.6)	.01

Abbreviation: IQR, interquartile range.

^a Unless otherwise indicated.

^b Reflects glottis visualization. Score range: 1 (good) to 4 (no glottis visualization).

^c Reflects glottis visualization as a percentage. Score range: 100% (good) to 0% (no glottis visualization).

^d Backward, upward, and rightward pressure (BURP) applied to the larynx. This maneuver improves visualization of the laryngeal structures and facilitates intubation.

^e Pressure applied to the cricoid cartilage with the goal of decreasing the risk of aspiration during intubation.

^f In the video laryngoscopy group, 2 patients were not intubated. In the direct laryngoscopy group, 3 patients were not intubated. Data were missing for 1 additional patient.

^g Defined as vomiting during the procedure.

^h Defined as 3 or more laryngoscopies, a total orotracheal intubation duration longer than 10 minutes, or both.

ⁱ Defined as a pulse arterial saturation of less than 90%.

^j Defined as a pulse arterial saturation of less than 80%.

^k Defined as an arterial systolic pressure of less than 90 mm Hg.

^l According to post hoc analysis.

^m Included esophageal intubation, aspiration, arrhythmia, and dental injury.

ⁿ Included death, cardiac arrest, severe cardiovascular collapse (arterial systolic pressure <90 mm Hg), and severe hypoxemia (pulse arterial saturation <80%).

to achieve intubation success did not differ between groups (Figure 2; eTable 2 and eTable 3 in Supplement 2).

The sensitivity analysis performed in the per-protocol population showed no significant between-group difference for the primary outcome in the subgroups with MACOCHA scores of less than 4 or scores of 4 or greater (eTable 4 and eTable 5 in Supplement 2).

Secondary Outcomes

There were 368 patients successfully intubated; therefore, no patients required alternative intubation or oxygenation methods. In the video laryngoscopy group, Cormack-Lehane grades of 1 or 2 (better glottis visualization) were more common, the percentage of glottic opening score was higher, and a gum elastic bougie was used more often during first-pass

oro-tracheal intubation. Most first intubation attempts were made by nonexperts (primarily residents, $n = 290$) and most subsequent attempts were made by experts, yielding no significant between-group differences (Table 3). First intubation attempts were successful more often when performed by experts (55 of 60 patients [91.7%]) compared with when performed by nonexperts (201 of 311 patients [64.6%]) (absolute difference, 27.1% [95% CI, 18.2%-35.8%]; $P = .001$).

Bag valve ventilation was the most common preoxygenation method used in both groups. The median duration of the intubation procedure of 3 minutes (range, 2-4 minutes) did not differ between the 2 groups (absolute difference, 0 [95% CI, 0-0]; $P = .95$). In patients with successful first-pass oro-tracheal intubation, the median duration of the intubation procedure did not significantly differ between the video laryngoscopy group (2 minutes) and the direct laryngoscopy group (2.5 minutes) (absolute difference, 0 [95% CI, 0-0]; $P = .61$).

The proportion of patients with severe life-threatening complications was higher in the video laryngoscopy group (9.5% vs 2.8% in the direct laryngoscopy group; absolute difference, 6.7% [95% CI, 1.8% to 11.6%]; $P = .01$), whereas no

Figure 2. Proportion of Patients Successfully Intubated According to Duration of the Intubation Procedure

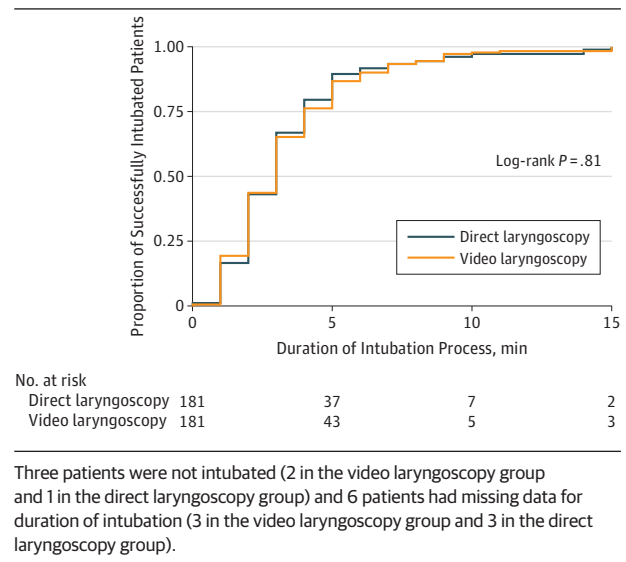


Table 3. Patient Data by Characteristics of Physician Making First Intubation Attempt and by Type of Preoxygenation Modality, Hypnotic Medication, and Neuromuscular Blocker

	No./Total (%)			
	Video Laryngoscopy	Direct Laryngoscopy	Absolute Difference (95% CI), %	P Value
Skill level of physician making first intubation attempt				
Nonexpert	157/186 (84.4)	154/185 (83.2)	1.2 (−6.3 to 8.6)	.76
Expert	29/186 (15.6)	31/185 (16.8)	−1.2 (−8.6 to 6.3)	
Description of nonexpert				
Emergency medicine resident	23/157 (14.7)	18/154 (11.7)	3.0 (−4.6 to 10.3)	.32
Anesthesiology resident	28/157 (17.8)	27/154 (17.5)	0.3 (−7.7 to 9.3)	
Internal medicine resident	92/157 (58.6)	102/154 (66.2)	−7.6 (−18.7 to 2.7)	
Other ^a	14/157 (8.9)	7/154 (4.5)	4.6 (−1.2 to 9.8)	
Description of expert				
Anesthesiologist	16/29 (55.2)	20/31 (64.5)	−9.3 (−34.1 to 15.4)	.60
Emergency physician	1/29 (3.4)	0/31 (0)	3.4 (−3.2 to 10.1)	
Medical intensivist	12/29 (41.4)	11/31 (35.5)	5.9 (−18.7 to 30.5)	
Preoxygenation modality				
Bag valve mask	95/184 (51.6)	95/181 (52.5)	−0.9 (−11.1 to 9.4)	.87
Noninvasive ventilation	39/184 (21.2)	46/181 (25.4)	−4.2 (−12.9 to 4.4)	.34
High-flow nasal cannula	20/184 (10.9)	19/181 (10.5)	0.4 (−6.0 to 6.7)	.91
Nonrebreather mask	46/184 (25.0)	44/181 (24.3)	0.7 (−8.1 to 9.5)	.88
Hypnotic medications				
Etomidate	164/184 (89.1)	165/182 (90.7)	−1.6 (−7.7 to 4.6)	.63
Propofol	9/184 (4.9)	8/182 (4.4)	0.5 (−3.8 to 4.8)	.82
Ketamine	11/184 (6.0)	6/182 (3.3)	2.7 (−1.6 to 7.0)	.22
Midazolam	14/184 (7.6)	14/182 (7.7)	−0.1 (−5.5 to 5.4)	.98
Other ^b	1/184 (0.5)	4/182 (2.2)	−1.7 (−4.1 to 0.7)	.21
None	0/184 (0)	1/182 (0.5)	−0.5 (−1.6 to 0.5)	.50
Neuromuscular blockers				
Succinylcholine	144/184 (78.3)	138/182 (75.8)	2.5 (−6.6 to 10.6)	.58
Rocuronium	29/184 (15.8)	24/182 (13.2)	2.6 (−4.7 to 9.7)	.48
Other ^c	7/184 (3.8)	14/182 (7.7)	−3.9 (−8.7 to 0.8)	.11
None	4/184 (2.2)	6/182 (3.3)	−1.1 (−4.5 to 2.2)	.51

^a No examples documented in the electronic report forms.

^b An example is pentothal.

^c An example is atracurium.

significant between-group difference was found for mild to moderate life-threatening complications. Evolution of SpO₂ during intubation did not differ between the 2 groups across admission subgroups for ratio of PaO₂ to FIO₂ (eFigure 1, eFigure 2, and eFigure 3 in Supplement 2).

Duration of mechanical ventilation, ICU length of stay, sepsis-related organ failure assessment score on day 1, sepsis-related organ failure assessment score on day 2, ICU mortality, and 28-day mortality did not differ between the 2 groups (eTable 6 in Supplement 2).

Discussion

In the MACMAN trial, video laryngoscopy did not improve the frequency of successful first-pass orotracheal intubation compared with direct laryngoscopy. Furthermore, the video laryngoscopy group had a higher frequency of severe life-threatening complications (but not mild to moderate life-threatening complications) and need for use of a gum elastic bougie during the first intubation attempt.

In observational studies,²³⁻²⁵ a propensity-adjusted study,²⁶ a single-center RCT,⁷ and in 2 meta-analyses of the data,^{27,28} video laryngoscopy improved the first-pass orotracheal intubation success rate compared with direct laryngoscopy. However, these studies had major methodological weaknesses such as (1) a retrospective design, before and after design, or single-center recruitment, (2) absence of routine neuromuscular blockade, and (3) exclusion of the patients with the most severe cases of hypoxemia (SpO₂ <92% after bag valve mask ventilation) from the RCT.⁷ Other studies^{8,9,17,29-31} failed to show improvements with use of video laryngoscopy compared with use of direct laryngoscopy. Similarly, in 2 recent single-center RCTs,^{32,33} the first-pass orotracheal intubation success rate was not higher with use of video laryngoscopy compared with use of direct laryngoscopy.

The present report adds to these results by providing data from a multicenter RCT with an objective primary outcome measure (ie, capnography), ensuring a low risk of bias and high external validity. Several factors may explain the discrepancy in results of early studies vs recent RCTs. One is a high success rate in the direct laryngoscopy group, related in particular to adherence to a standardized protocol,² including routine neuromuscular blockade.³ Thus, in the MACMAN trial, even the nonexperts had a first-pass intubation success rate of 70% with direct laryngoscopy, and the experts had a success rate of 93.2%. The direct laryngoscopy success rate confirms that the sample size was correctly estimated.

Improved glottis visualization with video laryngoscopy did not translate into a higher success rate for first-pass intubation because tracheal catheterization under indirect vision was more difficult, in keeping with earlier data.^{32,33} Conceivably, a video laryngoscope with an intubation channel might improve the success rate, although preliminary data obtained in the operating room are inconclusive.³⁴

The frequency of severe life-threatening complications was higher with video laryngoscopy than with Macintosh laryngoscopy. Previous RCTs in trauma patients found

higher mortality rates in the subgroups with traumatic brain injury⁹ or longer duration of the orotracheal intubation procedure.^{8,9,35} Consistent with the results reported herein, an RCT in ICU patients showed a lower median arterial oxygen saturation with video laryngoscopy (86% [interquartile range, 75%-93%]) than with direct laryngoscopy (95% [interquartile range, 85%-99%]; *P* = .04), possibly due to the longer median orotracheal intubation procedure duration with video laryngoscopy (221 seconds [interquartile range, 103-291 seconds] vs 156 seconds [interquartile range, 67-220 seconds] with direct laryngoscopy; *P* = .15).³²

The better visualization of the glottis with video laryngoscopy might lead to a false impression of safety when orotracheal intubation is performed by nonexperts. The subgroup analyses did not identify factors associated with life-threatening complications with video laryngoscopy. In addition, poorer alignment of the pharyngeal axis, laryngeal axis, and mouth opening despite good glottis visualization by video laryngoscopy can lead to mechanical upper airway obstruction and faster progression to hypoxemia.³⁶

Use of a gum elastic bougie during the first intubation attempt was more common with video laryngoscopy. Due to the indirect visualization of the glottis with video laryngoscopy, some manufacturers recommend using an intubation stylet. The manufacturer of the video laryngoscope used in this study does not recommend using a stylet because the blade curvature is similar to that of the Macintosh laryngoscope and direct glottis visualization is possible.³⁷ The 2 devices are also similar in regard to the grip handle and passage into the mouth and larynx. With the Macintosh laryngoscope, use of a gum elastic bougie (compared with a stylet³⁸) was associated with a higher success rate for orotracheal intubation in the event of poor glottis visibility; therefore, stylet use is considered inadvisable for difficult orotracheal intubation according to French guidelines.¹⁸

With video laryngoscopy, use of a gum elastic bougie has been reported to be as efficient as a stylet for improving success rates of first-pass orotracheal intubation.³⁹ A stylet was not used routinely for patients in the video laryngoscopy group. The use of a gum elastic bougie is more common in Europe than in the United States.⁶ Furthermore, in a trial involving routine use of a stylet,³³ success rates for first-pass orotracheal intubation were not significantly different between the video laryngoscopy and direct laryngoscopy groups.

This study has several limitations. It assessed a single type of video laryngoscope, which has a curved blade similar to the direct laryngoscope. Other video laryngoscopes with a hyperangulated blade or specific intubation channel might have produced different results. Most of the first attempts of intubation were made by nonexpert physicians for both the video laryngoscopy and direct laryngoscopy groups; however, the trial was intended to reflect actual clinical conditions in which orotracheal intubation is often performed by nonexperts.¹³ Physician intubation expertise requires theoretical skills, manikin practice, and supervised hands-on training. Adequate intubation training is defined as having performed at least 50 orotracheal intubation procedures under supervision.⁴⁰

Successful first-pass intubation was chosen as the primary outcome because several studies showed a strong correlation between the frequency of complications such as hypoxemia, cardiac arrest, and death and the number of laryngoscopy attempts.¹³ Blinding was not feasible so successful first-pass intubation defined by capnography was chosen because it is an objective outcome measure. The success rate of first-pass orotracheal intubation was consistent with previously published data.^{17,25} The duration of the orotracheal intubation procedure was not significantly different between the 2 groups.

Conclusions

Among patients in the ICU requiring intubation, video laryngoscopy compared with direct laryngoscopy did not improve first-pass orotracheal intubation rates and was associated with higher rates of severe life-threatening complications. Further studies are needed to assess the comparative effectiveness of these 2 strategies in different clinical settings and among operators with diverse skill levels.

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REFERENCES

1. Mort TC. The incidence and risk factors for cardiac arrest during emergency tracheal intubation: a justification for incorporating the ASA guidelines in the remote location. *J Clin Anesth*. 2004;16(7):508-516.
2. Jaber S, Amraoui J, Lefrant JY, et al. Clinical practice and risk factors for immediate complications of endotracheal intubation in the intensive care unit: a prospective, multiple-center study. *Crit Care Med*. 2006;34(9):2355-2361.
3. Mosier JM, Sakles JC, Stolz U, et al. Neuromuscular blockade improves first-attempt success for intubation in the intensive care unit: a propensity matched analysis. *Ann Am Thorac Soc*. 2015;12(5):734-741.
4. Jaber S, Jung B, Corne P, et al. An intervention to decrease complications related to endotracheal intubation in the intensive care unit: a prospective, multiple-center study. *Intensive Care Med*. 2010;36(2):248-255.
5. Griesdale DE, Bosma TL, Kurth T, Isac G, Chittock DR. Complications of endotracheal intubation in the critically ill. *Intensive Care Med*. 2008;34(10):1835-1842.
6. Frerk C, Mitchell VS, McNarry AF, et al; Difficult Airway Society Intubation Guidelines Working Group. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. *Br J Anaesth*. 2015;115(6):827-848.
7. Silverberg MJ, Li N, Acquah SO, Kory PD. Comparison of video laryngoscopy versus direct laryngoscopy during urgent endotracheal intubation: a randomized controlled trial. *Crit Care Med*. 2015;43(3):636-641.
8. Platts-Mills TF, Campagne D, Chinnock B, Snowden B, Glickman LT, Hendey GW. A comparison of GlideScope video laryngoscopy versus direct laryngoscopy intubation in the emergency department. *Acad Emerg Med*. 2009;16(9):866-871.
9. Yeatts DJ, Dutton RP, Hu PF, et al. Effect of video laryngoscopy on trauma patient survival: a randomized controlled trial. *J Trauma Acute Care Surg*. 2013;75(2):212-219.
10. Silverberg MJ, Kory P. Survey of video laryngoscopy use by US critical care fellowship training programs. *Ann Am Thorac Soc*. 2014;11(8):1225-1229.
11. 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):71-78.

12. Bailly A, Lascarrou JB, Le Thuaut A, et al; Clinical Research in Intensive Care and Sepsis Group. McGrath MAC videolaryngoscope versus Macintosh laryngoscope for orotracheal intubation in intensive care patients: the randomised multicentre MACMAN trial study protocol. *BMJ Open.* 2015;5(12):e009855.

13. Simpson GD, Ross MJ, McKeown DW, Ray DC. Tracheal intubation in the critically ill: a multi-centre national study of practice and complications. *Br J Anaesth.* 2012;108(5):792-799.

14. Baillard C, Fosse JP, Sebbane M, et al. Noninvasive ventilation improves preoxygenation before intubation of hypoxic patients. *Am J Respir Crit Care Med.* 2006;174(2):171-177.

15. Miguel-Montanes R, Hajage D, Messika J, et al. Use of high-flow nasal cannula oxygen therapy to prevent desaturation during tracheal intubation of intensive care patients with mild-to-moderate hypoxemia. *Crit Care Med.* 2015;43(3):574-583.

16. Sinclair RC, Luxton MC. Rapid sequence induction. *Contin Educ Anaesth Crit Care Pain.* 2005;5(2):45-48.

17. De Jong A, Clavieras N, Conseil M, et al. Implementation of a combo videolaryngoscope for intubation in critically ill patients: a before-after comparative study. *Intensive Care Med.* 2013;39(12):2144-2152.

18. Langeron O, Bourgain JL, Laccoureye O, Legras A, Orliaguet G. Difficult airway algorithms and management: question 5 [in French]. *Ann Fr Anesth Reanim.* 2008;27(1):41-45.

19. Levitan RM, Ochroch EA, Kush S, Shofer FS, Hollander JE. Assessment of airway visualization: validation of the percentage of glottic opening (POGO) scale. *Acad Emerg Med.* 1998;5(9):919-923.

20. Wang HE, Seitz SR, Hostler D, Yealy DM. Defining the learning curve for paramedic student endotracheal intubation. *Prehosp Emerg Care.* 2005;9(2):156-162.

21. Roux D, Reignier J, Thiery G, et al. Acquiring procedural skills in ICUs: a prospective multicenter study. *Crit Care Med.* 2014;42(4):886-895.

22. Ranieri VM, Rubenfeld GD, Thompson BT, et al; ARDS Definition Task Force. Acute respiratory distress syndrome: the Berlin definition. *JAMA.* 2012;307(23):2526-2533.

23. Lakticova V, Koenig SJ, Narasimhan M, Mayo PH. Video laryngoscopy is associated with increased first pass success and decreased rate of esophageal intubations during urgent endotracheal intubation in a medical intensive care unit when compared to direct laryngoscopy. *J Intensive Care Med.* 2015;30(1):44-48.

24. Kory P, Guevarra K, Mathew JP, Hegde A, Mayo PH. The impact of video laryngoscopy use during urgent endotracheal intubation in the critically ill. *Anesth Analg.* 2013;117(1):144-149.

25. Mosier JM, Whitmore SP, Bloom JW, et al. Video laryngoscopy improves intubation success and reduces esophageal intubations compared to direct laryngoscopy in the medical intensive care unit. *Crit Care.* 2013;17(5):R237.

26. Hypes CD, Stolz U, Sakles JC, et al. Video laryngoscopy improves odds of first-attempt success at intubation in the intensive care unit: a propensity-matched analysis. *Ann Am Thorac Soc.* 2016;13(3):382-390.

27. De Jong A, Molinari N, Conseil M, et al. Video laryngoscopy versus direct laryngoscopy for orotracheal intubation in the intensive care unit: a systematic review and meta-analysis. *Intensive Care Med.* 2014;40(5):629-639.

28. Griesdale DE, Liu D, McKinney J, Choi PT. Glidescope® video-laryngoscopy versus direct laryngoscopy for endotracheal intubation: a systematic review and meta-analysis. *Can J Anaesth.* 2012;59(1):41-52.

29. Michailidou M, O'Keeffe T, Mosier JM, et al. A comparison of video laryngoscopy to direct laryngoscopy for the emergency intubation of trauma patients. *World J Surg.* 2015;39(3):782-788.

30. Ural K, Subaiya C, Taylor C, Ramadhyani U, Scuderi-Porter H, Nossaman BD. Analysis of orotracheal intubation techniques in the intensive care unit. *Crit Care Resusc.* 2011;13(2):89-96.

31. Noppens RR, Geimer S, Eisel N, David M, Piepho T. Endotracheal intubation using the C-MAC® video laryngoscope or the Macintosh

laryngoscope: a prospective, comparative study in the ICU. *Crit Care.* 2012;16(3):R103.

32. Griesdale DE, Chau A, Isaac G, et al; Canadian Critical Care Trials Group. Video-laryngoscopy versus direct laryngoscopy in critically ill patients: a pilot randomized trial. *Can J Anaesth.* 2012;59(11):1032-1039.

33. Janz DR, Semler MW, Lentz RJ, et al. Randomized trial of video laryngoscopy for endotracheal intubation of critically ill adults. *Crit Care Med.* 2016;44(11):1980-1987.

34. Kleine-Brueggeny M, Greif R, Schoettler 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):670-679.

35. Walker L, Brampton W, Halai M, et al. Randomized controlled trial of intubation with the McGrath series 5 videolaryngoscope by inexperienced anaesthetists. *Br J Anaesth.* 2009;103(3):440-445.

36. Hirabayashi Y, Fujita A, Seo N, Sugimoto H. Distortion of anterior airway anatomy during laryngoscopy with the GlideScope videolaryngoscope. *J Anesth.* 2010;24(3):366-372.

37. Wallace CD, Foulds LT, McLeod GA, Younger RA, McGuire BE. A comparison of the ease of tracheal intubation using a McGrath MAC(®) laryngoscope and a standard Macintosh laryngoscope. *Anaesthesia.* 2015;70(11):1281-1285.

38. Noguchi T, Koga K, Shiga Y, Shigematsu A. The gum elastic bougie eases tracheal intubation while applying cricoid pressure compared to a stylet. *Can J Anaesth.* 2003;50(7):712-717.

39. Batuwitage B, McDonald A, Nishikawa K, Lythgoe D, Mercer S, Charters P. Comparison between bougies and stylets for simulated tracheal intubation with the C-MAC D-blade videolaryngoscope. *Eur J Anaesthesiol.* 2015;32(6):400-405.

40. Buis ML, Maissan IM, Hoeks SE, Klimek M, Stolker RJ. Defining the learning curve for endotracheal intubation using direct laryngoscopy: a systematic review. *Resuscitation.* 2016;99:63-71.