EDITORIAL

Video Laryngoscopy in the Intensive Care Unit
Seeing Is Believing, But That Does Not Mean It's True

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Tracheal intubation is a lifesaving skill essential to the practice of anesthesia, emergency medicine, and critical care. Since the invention of direct laryngoscopy blades by Miller and Macintosh in the 1940s, the technology used for tracheal intubation was largely unchanged until the introduction of video laryngoscopy in the late 1990s.[1] Today multiple video laryngoscopes provide excellent, albeit indirect, views of the larynx without the need for aligning the laryngeal axis with the clinician's line of sight. Evidence suggesting that the use of these devices improved visualization of the larynx and facilitated intubation in difficult airways led to the incorporation of video laryngoscopy into the American Society of Anesthesiologists' difficult airway algorithm in 2013.[2] The striking ease of achieving laryngeal visualization and proliferation of video laryngoscopy devices soon resulted in the extension of video laryngoscopy to use outside the operating room and to patients without a difficult airway. Early data suggested that video laryngoscopy might improve intubation success rates in the intensive care unit (ICU) and emergency department. However, the validity of this evidence was limited by observational design or abnormally low success rates in the direct laryngoscopy group.[3,4]

Related article

In this issue of *JAMA*, Lascarrou and colleagues[5] present the results of a multicenter randomized clinical trial (MACMAN) of video vs direct laryngoscopy for tracheal intubation in ICU patients. A total of 371 adults requiring urgent intubation from 7 centers in France were randomized to undergo intubation with either the video laryngoscope or direct laryngoscopy with a Macintosh blade. All patients underwent protocolized preoxygenation and anesthetic induction regimens, including the routine use of neuromuscular blockade. The investigators' primary outcome measure was success of first-pass intubation as confirmed by capnography. Both intention-to-treat and per-protocol analyses showed no significant difference between the video and direct laryngoscopy groups in the proportion of successful first-pass intubations (67.7% vs 70.3%; $P = .60$). The median time for intubation did not differ (3 minutes in each group; $P = .95$). Of potential concern was the suggestion that the incidence of severe life-threatening complications, such as severe hypoxemia and cardiac arrest, was higher in patients undergoing video laryngoscopy (9.5% vs 2.8%; $P = .01$), although this was not a prespecified analysis, and the investigators did not control for multiple comparisons.

Lascarrou and colleagues have conducted a well-designed and generalizable trial in a complex and clinically important setting—emergency or urgent intubation. More than 80% of the initial attempts at intubation in the trial were performed by trainees with limited expertise in laryngoscopy, which reflects practice in most academic centers. The use of a protocolized care bundle for prelaryngoscopy airway management ensured that both groups were managed similarly with regard to other techniques known to improve intubation success rates. A gum elastic bougie was used more commonly than a rigid stylet in the endotracheal tube, which may not reflect global practice, but it is unlikely that such differences in technique would alter the results substantially, especially given that the manufacturer of the video laryngoscope used in this study does not recommend the use of a stylet. With regard to the possibly increased life-threatening complications in the video laryngoscopy group, even if this analysis had been prespecified, a Bonferroni adjustment would require a P value of .0056 for significance. The risk of type I statistical error is therefore substantial. Still, this possible finding should give some pause and mandate inclusion of such complications as prespecified outcomes in future studies of video laryngoscopy. Importantly, the findings from this study regarding a specific video laryngoscope may or may not generalize to other video laryngoscopes.

The results of the trial by Lascarrou et al illustrate the fundamental problem with video laryngoscopy: it generates excellent views of the larynx but may not facilitate tracheal intubation. The use of video laryngoscopy can lead to the creation of blind spots, both visual and cognitive. Because the lens of the laryngoscope is located at the tip of the device, the pharynx and hypopharynx are not visualized during video laryngoscopy. Manipulating the endotracheal tube into view therefore occurs within this blind spot, and this can be difficult depending on the patient's pharyngeal anatomy. This phenomenon has been linked to higher rates of pharyngeal soft tissue injury and longer intubation times in patients undergoing video laryngoscopy as compared with direct laryngoscopy.[6,7] The view during video laryngoscopy can also create a cognitive blind spot: laryngoscopists may fail to abort a laryngoscopy attempt in a timely manner because they have such a clear view of the larynx. Failing to stop at this juncture may preclude or delay attempts to either reoxygenate or seek alternative methods of intubation, which in turn may prolong apnea time, leading to severe hypoxemia. The data from the trial by Lascarrou et al also support observations from other studies suggesting higher rates of severe

hypoxemia associated with video laryngoscopy.[8] Although the median intubation time between groups was equal in this trial, the reported intubation times reflect both anesthetic induction and laryngoscopy, and it is unknown whether the apneic period during a given laryngoscopy attempt differed between groups and could have contributed to this finding.

This clinical trial adds to a growing body of evidence that routine use of video laryngoscopy in ICU patients without an anticipated difficult airway does not improve intubation success rates.[9] Although the technology is appealing because it allows for excellent views of the larynx for both novice operators and their instructors, use of video laryngoscopy outside the patient population for which it has been found to be beneficial may result in an increase in complications ranging from soft tissue injury to cardiac arrest without improving the chance of first-pass intubation success. Additionally, while video laryngoscopy remains a key component of the laryngoscopist's repertoire, overreliance on the technology by trainees may result in a lost opportunity to perfect their direct laryngoscopy technique or learn other critical procedures such as fiber optic or laryngeal mask-assisted intubation. The pulmonary artery catheter provides a similar cautionary tale of a revolutionary medical device that provided a new, "objective" look at an elusive part of the body but proved in clinical practice to be not useful or even harmful.[10] Therefore, pragmatic studies such as the trial by Lascarrou et al are essential in the evaluation of any attractive medical technology to delineate its appropriate role in clinical practice. The best care for critically ill patients requires that clinicians also recognize important blind spots, and this trial has helped do so on an important question. Seeing is believing, but that does not necessarily mean it is true.

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Published Online: January 24, 2017. doi:10.1001/jama.2016.21036

Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Dr O'Gara reported receiving grants from the National Institutes of Health and from the Foundation of Anesthesia Education and Research. Dr Brown reported that his institution holds a patent for a noninvasive ventilation mask that he invented and also that his institution receives royalties for books he has authored on medical ethics and humanities. Dr Talmor reported no disclosures.

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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.

TRIAL REGISTRATION clinicaltrials.gov Identifier: NCT02413723

JAMA. doi:10.1001/jama.2016.20603
Published online January 24, 2017.

Editorial
Related article
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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 bundles[4] 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 procedure[8] and higher mortality.[9] Therefore, whether use of video laryngoscopes in ICUs[10] 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 intubation[11] compared with use of the Macintosh direct laryngoscope.

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.

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, nonblinded, multicenter, open-label, 2 parallel-group randomized clinical trial (RCT) conducted at 7 ICUs in France. The protocol[12] (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.

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 nonrebreathing (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 minutes[14]; 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 {SpO_2} <90%] or severe hypoxemia [SpO_2 <80%], esophageal intubation, aspiration, arrhythmia [ventricular tachycardia, ventricular fibrillation, salve 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 described[17] 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

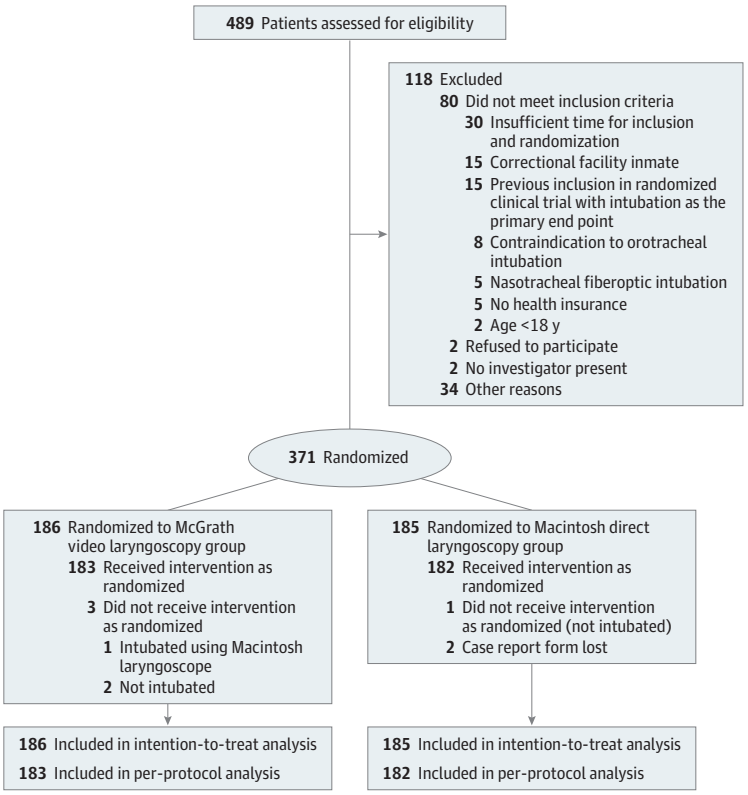
Based on previous data,[17,20,21] the expected rate of successful first-pass orotracheal intubation was 65% for patients in the direct laryngoscopy group. Assuming that video laryngoscopy would increase this proportion to 80%,[17] with type I error set at 5% and type II error set at 10%, 185 patients 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 enrollment[22] 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)
Snores	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; Fio_2, 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]			
	Video Laryngoscopy	Direct Laryngoscopy	Absolute Difference (95% CI), %	P Value
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

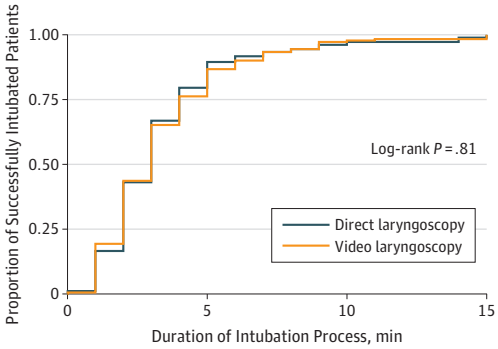
There were 368 patients successfully intubated; therefore, no patients required alternative intubation or oxygenation methods. In the video laryngoscopy group, Cormack-Lehane grades of 1 or 2 (better glottis visualization) were more common, the percentage of glottic opening score was higher, and a gum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

orotracheal 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 orotracheal 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



No. at risk

Direct laryngoscopy	181	37	7	2
Video laryngoscopy	181	43	5	3

Three patients were not intubated (2 in the video laryngoscopy group and 1 in the direct laryngoscopy group) and 6 patients had missing data for duration of intubation (3 in the video laryngoscopy group and 3 in the direct laryngoscopy group).

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 SpO_2 during intubation did not differ between the 2 groups across admission subgroups for ratio of Pao_2 to FIO_2 (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 (SpO_2 <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 injury[9] 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 stylet[38]) 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.

ARTICLE INFORMATION

Published Online: January 24, 2017. doi:10.1001/jama.2016.20603

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Author Contributions: Dr Lascarrou had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Drs Boisrame-Helms and Bailly contributed equally to the article.
Concept and design: Lascarrou, Bailly, Reignier.
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Statistical analysis: Lascarrou, Le Thuaut.
Obtained funding: Lascarrou, Reignier.
Administrative, technical, or material support: Lascarrou, Kamel, Colin, Messika, Dequin, Azoulay, Champigneulle, Reignier.
Supervision: Lascarrou, Kamel, Azoulay, Champigneulle, Reignier.

Conflict of Interest Disclosures: The authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Dr Ricard reported receiving travel reimbursement from Fisher & Paykel. Dr Mira reported receiving personal fees from LFB and Merck Sharp & Dohme for serving on advisory boards; and nonfinancial support from Astellas. Dr Messika reported receiving consulting fees from Basilea Pharmaceutica. Dr Azoulay reported receiving personal fees from Gilead, Astellas, and Alexion; and grants from Cubist and Alexion. No other disclosures were reported.

Funding/Support: The nonprofit health care institution Centre Hospitalier Département de la Vendée was the study funder and sponsor.

Role of the Funder/Sponsor: Centre Hospitalier Département de la Vendée had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

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Additional Contributions: We thank the health care staff and research nurses at the trial sites. We also thank A. Wolfe, MD, for assistance in preparing and reviewing the manuscript; S. Martin, PharmD (Clinical Reseach Unit, District Hospital Centre, La Roche Sur Yon, France), for reviewing the manuscript; E. Le Blanc (Delegation a la Recherche Clinique et a l'Innovation, CHU Nantes, Nantes, France) for managing the database; and J. Dimet, PharmD (Clinical Reseach Unit, District Hospital Centre, La Roche Sur Yon, France), for assistance with the administrative process. None of these persons were compensated for their contributions.

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