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Conventional vs Video-Assisted Laryngoscopy for Perioperative Endotracheal Intubations
A Randomized Clinical Trial

Benedikt Schmid, MD, PhD; Linda Grüßer, MD; Lukas Müller, MD; Maria Wittmann, MD; Achilles Delis, MD; Tugce Dinc Dogan, MD; Robert Werdehausen, MD; Christopher Neuhaus, MD; Peter Paal, MD; Carolin Claassen, MD; Philipp Helmer, MD; Paul Fischer, MD; Peter Kranke, MD; Patrick Meybohm, MD; Gregor Massoth, MD; for the German Society of Anaesthesiology and Intensive Care (GSAIC) Trials Group

Abstract

IMPORTANCE Video laryngoscopy is increasingly used in routine tracheal intubation in the operating room, but evidence regarding its clinical outcomes remains inconclusive. In particular, the role of hyperangulated video laryngoscopes as first-choice devices has not been studied sufficiently.

OBJECTIVE To determine whether video laryngoscopy—regardless of blade geometry or manufacturer—provides superior first-pass success compared with direct laryngoscopy (DL) during routine tracheal intubations.

DESIGN, SETTING, AND PARTICIPANTS This 3-arm randomized clinical trial (Conventional vs Video-Assisted Laryngoscopy for Perioperative Endotracheal Intubation [COVALENT]) was conducted at 6 academic or intermediate care centers in Germany and Austria between March 28, 2022, and February 17, 2025. Adults undergoing surgery under general anesthesia with the need for tracheal intubation were included in the trial. Adults undergoing surgery under any other form of anesthesia, those requiring nasal or planned fiberoptic intubation, and pregnant patients were excluded. Patients were sampled consecutively until trial staff capacity limits were met for any given day. Devices from different manufacturers were allowed to maximize generalizability. All data analyses followed a modified intention-to-treat approach.

INTERVENTION Tracheal intubation as part of general anesthesia induction preceding surgery. Patients were randomly assigned (1:1:1) to DL, video laryngoscopy with Macintosh blade (VLM), or video laryngoscopy with a hyperangulated blade (VLH). All interventions were performed by the anesthesiologists assigned to their respective cases.

MAIN OUTCOMES AND MEASURE The primary outcome was first-pass intubation success rate. After the laryngoscope and tracheal tube were inserted into the patient's oral cavity, retrieval of either marked a failed intubation attempt. Successful intubation was defined as positive capnography. Differences between success rates were tested applying the *z* test for unpooled variance and reported as absolute differences with corresponding 95% CIs.

RESULTS Of the 2532 patients (1426 males [56.3%]; mean [SD] age, 59.7 [15.4] years) randomly assigned to DL (n = 848), VLM (n = 841), or VLH (n = 843), 2423 (95.7%) were included in a modified intention-to-treat analysis. Both video laryngoscopy modalities were superior to DL regarding first-pass success (VLM: 82.9%, VLH: 87.6%, and DL: 78.2%; all $P < .001$). Unadjusted absolute risk differences for first-pass intubation success were 4.66 (95% CI, 4.45-4.78) percentage points for DL vs VLM, 9.34 (95% CI, 9.22-9.46) percentage points for DL vs VLH, and 4.68 (95% CI, 4.57-4.79)

(continued)

Key Points

Question What are the first-pass success rates for tracheal intubations using video laryngoscopy with a Macintosh blade (VLM) or video laryngoscopy with a hyperangulated blade (VLH) in the operating room compared with direct laryngoscopy (DL)?

Findings In this randomized clinical trial involving 2532 adult patients, first-pass success rates were significantly higher for VLM (82.9%) and VLH (87.6%) than for DL (78.2%).

Meaning The findings support the use of video laryngoscopy as a new standard of care for routine airway management.

+ Visual Abstract

+ Invited Commentary

+ Supplemental content

Author affiliations and article information are listed at the end of this article.

Abstract (continued)

percentage points for VLM vs VLH. VLM and VLH compared with DL had faster intubation success after a failed first attempt (mean [SD] time to positive capnography, 146.6 [103.6] and 147.5 [98.9] seconds vs 170.3 [100.4] seconds; *P* = .008). There were fewer complications of lip or dental injuries or blood on the blade for VLH compared with VLM and DL (10.9% [11 of 101] vs 23.2% [32 of 138] and 24.1% [42 of 174]).

CONCLUSIONS AND RELEVANCE This randomized clinical trial of DL vs VLM and VLH found that video laryngoscopy significantly improved first-pass success during intubation in the operating room compared with DL. The findings support the use of video laryngoscopy as a new standard of care for routine airway management.

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Introduction

Each year, more than 300 million patients undergo surgical procedures. Of those patients, an estimated 100 million receive tracheal intubation for airway management in the perioperative context.[1] Hypoxemia during intubation is a relevant complication during preoperative airway management.[2] During intubation, the anesthesiologist uses a laryngoscope to place the tracheal tube. Since the introduction of video laryngoscopes in 2001,[3] many studies have been performed to compare these camera-guided instruments with the conventional or direct method.

The laryngoscope blades regularly used are either a slightly curved Macintosh blade available for both direct laryngoscopy (DL) and video laryngoscopy devices or a hyperangulated blade, which can only be used with video laryngoscopes. Regardless of the type of laryngoscope, successful intubation at first attempt (first-pass success) has been established as the predominant quality measure.[4-7] Several studies have examined the universal use of video laryngoscopy in the operating room.[8-10] However, guidelines and systematic reviews vary in their recommendations and conclusions regarding the use of video laryngoscopy for routine airway management. Some experts advocate its use particularly in anticipated or known difficult airways, while others do not yet recommend a general switch from DL to video laryngoscopy for all patients due to insufficiently conclusive evidence and statistical heterogeneity.[11-16] This divergence of opinion highlights the need for trials that assess different video laryngoscopes under clinical conditions.

Recently, 4 trials set out to overcome these limitations. First, in 2 randomized clinical trials, Kriege et al[17,18] found that video laryngoscopy with a Macintosh blade (VLM) achieved higher first-pass success rates than DL in elective surgical cases and in patients with increased risk of aspiration. Second, Ruetzler et al[19] demonstrated superiority of video laryngoscopy with a hyperangulated blade (VLH) in a single-center cluster randomized trial. Köhl et al[20] compared VLH with VLM in patients with an anticipated difficult airway. All of these trials were limited to only 1 respective brand and model of video laryngoscopes. Currently, a comprehensive trial of video laryngoscopes under clinical conditions in the operating room is needed to fully evaluate their effectiveness.

To address the substantial lack of evidence, we implemented the pragmatic[21-23] multicenter Conventional vs Video-Assisted Laryngoscopy for Perioperative Endotracheal Intubations (COVALENT) randomized clinical trial incorporating both VLM and VLH with no restrictions on model or brand. We primarily hypothesized that both video laryngoscopy modalities are noninferior to DL. On the condition that this assumption held true, we further hypothesized that VLM and VLH are indeed superior to DL regarding first-pass success rate. Thus, the COVALENT trial aimed to determine whether video laryngoscopy—regardless of blade geometry or manufacturer—provides superior first-pass success compared with DL during routine tracheal intubations.

Methods

Trial Design and Oversight

Between March 28, 2022, and February 17, 2025, we conducted the multicenter, 3-armed parallel, COVALENT randomized clinical trial at 6 study sites across 2 countries (Germany and Austria). The trial sites included 5 university hospitals and 1 intermediate-level hospital center. Due to the high number of eligible adult patients, recruitment was carried out by sampling consecutive patients with a capacity cap, depending on the availability of study personnel on each given day at each site (eMethods in Supplement 1). Patients were screened for eligibility and included in the trial after providing written informed consent. The independent ethics review boards for each trial site approved the protocol, which was published previously.[24] The trial protocol and statistical analysis plan are available in Supplement 2. We followed the Consolidated Standards of Reporting Trials (CONSORT) reporting guideline.

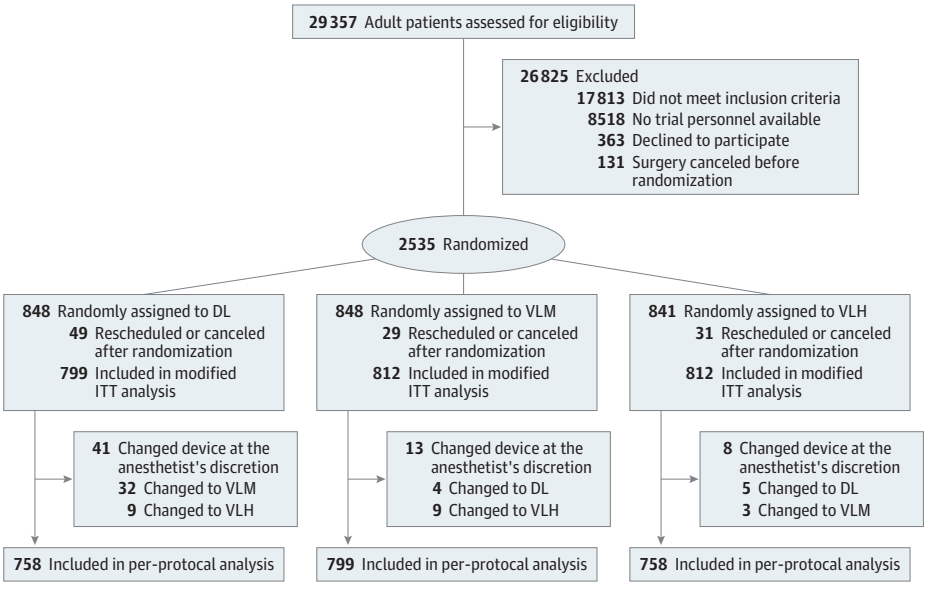
Included patients were randomly assigned in a 1:1:1 ratio to 1 of 3 arms: DL (control group), VLM, or VLH (**Figure 1**). Given the pragmatic nature of the trial, neither brands nor models of the laryngoscopes used in the interventions were specified in the trial protocol but were determined by local availability. The following video laryngoscopes were used: Storz C-MAC (Karl Storz SE & Co KG), GlideScope (Verathon Inc), McGrath MAC (Medtronic Ltd), and HEINE visionPRO (HEINE Optotechnik GmbH & Co KG). These laryngoscope manufacturers were not involved in the trial.

An interim analysis focusing on the feasibility of trial procedures (sufficient potential recruitment volumes, practicability of the application-based data collection interface, seamless integration into routine clinical workflows to support the pragmatic nature of the trial, and any safety concerns raised by involved parties) was planned after randomization of 200 patients. The information obtained for this interim observation was purely qualitative. No analyses regarding outcome effects were planned.

Patients

Adult patients were eligible if they were scheduled for elective surgery with the need for tracheal intubation. Exclusion criteria were pregnancy or the need for primary fiberoptic intubation, as judged by the examining anesthetist. Moreover, the anesthesiologist in charge of the intervention was allowed to put forth medical concerns barring the arbitrary use of 1 airway device over the other. For

Figure 1. CONSORT Flowchart of Study Participants



DL indicates direct laryngoscopy; ITT, intention to treat; VLH, video laryngoscopy with a hyperangulated blade; and VLM, video laryngoscopy with a Macintosh blade.

ethical reasons, medical concern was an exclusion criterion when announced before randomization; otherwise, a possible switch to a different study arm was recorded as such. During the initial phase of the trial, patients scheduled for bariatric or cardiac surgery were also excluded from the trial due to local standards. These exclusion criteria were lifted in an amendment to the trial protocol (May 4, 2023).

Trial Procedures

Randomization

Randomization was performed using permuted blocks by a web-based randomization algorithm integrated in the electronic case report form (eCRF) and stratified according to study site and Mallampati score class. Randomization determined the type of the laryngoscope and the geometry of the blade but not the manufacturer. Allocation was concealed by the electronic randomization system. Clinicians and research personnel were not blinded to the trial intervention. Allocation was nonverbally communicated to the clinicians shortly before anesthesia induction at the site of the intervention by showing them the randomization result on a handheld tablet computer. Thus, patients were blinded to trial group assignments.

All further proceedings in airway management followed local standards and were at the responsible anesthesiologist's discretion. Metal or plastic blades intended for single use or reprocessing were permissible. Primary use of a bougie or stylet was not restricted but recorded in the eCRF. Each tracheal intubation within the trial was observed and documented on site and in real time by previously trained study observers (medical students, study nurses, and physicians). Most outcomes were recorded using the Work Observation Method By Activity Timing (WOMBAT) software, version 3.0 (Macquarie University).[25] All other parameters were obtained from the patients' clinical records. All study data were centrally stored in OpenClinica, version 3.16 (OpenClinica LLC).

Anesthesia Clinicians

Intubations were performed only by anesthesiologists regularly assigned to the investigated patients. None of the anesthesiologists had received additional trial-specific training. All anesthesiologists stated that they had previously performed at least 25 intubations with video laryngoscopes.

End Points

The primary outcome was the rate of first-pass success (ie, successful intubation at first attempt). An attempt was considered to have failed if either the laryngoscope or the tracheal tube was retrieved from the patient's mouth.

The secondary outcomes included time to glottic view, as announced by the operator, and time to positive capnography (ie, successful intubation). For both end points, the clock was started when the laryngoscope blade first passed the patient's upper incisors. Other secondary outcomes were the occurrence of gastral or esophageal regurgitation, need for bronchoscopy as part of the intubation process, occurrence of audible click noises caused by the laryngoscope blade hitting the patient's teeth or actual dental injury, presence of blood on the laryngoscope blade after the intervention, any new lip bruising or swelling, need for intermittent ventilation between intubation attempts (at the anesthesiologist's discretion), switch in anesthesia clinician during the procedure, desaturation below 90%, and the anesthesiologist's self-assessment of the ease of intubation rated on a numeric rating scale (total score range: 0-10, with higher scores indicating easier intubation). Hoarseness, sore throat, and coughing 2 hours after anesthesia administration were also recorded. These predefined outcomes were part of a core outcome set proposed in 2017.[26]

Statistical Analysis

In a predefined hierarchical testing procedure, both VLM and VLH were initially tested for noninferiority against DL. The overall type I error rate in the primary analysis of the primary end point was set to .05; thus, both noninferiority tests were conducted at the local significance level of

P = .025 (1-sided *z* test with unpooled variance). Noninferiority was defined as equal or up to 5 percentage points lower than the first-pass success rate. This margin was in line with other works from the field (10% and 4.5%, respectively),[27,28] balancing the desire for patient safety on one hand and reasonably feasible sample sizes on the other. Only in the case that both interventions proved noninferior, ensuing tests for superiority were permissible (2-sided *z* test with unpooled variance). Because we applied the principle of fixed sequence hierarchical testing, we conducted these tests at the local significance level of *P* < .05 to meet the familywise error rate of .05. Following the same hierarchical testing strategy, we eventually tested for superiority between the 2 video laryngoscopy modalities. We assumed a 90% first-pass success rate in the control group (DL). A dropout rate of 10% was also anticipated. Targeting 90% statistical power, 842 patients had to be recruited in each arm, totaling 2532.

All data analysis was performed from April 1, 2025, to May 13, 2026, using R, version 4.4.2 (R Project for Statistical Computing[29]). Continuous data were reported as mean (SD). Kruskal-Wallis rank sum tests were performed for comparisons of continuous outcomes between the 3 arms. Fisher exact test was used for comparisons between groups of categorical outcomes. In the analysis of secondary outcomes, multiple testing was accounted for by Holm correction where appropriate. Secondary outcomes were generally tested assuming superiority of the video laryngoscopy devices. Data visualizations were plotted using the ggplot2 package in R.[30] Unless denoted otherwise, all analyses were in accordance with a modified intention-to-treat (mITT) approach (ie, all patients who received any intervention were analyzed according to their randomized group).[31] Sensitivity analyses were performed per protocol and included all patients in their assigned study arms but excluded patients who did not receive any intervention or crossed over to a different study arm. Crossover was the only major protocol deviation criterion in this regard.

Results

Patient Characteristics

Of the 2532 patients randomly assigned to DL (n = 848), VLM (n = 841), or VLH (n = 843), 2423 (95.7%) received treatment under an mITT regimen. These patients consisted of 1106 females (43.6%), 1425 males (56.3%), and 1 gender-diverse individual (<1.0%), with a mean (SD) age of 59.7 (15.4) years. A planned interim analysis after 200 randomized patients at the primary study center in Würzburg, Germany, revealed no feasibility issues; subsequently, more centers were added gradually. The main reason for noninclusion was planned general anesthesia using supraglottic airway devices or regional anesthesia. Patients whose surgical procedures were delayed or rescheduled on short notice were not always observed at that later point in time owing to limited staff resources. Details on recruitment are provided in Figure 1. Baseline characteristics of all randomized patients are provided in **Table 1**. Some baseline parameters were obtained from the patient's medical record, leading to some missing data (eg, Mallampati scores) due to incomplete records.

Primary End Point and Crossover Between Groups

First-pass success rates of the laryngoscopy modalities are reported in **Table 2**. Among the devices, VLH had the highest first-pass success rate at 87.6% (n = 711 patients), followed by VLM at 82.9% (n = 673 patients) and DL at 78.2% (n = 625 patients). Both VLM and VLH were noninferior to the DL control group, per the 1-sided *z* test (VLM vs DL: *z* = 2.36, *P* = .009; VLH vs DL: *z* = 4.98, *P* < .001). After significant noninferiority was shown, we tested for superiority following the predefined hierarchical testing procedure. In 2-sided *z* tests, VLM and VLH were significantly more effective in facilitating first-pass success than the DL (VLM vs DL: *z* = 2.36, *P* = .02; VLH vs DL: *z* = 4.98, *P* < .001). VLH was in turn superior to VLM (*z* = 2.66; *P* = .008). Unadjusted absolute risk differences for a successful first attempt were 4.66 (95% CI, 4.45-4.78) percentage points for DL vs VLM, 9.34 (95% CI, 9.22-9.46) percentage points for DL vs VLH, and 4.68 (95% CI, 4.57-4.79) percentage points for VLM vs VLH. Relative risks (RRs) for successful first-attempt intubation were significantly

Table 1. Characteristics of Study Population

Characteristic	Patients, No./total No. (%)			
	Overall	DL (n = 848)	VLM (n = 841)	VLH (n = 843)
Sex or gender				
Male	1425/2532 (56.3)	482/848 (56.8)	473/841 (56.2)	470/843 (55.8)
Female	1106/2532 (43.7)	366/848 (43.2)	367/841 (43.6)	373/843 (44.2)
Diverse	1/2532 (0.04)	0/848 (0)	1/841 (0.1)	0/843 (0)
Age, mean (SD), y	59.7 (15.4)	59.0 (15.8)	59.6 (15.5)	59.8 (15.5)
Surgical discipline				
Abdominal surgery	847/2527 (33.5)	282/848 (33.3)	267/839 (31.8)	298/840 (35.5)
Trauma surgery	477/2527 (18.9)	164/848 (19.3)	155/839 (18.5)	158/840 (18.8)
Urology	274/2527 (10.8)	95/848 (11.2)	93/839 (11.1)	86/840 (10.2)
Gynecology	157/2527 (6.2)	58/848 (6.8)	55/839 (6.6)	44/840 (5.2)
ENT surgery	209/2527 (8.3)	63/848 (7.4)	74/839 (8.8)	72/840 (8.6)
Thoracic surgery	49/2527 (1.9)	18/848 (2.1)	18/839 (2.1)	13/840 (1.5)
Ophthalmology	2/2527 (0.08)	1/848 (0.1)	1/839 (0.1)	0/840 (0)
Neurosurgery	98/2527 (3.9)	33/848 (3.9)	29/839 (3.5)	36/840 (4.3)
Cardiac surgery	70/2527 (2.8)	25/848 (2.9)	24/839 (2.9)	21/840 (2.5)
Other[a]	344/2527 (13.6)	109/848 (12.9)	123/839 (14.7)	112/840 (13.3)
BMI, mean (SD)	27.5 (6.2)	27.4 (5.9)	27.6 (6.7)	27.4 (6.1)
ASA physical status class				
I	259/2526 (10.3)	93/847 (11.0)	87/839 (10.4)	79/840 (9.4)
II	1248/2526 (49.4)	399/847 (47.1)	434/839 (51.7)	415/840 (49.4)
III	936/2526 (37.1)	326/847 (38.5)	289/839 (34.4)	321/840 (38.2)
IV	83/2526 (3.3)	29/847 (3.4)	29/839 (3.5)	25/840 (3.0)
History of OSA	210/2494 (8.4)	73/841 (8.7)	66/828 (8.0)	71/825 (8.6)
Upper-lip bite test				
1	1315/2339 (56.2)	422/777 (54.3)	447/781 (57.2)	446/781 (57.1)
2	820/2339 (35.1)	282/777 (36.3)	267/781 (34.2)	271/781 (34.7)
3	204/2339 (8.7)	73/777 (9.4)	67/781 (8.6)	64/781 (8.2)
Mallampati score				
1	825/2521 (32.7)	288/844 (34.1)	272/838 (32.5)	265/839 (31.6)
2	1218/2521 (48.1)	397/844 (47.0)	406/838 (48.4)	415/839 (49.5)
3	322/2521 (12.8)	113/844 (13.4)	108/838 (12.9)	101/839 (12.0)
4	156/2521 (6.2)	46/844 (5.5)	52/838 (6.2)	58/839 (6.9)
Thyromental distance, mean (SD), cm	8.4 (1.6)	8.4 (1.6)	8.4 (1.6)	8.4 (1.6)
Rapid sequence induction	272/2424 (11.2)	90/800 (11.3)	80/812 (9.9)	102/812 (12.6)
Baseline oxygen saturation, mean (SD), %	96.8 (8.5)	96.7 (8.8)	96.3 (10.5)	97.2 (5.5)
Sufficient preoxygenation	2192/2306 (95.1)	728/768 (94.8)	730/772 (94.6)	734/766 (95.8)
Train of Four count = 0	637/1088 (58.5)	199/351 (56.7)	225/366 (61.5)	213/371 (57.4)
Use of BURP maneuver	629/2421 (26.0)	325/799 (40.7)	195/811 (24.0)	109/811 (13.4)
Use of a stylet	1643/2421 (67.9)	279/799 (34.9)	588/811 (72.5)	776/811 (95.7)
Use of a bougie	3/2420 (0.1)	0/799 (0)	2/810 (0.2)	1/811 (0.1)
Use of other aids	7/2420 (0.3)	2/799 (0.3)	4/810 (0.5)	1/811 (0.1)
Video laryngoscope used				
GlideScope	135/1594 (8.5)	NA	8/796 (1.0)	127/798 (15.9)
McGrath MAC	262/1594 (16.4)	NA	194/796 (24.4)	68/798 (8.5)
Storz C-MAC	991/1594 (62.2)	NA	491/796 (61.7)	500/798 (62.7)
HEINE visionPRO	206/1594 (12.9)	NA	103/796 (12.9)	103/798 (12.9)
Experience of anesthesiologist				
≤5 y	1400/2390 (58.6)	475/791 (60.1)	462/801 (57.7)	463/798 (58.0)
>5 y	990/2390 (41.4)	316/791 (39.9)	339/801 (42.3)	335/798 (42.0)

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); BURP, backward upward rightward pressure; DL, direct laryngoscopy; ENT, ear, nose, and throat; NA, not applicable; OSA, obstructive sleep apnea; VLH, video laryngoscopy with hyperangulated blade; VLM, video laryngoscopy with Macintosh blade.

[a] Other surgical discipline includes those outside of the listed specialties or a combination of 2 or more specialties.

higher for both VLM and VLH over DL (VLM vs DL: RR, 1.06 [95% CI, 1.01-1.11]; VLH vs DL: RR, 1.12 [95% CI, 1.07-1.17]) and for VLM over VLH (RR, 1.06 [95% CI, 1.01-1.10]) (eTable 2 in Supplement 1). Unadjusted RRs for various subgroups did not suggest any subgroup-specific effects (eFigure in Supplement 1). First-pass success rates varied across study sites (Würzburg: 77.5% for DL, 77.9% for VLM, and 83.9% for VLH; Bonn: 74.0% for DL, 89.6% for VLM, and 89.1% for VLH); complete data are provided in eTable 6 in Supplement 1. However, study site did not affect the first-pass success rate in a generalized linear model (eTable 3 in Supplement 1).

Some patients were not (initially) treated with the devices to which they were randomly assigned. Use of another device was permissible at the discretion of the anesthesiologist responsible for each respective patient. Reassignments of this kind occurred in all 3 groups (DL: 41 patients; VLM: 13 patients; VLH: 8 patients) (Figure 1). All findings regarding the primary end point held true in a per-protocol sensitivity analysis (eTable 1 in Supplement 1). If the first intubation attempt failed, laryngoscopy devices were switched in several more cases. Details are shown in eTable 8 in Supplement 1.

Secondary End Points

A comprehensive overview of secondary end points is provided in **Table 3**. VLM and VLH compared with DL resulted in comparably fast mean (SD) time to glottic visualization (16.7 [33.2] seconds and 14.1 [36.3] seconds vs 20.5 [41.2] seconds; $P = .04$), while ensuring equally short times to first positive capnography in the overall study cohort. Moreover, VLM and VLH compared with DL were associated with decreased necessity for intermittent ventilation in patients (35 of 809 [4.3%] and 33 of 810 [4.1%] vs 94 of 795 [11.8%]; $P < .001$) or switch in anesthesia clinician (16 of 812 [2.0%] and 19 of 812 [2.3%] vs 38 of 799 [4.8%]; $P = .02$). Self-reported mean (SD) rating of ease of intubation (on a 1-10 numeric rating scale) was, in turn, higher with both VLM and VLH than with DL (8.1 [2.2] and 8.3 [2.0] vs 7.3 [3.0]; $P < .001$).

When the first intubation attempt failed (n = 414), mean (SD) time to glottic view was prolonged for all 3 modalities. However, VLH facilitated glottic view significantly faster than VLM or DL (25.4 [50.8] seconds vs 42.7 [66.6] or 50.7 [75.0] seconds; $P < .001$) (**Figure 2**; eTable 4 in Supplement 1). Mean (SD) time to positive capnography was significantly shorter for both VLM and VLH vs DL (146.6 [103.6] and 147.5 [98.9] seconds vs 170.3 [100.4] seconds; $P = .008$) (Figure 2; eTable 4 in Supplement 1). Self-reported overall mean (SD) rating of ease of intubation was still significantly higher for both VLM and VLH than DL (5.8 [2.6] and 6.2 [2.8] vs 4.1 [3.4]; $P < .001$) when a first attempt failed. A composite of incidence injuries (including lip or dental injuries or blood on the blade) was significantly lower for VLH alone compared with VLM and DL (10.9% [n = 11 of 101] vs 23.2% [n = 32 of 138] and 24.1% [n = 42 of 174]) (eTable 7 in Supplement 1). Incidence of postoperative sore throat, hoarseness, or cough was recorded in 1441 of 2532 patients (56.9%). There were no relevant differences between groups (eTable 5 in Supplement 1). Over the entire course of the trial, no serious adverse events were recorded.

Stylet Use

Table 1 shows how use of a stylet (in any intubation attempt) varied markedly between study arms (VLM: 588 of 811 [72.5%]; VLH: 776 of 811 [95.7%]; DL: 279 of 799 [34.9%]). In a post hoc analysis, we found first-pass success rates among intubations that used a stylet during first attempt: 83.3% (109 of 130) for DL, 92.9% (392 of 422) for VLM, and 89.9% (605 of 680) for VLH.

Table 2. First-Pass Success Rates of Tracheal Intubations Using Different Laryngoscopes

	Patients, No. (%)			
First-pass success	DL	VLM	VLH	Total
Yes	625 (78.2)	673 (82.9)	711 (87.6)	2009 (82.9)
No	174 (21.8)	139 (17.1)	101 (12.4)	414 (17.1)
Total	799 (100)	812 (100)	812 (100)	2423 (100)

Discussion

The COVALENT trial found that use of video laryngoscopy resulted in significantly higher first-pass success compared with use of DL. The first-pass success rates observed in this trial (DL: 78.2%, VLM: 82.9%, VLH: 87.6%) align with or exceed those rates previously reported and confirm the effectiveness of video laryngoscopy in a clinical scenario.

To our knowledge, this trial improved on the generalizability of the evidence from previous meta-analyses[14] and preliminary randomized clinical trials[17-20] by including both Macintosh and hyperangulated blades and laryngoscopes from various manufacturers. As shown in eTable 6 in Supplement 1, first-pass success rates varied across study sites, reflecting differences in local experience, case mix, and implementation inherent in pragmatic multicenter trials. This trial was not designed to assess possible differences between video laryngoscope manufacturers. From the data at hand, there was no reason to assume marked differences, suggesting robustness and versatility of the technique. Numbers needed to treat were 21.5 (95% CI, 20.9-22.2) for VLM and 10.7 (95% CI, 10.6-10.8) for VLH.

After the initial intubation attempt failed, VLH facilitated more rapid glottic visualization and successful intubation while being rated as less difficult, which is associated with fewer procedural complications and less likelihood to cause harm to patients. This finding aligns with recent data on

Table 3. Secondary Outcomes During and After Tracheal Intubation

Characteristic	Patients, No./total No. (%)				Adjusted *P* value[a,b]
	Overall	DL (n = 799)	VLM (n = 812)	VLH (n = 812)	
Time to glottic view, mean (SD), s	17.1 (37.1)	20.5 (41.2)	16.7 (33.2)	14.1 (36.3)	.04
Time to first positive capnography, mean (SD), s	72.4 (63.5)	74.1 (71.8)	70.9 (59.4)	72.5 (58.9)	>.99
No. of intubation attempts					
1	2009/2423 (82.9)	625/799 (78.2)	673/812 (82.9)	711/812 (87.6)	NA
2	290/2423 (12.0)	116/799 (14.5)	102/812 (12.6)	72/812 (8.9)	
3	88/2423 (3.6)	39/799 (4.9)	29/812 (3.6)	20/812 (2.5)	
4	20/2423 (0.8)	9/799 (1.1)	4/812 (0.5)	7/812 (0.9)	
5	12/2423 (0.5)	8/799 (1.0)	3/812 (0.4)	1/812 (0.1)	
7	4/2423 (0.2)	2/799 (0.3)	1/812 (0.1)	1/812 (0.1)	
Cormack-Lehane grade					
1	1744/2361 (73.9)	453/771 (58.8)	589/789 (74.7)	702/801 (87.6)	NA
2	482/2361 (20.4)	222/771 (28.8)	169/789 (21.4)	91/801 (11.4)	
3	108/2361 (4.6)	76/771 (9.9)	26/789 (3.3)	6/801 (0.7)	
4	27/2361 (1.1)	20/771 (2.6)	5/789 (0.6)	2/801 (0.2)	
Regurgitations recorded	6/2421 (0.2)	3/797 (0.4)	3/812 (0.4)	0/812 (0)	>.99
Bronchoscopies needed	1/2423 (0.04)	0/799 (0)	0/812 (0)	1/812 (0.1)	>.99
Dental clicks or injuries	123/2421 (5.1)	35/799 (4.4)	37/812 (4.6)	51/810 (6.3)	>.99
Blood on laryngoscopy blade	90/2417 (3.7)	35/797 (4.4)	32/810 (4.0)	23/810 (2.8)	>.99
Bruised or swollen lip	54/2414 (2.2)	21/795 (2.6)	19/809 (2.3)	14/810 (1.7)	>.99
Intermittent ventilation necessary	162/2414 (6.7)	94/795 (11.8)	35/809 (4.3)	33/810 (4.1)	<.001
Switch in anesthesia clinician necessary	73/2423 (3.0)	38/799 (4.8)	16/812 (2.0)	19/812 (2.3)	.02
Desaturation below 90%	43/2420 (1.8)	15/798 (1.9)	14/810 (1.7)	14/812 (1.7)	>.99
Ease of intubation self-rating, mean (SD)	7.9 (2.5)	7.3 (3.0)	8.1 (2.2)	8.3 (2.0)	<.001

Abbreviations: DL, direct laryngoscopy; NA, not applicable; VLH, video laryngoscopy with hyperangulated blade; VLM, video laryngoscopy with Macintosh blade.

[a] One-way analysis of variance was used for comparisons of continuous variables, and Fisher exact test was used for categorical variables.

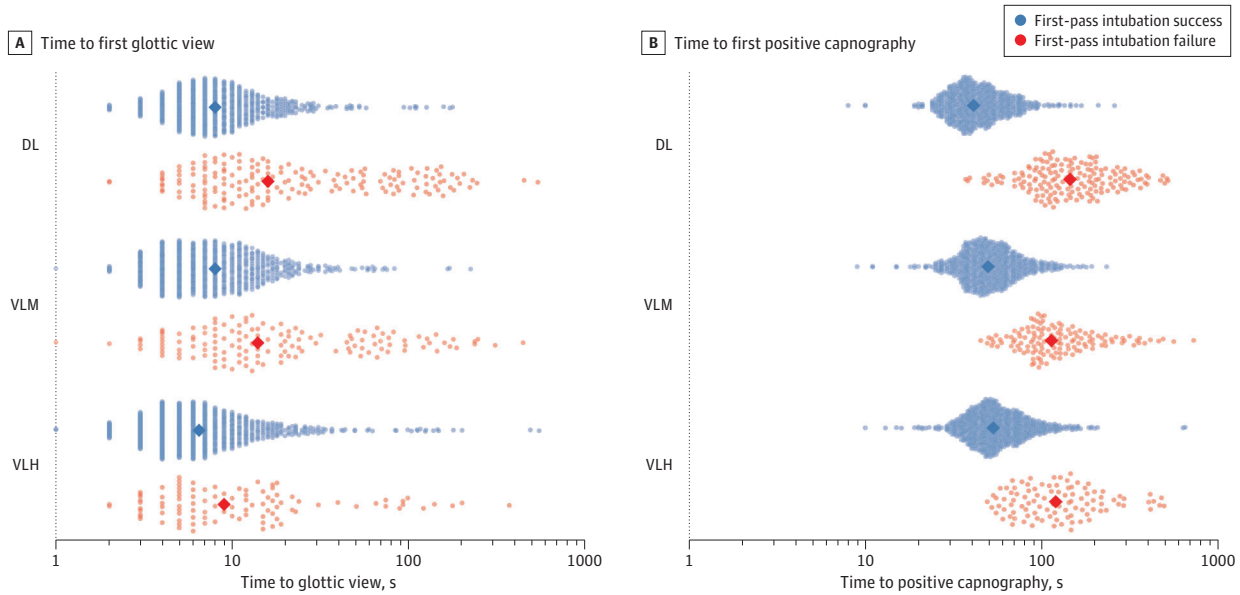
[b] Holm correction was used for multiple testing.

hyperangulated blades used in anticipated difficult airways.[20] The present trial extends this previous evidence to a broad and unselected perioperative patient population, including approximately 10% of patients with rapid sequence induction (Table 1). The superior performance of hyperangulated blades underscores their potential value beyond niche indications. The findings from this trial support recent recommendations advocating for the universal adoption of video laryngoscope as the first-line device in routine airway management.[32]

Limitations

Several study limitations merit consideration. First, clinicians and observers were not blinded to the group assignments, which may have introduced performance or detection bias. Second, the pragmatic design, while enhancing external validity, precluded detailed assessment of brand-specific effects. On the other hand, this pragmatic, device-agnostic design enhanced the applicability of our findings across diverse health care systems. Third, crossover from 1 study arm to another was disproportionately frequent in the control group. Given that crossover occurred only at the discretion of the responsible anesthesia clinician when they deemed the patient to be more unstable than anticipated, we supposed that the switch to an airway management strategy perceived as safer (ie, video laryngoscopy) led to the slightly higher exodus of patients from the DL group. Although we cannot rule out that this crossover introduced additional bias, primary outcome estimates were virtually identical in a per-protocol sensitivity analysis. Fourth, clinician experience varied markedly, even if we did not collect data on the number of intubations performed by each operator prior to the trial. However, previous studies have shown that little experience with video laryngoscopy is necessary to achieve sufficient success rates (as low as 20-29 intubations[33] or even only 12 intubations[34]). We are confident that our approach reflects typical clinical settings and strengthens the generalizability of the findings. Fifth, postoperative outcomes (hoarseness, cough, or sore throat) were only collected in 2 of the 6 sites, which translates to 56.9% of patients. Generalizability of these findings may therefore be limited. Lastly, parts of the differences in first-pass success may be influenced by the unevenly distributed use of a stylet between study arms. A post hoc analysis

Figure 2. Scatterplots of Secondary Outcome Parameters



Diamonds represent the median, and circles represent individual values of duration. DL indicates direct laryngoscopy; VLH, video laryngoscopy with a hyperangulated blade; and VLM, video laryngoscopy with a Macintosh blade.

suggested that use of a stylet during the first intubation attempt possibly helps improve first-pass success rates. This association has been shown in critically ill adults.[35]

Conclusions

Data from the COVALENT randomized clinical trial of DL vs VLM and VLH support the use of video laryngoscopy as the new standard of care for routine tracheal intubation in the operating room. Its use—particularly with hyperangulated blades—elevated first-pass success, likely reduced complications, and improved overall procedural efficiency.

ARTICLE INFORMATION

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Corresponding Author: Benedikt Schmid, MD, PhD, Department of Anaesthesiology, Intensive Care, Emergency and Pain Medicine, University Hospital Würzburg, Oberdürrbacher Strasse 6, 97080 Würzburg, Germany (schmid_b@ukw.de).

Author Affiliations: Department of Anaesthesiology, Intensive Care, Emergency and Pain Medicine, University Hospital Würzburg, Würzburg, Germany (Schmid, Helmer, Fischer, Kranke, Meybohm); Department of Anaesthesiology, Medical Faculty, RWTH Aachen University, Aachen, Germany (Grüßer, Müller); Department of Anaesthesiology and Intensive Care Medicine, University Hospital Bonn, Bonn, Germany (Wittmann, Delis, Dinc Dogan, Massoth); Department of Anaesthesiology and Intensive Care, Medical Faculty, University of Leipzig, Leipzig, Germany (Werdehausen); Department of Anaesthesiology, Medical Faculty Heidelberg, Heidelberg University, Heidelberg, Germany (Neuhaus); Department of Anaesthesiology and Intensive Care Medicine, St John of God Hospital, Paracelsus Medical University, Salzburg, Austria (Paal, Claassen).

Author Contributions: Dr Schmid 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.

Concept and design: Schmid, Müller, Kranke, Meybohm.

Acquisition, analysis, or interpretation of data: Schmid, Grüßer, Müller, Wittmann, Delis, Dinc Dogan, Werdehausen, Neuhaus, Paal, Claassen, Helmer, Fischer, Meybohm, Massoth.

Drafting of the manuscript: Schmid, Neuhaus, Kranke, Meybohm, Massoth.

Critical review of the manuscript for important intellectual content: Grüßer, Müller, Wittmann, Delis, Dinc Dogan, Werdehausen, Neuhaus, Paal, Claassen, Helmer, Fischer, Kranke, Meybohm, Massoth.

Statistical analysis: Schmid, Fischer, Kranke.

Obtained funding: Schmid, Kranke.

Administrative, technical, or material support: Grüßer, Müller, Wittmann, Dinc Dogan, Neuhaus, Paal, Claassen, Meybohm.

Supervision: Schmid, Wittmann, Werdehausen, Paal, Kranke, Meybohm, Massoth.

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SUPPLEMENT 1.

eMethods.

eFigure. Analysis of Predefined Subgroups on the Primary Outcome

eTable 1. Percentages of First-Pass Success Across Study Arms After Per-Protocol Analysis

eTable 2. Relative Risks of First-Pass Intubation