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Video Laryngoscopy vs Direct Laryngoscopy for Endotracheal Intubation in the Operating Room
A Cluster Randomized Clinical Trial

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IMPORTANCE Endotracheal tubes are typically inserted in the operating room using direct laryngoscopy. Video laryngoscopy has been reported to improve airway visualization; however, whether improved visualization reduces intubation attempts in surgical patients is unclear.

OBJECTIVE To determine whether the number of intubation attempts per surgical procedure is lower when initial laryngoscopy is performed using video laryngoscopy or direct laryngoscopy.

DESIGN, SETTING, AND PARTICIPANTS Cluster randomized multiple crossover clinical trial conducted at a single US academic hospital. Patients were adults aged 18 years or older having elective or emergent cardiac, thoracic, or vascular surgical procedures who required single-lumen endotracheal intubation for general anesthesia. Patients were enrolled from March 30, 2021, to December 31, 2022. Data analysis was based on intention to treat.

INTERVENTIONS Two sets of 11 operating rooms were randomized on a 1-week basis to perform hyperangulated video laryngoscopy or direct laryngoscopy for the initial intubation attempt.

MAIN OUTCOMES AND MEASURES The primary outcome was the number of operating room intubation attempts per surgical procedure. Secondary outcomes were intubation failure, defined as the responsible clinician switching to an alternative laryngoscopy device for any reason at any time, or by more than 3 intubation attempts, and a composite of airway and dental injuries.

RESULTS Among 8429 surgical procedures in 7736 patients, the median patient age was 66 (IQR, 56-73) years, 35% (2950) were women, and 85% (7135) had elective surgical procedures. More than 1 intubation attempt was required in 77 of 4413 surgical procedures (1.7%) randomized to receive video laryngoscopy vs 306 of 4016 surgical procedures (7.6%) randomized to receive direct laryngoscopy, with an estimated proportional odds ratio for the number of intubation attempts of 0.20 (95% CI, 0.14-0.28; $P < .001$). Intubation failure occurred in 12 of 4413 surgical procedures (0.27%) using video laryngoscopy vs 161 of 4016 surgical procedures (4.0%) using direct laryngoscopy (relative risk, 0.06; 95% CI, 0.03-0.14; $P < .001$) with an unadjusted absolute risk difference of −3.7% (95% CI, −4.4% to −3.2%). Airway and dental injuries did not differ significantly between video laryngoscopy (41 injuries [0.93%]) vs direct laryngoscopy (42 injuries [1.1%]).

CONCLUSION AND RELEVANCE In this study among adults having surgical procedures who required single-lumen endotracheal intubation for general anesthesia, hyperangulated video laryngoscopy decreased the number of attempts needed to achieve endotracheal intubation compared with direct laryngoscopy at a single academic medical center in the US. Results suggest that video laryngoscopy may be a preferable approach for intubating patients undergoing surgical procedures.

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Supplemental content

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Securing airways is a priority for anesthesiologists, surgeons, critical care, and emergency medicine physicians. Although tracheal intubation is nearly always ultimately successful, approximately 8% of patients require multiple intubation attempts.[1] Repeated intubation attempts may result in respiratory and hemodynamic complications, including hypoxemia, regurgitation, aspiration, airway trauma, and even cardiac arrest.[2-9]

It can be difficult to visualize the glottis and vocal cords with direct laryngoscopy although passing a tube is usually easy when structures are visible. Video laryngoscopy, which was introduced in 2001, may improve visualization of airways but is sometimes associated with prolonged and failed intubation attempts.[10-13] In a trial of 371 patients in the intensive care unit, for example, video laryngoscopy not only failed to improve first-attempt intubation success but also was associated with more frequent severe life-threatening complications, including death, cardiac arrest, severe cardiovascular collapse, and severe hypoxemia (17 of 179 patients [9.5%]), than with direct laryngoscopy (5 of 179 patients [2.8%]).[13] In contrast, other trials have reported improved glottis visualization and better first-pass success with video laryngoscopy.[14-17] The extent to which video laryngoscopy might facilitate intubation in patients undergoing surgical procedures during routine clinical practice remains unclear.

This trial therefore compared video laryngoscopy with direct laryngoscopy on the number of intubation attempts required to correctly position a single-lumen tube. Specifically, the trial tested the primary hypothesis that fewer intubation attempts would be required when initial laryngoscopy was performed with a video laryngoscope rather than a direct laryngoscope in patients being intubated in the operating room for cardiac, thoracic, or vascular surgical procedures. Secondarily, the trial tested the hypotheses that video laryngoscopy would reduce the number of intubation failures and a composite of airway and dental injuries.

Key Points

Question What is the effect of initial video laryngoscopy or direct laryngoscopy on number of intubation attempts in patients being intubated for cardiac, thoracic, or vascular surgical procedures?

Findings In this cluster randomized trial including 8429 surgical procedures in 7736 patients, more than 1 intubation attempt was required in 1.7% of patients randomized to receive video laryngoscopy. More than 1 intubation attempt was required in 7.6% of patients randomized to receive direct laryngoscopy.

Meaning In this study of adults having elective or emergent surgical procedures requiring single-lumen endotracheal intubation for general anesthesia, hyperangulated video laryngoscopy increased initial intubation attempt success and reduced the number of intubation attempts compared with direct laryngoscopy.

Methods

Study Design and Oversight

This cluster randomized multiple crossover clinical trial was conducted at a single US academic hospital. The Cleveland Clinic institutional review board approved the study. Individual consent was waived because the intervention was low risk, participants were likely to benefit, and because cluster trials are impractical with individual consent. Adults aged 18 years or older scheduled for elective or emergent cardiac, thoracic, or vascular surgical procedures who required single-lumen endotracheal intubation for general anesthesia were enrolled. Race and ethnicity characteristics were not recorded as they were deemed to have no bearing on number of intubation attempts. Patients were enrolled from March 30, 2021, to December 31, 2022. Patients who had clinical indications for awake fiberoptic intubation, were already intubated, and those in whom clinicians refused to participate in this trial were excluded. An independent committee oversaw the conduct of this trial and adverse events while remaining masked to the primary outcome. Initially 3 interim analyses at 25%, 50%, and 75% of maximum expected enrollment were planned. The trial could have been stopped for efficacy after the first interim analysis (at 25% of enrollment) but was continued to the second to improve precision in the treatment effect estimate. The trial was subsequently stopped at the second interim analysis (50% of expected enrollment).

Participating clinicians watched an instructional video about proper use of the hyperangulated trial video laryngoscope, and each had the opportunity to train on manikins as needed. Furthermore, all faculty attending anesthesiologists and nurse anesthetists (excluding both rotating nurse anesthetists and anesthesia residents) used the hyperangulated video laryngoscope for each intubation procedure for 2 weeks before trial enrollment began.

Reporting is consistent with Consolidated Standards of Reporting Trials (CONSORT) reporting guideline recommendations. The full protocol, statistical analysis plan, and change log are presented in Supplement 1.

Randomization

A cluster randomized multiple crossover design was used for this trial. The cardiac surgical suite was divided into 2 sets of 11 operating rooms. Each set was treated as a unit and randomized to receive video or direct laryngoscopy in 1-week blocks, always with 1 set randomized to each approach. For analysis, each operating room within a set was considered a separate cluster. Randomization, 1:1 and unstratified, was based on computer-generated codes maintained in a web-based system that investigators accessed a day before each new treatment block began. Randomizations were communicated on a weekly basis to clinicians verbally and by information posters attached to the anesthesia machines.

Protocol

Clinicians were free to use any type of general anesthesia and to provide supplemental regional anesthesia. Fluid management, type and dose of anesthetic medications, and postoperative analgesia were also per clinical preference.

Patients were positioned supine on the operating table with the head elevated and oxygenated with 100% oxygen until the

fraction of expired oxygen exceeded 80%. General anesthesia was induced, usually with a combination of lidocaine 1 mg/kg, propofol 1 to 3 mg/kg or etomidate 0.2 to 0.3 mg/kg, fentanyl 1 to 3 µg/kg, and succinylcholine 1.5 mg/kg or rocuronium 1.0 mg/kg. During manual bag-mask ventilation, an oral or nasal airway was used if clinically indicated. Patients were intubated approximately 3 minutes after administration of a neuromuscular blocking medication.

Patients were randomized to receive laryngoscopy performed with either video laryngoscope (GlideScope; Verathon Inc) with an appropriately sized hyperangulated blade, usually size 3 or 4, or direct laryngoscopy with an appropriately sized Macintosh blade, usually size 3 or 4. Intubation was attempted with an appropriately sized single-lumen endotracheal tube, usually size 7.5 to 8 mm. In patients randomized to receive direct laryngoscopy, stylets were used per clinical preference. In patients randomized to receive video laryngoscopy, endotracheal tubes were equipped with stylets (GlideRite; Verathon Inc).[18] Minor external airway manipulations such as the backward, upward, rightward, pressure applied to the larynx maneuver, head elevation, and pressure applied to the cricoid cartilage were allowed to improve visualization.

The initial intubation attempt was deemed to have failed if it did not result in successful endotracheal intubation, with or without an attempt to pass the tube. Up to 3 attempts with the initial laryngoscopy were allowed, and clinicians were permitted to switch to any alternative airway device after the initial attempt, if clinically indicated. The initial intubation was usually performed by a resident or nurse anesthetist. Subsequent attempts were undertaken by the same clinician or the attending anesthesiologist. Once the trachea was intubated, the endotracheal tube was connected to the anesthesia circuit and general anesthesia was maintained as clinically indicated. After surgical procedures, patients were transferred to a postanesthesia or intensive care unit.

Outcomes

The primary outcome was number of intubation attempts for a given surgical procedure. Per clinical routine, an initial attempt was defined by insertion of a laryngoscope blade and/or endotracheal tube into a patient's mouth, as recorded in the electronic medical record. Subsequent attempts were defined by reinsertion of an endotracheal tube or insertion of the same or a new laryngoscope blade.

Secondary outcomes were intubation failure and a composite of airway or dental injuries: intubation failure was defined by either the responsible clinician switching to an alternative laryngoscopy device for any reason at any time or by more than 3 intubation attempts.

Airway injury was defined as any bleeding or apparent injury to the lips, mouth, pharynx, vocal cords, or other airway structures as noted and recorded by the anesthesia team. Dental injury was defined as an injury to the teeth as recorded by the anesthesia team.

Data were exclusively obtained from electronic anesthesia and hospital records including preoperative airway characteristics, difficulties encountered during anesthetic induction, and anesthetic management. Type of surgical procedure was characterized from *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10)* codes using Agency for Healthcare Research and Quality Clinical Classifications Software.[19] The training level of the clinician who made the initial and subsequent intubation attempts was also captured.

Statistical Analysis

Our modified intention-to-treat principle analysis included all randomized patients who had attempted video or direct laryngoscopy. However, for primary analyses some cases were excluded for various reasons specified in eTable 1 in Supplement 2. Assumptions of statistical tests were assessed using graphic and statistical methods. All outcomes were measured and analyzed at the individual surgical procedure level, with appropriate incorporation for within-cluster correlations and correlations within surgical procedures, as feasible.

Adjustments for potential confounding due to variables in **Table 1** were conducted using inverse probability of treatment weighting based on propensity scores with stabilized weights[20] with simultaneous use of propensity score calibration[21] to impute propensity scores for missing weight, body mass index (calculated as weight in kilograms divided by height in meters squared), and modified Mallampati scores (visible structures: I, soft palate, entire uvula, fauces, pillars; II, soft palate, majority of uvula, fauces; III, soft palate, base of uvula; and IV, only hard palate).

Balance of randomized groups on baseline characteristics was assessed using absolute standardized difference, defined as the absolute difference in means, mean ranks, or proportions divided by the pooled SD, both with and without weighting baseline variables. Baseline variables with absolute standardized difference greater than 0.1 were defined as imbalanced.

Primary Outcome

The effect of video vs direct laryngoscopy on the number of intubation attempts was assessed using a proportional odds cumulative logit generalized estimating equation model[22] considering the outcome to be ordinal, and adjusting for confounding by applying stabilized inverse probability of treatment weighting.[20] Fixed effects for treatment, period (as a continuous number from 1 to number of periods), and operating room were included, with adjustment for within-patient correlation using an independence generalized estimating equation working correlation matrix. The proportional odds assumption was assessed using the score test and found to hold sufficiently well.

Multiple sensitivity analyses to assess the effects of COVID-19 precautions used by some clinicians, staff refusals to follow the randomization for various reasons, history of previous difficult intubation, and a technical error in the randomization during 3 weeks of the study were conducted. Treatment effect heterogeneity was also assessed across levels of selected baseline variables on the primary outcome.

Table 1. Patient and Procedure Characteristics (N = 8429)

Characteristic	Unadjusted			Adjusted[a]		
	Video (n = 4413)	Direct (n = 4016)	ASD[b]	Video (n = 4419)	Direct (n = 4005)	ASD[b]
Age, mean (SD), y	63 (13)	63 (14)	0.017	63 (13)	63 (14)	0.000
Height, mean (SD), cm	173 (10)	173 (10)	0.013	173 (10)	173 (10)	0.003
Weight, mean (SD), kg	86 (21) [4412]	84 (20) [4015]	0.124	85 (21)	85 (20)	0.016
BMI, mean (SD)	29 (6.5) [4412]	28 (6.0) [4015]	0.130	28 (6.3)	28 (6.1)	0.019
Sex, No. (%)						
Male	2880 (65)	2599 (65)	0.011	2870 (35)	2615 (65)	0.007
Female	1533 (35)	1417 (35)		1549 (35)	1390 (35)	
Admission category, No. (%)						
Elective	3711 (84)	3424 (85)	0.032	3744 (85)	3392 (85)	0.001
Emergency	702 (16)	592 (15)		675 (15)	613 (15)	
Surgical procedure type, No. (%)						
Cardiac	3317 (75)	2934 (73)	0.051	3279 (74)	2977 (74)	0.008
Vascular	559 (13)	560 (14)		581 (13)	530 (13)	
Other	474 (11)	453 (11)		489 (11)	436 (11)	
Thoracic	63 (1.4)	69 (1.7)		70 (1.6)	62 (1.5)	
Level of first intubation clinician, No. (%)[c]						
CRNA	1672 (38)	1611 (40)	0.070	1724 (40)	1558 (39)	0.008
Resident	1357 (31)	1157 (29)		1314 (30)	1198 (30)	
Fellow	603 (14)	582 (15)		622 (14)	557 (14)	
SRNA	639 (15)	536 (13)		616 (14)	563 (14)	
Attending anesthesiologist	113 (2.6)	112 (2.8)		119 (2.7)	106 (2.6)	
Medical student	29 (0.66)	18 (0.45)		24 (0.55)	22 (0.56)	
ASA physical status, No. (%)[c]						
1 (Healthy)	6 (0.14)	14 (0.35)	0.049	9 (0.20)	10 (0.24)	0.002
2 (Mild systemic illness)	74 (1.7)	94 (2.3)		89 (2.0)	79 (2.0)	
3 (Severe systemic illness)	694 (16)	668 (17)		715 (16)	644 (16)	
4 (Life-threatening systemic illness)	3605 (82)	3211 (80)		3574 (81)	3244 (81)	
5 (Not expected to survive without the operation)	34 (0.77)	29 (0.72)		33 (0.75)	29 (0.73)	
Modified Mallampati score, No./total No. (%)[d]						
I (Soft palate, uvula, pillars visible)	1078/4385 (25)	1109/3992 (28)	0.122	1150 (26)	1039 (26)	0.000
II (Soft palate, major part of uvula visible)	2583/4385 (59)	2406/3992 (60)		2610 (60)	2374 (60)	
III (Soft palate, base of uvula visible)	660/4385 (15)	453/3992 (11)		584 (13)	528 (13)	
IV (Only hard palate visible)	64/4385 (1.5)	24/3992 (0.60)		47 (1.1)	39 (0.99)	
History of difficult intubation within past 5 y, No. (%)	138 (3.1)	112 (2.8)	0.020	131 (3.0)	119 (3.0)	0.001

Abbreviations: ASA, American Society of Anesthesiologists; ASD, absolute standard difference; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CRNA, certified registered nurse anesthetist; SRNA, state registered nurse aide.

[a] Summaries for operating rooms are reported in eTable 2 in Supplement 2. All variables in this table as well as operating room were adjusted using the inverse probability of treatment weighting and propensity score calibration method in analyses.

[b] Variables with ASD less than 0.10 were considered imbalanced.

[c] Totals not equal to 100% due to rounding error.

[d] The Mallampati score is an assessment to describe the relative size of the base of the tongue compared with the oropharyngeal opening in hopes of predicting the difficult airway.

Secondary Outcomes and Exploratory Outcomes

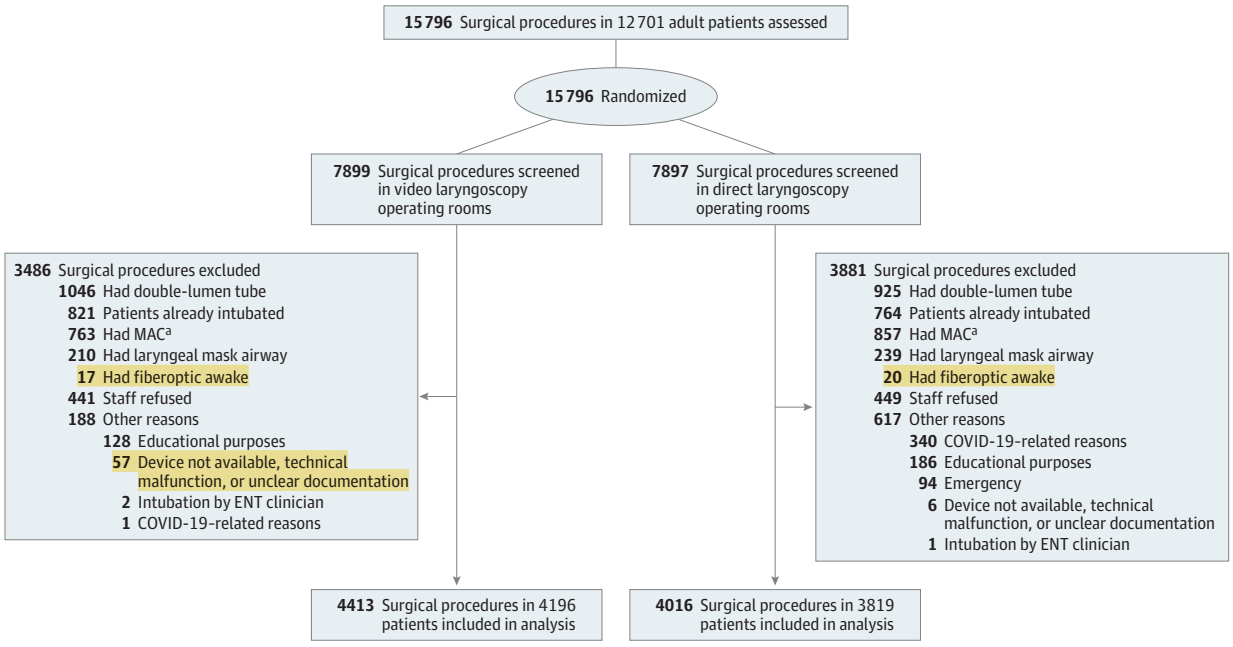
The effect of video vs direct laryngoscopy on intubation failure and on the collapsed composite of airway or dental injury were analyzed with a generalized linear mixed-effects log-binomial model (with log link to estimate relative risk for these binary outcomes) while adjusting for period (continuous), operating room and within-patient correlation, weighted by the stabilized weights.

The effect of video laryngoscopy vs direct laryngoscopy on maximum mean arterial pressure and heart rate in the 5 minutes after intubation was assessed using a linear mixed-effects model considering period within operating room as a random effect and adjusting for the within-patient correlation, weighted by the stabilized weights. A Wilcoxon-Mann-Whitney test was also conducted as sensitivity analysis. The treatment effect on the duration of intubation was assessed with a Wilcoxon-Mann-Whitney test.

Interim Monitoring and Sample Size Considerations

A group sequential design was planned to assess efficacy and futility at each quarter of the maximum sample size (N = 14 943)

Figure. Study Flow Diagram



ENT indicates ears, nose, and throat; MAC, monitored anesthesia care.

[a] MAC is a type of anesthesia service in which an anesthesia clinician continually monitors and supports the patient's vital functions; diagnoses and treats clinical problems that occur; administers sedative, anxiolytic, or analgesic medications if needed; and converts to general anesthesia if required.

with a γ spending function and γ parameters of −4 (conservative, similar to the O'Brien Fleming boundary) for efficacy and −1 (between the O'Brien-Fleming boundary and Pocock bounds) for futility.[23] For the second analysis, after which the study was stopped for efficacy with 56.4% of the maximum sample size (n = 8429), the z statistic boundary was greater than 2.705 for efficacy and less than or equal to 0.73 for futility, corresponding to an α level for this analysis of 0.0068. Therefore, 99.32% CIs are reported throughout, but are referred to as 95% CIs to indicate that α was controlled at 5% across the interim analyses.

In a previous study[24] approximately 10% of patients required more than 1 intubation attempt in the direct laryngoscopy group vs approximately 4% in the video laryngoscopy group[24] (direct laryngoscopy 1 attempt 90%, ≥2 attempts 4%; video laryngoscopy 1 attempt 96%, ≥2 attempts 4%). The proportion having 1, 2, 3, or more than 3 attempts was assumed to be 0.90, 0.04, 0.03, and 0.03 in the direct laryngoscopy group and 0.92, 0.04, 0.02, and 0.02 with video laryngoscopy. Detecting this or a larger difference with 90% power at the .05 significance level with a Wilcoxon-Mann-Whitney test would require a total of 8800 patients. After accounting for within-cluster correlations[25] and further adjustment for interim analyses, a maximum total of 14 943 patients was required.

At the first interim analysis the protocol specified to reassess the distribution of the primary outcome in the direct laryngoscopy group (because the prevalence can be considered a nuisance parameter analogous to SD for a continuous outcome) as well as the assumed correlations. The plan was to resize the study if the required N based on the observed parameter estimates was noticeably higher than the original calculations, keeping the planned treatment effect the same. This reassessment was not performed because the efficacy boundary had already been crossed after the first assessment.

All tests were 2-tailed. The overall significance level for the trial was .05. Accounting for the group sequential design across the interim analyses, the significance criterion for primary and secondary outcomes at the final analysis (second of 4 planned) was $P < .0068$. Main analyses were conducted with various procedures using SAS version 9.4 (SAS Institute); interim monitoring was conducted using East 6.4.1 (Cytel Corporation).

Results

From March 30, 2021, to December 31, 2022, for a total of 90 one-week periods, 15 796 surgical procedures were screened, of which 7367 were not eligible and were thus excluded (**Figure**). Among 8429 surgical procedures in 7736 patients, the median patient age was 66 (IQR, 56-73) years, 35% (2950) were women, 65% (5479) were men, and 85% (7135) had elective surgical procedures. The most common reasons for exclusion were need for a double-lumen tube, patient already intubated, or no need for endotracheal intubation. Most reasons for exclusion were balanced by randomized group (eTable 1 in Supplement 2). More surgical procedures were excluded from the direct laryngoscopy group because patients with suspected COVID-19 had their initial intubation attempt with a video

Table 2. Treatment Effect on the Primary and Secondary Outcomes

Outcome	Video laryngoscopy (n = 4413)	Direct laryngoscopy (n = 4016)	Treatment effect estimate (95% CI)[a]	*P* value[b]
Primary outcome				
Intubation attempts per patient, No. (%)				
1	4336 (98.3)	3710 (92.4)	0.20 (0.14-0.28)[c]	<.001
2	70 (1.6)	277 (6.9)		
3	3 (0.07)	27 (0.67)		
>3	4 (0.09)	2 (0.05)		
Sensitivity analysis				
Negative binomial regression	NA	NA	0.94 (0.92-0.95)[d]	<.001
Wilcoxon-Mann-Whitney, median (IQR)	1 (1-1)	1 (1-1)	0 (0-0)[e]	<.001
Including all exclusions due to COVID-19, staff preferences, educational purposes[f]	NA	NA	0.26 (0.19-0.36)[c]	<.001
Secondary outcome, No. (%)				
Intubation failure	12 (0.27)	161 (4.0)	0.06 (0.03-0.14)[g]	<.001
Composite injury	41 (0.93)	42 (1.1)	0.87 (0.48-1.58)[g]	.53
Airway injury[h]	40 (0.9)	40 (1.0)	0.89 (0.46-1.72)[g]	.61
Dental injury[h]	1 (0.02)	2 (0.05)	0.49 (0.08-3.00)[g]	.25

Abbreviation: NA, not applicable.

[a] The CIs are interim-analysis adjusted and so are actually 99.32% but referred to as 95% for simplicity and to emphasize that α was controlled at 5% throughout the study.

[b] Significant if *P* < .0068 (corresponding to group sequential efficacy boundary at second interim analysis).

[c] Proportional odds ratio (95% CI) and *P* value estimated from generalized linear mixed-effects cumulative logit generalized estimating equation model adjusting for period (continuous), operating room, and within-patient correlation, weighted by the stabilized weights.

[d] Incidence rate ratio (95% CI) and *P* value were estimated from negative binomial regression model adjusting for period (continuous), operating room, and within-patient correlation, weighted by the stabilized weights.

[e] Median difference (95% CI) was estimated from the Hodges-Lehmann estimator of location shift between groups and *P* value from Wilcoxon rank sum test.

[f] Including exclusions due to COVID-19, staff preferences, and educational purposes (eTable 3 in Supplement 2).

[g] Relative risk (95% CI) and *P* value were estimated from generalized linear mixed-effects log-binomial model (log link) adjusting for period (continuous), operating room, and within-patient correlation, weighted by the stabilized weights.

[h] *P* values of .0034 (ie, .0068/2) were considered significant for individual components and 99.66% CI were presented with their relative risks.

laryngoscopy per local and national guidelines.[26,27] A total of 8429 eligible surgical procedures in 7736 patients, with 4413 patients randomized to receive video laryngoscopy and 4016 randomized to receive direct laryngoscopy, were included.

Among 8429 intubations, 3283 (38.9%) were performed by nurse anesthetists, 2514 (29.8%) by residents, 1185 (14.1%) by fellows, 1175 (13.9%) by student nurse anesthetists, 225 (2.7%) by attending anesthesiologists, and 47 (0.6%) by medical students. Patient demographic and procedural characteristics are reported in Table 1 and eTable 2 in Supplement 2. Oxygen saturation measured by pulse oximetry from anesthesia induction until 5 minutes after intubation is summarized in eTable 5 in Supplement 2.

Primary Outcome

Patients randomized to receive video laryngoscopy had a significantly lower number of intubation attempts compared with those randomized to receive direct laryngoscopy, with an estimated proportional odds ratio (video/direct) of 0.20 (95% CI, 0.14-0.28) (*P* < .001) (**Table 2**), indicating that a patient randomly chosen to receive video laryngoscopy had 80% higher odds of requiring fewer intubation attempts compared with a patient randomly chosen to receive direct laryngoscopy. The proportional odds assumption held reasonably well. No interaction between treatment and operating room was found. Sensitivity analyses including cases with staff refusals and other reasons for exclusion gave similar results (Table 2; eTable 3 in Supplement 2).The results of other sensitivity analyses are available in eAppendix 2 in Supplement 2. The effect of video laryngoscopy on the primary outcome was found to differ by sex, body mass index, and American Society of Anesthesiologists physical status using a *P* < .05 significance criteria for interactions (eFigure 1 and eFigure 2 in Supplement 2). The percentage of surgical procedures with 1 intubation attempt by operating room and treatment group is reported in eTable 6 in Supplement 2.

Secondary Outcomes

Patients randomized to receive video laryngoscopy had a significantly lower number of intubation failures in a generalized linear mixed-effects model considering period within operating room as a random effect. Intubation failure occurred in 12 of 4413 surgical procedures (0.27%) using video laryngoscopy vs 161 of 4016 surgical procedures (4.0%) using direct laryngoscopy (relative risk, 0.06; 95% CI, 0.03-0.14; *P* < .001) with an unadjusted absolute risk difference of −3.7% (95% CI, −4.4% to −3.2%) (Table 2). The composite outcome of airway or dental injury did not differ significantly between patients randomized to receive video laryngoscopy vs direct laryngoscopy, with estimated relative risk of 0.87 (95% CI, 0.48-1.58; *P* = .53). Analyses of individual components gave results similar to the composite

outcome (Table 2). Results for exploratory outcomes are reported in eTable 4 in Supplement 2.

Discussion

This single-center study of patients having cardiac, thoracic, or vascular surgical procedures with endotracheal intubation performed in the operating room found that those randomized to receive video laryngoscopy had fewer multiple intubation attempts compared with direct laryngoscopy (7.6% to 1.7%). Furthermore, 4% of patients randomized to receive direct laryngoscopy group were changed to a different intubation approach vs 0.27% of those randomized to receive video laryngoscopy.

Improved outcomes with video laryngoscopy were consistent with a 2023 trial of 2092 adults with apparently healthy airways who were randomized to receive video vs direct intubation for elective surgical procedures: 6% required multiple intubation attempts with video laryngoscopy compared with 18% with direct laryngoscopy.[28] Multiple attempts were required in approximately 3 times as many patients with each device in this trial as in the present trial, even though the present trial was not restricted to patients with apparently healthy airways and few intubation attempts were by attending anesthesiologists. The need for repeated intubation attempts in our trial was also broadly consistent with a large retrospective analysis in which multiple intubation attempts were required in 9% of patients with direct laryngoscopy.[1]

In contrast, a 2022 meta-analysis of 66 studies with a total of 8086 patients reported only a moderate increase in successful initial intubation attempts with hyperangulated video laryngoscopy (relative risk,1.03; 95% CI, 1.00-1.05, low certainty evidence).[29] However, the meta-analysis was largely based on small trials. While all clinicians were presumably experienced with direct laryngoscopy, experience with video laryngoscopy and hyperangulated blades may have been insufficient in some trials, thus underestimating benefit.

Airway injuries were similar in each group, with an incidence of 1%, representing approximately 40 events in each group. However, airway injuries reflect the sum of all airway manipulations rather than just the initial randomization method because clinicians could switch to any airway approach after the initial attempt. Airway damage is most likely in patients in whom laryngoscopy or intubation is difficult, and especially in those who require multiple, and often increasingly strained, attempts. It is thus not possible to clearly attribute injury to specific devices, but there is no evidence to suggest that video laryngoscopy increased the risk of airway injuries.

A wide range of video laryngoscopes is commercially available and blade design is heterogeneous. While some video laryngoscopy blades are broadly based on the original Macintosh blade shape, other designs use a hyperangulated shape that promotes visualization of anterior airway structures.[30,31] Hyperangulated blades generally provide excellent views of the glottis, but it is sometimes impossible to pass an endotracheal tube through the vocal cords.[17,30] Stylets are therefore often required with hyperangulated blades, whereas it is usually easy enough to intubate without one using conventional direct visualization. Consequently, a stylet was used for all video laryngoscopy-assisted intubations as recommended by the manufacturer, but clinicians were allowed to use a stylet or not per their preference for direct laryngoscopy.

The observed improvement with video laryngoscopy may be clinically important, as several large observation studies and randomized trials reported, that multiple intubation attempts promote complications including aspiration, hypoxemia, airway injury, and even death.[2,3,5-7] Nonetheless, a 2023 trial did not report associations between the number of intubation attempts and complications.[32]

Limitations

This study has several limitations. First, as a single-center study, results may not be generalizable to other institutions. Second, patient positioning was not protocolized. Third, determination of adequate neuromuscular block was not standardized. Insufficient neuromuscular block and inadequate anesthesia depth might have caused patient movement or airway responses such as coughing or bucking that could have made endotracheal intubation more difficult. However, it seems unlikely that experienced anesthesia clinicians would intubate without sufficient neuromuscular relaxation. Fourth, exclusion of some patients by clinicians may have led to selection bias. However, the number of excluded patients was relatively low and well balanced between the groups, except for patients who were suspected to have COVID-19 infection. Fifth, only anesthesia clinicians participated in this study, and results may differ with nonanesthesia trained clinicians.

Conclusions

In this cluster randomized multiple crossover clinical trial, among adults having elective or emergent cardiac, thoracic, or vascular surgical procedures who required single-lumen endotracheal intubation for general anesthesia, hyperangulated video laryngoscopy decreased the number of attempts needed to achieve endotracheal intubation in the operating room compared with direct laryngoscopy at a single academic medical center in the US. Results suggest that video laryngoscopy may be a preferable approach for intubating patients undergoing surgical procedures.

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