

Success of Intubation Rescue Techniques after Failed Direct Laryngoscopy in Adults

A Retrospective Comparative Analysis from the Multicenter Perioperative Outcomes Group

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This article has been selected for the ANESTHESIOLOGY CME Program. Learning objectives and disclosure and ordering information can be found in the CME section at the front of this issue.

ABSTRACT

Background: Multiple attempts at tracheal intubation are associated with mortality, and successful rescue requires a structured plan. However, there remains a paucity of data to guide the choice of intubation rescue technique after failed initial direct laryngoscopy. The authors studied a large perioperative database to determine success rates for commonly used intubation rescue techniques.

Methods: Using a retrospective, observational, comparative design, the authors analyzed records from seven academic centers within the Multicenter Perioperative Outcomes Group between 2004 and 2013. The primary outcome was the comparative success rate for five commonly used techniques to achieve successful tracheal intubation after failed direct laryngoscopy: (1) video laryngoscopy, (2) flexible fiberoptic intubation, (3) supraglottic airway as part of an exchange technique, (4) optical stylet, and (5) lighted stylet.

Results: A total of 346,861 cases were identified that involved attempted tracheal intubation. A total of 1,009 anesthesia providers managed 1,427 cases of failed direct laryngoscopy followed by subsequent intubation attempts ($n = 1,619$) that employed one of the five studied intubation rescue techniques. The use of video laryngoscopy resulted in a significantly higher success rate (92%; 95% CI, 90 to 93) than other techniques: supraglottic airway conduit (78%; 95% CI, 68 to 86), flexible bronchoscopic intubation (78%; 95% CI, 71 to 83), lighted stylet (77%; 95% CI, 69 to 83), and optical stylet (67%; 95% CI, 35 to 88). Providers most frequently choose video laryngoscopy (predominantly GlideScope® [Verathon, USA]) to rescue failed direct laryngoscopy (1,122/1,619; 69%), and its use has increased during the study period.

Conclusions: Video laryngoscopy is associated with a high rescue intubation success rate and is more commonly used than other rescue techniques. ([ANESTHESIOLOGY 2016; 125:656-66](#))

FAILED tracheal intubation is a concerning event that may lead to increased patient morbidity and mortality. Our current prediction techniques are imperfect, leading to its occurrence despite careful preprocedural airway risk assessment. A true medical emergency exists when difficult intubation occurs in combination with difficult bag-mask ventilation that impairs oxygenation. This emergency can occur when failed laryngoscopy attempts are persistent.^{1,2}

Safe management requires timely decision-making and may require the use of alternative techniques to ensure successful tracheal intubation. Current intubation rescue techniques include video laryngoscopy, flexible bronchoscopic intubation, the use of a lighted stylet, or insertion of a

What We Already Know about This Topic

- Airway management guidelines suggest various options after failed direct laryngoscopy
- We lack knowledge of the effectiveness of each alternative technique for achieving successful tracheal intubation

What This Article Tells Us That Is New

- In this large, multicentered, retrospective observational study, 1,619 rescue attempts after a failed tracheal intubation were performed in 1,427 out of 346,861 cases
- Video laryngoscopy was the most frequently chosen rescue technique (69%) and resulted in the highest success rate (92%) among the alternative techniques

This article is featured in "This Month in Anesthesiology," page 1A. Corresponding article on page 615. This work was an oral abstract presentation at the American Society of Anesthesiologists Annual Meeting in New Orleans, Louisiana, on October 14, 2014.

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supraglottic airway (SGA) as a conduit to tracheal intubation. Widely used algorithms do not provide clear guidance on which techniques to use after direct laryngoscopy fails.³ If ventilation is adequately restored, the guidelines do suggest the use of alternate devices to maintain ventilation or secure the airway with a tracheal tube.

Several techniques have been advocated to facilitate successful tracheal intubation after failed direct laryngoscopy. One retrospective effectiveness study across two centers demonstrated that rescue using the GlideScope® video laryngoscope (Verathon, USA) was successful in 94% (224 of 239) of cases after failed direct laryngoscopy.⁴ According to a large observational study, the Pentax AWS® (Pentax, Japan) was found to achieve successful intubation in 99% (268 of 270) of cases where direct laryngoscopy failed to achieve an adequate laryngeal view for intubation.⁵ In a large observational study of a new algorithm involving a small group of providers and select group of patients, failed direct laryngoscopy was rescued utilizing the Airtraq® (Prodol, Spain) system in 27 of 28 cases.⁶ Others reported that when mask ventilation and intubation are both difficult, SGAs restore ventilation in 94% of cases (16 of 17).⁷ Other devices have been advocated as useful rescue intubation tools in smaller case series.^{8–11} However, collectively, the aforementioned studies do not provide the evidence necessary for a direct comparison between individual rescue techniques as they either focus on only one technique, the practice in one single center, or represent small case series.

Therefore, we designed a study to help determine the comparative effectiveness of intubation rescue techniques suggested by the American Society of Anesthesiologists Difficult Airway Algorithm³ by analyzing a large database of perioperative medical records from seven large tertiary care centers across the United States. We tested the hypothesis that video laryngoscopy is associated with a higher success rate compared to other recommended techniques (flexible fiberoptic intubation, lighted stylet, optical stylet, and SGA as a conduit to tracheal intubation).

Methods

The experimental design was a multicentered, retrospective observational study utilizing the Multicenter Perioperative

Outcomes Group (MPOG) database. MPOG is a consortium of institutions formed in 2008 with a shared data set facilitating the investigation of perioperative outcomes. The structure of this database has been described previously in great detail.^{12,13} In brief, each institution uses an intraoperative electronic medical record and routinely extracts data into a common research database structure and common clinical lexicon to enable comparison of medications, procedures, techniques, and outcomes across centers. Rigorous data visualization techniques and case validation are used to maximize data quality and consistency in the centralized database.

Institutional Review Board approval was obtained from each MPOG (Ann Arbor, Michigan) center to contribute and analyze deidentified data in a central data repository. A requirement for written informed consent was waived for these purposes. The clinical investigation protocol, including planned primary and secondary outcomes and statistical analysis plan, was presented to the MPOG Perioperative Clinical Research Committee in 2012, reviewed and critiqued by the members, and then approved for data extraction. A detailed proposed query plan, data collection sheet, and data definitions are included in the MPOG protocol that was registered with the MPOG research committee.

The analysis was based on the systematic evaluation of electronic medical records collected from seven large tertiary care academic institutions in the MPOG consortium between January 2004 and January 2013: University of Michigan, Oregon Health & Science University, Oregon, Michigan; University of Colorado, Aurora, Colorado; University of Virginia, Charlottesville, Virginia; University of Oklahoma, Oklahoma City, Oklahoma; University of Vermont, Burlington, Vermont; and University of Utah, Salt Lake City, Utah. These centers were selected among many MPOG contributing centers based upon the availability of structured documentation elements for key variables necessary for analysis: intubation device(s) used, number of laryngoscopy attempts, laryngeal view achieved, and bag-mask ventilation assessment. Details of the intubation procedures are documented in a structured format at each institution and mapped to a shared MPOG data structure.

Included in the final analysis were electronic medical records from all adult patients (greater than 18 years of age) who had tracheal intubation attempted initially with direct laryngoscopy and then rescue attempted with the technique of interest (video laryngoscopy, flexible fiberoptic intubation, lighted stylet, optical stylet, and SGA as a conduit to tracheal intubation). The following events were excluded from further analysis: the use of direct laryngoscopy alone, primary technique that was not a direct laryngoscopy, or pediatric patients (less than 18 years of age). Cases in which direct laryngoscopy was performed only to document laryngeal view for future purposes were considered not to be direct laryngoscopy as the primary technique as intubation was not intended by direct laryngoscopy.

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The primary outcome was the successful tracheal intubation rate of (1) video laryngoscopy, (2) flexible fiberoptic laryngoscopy, (3) SGA as a conduit to intubation, (4) optical stylet, or (5) lighted stylet performed after failed initial direct laryngoscopy. Although the documentation templates of the institutions did not include a standard definition of an “intubation attempt,” for purposes of this analysis, we defined a “failed attempt” as the documented use of a device with or without attempted tube passage that did not result in successful tracheal intubation. The use of a bougie or an introducer with direct laryngoscopy was not considered a failure unless direct laryngoscopy was abandoned. An “intubation rescue technique” was recorded as successful when it resulted in successful tracheal intubation, regardless of the number of attempts with that technique. In contrast, the “intubation rescue technique” was recorded as a failure if the record showed that the provider switched to a different rescue technique or reverted to direct laryngoscopy. Rescue techniques were then categorized into one of the identified groups (table 1). Cases that did not clearly discriminate an “intubation attempt” or “intubation rescue technique” as defined here were excluded from further analysis (fig. 1).

A secondary outcome was the tracheal intubation success rate of the five intubation rescue techniques of interest in the subgroup of patients with “difficult or impossible mask ventilation.” Patients were included into this subgroup analysis if a mask ventilation scaled score of 3 or 4¹⁴ was documented or if the mask ventilation narrative indicated “two-hand mask ventilation,” or documented that the patient could not be ventilated by mask at all. An additional secondary outcome was any documentation of airway-related trauma assessed as (1) no injury, (2) dental trauma, (3) pharyngeal injury, (4) tracheal injury, and (5) death.

The primary automated query (fig. 1) identified all cases that involved multiple attempts at laryngoscopy and the use of alternative intubation techniques, or cases with four or more laryngoscopy attempts. In all identified electronic records, the intubation narrative was queried as to whether one or more of the five devices of interest were mentioned by searching for the following terms: “video,” “could not intubate,” “could not ventilate,” “lightwand,” “fiberoptic,” “video,” “CMAC,” “C-MAC,” “stylet,” “storz,” “glidescope,” “glide,” “mcgrath,” “shikani,” “bullard,” “bonfils,” “aintree,” “fiberoptic,” “intubating LMA,” “airq,” “air-q,” “gscope,” “fast track,” “fast trach,” “cricothyrotomy,” “trach,” “lma,”

and “sga.” Each institution has a structured airway management template, but not all templates had discreet fields for which device was used first. Therefore, each anesthesia record, in its entirety, was manually reviewed by investigators (M.F.A., D.W.H., A.W.W., L.J., J. Ragheb, D.A.B., W.C.P., J. Rao, J.L.E., P.B., D.A.C., S.K.) to establish the primary and secondary outcomes. First, the intraoperative record was reviewed in detail to determine whether the patient did indeed undergo initial direct laryngoscopy followed by an alternative intubation technique. The case was excluded from further analysis if the documentation was unclear regarding the sequence of events. Cases in question were reviewed by a second reviewer in order to determine inclusion versus exclusion of the case and finally by a third reviewer if any debate remained. All other successful airway management strategies were also recorded, which included “surgical airway,” “patient awoken and case cancelled,” “patient awoken and flexible fiberoptic endoscopy,” “supraglottic airway used for the case,” and “return to direct laryngoscopy after failed rescue.” Before reviewer analysis of individual anesthesia records, the data collection definitions were communicated and a tutorial on data definitions was performed for all reviewers. The primary query captured many intubations that were not included, but appropriately screened because multiple attempts were noted along with free text notations of rescue devices of interest. An example of this exclusion was a successful intubation utilizing direct laryngoscopy after multiple attempts, but a bronchoscope was used for further diagnostic purposes, not as a rescue for intubation.

In an attempt to further characterize the affected patient population, severable variables were also recorded. Elements of the airway exam from those institutions that had provided these elements as a part of the electronic medical record to MPOG were included. For the purposes of this analysis, cases were determined to be “at higher risk of difficult direct laryngoscopy” when the presence of the following objective criteria were identified: “Mallampati classification score of 3 or 4,” “limited cervical motion,” “limited mouth opening” (*i.e.*, less than 3 cm), “limited jaw protrusion” (*i.e.*, unable to protrude the lower teeth in front of the upper teeth), “short thyromental distance” (*i.e.*, less than 6 cm), or “radiation changes to the neck.” Furthermore, counts of the number of previous direct laryngoscopy attempts before rescue were recorded. Also, hypoxemia associated with airway management was recorded and defined as SpO₂ less than 90% for

Table 1. Airway Rescue Techniques and Comparative Success Rates of the Common Rescue Strategies

Rescue Technique (Total n = 1,511)	Success, n (%) (95% CI)	Failure, n (%) (95% CI)	P Values
Video laryngoscopy (n = 1,122)	1,032 (92) (90–93)	90 (8) (7–10)	Reference group
SGA conduit (n = 82)	64 (78) (68–86)	18 (22) (14–32)	0.0001
Flexible fiberoptic (n = 170)	132 (78) (71–83)	38 (22) (17–29)	0.0001
Lighted stylet (n = 128)	98 (77) (69–83)	30 (23) (17–31)	0.0001
Optical stylet (n = 9)	6 (67) (35–88)	3 (33)	0.031

SGA = supraglottic airway.

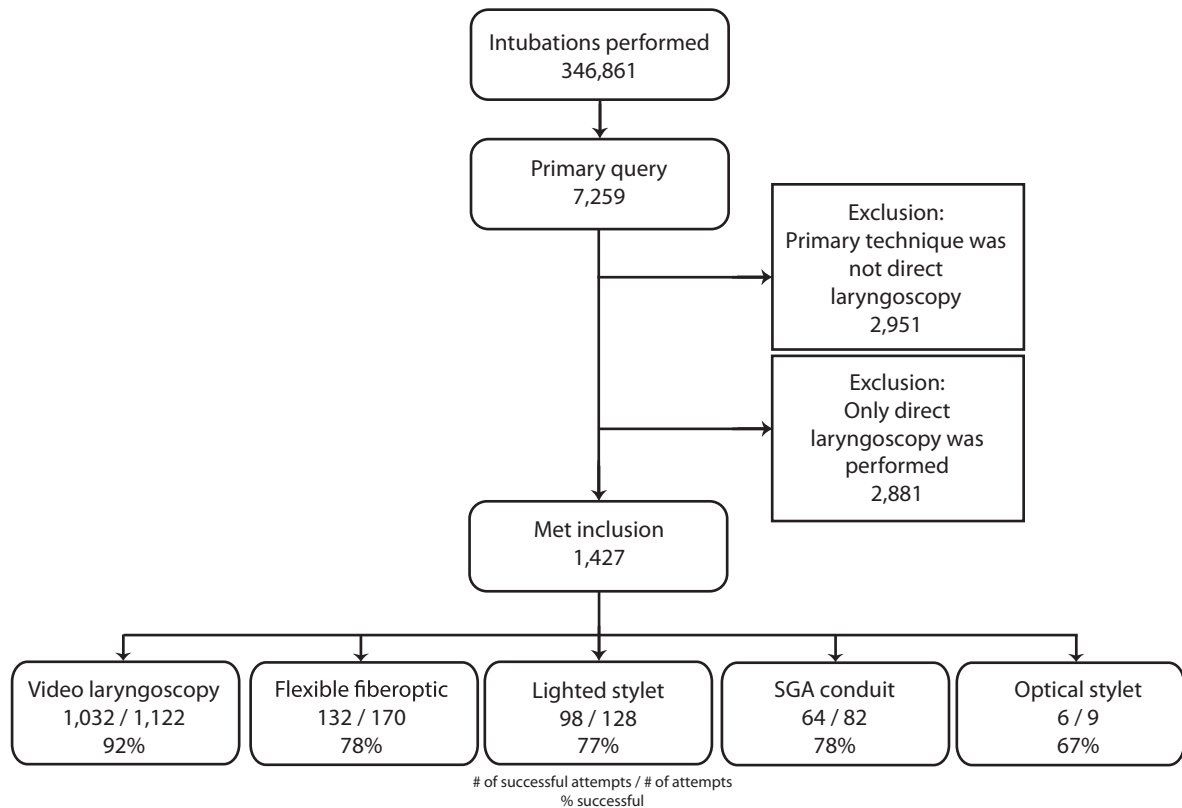


Fig. 1. Flow diagram of case inclusion and airway outcome. Among a large cohort of patients requiring tracheal intubation in the Multicentered Perioperative Outcome Group data set, the “primary query” was identified by electronic search that included airway management details of interest. After manual review of these records, the final sample of cases was grouped into common airway management rescue techniques after failed direct laryngoscopy. Each case resulted in one or more attempted rescue techniques. Success rates for these techniques are included. SGA = supraglottic airway.

at least 1 min. Finally, a summative count of “higher risk” attempts was recorded and defined by attempts involving either SpO_2 less than 90% for 1 min or longer, concomitant difficult/impossible bag-mask ventilation or after at least two previous failed attempts at direct laryngoscopy.

Statistical Analysis

Statistical analysis was performed using SPSS version 21 (USA). To determine if there was a statistically significant difference among the proportions of successful tracheal intubations and the five identified groups, a chi-square test was used. To compare the successful tracheal intubation rates with the five devices in the setting of failed direct laryngoscopy and difficult or impossible mask ventilation (secondary outcome), the data were recategorized based upon the stated outcome and chi-square test was used. $P < 0.05$ was considered statistically significant. Proportions are represented with exact 95% CIs.

A mixed-effects logistic regression model was performed to determine if there was any variation among the individual institutions. The binary outcome was success or failure using video laryngoscopy. Due to low sample-size issues, video laryngoscopy was the only model we were able to perform. The fixed effect was having two or more of the preoperative

airway predictors as a binary concept. The random effect was the institution. The variance estimate across the institutions was used to calculate the median odds ratio (MOR). The MOR calculates the variation for a random effect (institution) similar to fixed-effects odds ratios. An MOR of 1 means that there is no variation across the institutions.¹⁵ Stata SE version 13 (Chicago, Illinois) was used for this portion of the analysis. A convenience sample size of the seven MPOG institutions’ clinical volume was chosen due to the absence of existing data regarding direct laryngoscopy rescue rates and usage patterns of rescue devices at these seven centers. On *post hoc* analysis (using nQuery), when the sample size in each of the five groups is 64, a 0.050-level chi-square test will have 80% power to detect a difference in proportions characterized by a variance of proportions of 0.006344 and an average proportion of 0.784.

Results

A total of 346,861 cases across seven institutions in the United States were identified that involved attempted or successful tracheal intubation using direct laryngoscopy and had adequate reporting of the necessary airway documentation fields (fig. 1). Out of these, 7,259 cases (2%) were identified by automated primary query to involve multiple

attempts at laryngoscopy and notation of rescue techniques of interest. Manual review of each of these records identified 1,427 cases (20%) that met inclusion criteria of an initial attempt(s) of unsuccessful direct laryngoscopy followed by rescue intervention(s) using some other means. These airways were managed by 1,009 distinct anesthesia providers (353 attending anesthesiologists, 449 resident anesthesiologists, and 207 certified registered nurse anesthetists). Among the 1,427 cases, there were 1,619 attempts at intubation rescue. The majority of these rescues ($n = 1,511$ of 1,619; 93%) involved one of the five rescue strategies related to the primary hypothesis (video laryngoscopy, flexible fiberoptic intubation, lighted stylet, optical stylet, and SGA as a conduit to tracheal intubation). The patients included in the analysis were 60% of male gender and had a mean age of 57 ± 14 yr.

Table 1 summarizes the primary outcome data. Providers most frequently choose video laryngoscopy to rescue the airway ($n = 1,122$ out of 1,619 attempts; 69%). In far fewer cases, flexible fiberoptic ($n = 170$; 11%), lighted stylet ($n = 128$; 8%), SGA conduit ($n = 82$; 5%), or optical stylet ($n = 9$; 0.6%) were chosen as the rescue technique. The SGA conduits were used for tracheal intubation performed either blindly ($n = 43$) or with the aid of a bronchoscope ($n = 39$). Other management attempts included a return to direct laryngoscopy again ($n = 61$; 4%); surgical airway ($n = 11$; 0.7%); an SGA to maintain ventilation throughout the entire case ($n = 26$; 2%); waking up the patient followed by awake fiberoptic intubation ($n = 8$; 0.7%); or case cancellation ($n = 2$; 0.1%). Using video laryngoscopy resulted in a high success rate (92%, 95% CI, 90 to 93) that was significantly higher than that for the other four primarily studied rescue techniques: SGA conduit (78%; 95% CI, 68 to 86; $P < 0.001$), flexible fiberoptic intubation (78%; 95% CI, 71 to 83; $P < 0.001$), lighted stylet (77%; 95% CI, 69 to 83; $P < 0.001$), or optical stylet (67%; 95% CI, 47 to 99; $P < 0.001$). We demonstrated that there was very small variance (0.2%) of successful video laryngoscopy across the institutions when controlling for preoperative airway risk factors. However, the MOR was 1.00, which indicates no significant variation across institutions.

Table 2 lists the different video laryngoscopy systems used to rescue failed direct laryngoscopy ($n = 1,122$) and their

respective success rates. Most rescues using a video laryngoscopy system ($n = 1,003$) involved the GlideScope (89%); in 6%, the Storz DCI® or C-MAC® video laryngoscopes (Karl Storz, Germany); in 4%, the Bullard scope (Circon ACMI, USA), and in less than 1% the Pentax, McGrath® (Aircraft Medical, United Kingdom), and Airtraq systems. The success rates of the three most frequently used video laryngoscopy techniques were similar (90 to 92%). The frequency of the use of other devices was very low in this sample, which precluded a meaningful comparative analysis.

Figure 2 illustrates the proportional increase in the use of video laryngoscopy for the rescue of failed direct laryngoscopy during the period that is reflected in these data. In contrast, the use of flexible fiberoptic intubation or optical stylets in this event has proportionally waned.

Table 3 summarizes the results from a subgroup analysis of those cases of failed direct laryngoscopy that also involved difficult or impossible mask ventilation ($n = 145/1,427$; 10%). Similar to the results for the whole sample, video laryngoscopy was chosen most frequently for the attempt to rescue failed direct laryngoscopy (69%). Video laryngoscopy resulted in a higher success rate (88%; 81 to 93) than flexible fiberoptic intubation (54%; 35 to 71; $P = 0.0003$).

When video laryngoscopy failed as rescue means ($n = 90$; 8%), the airway was most often successfully secured when using flexible fiberoptic intubation ($n = 30$) or by return to direct laryngoscopy ($n = 29$), often with the use of a bougie ($n = 15$).

Table 4 summarizes the number of failed direct laryngoscopy attempts before conversion to any of the five rescue techniques of interest. The majority of rescue intubations occurred after one failed direct laryngoscopy attempt in 1,023 of 1,511 cases (68%). For 78% (1,116 of 1,427) of these studied failed direct laryngoscopy cases, information was available for the type of direct laryngoscopy blade used. In 606 of 1,116 (54%) cases, only a Macintosh blade was used, whereas in 180 of 1,116 (16%) cases, only a Miller blade was used. In 330 of 1,116 (30%) cases, both blades were used during the initial attempt. After only Macintosh laryngoscopy, alternatives were approached after one attempt in 463 of 606 cases (76%).

Table 5 describes the details of the preoperative airway examination recorded and episodes of hypoxemia associated

Table 2. Video Laryngoscopy Devices Used and Comparative Success Rates

Device Used (n = 1,238)	Rescue Success, n (%)	95% CI	Comparison of Device vs. GlideScope, P Values
GlideScope (n = 1,122)	1,032 (92)	90–93	Reference group
C-MAC/Storz DCI (n = 66)	61 (92)	83–97	0.907*
Bullard (n = 40)	36 (90)	77–96	0.645*
Pentax AWS (n = 7)	7 (100)	N/A	1.000†
McGrath (n = 1)	1 (100)	N/A	1.000†
Airtraq (n = 2)	1 (50)	9–91	0.155†

*Pearson chi-square test. †Fisher exact test.



Fig. 2. Rescue techniques attempted over time. This diagram illustrates the proportional use of each studied rescue technique of interest over time. During this period, the use of video laryngoscopy has substantially grown, while the use of all other rescue techniques has proportionally decreased. SGA = supraglottic airway.

with airway management. Depending on the variable and contributing institution, 79% (n = 1,122) of the 1,427 cases of failed direct laryngoscopy had preoperative airway examinations available for review. The final tally for data completion demonstrated that 54 to 63% of the 1,427 cases had valid preoperative airway examination details, depending on the variable. Based on the available data, 28% (n = 313 of 1,122) of the cases where direct laryngoscopy failed had two or more predetermined predictors of difficult direct laryngoscopy recorded. An episode of hypoxemia as defined by SpO₂ of less than 90% for at least 1 min around the time of intubation was observed in 372 of 1,511 (25%) rescue attempts. A total of 782 of 1,511 (52%) cases were considered “higher risk” as defined by an episode of hypoxemia, or after difficult/impossible mask ventilation, or after two failed previous attempts at direct laryngoscopy.

Acute complications were rare: pharyngeal injury was reported in 12 cases, and all occurrences were associated with the use of video laryngoscopy as rescue (n = 12/1,122; 1.1%). Pharyngeal injuries noted frank blood coming from the mouth (n = 8 GlideScope, n = 1 Airtraq, n = 1 C-MAC)

or a laceration to the tonsillar pillar (n = 1 GlideScope) or a laceration to the epiglottis (n = 1 GlideScope). Dental injury was reported in four cases (0.3%). Tracheal trauma was not documented for any patient.

Discussion

This multicentered, retrospective observational study has revealed important new information. First, the use of video laryngoscopy in the setting of failed direct laryngoscopy is associated with a statistically significant higher success rate than the other commonly performed alternative techniques, such as flexible fiberoptic intubation, intubation through SGA devices, or optical stylets. Second, the use of video laryngoscopy, predominantly with the GlideScope during the period studied, has become the preferred method to achieve successful tracheal intubation after this event. Third, video laryngoscopy retains a high success rate after failed tracheal intubation by initial direct laryngoscopy combined with difficult/impossible mask ventilation. Fourth, the data confirm that failure of initial direct laryngoscopy remains difficult to predict, as only 28% of the affected patients had more than

Table 3. Airway Rescue Techniques and Comparative Success Rates in Patients with Difficult or Impossible Mask Ventilation

Rescue Technique (n = 155)	Success, n (%) (95% CI)	Failure, n (%) (95% CI)	P Values
Video laryngoscopy (n = 107)	94 (88) (81–93)	13 (12) (7–20)	Reference group
SGA conduit (n = 12)	10 (83) (55–95)	2 (17) (1–35)	0.6474
Flexible fiberoptic (n = 26)	14 (54) (35–71)	12 (46) (29–65)	0.0003
Lighted stylet (n = 9)	6 (67) (35–88)	3 (33) (12–65)	0.1080
Optical stylet (n = 1)	1 (100) (1–21)	0 (0)	0.108

SGA = supraglottic airway.

Table 4. Previous Number of Attempts at Direct Laryngoscopy Before Rescue Techniques of Interest

No. of Previous Direct Laryngoscopy Attempts/Blades Used	Video Laryngoscopy (n = 1122)			Flexible Fiberoptic (n = 170)			Lighted Stylet (n = 128)			Supraglottic Airway (n = 82)			Optical Stylet (n = 9)			
	Total (%)	Success (%)	Failure (%)	Total (%)	Success (%)	Failure (%)	Total (%)	Success (%)	Failure (%)	Total (%)	Success (%)	Failure (%)	Total (%)	Success (%)	Failure (%)	
1	760 (68)	699 (92)	61 (8)	112 (66)	85 (76)	27 (24)	92 (72)	67 (73)	25 (27)	53 (65)	40 (75)	13 (25)	6 (67)	5 (83)	1 (17)	
2	253 (23)	237 (94)	16 (6)	29 (17)	25 (86)	4 (14)	30 (23)	27 (90)	3 (10)	15 (18)	12 (80)	3 (20)	1 (11)	1 (100)	0 (0)	
3	88 (8)	77 (88)	11 (13)	24 (14)	19 (79)	5 (21)	7 (5)	4 (57)	3 (43)	12 (15)	10 (83)	2 (17)	1 (11)	0 (0)	1 (100)	
4	20 (%2)	18 (90)	2 (10)	3 (2)	1 (33)	2 (67)				2 (2)	2 (100)	0 (0)	0 (0)	0 (0)	0 (0)	
5	1 (0)	1 (1)	0 (0)	1 (1)	1 (100)	0 (0)							1 (11)	0 (0)	1 (100)	
6				1 (1)	1 (100)	0 (0)										
Blade type (from 1,181 of 1,485 cases)																
Macintosh only	509	477 (94)	32 (6)	55	45 (82)	10 (18)	38	26 (68)	12 (32)	26	21 (81)	4 (19)	1	0 (0)	1 (100)	
Miller only	149	134 (90)	15 (10)	26	15 (58)	11 (42)	15	6 (40)	9(60)	10	7 (70)	3 (30)	0	0 (0)	0 (0)	
Both	246	216 (88)	30 (12)	49	43 (88)	6 (12)	26	22 (85)	4 (15)	27	19 (70)	8 (30)	4	2 (50)	2 (50)	

Table 5. Airway Management Conditions During Rescue Attempts

Intubation Condition	Video Laryngoscopy (n = 1,122)			Flexible Fiberoptic (n = 170)			Lighted Stylet (n = 128)			Supraglottic Airway (n = 82)			Optical Stylet (n = 9)		
	Total (%)	Success (%)	Failure (%)	Total (%)	Success (%)	Failure (%)	Total (%)	Success (%)	Failure (%)	Total (%)	Success (%)	Failure (%)	Total (%)	Success (%)	Failure (%)
Hypoxemia (SpO ₂ < 90% for at least 1 min)	226 (20)	191 (85)	35 (15)	64 (38)	43 (67)	21 (33)	41 (32)	27 (66)	14 (34)	38 (46)	29 (76)	9 (24)	3 (33)	2 (67)	1 (33)
Anticipated difficulty (>2 predictors of difficulty)	219 (20)	205 (94)	14 (6)	49 (29)	38 (78)	11 (22)	29 (23)	22 (76)	7 (24)	13 (16)	11 (85)	2 (15)	3 (33)	2 (67)	1 (33)
Higher risk	540 (48)	490 (91)	50 (9)	109 (64)	79 (72)	30 (28)	73 (57)	56 (77)	17 (23)	53 (65)	42 (79)	11 (21)	7 (77)	4 (57)	3 (43)

Higher risk = summary of events that involved either hypoxemia for at least 1 min, difficult or impossible bag-mask ventilation, or occurred after at least two previous direct laryngoscopy attempts.

two classical predictors for difficult airway. Finally, despite its multiple risks, complications were rare after failed initial direct laryngoscopy with a 1% risk for pharyngeal injury when video laryngoscopy was attempted during rescue.

Our findings are the result of systematic analysis of a large number of perioperative tracheal intubations from several large anesthesia practices. The resulting data are highly relevant because they not only allow the inclusion of a uniquely large number of failed initial direct laryngoscopies ($n = 1,427$) and the analysis of their subsequent management, but they also reflect the current practice of perioperative airway management practice in tertiary medical centers across the United States. To our knowledge, this is the largest and most diverse study of its kind, and we consider the results highly relevant for clinical anesthesiologists and the field of perioperative airway management at large.

In essence, our new findings quantify the success of video laryngoscopy in routine clinical practice: video laryngoscopy is used in the vast majority of airway rescue events where initial direct laryngoscopy has failed and its use is associated with a high likelihood of success. This success rate was maintained during times of increased urgency such as during threatened or actual failed ventilation, after multiple failed direct laryngoscopy attempts, and in the setting of hypoxemia. Additionally, we found that the use of video laryngoscopy for the rescue of failed initial direct laryngoscopy has increased over the past decade from less than 30% in 2004 to over 80% of rescues more recently (fig. 2). It appears that clinical practice may be gravitating toward a reduction in the number of laryngoscopy attempts, as these rescues mostly occurred after only one failed direct laryngoscopy attempt. Although persistence with direct laryngoscopy may have resulted in ultimate success, our data suggest that in recent years, providers are avoiding this practice. However, the data do not allow us to determine why practitioners now more frequently prefer video laryngoscopy over other rescue strategies. We speculate that this preference reflects today's widespread availability of video laryngoscopy, an anticipated high success rate, and growing comfort and familiarity with using this technique. Nevertheless, we consider it a practice improvement that the growing use of video laryngoscopy is associated with a reduced incidence of multiple attempts at direct laryngoscopy. This work builds on previous studies examining rescue techniques after failed direct laryngoscopy that had limited relevance due to single-center data, small number of providers, limited sample size, or lack of comparisons. Our new findings confirm those of the existing studies, suggesting that video laryngoscopy rescues initial failed direct laryngoscopy with success rates between 80 and 95%.^{4,5,11,16} Similarly, SGAs have been previously proposed as effective rescue means when used as a conduit for intubation with reported success rates of 87 to 94% in 23 or 15 cases, respectively.^{17,18} A previous prominent single-center study evaluating that 12,225 patients proposed a novel difficult

airway algorithm incorporating video laryngoscopy was limited to only 29 failed direct laryngoscopy events performed by 15 anesthesiologists.⁶ For the first time, we have a multicenter perspective on the performance of the new-generation video laryngoscope and alternate intubation techniques. Furthermore, after a center-effects analysis, we observed little variance across institutions regarding the success rate of video laryngoscopy in rescuing failed direct laryngoscopy. We believe that this data set demonstrates that modern day video laryngoscopy is used with a high success of tracheal intubation when initial direct laryngoscopy fails. However, despite the very large number of cases analyzed in this study, interpretation of comparative success rates is limited since the choice of the rescue device was not randomized but rather at the discretion of each provider. It is possible that specific patient features, personal preferences, or immediate availability have biased the practitioner's decision to use one rescue technique over another.

Our observation of a high use of video laryngoscopy (with a maintained high rate of successful intubation rescue) in the presence of difficult or impossible mask ventilation describes a practice in variance to existing guidance. The current failed ventilation pathway of the American Society of Anesthesiologists airway algorithm suggests consideration of an SGA.³ This suggestion is based upon expert opinion and supplemented by a single small study predating modern video laryngoscopy in which the use of the SGA restored ventilation in 16 of 17 cases of difficult mask ventilation and difficult intubation.⁷ Our study similarly reports 10 cases of SGA airway rescue with two reported failures to successfully intubate in this setting. In eight of these cases, a tracheal tube was effectively placed, and in one case, the SGA was used for definitive airway management. However, it is surprising that in contrast to established guidelines, providers more frequently ($n = 107$ of 155; 69%) chose to use video laryngoscopy in the setting of difficult or impossible ventilation rather than other efforts to restore ventilation, and this practice retained a high success rate of successful tracheal intubation of 88% ($n = 94$ of 107). Indeed, the low incidence of using SGAs to restore ventilation when difficult intubation and difficult ventilation are encountered echoes the findings of a recent MPOG study specifically examining this event.¹⁹

Although our data are informative regarding the effectiveness of intubation rescue devices, they must be cautiously applied to individual patient care. Provider experience, device availability, and patient-specific airway and cardiopulmonary features must drive the choice of rescue device. These data are impactful because they significantly advance our knowledge of success for the techniques analyzed in a practice setting that is diverse and allow provider choice among different rescue strategies. Nevertheless, our results do not preclude other practice settings from achieving high rescue success rates with alternate strategies that are well established in those environments.

We recorded 12 cases of pharyngeal injury in this data set and all occurred when video laryngoscopy was attempted after the failure of initial direct laryngoscopy. Pharyngeal injury during primary airway management with video laryngoscopy has been described previously.^{20–26} While previous reports indicate a low incidence, our analysis indicates an increased risk of pharyngeal injury of 1% (12 of 1,122 cases) when video laryngoscopy is used after failed direct laryngoscopy. Moreover, based on the study design, it cannot be ruled out that true incidence is higher since the data did not include postoperative observations or longer term outcome data. While the true incidence remains unclear, video laryngoscopy may require specific precautions to reduce the risk of pharyngeal injury. In particular, providers should focus attention on the oral and pharyngeal cavities during blade insertion and/or tube placement, not just on the video screen.

Our analysis has several limitations. First, we could not determine provider experience with the given devices since the record remains unclear as to which of the providers failed with direct laryngoscopy and which one of them was involved in any of the subsequent intubation attempts. Procedural experience of the laryngoscopist cannot be used to further interpret the data. Second, the data provided regarding hypoxemia cannot be precisely coincided with the intubation event, but rather was gathered in association with the time of intubation, as documented by the anesthesia provider. Consequently, it is unclear whether rescue techniques were chosen because of hypoxemia or if the hypoxemia was a result of persistence with a given rescue technique. Third, data about the results of preoperative airway assessment were not available for every study patient. Therefore, it is not possible to conclude whether or not all failed direct laryngoscopies represented patients with unanticipated difficult airways. Fourth, the data did not allow interpretation of the timing, type, or dosage of muscle relaxation around the time of airway interventions. Fifth, *post hoc* sample size estimates confirm that the study may not have been sufficiently powered to detect outcome differences between all groups. Finally, the retrospective observational nature of this study limits the interpretation of the frequency of airway rescue and the rescue success rates observed in this study population.

In summary, we found that video laryngoscopy was associated with a higher rate of successful tracheal intubation compared to the other commonly performed techniques in the perioperative practice of large tertiary care academic medical centers. Furthermore, video laryngoscopy (especially use of the GlideScope) was the most frequent technique chosen to rescue failed direct laryngoscopy. In contrast to current recommendations, we found video laryngoscopy to be used frequently for airway rescue when difficult mask ventilation occurred after failed direct laryngoscopy. Nevertheless, its use was associated with a high

success rate for rescue. We found the use of video laryngoscopy in rescue laryngoscopy to be associated with a 1% risk for pharyngeal injury. These findings may help guide equipment provision and clinical use when managing cases of failed direct laryngoscopy. The data may also serve as evidence when reviewing existing airway algorithms or developing new guidelines. Further research is necessary to identify specific factors of patients and provider experience that might determine airway rescue success when using specific devices.

Acknowledgments

The authors would like to thank the members of Perioperative Clinical Research Committee from the Multicenter Perioperative Outcomes Group (Ann Arbor, Michigan; members are listed in the Appendix).

Research Support

Supported by a Foundation for Anesthesia Education and Research Medical Student Anesthesia Research Fellowship (Schaumburg, Illinois; to Dr. Willett).

Competing Interests

Dr. Aziz and Dr. Brambrink have received research funding from Karl Storz Endoscopy (El Segundo, California). Dr. Aziz has also received honoraria for speaking from this vendor. Dr. Healy is a paid scientific advisor to Brio Device LLC (airway device development) (Ann Arbor, Michigan). The other authors declare no competing interests.

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Appendix

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ANESTHESIOLOGY REFLECTIONS FROM THE WOOD LIBRARY-MUSEUM

From *The Tempest* and *Henry IV*: Shakespearean Snoring and Colton Gas



Inspired by Shakespeare's *The Tempest*, an unknown artist painted ca. 1780 the Bard's characters Duke Prospero (*center*), his daughter Miranda (*left*) and the spirit Ariel (*right*). Also from *The Tempest*, the brother of the King of Naples, Sebastian, observed that Prospero's brother "dost snore distinctly; There's meaning in ... snores." The author of *Shakspeare* [sic] and *the Bible*, nitrous oxide pioneer G.Q. Colton (1814–1898) used the snoring of partial airway obstruction to judge whether his Manhattan patients were anesthetized deeply enough by "Colton gas" for dental extraction. And quoting the title character from Shakespeare's *Henry IV*, Colton had no intent to administer "vapours ... to strangle" or smother hapless patients. (Copyright © the American Society of Anesthesiologists' Wood Library-Museum of Anesthesiology.)

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