Videographic Assessment of Tracheal Intubation Technique in a Network of Pediatric Emergency Departments: A Report by the Videography in Pediatric Resuscitation (VIPER) Collaborative

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Study objective: We sought to describe the tracheal intubation technique across a network of children's hospitals and explore the association between intubation technical adjuncts and first-attempt success as well as between laryngoscopy duration and the incidence of hypoxemia.

Methods: We conducted a prospective observational study in 4 tertiary pediatric emergency departments of the Videography in Pediatric Resuscitation Collaborative. Children undergoing tracheal intubation captured on video were eligible for inclusion. Data on intubator background, patient characteristics, technical characteristics (eg, use of videolaryngoscopy and apneic oxygenation), and procedural outcomes were obtained through a video review.

Results: We obtained complete data on first attempts in 494 patients. The first-attempt success rate was 67%, the median laryngoscopy duration was 35 seconds (interquartile range 25 to 40), and hypoxemia occurred in 15% of the patients. Videolaryngoscopy was used for at least a part of the procedure in 48% of the attempts, and it had no association with success or the incidence of hypoxemia. Attempts in which videolaryngoscopy was used for the entire procedure (compared with direct laryngoscopy for the entire procedure) had a longer duration (the difference between the medians was 6 seconds; 95% confidence interval, 1 to 12 seconds). Intubation attempts longer than 45 seconds had a greater incidence of hypoxemia (29% versus 6%). Furthermore, apneic oxygenation was used in 8% of the first attempts.

Conclusion: Among children undergoing tracheal intubation in a group of pediatric emergency departments, first-attempt success occurred in 67% of the patients. Videolaryngoscopy use was associated with longer laryngoscopy durations but was not associated with success or the incidence of hypoxemia. [Ann Emerg Med. 2022;■:1-11.]

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INTRODUCTION

Background

Tracheal intubation is a fundamental procedure for critically ill and injured children. However, studies of the outcomes of pediatric tracheal intubation have consistently shown that first-attempt success is less common, and physiologic deterioration more common, in children than in adults.[1,2] The reasons for this discrepancy are multifactorial: pediatric cardiorespiratory physiology makes children more prone to oxyhemoglobin desaturation and bradycardia during laryngoscopy[3,4]; differences in the anatomy of the pediatric airway can be challenging[5]; and clinical experience with pediatric intubation at the level of individual providers is uncommon and, possibly, declining in frequency.[6-9] This combination of factors makes research on the optimal pediatric tracheal intubation technique a high priority. Additionally, adjunctive techniques such as videolaryngoscopy and apneic oxygenation are understudied in the pediatric population outside of the operating room.

Importance

In 2012, Kerrey et al[1] published a single-center report in the *Annals of Emergency Medicine*, summarizing an analysis of pediatric tracheal intubation in a tertiary emergency department (ED), which was assessed using a program

Editor's Capsule Summary

What is already known on this topic

Video laryngoscopy is a common intubation alternative to direct visualization.

What question this study addressed

Which technique exhibits the best first-pass success in children?

What this study adds to our knowledge

In this multicenter, observational, videotape-review study of 494 pediatric emergency department intubations, the choice of videolaryngoscopy demonstrated similar first-pass success, hypoxemia frequency, and laryngoscopy duration—excepting the subset for whom videolaryngoscopy was used throughout the entire procedure, in which the laryngoscopy duration was modestly longer (median, 40 versus 34 seconds).

How this is relevant to clinical practice

For the typical pediatric airway, video and direct laryngoscopy are similarly effective.

involving video recording and review. The findings of that study included a first-attempt success rate of 52% and an incidence of oxyhemoglobin desaturation of 38%, both significantly worse than that reported in most previous studies of pediatric tracheal intubation outside of the operating room.[2,10] A subsequent analysis of data collected from a video review, compared with data collected from a chart review, found significant shortcomings in data completeness when tracheal intubation events were reviewed using medical records alone.[11] Video review has been described as "rendering... results decidedly reliable and precise and setting a new criterion standard methodology for airway management research."[12]

Goals of This Investigation

The Videography In Pediatric Resuscitation (VIPER) Collaborative was established by a group of investigators at tertiary children's hospitals with videography programs in the resuscitation areas of their EDs.[13] The goal of the collaborative is to expand video-based research on pediatric resuscitation to a multicenter setting, allowing accurate examination of tracheal intubation and other critical procedures. In the present study, we sought to describe the landscape of the tracheal intubation technique across 4 VIPER sites using a video review as a primary data source. Our goal was to accurately characterize the technical aspects of pediatric intubation, with the secondary aim of exploring the association between specific technical aspects and procedural outcomes.

MATERIALS AND METHODS

Study Design and Setting

The VIPER Collaborative is a multisite research group of pediatric hospitals where video recording is used for quality assurance in the ED resuscitation area.[13] We conducted a prospective observational cohort study in the EDs of 4 tertiary children's hospitals contributing data to the VIPER Collaborative registry (Children's Hospital of Philadelphia, Children's National Hospital, Cincinnati Children's Hospital, and Medical Center, Children's Hospital Colorado). The study was approved by the institutional review board of the Children's Hospital of Philadelphia.

At each site, resuscitative care in the ED is video recorded as a part of intradivisional continuous quality assurance programs. Video recording occurs automatically for all events, and patient or parent consent is included as a part of the overall consent for treatment; however, events for which consent is not obtained are immediately deleted. Video recording is performed using 3 synchronized camera views and a patient monitor view (LiveCapture, BLine Medical; Ocularis OnSSI, Qognify Inc). The videos are reviewed, and deidentified data on common resuscitative procedures, including tracheal intubation, are collected. Following each site's specific retention period, the videos are deleted and are not a part of the patient medical record.

The creation and testing of the VIPER database have been reported elsewhere. Briefly, the database was created by the investigators through an iterative process using video-recorded simulations as a source of test data. A duplicate review of tracheal intubation events by multiple investigators during these simulations yielded high interrater agreement, with $\kappa > 0.8$ for all categorical data fields and ICC >0.96 for continuous (time-based) data fields.[13]

Selection of Participants

We screened all children undergoing attempted tracheal intubation in the resuscitation areas of the enrolled sites' EDs. We excluded events in which video recording did not occur (eg, intubations outside of the resuscitation area), video review was not possible because of technical complications, or intubation was attempted using a method other than laryngoscopy (eg, surgical or fiberoptic). Tracheal intubation in each study site ED is performed by a

pool of physicians, including those from pediatric emergency medicine, pediatric critical care medicine, adult emergency medicine, anesthesiology, and neonatology; all physicians allowed to perform tracheal intubation in the ED are required to have completed a mandatory period of supervised training prior to being permitted to perform tracheal intubation in the ED. We categorized physicians attempting tracheal intubation based on their training background (pediatrics, emergency medicine, and anesthesia) and level of training (resident, fellow, and attending), classifying this field into 6 categories, as previously reported by Kerrey et al.[1] At each enrolled site, a C-MAC videolaryngoscope (Karl Storz Endoscopy-America, Inc) is the first-line device used for all intubations. The decision to use the video display of the C-MAC videolaryngoscope for indirect visualization (as opposed to direct laryngoscopy) and/or coaching is performed at the discretion of the intubator and supervising physician (where applicable).

Measurements

The study team members at each site reviewed the video-recorded events in which tracheal intubation was attempted. A list of data fields collected during each attempt is shown in Table E1 (available at http://www.annemergmed.com.) We defined, a priori, an intubation attempt as the insertion of a laryngoscope blade into a patient's mouth and its subsequent removal, regardless of whether endotracheal tube placement was attempted. We defined oxygenation start and stop time as the use of 100% oxygen using either a nonrebreather or a bag-valve-mask device; if the delivery of oxygen was interrupted for 10 seconds or longer, the start time was recalculated according to when oxygen delivery was restored.

We defined the laryngoscopy technique (videolaryngoscopy versus direct visualization) during 2 time periods for each tracheal intubation attempt: (1) the glottic visualization phase, defined as the time from when the blade was inserted into the patient's mouth to when the intubator began to insert an endotracheal tube into the oropharynx, and (2) the tube placement phase, defined as the time from when an endotracheal tube was inserted into the oropharynx to when the blade was removed and the attempt was completed (regardless of whether the tube was successfully placed in the trachea). An overall tracheal intubation attempt was defined as "direct visualization" if the intubator had their line of sight directed at the patient's mouth for majority of both the phases. In contrast, an attempt was defined as "videolaryngoscopy" if the intubator's line of sight was directed at the display of the videolaryngoscope (Figure 1). Tracheal intubation attempts in which the intubator switched from one technique to the other (eg, visualization using direct laryngoscopy and tube placement using videolaryngoscopy or vice versa) were categorized separately.

Cricoid pressure was defined as the application of pressure by an assistant's hand on the front of the patient's neck during the attempt. External laryngeal manipulation was defined as the intubator using their right hand to improve visualization during the attempt. Lip retraction was defined as an assistant using a finger to stretch the right corner of the patient's mouth open during tube insertion.[14] Apneic oxygenation refers to the use of high-flow nasal cannula oxygen during laryngoscopy and tube insertion. Coaching was defined as a supervising clinician at the head of the bed giving verbal directions to the intubator during the attempt.

Outcomes

We examined 3 outcomes of interest: (1) tracheal intubation success, (2) time of laryngoscopy, and (3) occurrence of hypoxemia. A successful attempt was one in which an endotracheal tube was successfully placed in the trachea prior to the removal of the laryngoscope, as evidenced by exhaled carbon dioxide detection using either a colorimetric device or waveform capnography (both of which are apparent from video review). For patients with cardiac arrest, we anticipated that exhaled carbon dioxide detection might exhibit imperfect specificity (ie, a successfully intubated patient might not yield detectable exhaled carbon dioxide); therefore, it was agreed upon a priori that such cases would be reviewed for secondary signs of successful tube placement such as chest wall motion with positive pressure ventilation.

We defined laryngoscopy duration as the time from the insertion of a laryngoscope blade into the patient's mouth to the removal of the blade for any reason, regardless of whether a tube was inserted. The time of tube entry was defined as the time when an endotracheal tube was seen to be advanced into the oropharynx of the patient. Using these time points, we divided the total time of laryngoscopy into 2 components: time between blade insertion and tube entry (glottic visualization time) and time from tube entry to blade removal (tube placement time).

We defined hypoxemia using pulse oximetry, with SpO_2 falling below 90% during or immediately after the attempt. The duration of hypoxemia was calculated as the difference between the time, in seconds, when the SpO_2 fell below 90% and when it increased to 90% or above again. Patients who did not have measurable vital signs (eg, cardiac arrest)

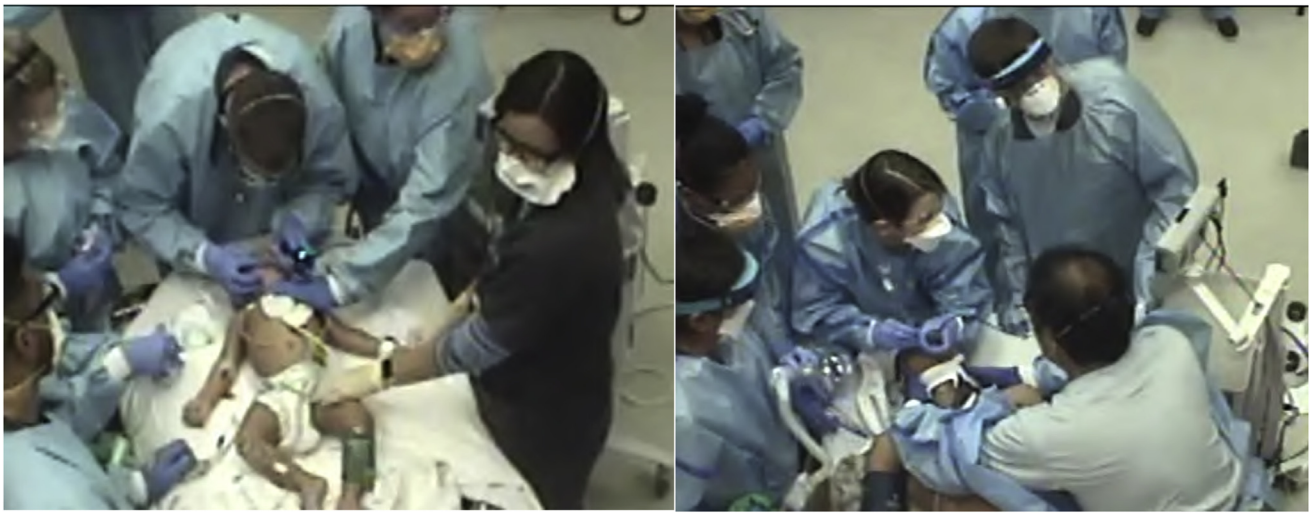

Figure 1. Sample images illustrate direct laryngoscopy and videolaryngoscopy. On the left is an example of an intubator using direct laryngoscopy (line of sight directed toward the patient's face) during the glottic visualization phase of the procedure; on the right is an intubator using videolaryngoscopy (line of sight directed toward the video display) during the tube placement phase of the procedure. The views shown here were taken from one study site; each of the VIPER sites has a video configuration that provides a similar set of viewpoints.

or those who were hypoxemic prior to intubation were excluded from this analysis.

Analysis

All data were summarized descriptively. The patients were categorized based on age as either infants (<1 year) or older children. For the dichotomous outcomes of intubation success and the occurrence of hypoxemia, we calculated the risk difference between attempts performed with and without each of a set of clinical covariates (patient age, cervical spine immobilization, and technical adjuncts to laryngoscopy and tube placement). For the continuous outcome of laryngoscopy duration, we calculated the generalized Hodges-Lehmann median differences for the same set of procedural technical adjuncts. All measures of effect size were calculated using Stata, version16 (Stata Corp).

RESULTS

Characteristics of Study Subjects

We identified 508 patients across all the sites who underwent tracheal intubation captured on video during the study period. Data on intubation success were available for 494 of the 508 (97%) patients. Table 1 lists the number

Table 1. Site-specific data on enrollment and success by provider category.

Study Site	A	B	C	D
Enrollment period	7/16 to 8/20	2/17 to 11/18	8/18 to 5/20	11/18 to 8/20
Enrolled patients	194	113	48	139
Trauma	41	35	6	25
Excluded*	2	2	0	2
First-attempt success by provider category				
Pediatric resident	1/1 (100%)	2/4 (50%)	3/12 (25%)	1/1 (100%)
EM resident	28/36 (79%)	7/9 (78%)	5/7 (71%)	7/10 (70%)
PEM fellow	61/112 (55%)	52/68 (76%)	12/20 (60%)	77/98 (79%)
PEM attending	7/11 (64%)	3/5 (60%)	0/3 (0%)	7/11 (64%)
PCCM fellow	13/15 (87%)	3/7 (43%)	NA	NA
Anesthesia	15/19 (78%)	17/22 (78%)	4/5 (80%)	7/9 (78%)
Other	NA	NA	NA	6/10 (60%)

EM, emergency medicine; *NA,* not applicable; *PCCM,* pediatric critical care medicine; *PEM,* pediatric emergency medicine.
*Intubation events either outside of the resuscitation area or not captured on video.

Table 2. Effect of patient and procedure characteristics on first-attempt success.

Covariate	First-Attempt Success Rate	Risk Difference (95% CI)	Data Missing
Age category, y			
0 to 1	75/149 (50%)	−25% (−35% to −15%)	0
1 to 6	119/158 (75%)	Reference	
6 to 10	42/54 (78%)	2% (−10% to 15%)	
10 to 15	38/59 (64%)	−11% (−25% to 3%)	
>15	55/74 (74%)	−1% (−13% to 11%)	
Cervical spine immobilized			
Yes	36/53 (68%)	4%	176 (36%)
No	169/265 (64%)	(−9% to 18%)	
Cricoid pressure			
Yes	115/167 (69%)	4%	21 (4%)
No	198/306 (65%)	(−4% to 13%)	
External laryngeal manipulation/bimanual laryngoscopy			
Yes	7/11 (64%)	0%	130 (26%)
No	224/353 (63%)	(−29% to 29%)	
Lip retraction (only if tube placement was attempted)			
Yes	64/138 (46%)	−28%	18 (3%)
No	253/338 (75%)	(−38% to −19%)	
Apneic oxygenation*			
Yes	17/21 (81%)	19%	96 (19%)*
No	206/334 (62%)	(2% to 37%)	
Coaching by supervisor			
Yes	167/271 (62%)	−11%	24 (5%)
No	145/199 (73%)	(−20% to −3%)	
Video use during majority of the glottic visualization phase			
Yes	111/168 (66%)	−2%	91 (18%)
No	159/235 (68%)	(−11% to 8%)	
Video use during majority of the tube placement phase			
Yes	141/185 (76%)	4%	135 (25%)
No	126/174 (72%)	(−5% to 13%)	
Video use during the entire procedure (versus direct visualization)			
Yes	102/136 (75%)	2%	NA
No	116/164 (73%)	(−8% to 12%)	

CI, Confidence interval; *NA*, not applicable.
*Forty-three first attempts were made in patients without measurable pulse oximetry readings.

of patients enrolled and the enrollment period at each site, along with the proportion of trauma versus medical resuscitations. During each site's respective enrollment period, no intubations occurred for which fiberoptic or surgical airway management was necessary.

Main Results

Intubation success. The overall first-attempt success rate was 329/494 (67%) among all enrolled patients. A median of one attempt (range, 1 to 6; interquartile range [IQR], 1 to 2) was made per patient. Tracheal intubation was successfully completed in 480 of the 494 (97%) patients in 14 patients with out-of-hospital cardiac arrest, resuscitation was terminated, without the return of spontaneous circulation and without successful completion of tracheal intubation. There was no difference in first-attempt success between medical and trauma patients. Table 1 summarizes the first-attempt success rate based on intubator background.

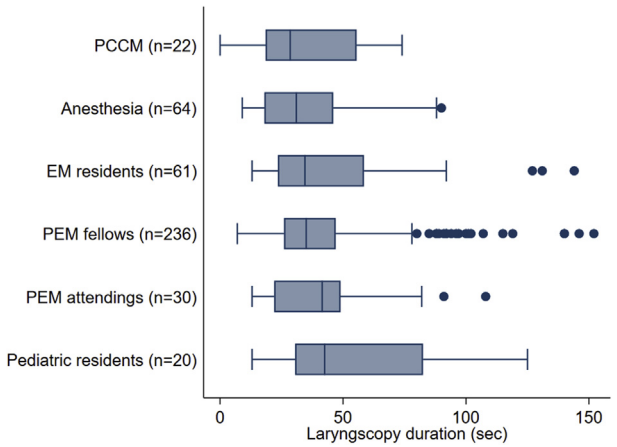

Figure 2. Laryngoscopy duration during first attempts stratified by intubator background.

Table 2 summarizes the effect of the procedural covariates and age categories on first-attempt success. Videolaryngoscopy was used for at least one phase of tracheal intubation attempts in 48% of all attempts. In 48 (11%) attempts, direct laryngoscopy was used during glottic visualization, and the intubator switched to videolaryngoscopy during tube placement; furthermore, in 6 (1%) attempts, the opposite sequence occurred (videolaryngoscopy during visualization, followed by direct laryngoscopy during tube placement).

Laryngoscopy duration. The median duration of laryngoscopy for all attempts was 35 seconds (IQR, 24 to 50 seconds). Laryngoscopy duration stratified by provider group is shown in Figure 2. Table 3 shows the effect of the procedural adjuncts and age categories on laryngoscopy duration.

Hypoxemia. Seventy-two first attempts were made in patients without measurable oxygen saturation (cardiac arrest or severe shock). Among patients with measurable vital signs, 149 patients had an SpO_2 of less than 90% at the time of their first attempt, measured using pulse oximetry. Among patients with a preintubation pulse oximeter reading of 91% or greater (n=273), hypoxemia occurred in 41 of the 273 (15%) patients during their first attempt. The median duration of preoxygenation prior to the first tracheal intubation attempt was 997±996 seconds. For subsequent attempts, the median duration was 175±239 seconds. The median duration of hypoxemia, when it did occur, was 77 seconds (IQR, 42-208 seconds). Table 4 shows the effect of the procedural adjuncts and age categories on the incidence of hypoxemia.

Impact of videolaryngoscopy. The intubators used videolaryngoscopy for at least a part of the procedure during 187 of 404 (46%) first attempts, for which data were available. For first attempts in which tube insertion was attempted, videolaryngoscopy was used for both glottic visualization and tube placement in 155 of 375 (41%) first attempts; however, direct laryngoscopy was used during both the phases in 164 of 375 (44%) first attempts. In 48 (13%) first attempts, direct laryngoscopy was used to obtain a view of the glottis and videolaryngoscopy was used for tube insertion; in 8 (2%) first attempts, videolaryngoscopy was used during visualization and direct laryngoscopy during tube placement. There was no association between the use of videolaryngoscopy and success. Attempts in which videolaryngoscopy was used for the entire procedure were longer than attempts in which direct laryngoscopy was used.

LIMITATIONS

Our study was conducted at 4 tertiary children's hospitals. The epidemiology of pediatric illness and injury cared for at the study sites was generally similar. Site-specific differences in how pediatric tracheal intubation is performed in the ED were not accounted for in our study. As an example, one study site has already published the results of quality improvement work based on changes in the approach to tracheal intubation in the ED as a result of their video review program, as discussed below.[15] Similarly, all the study sites had fellowship trainees in pediatric emergency medicine and pediatric critical care medicine, who accounted for majority of the intubations performed at each site. Generalizing these results to a nontertiary setting, pediatric care in a general ED, or a clinical setting without trainees among a pool of providers expected to perform intubations might be difficult.

The VIPER registry began collecting data in 2015. The 4 sites participating in the collaborative in the current study joined at different time points, and as a result, there was differential enrollment in terms of the number of cases per site in the database. We believe that given both the similar epidemiology at the children's hospitals and the objective nature of the data fields collected, this phenomenon should not result in a significant bias in our results.

The highly granular data collection involved in this registry allowed precise measurement of the tasks in seconds and could detect small differences in times between the groups. However, the clinical significance of the small differences (eg, 6 seconds longer with videolaryngoscopy) in time during intubation is less clear. Although completing intubation efficiently is desired, the benefit of additional time dedicated to measures for optimal safety and the likelihood of success during intubation may outweigh these small differences in times. Additionally, shorter laryngoscopy

Table 3. Effect of patient and procedure characteristics on laryngoscopy duration.

Covariate	Laryngoscopy Duration, Seconds (Median, IQR)	Effect Size, Seconds (95% CI)	Data Missing
Age category, y			7 (1%)
0 to 1	42 (29 to 58)	10 (5 to 14)	
1 to 6	29 (21 to 45)	Reference	
6 to 10	37 (26 to 52)	5 (0 to 11)	
10 to 15	31 (23 to 41)	1 (−4 to 6)	
>15	34 (21 to 50)	2 (−3 to 7)	
Cervical spine immobilized			176 (36%)
Yes	36 (23 to 61)	0	
No	36 (25 to 54)	(−7 to 7)	
Cricoid pressure			25 (5%)
Yes	41 (30 to 61)	9	
No	32 (22 to 47)	(5 to 13)	
External laryngeal manipulation/bimanual laryngoscopy			129 (26%)
Yes	54 (26 to 66)	9	
No	36 (24 to 54)	(−8 to 26)	
Lip retraction (only if tube placement was attempted)			22 (4%)
Yes	45 (25 to 50)	2	
No	33 (24 to 50)	(−2 to 6)	
Apneic oxygenation*			96 (19%)*
Yes	26 (24 to 38)	−8	
No	39 (25 to 59)	(−14 to −3)	
Coaching by supervisor			29 (6%)
Yes	39 (27 to 58)	7	
No	30 (21 to 45)	(4 to 11)	
Video use during majority of the glottic visualization phase			90 (18%)
Yes	38 (26 to 52)	4	
No	32 (22 to 48)	(0 to 8)	
Video use during majority of the tube placement phase			115 (23%)
Yes	35 (25 to 53)	2	
No	33 (21 to 48)	(−1 to 6)	
Video use during the entire procedure (versus direct visualization)			NA
Yes	40 (28 to 64)	6	
No	34 (22 to 49)	(1 to 12)	

CI, Confidence interval; *NA*, not applicable.
*Forty-three first attempts were made in patients without measurable pulse oximetry readings.

durations may also occur in attempts in which no tube placement is attempted. A cutoff of 30 seconds for laryngoscopy and its association with desaturation in our data set is comparable with findings reported by the members of our group in a previous single-center report.[16] Therefore, future research using this method will likely help determine critical intervals and cut points in procedural duration that improve procedural outcomes.

DISCUSSION

In this multisite, pediatric observational study, we found that the first-attempt success rate during tracheal intubation was 67%. The overall success rates in the present study are similar to those reported by Kerrey et al[1] in their previous study and first-attempt success rates in the NEAR4KIDS multisite pediatric intensive care unit database.[2] These results are different from those of many previously published studies of pediatric tracheal intubation in the ED, including a recent report of pediatric cases from the National Emergency Airway Registry, in which a first-attempt success rate of 79% was reported.[17] This lattermost study reported a median of 20 pediatric intubations per year at their sites, which likely means that few of the sites were tertiary children's hospitals. Children with more complicated medical conditions and intubators with more

Table 4. Effect of patient and procedure characteristics on hypoxemia (n=273).

Covariate	Incidence of Hypoxemia	Risk Difference (95% CI)	Data Missing
Age category, y			0
0 to 1	22/74 (30%)	19% (6% to 31%)	
1 to 6	10/90 (11%)	Reference	
6 to 10	2/31 (6%)	−5% (−15% to 6%)	
10 to 15	4/36 (11%)	0 (−12% to 12%)	
>15	3/42 (7%)	−4% (−14% to 6%)	
Laryngoscopy duration			15 (5%)
<30 seconds	6/94 (6%)	Reference	
30 to 45 seconds	3/70 (4%)	−2% (−8% to 5%)	
>45 seconds	32/109 (29%)	23% (13% to 33%)	
Cervical spine immobilized			44 (16%)
Yes	4/41	5%	
No	27/188	(−15% to 6%)	
Cricoid pressure			0
Yes	19/83	11%	
No	22/190	(1% to 21%)	
External laryngeal manipulation/bimanual laryngoscopy			3 (1%)
Yes	2/8	10%	
No	39/262	(−20% to 40%)	
Lip retraction (only if tube placement was attempted)			0
Yes	9/69	−3%	
No	32/204	(−12% to 7%)	
Apneic oxygenation			11 (4%)
Yes	2/18 (11%)	−4%	
No	38/206 (18%)	(−20% to 11%)	
Coaching by supervisor			0
Yes	26/170	1%	
No	15/103	(−8% to 9%)	
Video use during majority of the glottic visualization phase			44 (16%)
Yes	12/82	1%	
No	20/147	(−8% to 10%)	
Video use during majority of the tube placement phase			53 (19%)
Yes	16/105	2%	
No	15/115	(−7% to 11%)	
Video use during the entire procedure (versus direct visualization)			NA
Yes	11/65	3%	
No	15/110	(−8% to 14%)	

CI, Confidence interval; *NA*, not applicable.

limited ongoing exposure to intubations are likely to present at children's hospitals and may account for some of this difference.[6,9] Additionally, our data may support the notion that video review is a more accurate and unbiased data source for studying airway management.[1,11]

The intubators used videolaryngoscopy for at least a part of the tracheal intubation procedure in 48% of all attempts; 35% of attempts were performed using videolaryngoscopy through both the phases of the procedure. Our data did not show an effect on success when videolaryngoscopy was compared with direct laryngoscopy; the laryngoscopy duration was slightly longer when videolaryngoscopy was used. Our findings are consistent with data from anesthesiology studies, which have consistently shown that videolaryngoscopy results in equivalent or better success rates, with longer times to intubation, in children outside of the neonatal age range.[18-20] A recent Cochrane systematic review of the use of videolaryngoscopy in pediatric (nonneonatal) tracheal intubation was limited to studies conducted in the operating room. In contrast, simultaneous meta-analyses in neonatal and adult patients included studies from nonanesthesia settings in their results.[20,21]

Studies of pediatric intubation using videolaryngoscopy outside of the operating room have yielded mixed results. Eisenberg et al[22] published a 10-year retrospective single-center study on the incorporation of videolaryngoscopy into practice in a pediatric ED, finding that videolaryngoscopy use became almost ubiquitous over time but that success rates were not significantly different from those of historical controls that used direct laryngoscopy. Importantly, the authors acknowledged that videolaryngoscopy use in their study was a dichotomous data field coded as "yes" for any use of a videolaryngoscope, whether for visualization, tube insertion, or assistance from a supervisor watching the display. Grunwell et al[23] published an analysis of more than 8,000 intubations over 15 years in a multicenter pediatric intensive care unit registry; videolaryngoscopy was reported to be used in 0% to 55% of the cases depending on the site, and it had no association with intubation success.[23] Kaji et al[17] reported pediatric cases in the National Emergency Airway Registry and found that the use of a videolaryngoscope was associated with improved first-attempt success. Importantly, both these studies classified multiple devices (eg, C-MAC, GlideScope, AirTraq, and Pentax) equivalently as videolaryngoscopes despite important differences in the techniques associated with each device. With regard to the C-MAC videolaryngoscope specifically, the authors of the latter article explicitly reported the limitation of a misclassification bias because the chart review did not clearly describe the manner in which the C-MAC video display was used.

Videolaryngoscopy can be performed using many different available devices, including devices with hyperangulated blades designed to be used exclusively for indirect visualization (eg, GlideScope). The 4 sites enrolled in the VIPER Collaborative used a C-MAC videolaryngoscope, which uses blades of a shape and conformation identical to those of the standard straight and curved blades used in standard direct laryngoscopes; these devices can be used for either direct or indirect visualization during intubation. As described above, the C-MAC videolaryngoscope for either direct or indirect visualization is used at the discretion of the clinical team; the video display is connected and available for all cases but is not necessarily used. Thus, some ambiguity exists in defining videolaryngoscopy in cases in which an intubator looks at the patient and at the screen at differing points during the procedure. We chose to define videolaryngoscopy for each phase of the procedure based on whether the intubator used an indirect view for most of that phase. Using video review, we were able to specifically describe each attempt in its entirety, including cases in which a "hybrid" approach was used. In our study, the intubator switched from one approach to the other (direct visualization to videolaryngoscopy or vice versa) in 15% of first attempts; however, we chose not to categorize these attempts as videolaryngoscopy because we believed that it would not be possible to determine the effect of indirect visualization of an attempt in its entirety in these cases. We believe that our use of video review to characterize the procedure more accurately has the potential to delineate the optimal means of using videolaryngoscopy in pediatric airway management by clarifying which patient categories benefit the most, which intubator groups have optimal success (or require targeted training to improve success), or which additional procedural adjuncts (eg, laryngeal manipulation, standardized coaching language, shape and position of the endotracheal tube during insertion under direct visualization) may improve success when combined with videolaryngoscopy.

The laryngoscopy duration averaged 35 seconds across all first attempts and had an average duration of 6 seconds longer during attempts with videolaryngoscopy. Rinderknecht et al[16] published single-center data on pediatric tracheal intubation, showing a median duration of 35 seconds and an association between laryngoscopy duration exceeding 30 seconds and a 5-fold increased odds ratio of oxyhemoglobin desaturation. In a subsequent study from the same group, Kerrey et al[15] reported the results of a quality improvement initiative at their center, where all tracheal intubation attempts were mandatorily limited to 45 seconds; implementing this change resulted in a decrease in the incidence of desaturation from 33% to 16%. The combined data from all 4 of our enrolled sites yielded a similar median duration of laryngoscopy compared with that in this single-center report; in our study, 63% of all attempts exceeded 30 seconds and 53% exceeded 45 seconds. Additionally, desaturation occurred more often after 30 seconds of laryngoscopy.

Among patients with measurable vital signs and without preintubation desaturation, hypoxemia occurred in 20% of first attempts. Published data from healthy children in the operating room have shown that ventilation with 100% oxygen for 3 minutes yields an optimal degree of preoxygenation prior to tracheal intubation to avoid desaturation.[24] Our data showed that the median duration of oxygenation prior to any subsequent attempt beyond the first attempt was 176 seconds and that the median duration of oxygenation for more than 50% of all attempts was less than 2 minutes. Not surprisingly, the incidence of hypoxemia increased with the laryngoscopy duration. Apneic oxygenation has been shown to be beneficial in preventing hypoxemia during tracheal intubation in adults, but experience with

pediatric intubation is limited.[25-29] A recent review only identified 3 observational studies of children undergoing intubation in the ED, with a total combined sample size of fewer than 500 patients.[26,28,29] In our study, apneic oxygenation was infrequently used (8% of all attempts), making it difficult to draw conclusions about its effectiveness. Although we found that attempts with apneic oxygenation had a shorter median duration, this is a counterintuitive finding, given that apneic oxygenation is designed to make a patient tolerate a longer apneic period safely. It is more likely that intubator experience is a confounder here, wherein more experienced intubators are more likely to use apneic oxygenation.

Adjunctive techniques such as cricoid pressure, external laryngeal manipulation, and lip retraction were infrequently used. Recent published studies from the NEAR4KIDS database demonstrated an association between poorer success rates and a higher incidence of gastric regurgitation in children when cricoid pressure was used during tracheal intubation[30]; the 2020 Pediatric Advanced Life Support recommendations from the American Heart Association no longer recommend the routine use of cricoid pressure in children during tracheal intubation.[31] Our data corroborate the notion that cricoid pressure is not associated with improved success rates. External laryngeal manipulation, also called bimanual laryngoscopy, has been shown to improve tracheal intubation success in adults[32,33]; in our data, external laryngeal manipulation was infrequently used (4% of all attempts) and did not improve success. Lip retraction was associated with poorer first-attempt success. In a recent single-center study using video review, Shiima et al[14] demonstrated that lip retraction was independently predictive of tracheal intubation success in children, even when controlled for patient age and intubator background. Our data across the multiple sites do not support the positive impact of that technique.

In summary, our prospective multisite video-based registry of pediatric intubation in the ED demonstrated a first-attempt success rate of 67%, similar to that in the single-center report by Kerrey et al using a comparable methodology. Videolaryngoscopy is frequently used and is not associated with success or the incidence of hypoxemia. Intubation attempts with videolaryngoscopy for the entire procedure were longer than attempts with direct laryngoscopy. The use of video review is a reliable method for accurately assessing and characterizing intubations, and future research should expand on this methodology to better delineate the optimal use of specific aspects of the intubation technique to improve success and safety for children in the ED.

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