

Techniques and Trends, Success Rates, and Adverse Events in Emergency Department Pediatric Intubations: A Report From the National Emergency Airway Registry

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Study objective: We describe emergency department (ED) intubation practices for children younger than 16 years through multicenter prospective surveillance.

Methods: Academic and community EDs in the United States, Canada, and Australia recorded data electronically, from 2002 to 2012, with verified greater than or equal to 90% reporting.

Results: Ten of 18 participating centers provided qualifying data, reporting 1,053 encounters. Emergency physicians initiated 85% of intubations. Trainees initiated 83% (95% confidence interval [CI] 81% to 85%). Premedication became uncommon, reaching less than 30% by the last year. Etomidate was used in 78% of rapid sequence intubations. Rocuronium use increased during the period of study, whereas succinylcholine use declined. Video laryngoscopy increased, whereas direct laryngoscopy declined. The first attempt was successful in 83% of patients (95% CI 81% to 85%) overall. The risk of first-attempt failure was highest for infants (relative risk versus all others 2.3; 95% CI 1.8 to 3.0). Odds of first-attempt success for girls relative to boys were 0.57. The odds were 3.4 times greater for rapid sequence intubation than sedation without paralysis. The ultimate success rate was 99.5%.

Conclusion: Because we sampled only 10 centers and most of the intubations were by trainees, our results may not be generalizable to the typical ED setting. We found that premedication is now uncommon, etomidate is the predominant induction agent, and rocuronium and video laryngoscopy are used increasingly. First-attempt failure is most common in infants. [Ann Emerg Med. 2016;67:610-615.]

Please see page 611 for the Editor's Capsule Summary of this article.

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INTRODUCTION

Background

The operators, medications, and devices used for emergency intubation of adults have changed markedly in the past 3 decades.¹ One major change has been the proliferation of video laryngoscopes.¹ However, fewer data are available on the emergency intubation of children. Has video laryngoscopy become more common? Is succinylcholine still the dominant neuromuscular blocking agent? How often does intubation in children require multiple attempts? Which children are most at risk for failure on the first attempt?

Importance

Children are intubated less commonly than adults. They have larger tongues and more anterior airways, and they desaturate more quickly. First-attempt success is an important marker of intubation safety,²⁻⁴ with multiattempt

intubations associated with peri-intubation adverse events, especially esophageal intubation and hypoxia.

Goals of This Investigation

We conducted real-time passive multicenter surveillance of emergency department (ED) intubations of children, spanning more than 10 years. We report descriptive data, including trends over time and predictors of first-attempt success in the largest pediatric ED intubation sample to date, to our knowledge. We compare our findings with adult data from the same investigation.¹

MATERIALS AND METHODS

Study Design and Setting

The National Emergency Airway Registry (NEAR) is an international prospective multicenter registry approved by the institutional review boards of participating academic and

Editor's Capsule Summary

What is already known on this topic

Airway management practice has been evolving over time.

What question this study addressed

What changes have occurred in emergency department pediatric intubation management from 2002 to 2012?

What this study adds to our knowledge

In this 10-center registry study of 1,053 pediatric intubation encounters performed largely by trainees, progressive increases were observed in the use of video laryngoscopy and in rocuronium as the paralytic choice.

How this is relevant to clinical practice

This large surveillance study describes airway management practice trends.

community hospitals (participating centers shown in Table E1, available online at <http://www.annemergmed.com>). Some centers contributed less than 1% of the intubation totals. These EDs are adult-only EDs or are in close proximity to dedicated pediatric hospitals where children are preferentially triaged by emergency medical services, and thus intubation in these locations would happen only when an acutely ill child was brought in by private vehicle and needed stabilization before transfer to a pediatric ED.

Methods of Measurement

We have previously described the methods for NEAR data collection, quality control, data fields, and analysis.¹ We present data collected from July 1, 2002, through December 31, 2012.

We performed all analyses with SAS (version 9.12; SAS Institute, Inc., Cary, NC). We used the surveyfreq and surveylogistic procedures to properly account for clustering by center in all analyses. To evaluate predictors of first-attempt success, we developed a logistic regression model with predictors chosen a priori. These were age, sex, use of a paralytic, and use of video laryngoscopy. However, after we generated Figure 1, it was apparent that the age effect observed was attributable to a different success rate among infants versus all others. Therefore, instead of age as a continuous variable, we used a dichotomous predictor, age less than or equal to 1 year versus age greater than or equal to 1 year.

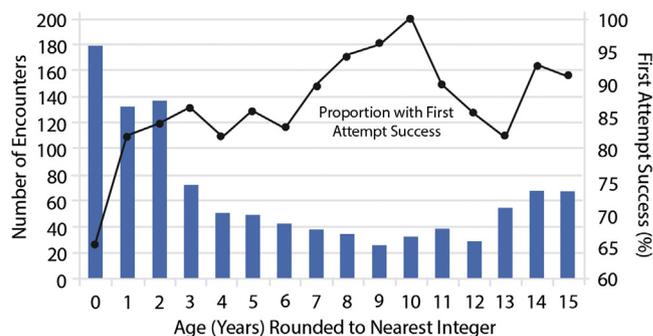


Figure 1. Number of participants and first-attempt success, by age.

RESULTS

Of 18 reporting NEAR sites, we excluded 5 for failing to maintain consistent compliance standards, and of the remaining 13, 10 recorded 1,053 pediatric intubation encounters (median age 7 years; interquartile range 3 to 13 years), which were analyzed for this report. The indications for intubation are reported in Table 1. Half were trauma encounters. Figure 1 shows participants' ages rounded to the nearest integer (median 7 years; interquartile range 3 to 13 years).

Table 2 shows intubation characteristics for all encounters and rates of first-attempt success. Affirmative

Table 1. Conditions necessitating intubation (reported by respondents as "indication for intubation").

Condition Necessitating Intubation	Frequency	Percentage (95% CI)
Traumatic head injury	317	30 (20-40)
Seizure	121	11 (6.7-16.3)
Polytrauma	91	8.6 (4.8-12.5)
Pneumonia	74	7.0 (2.8-11.3)
Other	72	6.8 (1.1-12.5)
Cardiac arrest	67	6.4 (3.9-8.9)
Altered mental status, not overdose	43	4.1 (0-9.6)
Shock	35	3.3 (0.72-5.9)
Coma	33	3.1 (2.1-4.2)
Overdose	33	3.1 (0.87-5.4)
Combative trauma	29	2.8 (1.4-4.1)
Gunshot/knife stab wound	27	2.6 (1.5-3.7)
Face/neck trauma	27	2.6 (0.73-4.4)
Airway obstruction	21	2.0 (1.1-2.9)
Arrest	21	2.0 (0.09-3.9)
Asthma	13	1.2 (0.53-1.9)
Burn/inhalation injury	9	0.9 (0-0.6)
Shock	9	0.9 (0.14-1.6)
CHF	3	0.3 (0-0.6)
GI bleed	3	0.3 (0-0.7)
Anaphylaxis	2	0.2 (0-0.4)
Acute MI	1	0.1 (0-0.3)
COPD	1	0.1 (0-0.2)
Stroke	1	0.1 (0-0.2)
Total	1,053	100

CHF, Congestive heart failure; GI, gastrointestinal; MI, myocardial infarction; COPD, chronic obstructive pulmonary disease.

Table 2. First-attempt intubation characteristics and first-pass success.

Intubation Variable	Initial Attempt	Percentage of All Encounters, % (95% CI)	First Attempt Successful	First Attempt Successful, % (95% CI)
Indication (total=1,053)				
Trauma	530	50 (36-65)	475	90 (87-92)
Medical	451	43 (29-57)	350	78 (70-85)
Other	72	6.8 (1.1-12.5)	51	71 (53-88)
Operator (total=1,053)				
Emergency medicine PGY1	37	3.5 (0-7.4)	31	84 (68-99)
Emergency medicine PGY2	165	16 (2.2-29)	141	85 (79-92)
Emergency medicine PGY3 or 4	538	51 (13-89)	473	88 (86-90)
Emergency medicine attending physician	140	13 (0-38)	109	78 (73-83)
Pediatric emergency medicine	38	4.9 (3.6-6.2)	29	76 (45-100)
Pediatrics	68	6.5 (0-19)	40	59 (56-62)
Anesthesia	30	2.8 (0-7.7)	27	90 (79-100)
Other	19	1.8 (0-4.1)	15	79 (50-100)
Emergency medicine (unspecified)	18	1.7 (0-5.0)	11	61 (42-80)
Method (total=1,053)				
Oral rapid sequence intubation	848	81 (72-89)	724	85 (79-92)
Oral, no meds	171	16 (9.6-23)	133	78 (70-86)
Oral sedation only	29	2.8 (0.13-5.4)	16	55 (26-84)
Oral, topical or sedation	1	0.1 (0-0.3)		*
Oral paralysis only	1	0.1 (0-0.3)		
Nasal, no meds	1	0.1 (0-0.2)		
Other	2	0.2 (0-0.4)		
Device (total=1,053)				
Direct laryngoscope	988	94 (87-100)	818	83 (77-89)
Video laryngoscope	35	3.3 (0-7.9)	34	97 (88-100)
GlideScope	16	1.5 (0-3.3)	14	88 (82-93)
Direct laryngoscope and bougie	6	0.6 (0.1-1.0)	5	83 (67-100)
Flexible fiberoptics	2	0.2 (0-0.4)		*
LMA	1	0.1 (0-0.4)		
I-LMA with intubation	1	0.1 (0-0.3)		
Lighted stylet	1	0.1 (0-0.3)		
Other	3	0.3 (0-0.6)		
Induction (total=1,053)				
Etomidate	670	64 (45-82)	586	87 (82-93)
Midazolam	85	8.1 (0-16)	61	72 (57-87)
Ketamine	27	2.5 (1.8-3.3)	20	74 (62-87)
Diazepam	10	1.0 (0-2.3)	6	60 (48-72)
Propofol	9	0.9 (0-2.1)	8	89 (68-100)
Pentothal	7	0.7 (0-1.7)	5	71 (35-100)
Methohexital	1	0.1 (0-0.3)		*
None	244	23 (14-32)	189	77 (73-82)
Paralytic (total=1,053)				
Succinylcholine	555	53 (45-60)	472	85 (79-92)
Rocuronium	242	23 (11-35)	215	89 (79-99)
Vecuronium	27	2.6 (0-5.6)	20	74 (61-87)
Pancuronium	5	0.5 (0-1.2)		*
None	224	21 (12-31)	164	73 (64-82)

LMA, Laryngeal mask airway; I-LMA, intubating laryngeal mask airway.

*Results not shown because of very small cell sizes.

documentation of successful intubation was provided in 99.5% of cases (95% confidence interval [CI] 99% to 100%). Trainees performed 83% of first attempts (95% CI 57% to 100%). Peri-intubation adverse events were reported in 15% of all encounters (Table 3), with no surgical airways reported.

Our trends analysis showed a declining use of pretreatment medications (Figure 2A), consistent preference for etomidate

as the induction agent (Figure 2B), and a declining use of succinylcholine in favor of rocuronium (Figure 2C and D). Children younger than 2 years were more likely to be intubated without a paralytic (39% versus 13% for those aged ≥ 2 years; relative risk 3.0; 95% CI 1.7 to 5.1). Video laryngoscopy became increasingly common during the study period (Figure 3). These trends mirrored those observed in our concurrent study of adults.¹

Table 3. Peri-intubation adverse events.

Adverse Event	Frequency	Total Adverse Events, %	Total Encounters, %
Esophageal intubation, immediate recognition	43	28.1	4.1
Other*	29	19	2.8
Main stem intubation	26	17	2.5
Cardiac arrest*	18	12	1.7
Hypotension-required intravenous fluid	8	5.2	0.76
Vomiting without aspiration	7	4.6	0.66
Dysrhythmia	5	3.3	0.47
Vomiting with aspiration	7	4.6	0.66
Epistaxis	3	2.0	0.28
Direct airway injury	2	1.3	0.19
Esophageal intubation, delayed recognition	2	1.3	0.19
Pneumothorax	1	0.65	0.09
Dental trauma	1	0.65	0.09
Laryngospasm	1	0.65	0.09

*Data were not collected to indicate what "other" intubation events were or whether cardiac arrest was incidental or thought to be due to intubation attempts.

The first attempt was successful in 83% of encounters (95% CI 77% to 90%). Table 2 shows first-attempt success across categories. First-attempt success was less likely as age decreased (Figure 1). For our multivariable logistic regression model, we coded age as infants (age ≤ 1 year) versus all others and excluded the 8 encounters in which a device other than a video laryngoscope or a direct laryngoscope was used (Table 2). The results are shown in Table 4 and showed significantly enhanced first-attempt success with video laryngoscopy and significantly diminished success in infants and girls. In our adult data, the odds of first-attempt success for women were 0.86 relative to men (95% CI 0.79 to 0.94).¹

Paralytic use was not a significant predictor in this overall analysis, which included "crash airways" in which no medications were used. However, when we restricted the analysis to the 877 intubation attempts using either rapid sequence intubation or sedation without paralysis, we found that rapid sequence intubation was associated with 3.4 times higher odds of first-attempt success (95% CI 1.5 to 7.4). In this subgroup, findings for infancy, sex, and use of video laryngoscopy did not differ (data not shown).

LIMITATIONS

The principal limitation of this study is that most intubations were performed by trainees in academic general or adult-only institutions and thus may not represent community ED practice or that of dedicated pediatric EDs.

Generalizability is further limited in that more than a quarter of initially participating sites were dropped for inadequate documentation.

Our study is also subject to the limitations of self-report. Kerrey et al⁵ observed that chart documentation underreported the actual frequency of first-attempt failures and adverse events compared with video review, and this could be the case with our data as well.

Given institutional review board requirements on data deidentification, we could not identify any patients who appeared in the registry more than once and limit our data to their first intubation encounter. We think it unlikely that individuals being encountered multiple times had any distorting effect on our findings.

Our data collection did not detail what "other" intubation adverse events were or whether the recorded episodes of cardiac arrest were incidental or thought to be due to intubation attempts. In retrospect, such information would have been useful to report, although it may not be possible to distinguish.

DISCUSSION

We detail practice trends in a multicenter registry of 1,053 pediatric ED intubations from 10 centers. We found that pretreatment agents are uncommon, with prefasciculation essentially never used. There was a consistent preference for etomidate as the induction agent despite concerns about adrenal suppression,⁶ with ketamine used for less than 3%. Etomidate was the dominant induction agent in our corresponding adult study¹ and in the pediatric series by Sagarin et al.⁷

We observed an increase in use of rocuronium and a decrease in use of succinylcholine during the course of the study period, as we also observed in adults.¹ However, in contrast with the adult findings, 39% of children younger than 2 years and 13% of those aged 2 to 15 years were intubated without any paralytic. Succinylcholine was administered in 56% of all rapid sequence intubation encounters for children younger than 2 years, suggesting little concern for undiagnosed muscular dystrophy.

No surgical airways were recorded in any of these 1,053 encounters. As observed in adults,¹ video laryngoscopy increased over time, with use in 50% of children in the last year. Video laryngoscopy is known to improve both glottic view and first-pass success.^{1-3,8-10}

We observed first-attempt success in 83% of pediatric intubation encounters, the same frequency we observed in adults.¹ This is higher than that observed in a Korean study (68%)¹¹ and in a previous NEAR pediatric study (72%).⁷

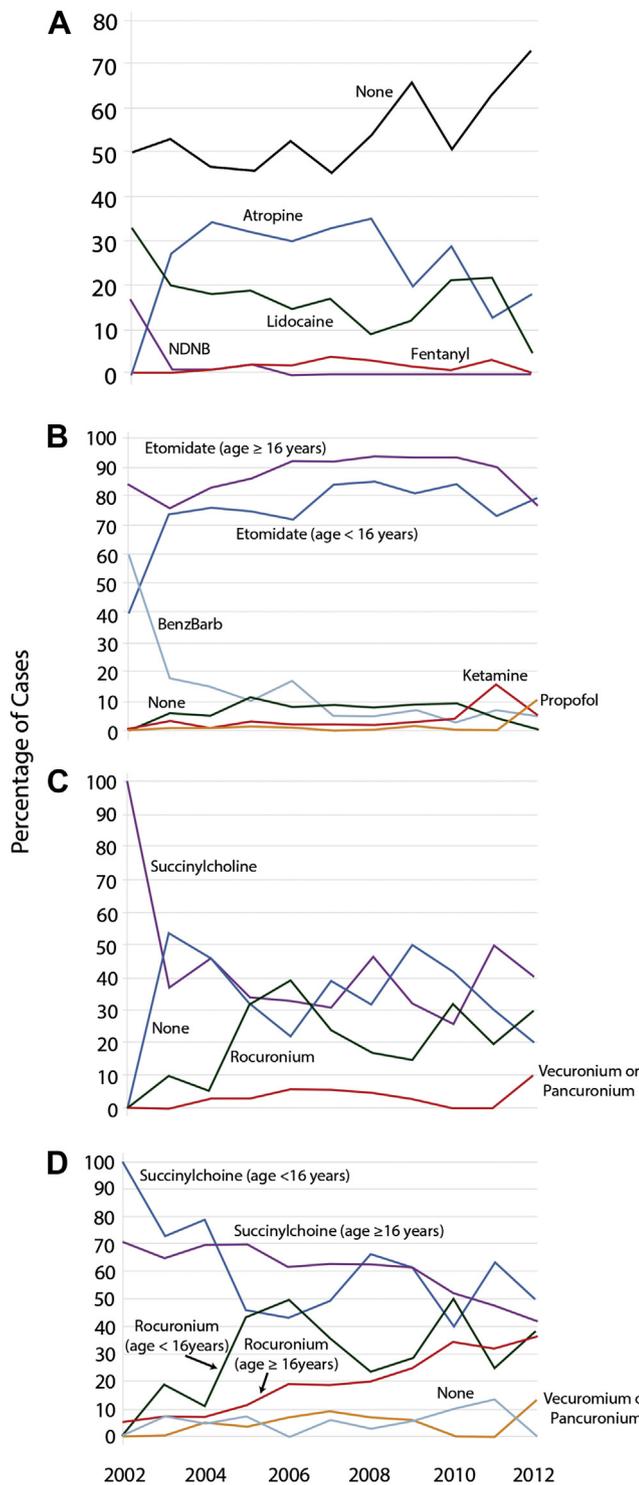


Figure 2. Pretreatment and induction agent use over time. *A*, Use of premedications decreased overall, and use of atropine in particular decreased. *B*, Etomidate is the predominant induction medication for intubation of children. Etomidate use for patients aged 16 years or older is shown with a dashed line for comparison purposes. Other agents are not shown for this age group because they were rarely used. *C*, Succinylcholine continues to be used more commonly than nondepolarizing agents, even in children younger than 2 years. Use of no

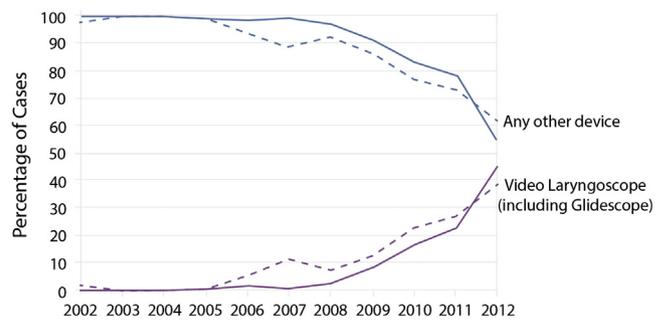


Figure 3. Proportion of pediatric intubations with the CMAC, the Macintosh video laryngoscope, or the GlideScope. The denominator includes all methods shown in Table 2. (*P* value for change over time <.001, by logistic regression accounting for clustering.) Data for children younger than 16 years are shown in solid lines, and data from patients aged 16 years or older are shown in dashed lines.

As in our adult cohort, attending physicians had lower first-pass success than trainees, which may reflect their assignment to the more difficult intubations or to skill degradation because of the infrequency of intubation performance.

Rapid sequence intubation was 3.4 times more likely to be followed by first-attempt success than sedation without paralysis, mirroring results of previous research.^{1,7,12} We cannot infer causality from this association, however, because more-skilled intubators may prefer paralytics.

First-attempt success was more likely with video than with direct laryngoscopy, supporting its first-line use. Its advantages include the ability to revert to direct visualization in the setting of device failure (although not with the GlideScope), improved glottic views, and the ability of supervisors to watch the attempt.^{8,13}

As has been noted before,⁷ we observed the lowest first-attempt success rate in infants, likely because they are intubated less frequently and have larger tongues and heads. Infant intubation attempts must be aborted when rapid desaturation occurs, which is common because of the fragility of infantile respiratory physiology. Provider anxiety and inexperience may also be contributors. ED practice may be ideally supplemented with practice bagging and intubating infant manikins, familiarization with infant-sized equipment, and careful preoxygenation.

paralytic is common in this age group. *D*, In children aged 2 years or older, succinylcholine and rocuronium are the most commonly used paralytics. Use of these agents for patients aged 16 years or older is shown with a dashed line for comparison purposes. Other agents are not shown for this age group because they were rarely used. *BenzBarb*, Benzodiazepine or barbiturate; *NDNB*, non-depolarizing neuromuscular blocker.

Table 4. Predictors of first-attempt success.

Predictor	Odds Ratio	95% CI
Infancy	0.39	0.26–0.58
Sex (female vs male)	0.57	0.46–0.73
Paralytic vs none (including crash airways)*	1.6	0.78–3.2
Video vs direct laryngoscopy	3.4	1.5–7.6

*As discussed in the text, excluding "crash airways" (ie, encounters in which no medications at all were used), Rapid sequence intubation was found to predict 3.4 times higher odds of first-attempt success than sedation without paralysis (95% CI 1.5 to 7.4).

We found that girls had significantly greater first-attempt failure than boys, even when adjusted for relevant confounders. In our corresponding adult data, women also had greater first-attempt failure than men.¹ A previous single-center study found that girls had 2.6 times the odds of a too-deeply-placed endotracheal tube and that this was associated with hypoxemia, atelectasis, and difficult ventilation; however, a larger multicenter Korean study found no such risk.^{11,14} The biological mechanism for a sex-related difference is unknown. Given the unexpectedness of this finding, it should be considered hypothesis generating and deserving of further investigation.

In summary, to our knowledge we present the largest ED pediatric intubation sample published to date. We found a strong ongoing preference for etomidate for induction, and increasing use of rocuronium and video laryngoscopy. Infants are at the highest risk of first-attempt intubation failure.

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Author contributions: DJP and CAB monitored data collection and compliance. DJP and RMW drafted the article. DJP analyzed the data and made final editorial decisions. All authors contributed to study design, data monitoring, and article development. RMW conceived of and oversaw the project. DJP takes responsibility for the paper as a whole.

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REFERENCES

- Brown CA 3rd, Bair AE, Pallin DJ, et al. Techniques, success, and adverse events of emergency department adult intubations. *Ann Emerg Med.* 2015;65:363-370.e361.
- Mosier J, Chiu S, Patanwala AE, et al. A comparison of the GlideScope video laryngoscope to the C-MAC video laryngoscope for intubation in the emergency department. *Ann Emerg Med.* 2013;61:414-420.e411.
- Sakles JC, Chiu S, Mosier J, et al. The importance of first pass success when performing orotracheal intubation in the emergency department. *Acad Emerg Med.* 2013;20:71-78.
- Mort TC. Emergency tracheal intubation: complications associated with repeated laryngoscopic attempts. *Anesth Analg.* 2004;99:607-613; table of contents.
- Kerrey BT, Rinderknecht AS, Geis GL, et al. Rapid sequence intubation for pediatric emergency patients: higher frequency of failed attempts and adverse effects found by video review. *Ann Emerg Med.* 2012;60:251-259.
- Pallin DJ, Walls RM. The safety of single-dose etomidate. *Intensive Care Med.* 2010;36:1268; author reply 1269-1270.
- Sagarin MJ, Chiang V, Sakles JC, et al. Rapid sequence intubation for pediatric emergency airway management. *Pediatr Emerg Care.* 2002;18:417-423.
- Brown CA 3rd, Bair AE, Pallin DJ, et al. Improved glottic exposure with the Video Macintosh Laryngoscope in adult emergency department tracheal intubations. *Ann Emerg Med.* 2010;56:83-88.
- Sakles JC, Mosier JM, Chiu S, et al. Tracheal intubation in the emergency department: a comparison of GlideScope(R) video laryngoscopy to direct laryngoscopy in 822 intubations. *J Emerg Med.* 2012;42:400-405.
- Sakles JC, Mosier J, Chiu S, et al. A comparison of the C-MAC video laryngoscope to the Macintosh direct laryngoscope for intubation in the emergency department. *Ann Emerg Med.* 2012;60:739-748.
- Choi HJ, Je SM, Kim JH, et al. The factors associated with successful paediatric endotracheal intubation on the first attempt in emergency departments: a 13-emergency-department registry study. *Resuscitation.* 2012;83:1363-1368.
- Walls RM, Brown CA 3rd, Bair AE, et al. Emergency airway management: a multi-center report of 8937 emergency department intubations. *J Emerg Med.* 2011;41:347-354.
- Brown CA 3rd, Pallin DJ, Walls RM. Video laryngoscopy and intubation safety: the view is becoming clear. *Crit Care Med.* 2015;43:717-718.
- Johnson KM, Kimia A, Nagler J. Factors associated with misplaced endotracheal tubes during intubation in pediatric patients. Poster presented at: American Academy of Pediatrics meeting; San Diego, CA, October 10, 2014.

Table E1. Participating EDs.

Institution	Location	Residency	Trauma Center Level	Census	Encounters	%
Akron City Hospital	Akron, OH	Y	I	70,000	2	0.19
Brigham and Women's	Boston, MA	Y	I	60,000	4	0.38
Doctors Medical Center	San Pablo, CA	N	II	80,000	141	13
Maricopa Medical Center	Phoenix, AZ	Y	I	60,000	140	13
Medical University of South Carolina	Charleston, SC	Y	I	50,000	100	10
Pitt County Hospital	Greenville, NC	Y	I	120,000	18	1.7
University of California–Davis	Sacramento, CA	Y	I	70,000	470	45
University of Cincinnati	Cincinnati, OH	Y	I	85,000	10	0.95
University of Nebraska	Omaha, NE	Y	I	50,000	72	6.8
University of Southern California	Los Angeles, CA	Y	I	150,000	96	9.1
Total					1,053	100