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Clinical paper

Association of patient age with first pass success in out-of-hospital advanced airway management☆

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Abstract

Background: First pass advanced airway insertion success is associated with fewer adverse events. We sought to compare out-of-hospital endotracheal intubation (ETI) and supraglottic airway (SGA) first-pass success (FPS) rates between adults and children in a national cohort of EMS agencies.

Methods: We analyzed data from 2017 using a national cohort of 731 EMS agencies. Using multivariable logistic regression, we compared the odds of ETI and SGA FPS between adult (age >14 years) and pediatric (age ≤14 years) patients, adjusting for gender, ethnicity, indication, and drug facilitation. We performed a sensitivity analysis of all patients using age as a continuous variable for both ETI and SGA FPS. Finally, we calculated the odds of FPS using all possible age break points between 10 and 18 years old.

Results: A total of 29,368 patients (28,846 adults and 522 children) received ETI (22,519) or SGA (6849). ETI FPS was higher in adults than children; 72.7% vs, 58.5%, (OR 1.80, 95% CI 1.49–2.17). SGA FPS was similar between adults and children; 89.8% vs 84.6%, (OR 1.63, CI 0.70–3.31). When analyzed as a continuous variable, ETI FPS remained associated with age in years: OR 1.007 (CI 1.006–1.009) and SGA FPS showed no significant association with age: OR 0.999 (0.995–1.004). The OR for ETI FPS were higher in adults than pediatrics at all potential age break points between 10 and 18 years old. The OR for SGA FPS was significantly more likely in adults than pediatrics using 16 as a break point but not significantly different between adults and pediatrics using any other age break point.

Conclusion: In this national cohort of out-of-hospital patients, ETI FPS was higher for adults than children. SGA FPS did not significantly vary with age. SGA FPS was higher than ETI FPS at all ages.

Keywords: EMS, Airway management, Pediatrics

Introduction

Advanced airway management (AAM), including endotracheal intubation (ETI) and insertion of supraglottic airways (SGA) is commonly performed by EMS personnel in the out-of-hospital setting.[1–3] ETI success rates are generally lower than in-hospital settings, and ETI success seems to vary by agency and geographic location.[2–13,2–4] Multiple adverse events, including unrecognized esophageal intubation and peri-intubation hypoxia, have been reported with out-of-hospital AAM.[14–22] ETI First Pass Success (FPS) has been associated with fewer adverse events including hypoxia, bradycardia, aspiration, and cardiac arrest.[11,23,24,25]

Out-of-hospital AAM is less common in children than adults and AAM success rates are also lower in children than adults.[26–29] The association of patient age with ETI and SGA FPS is unknown. We sought to determine the association between age and FPS of EMS AAM: ETI and SGA insertion.

☆ Presented at: (1) EMS World Expo, Nashville, TN. October 2018. (2) Texas EMS. Fort Worth, TX. November 2018. (3) NAEMSP. Austin, TX January 2019.

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https://doi.org/10.1016/j.resuscitation.2019.06.002
Received 27 January 2019; Received in revised form 28 May 2019; Accepted 3 June 2019

Methods

Study design

We analyzed clinical data from ESO Solutions (Austin, Texas), a provider of EMS electronic health records (EHR). The Institutional Review Board of Baylor Scott & White Research approved this study.

Study setting and population

ESO is a provider of electronic solutions to EMS documentation needs. The organization provides a server-based NEMSIS-compliant EHR to over 2000 EMS agencies in 48 US states, territories, and the District of Columbia. NEMSIS (the National EMS Information System) is a national database of EMS events collected using an adopted data dictionary.[30] The system includes over 3.3 million EMS calls for service per year. The software allows for the real-time collection of clinical, operational, and billing data on each patient encounter using definitions provided by NEMSIS. The system includes data validation rules for certain elements, including some for procedures. These rules assure a uniform dataset between agencies.

Each agency has the option of allowing their blinded data to be used by researchers. We analyzed data from 887 consenting agencies who have agreed to this use. The dataset contains data elements that describe the patient's demographics (age, sex, race, ethnicity, state, weight), clinical status (clinical impression, method of AAM, any medications given, vital signs, etc), but no clinical outcome data.

Selection of patients

We analyzed records from all 911 calls between January 1, 2017 and January 6, 2018 who had at least one AAM attempt. We excluded patients over 100-years-old to satisfy privacy concerns and out of concern that their age may have been entered incorrectly.

Intervention

Providers reported the AAM method used. Available AAM methods varied by EMS agency. We grouped AAM attempts into ETI and SGA attempts. The ETI group contained those patients who had an attempt documented using one of the following techniques: orotracheal intubation, video laryngoscopy, nasotracheal intubation, rapid sequence intubation (RSI), and sedation assisted intubation (SAI). We defined Sedation Assisted Intubation (SAI) as an AAM with concurrent administration of a sedative agent (propofol, ketamine, etomidate, or a benzodiazepine) and Rapid Sequence Intubation (RSI) as AAM performed with administration of a neuromuscular blocking agent.

The SGA group included patients with the following procedures: iGel, King LT, or laryngeal mask airway (LMA). We did not separate the analysis by SGA type for two reasons. First, the numbers of each individual procedure were not sufficient to give meaningful data. Second, it was not clear from the dataset which agencies had which options available for documentation. For example, some agencies using RSI may not have the RSI documentation option available and instead documented an orotracheal intubation and documented the medications separately. The ESO system requires each procedure attempt to be documented as a distinct data entry. Each attempt is

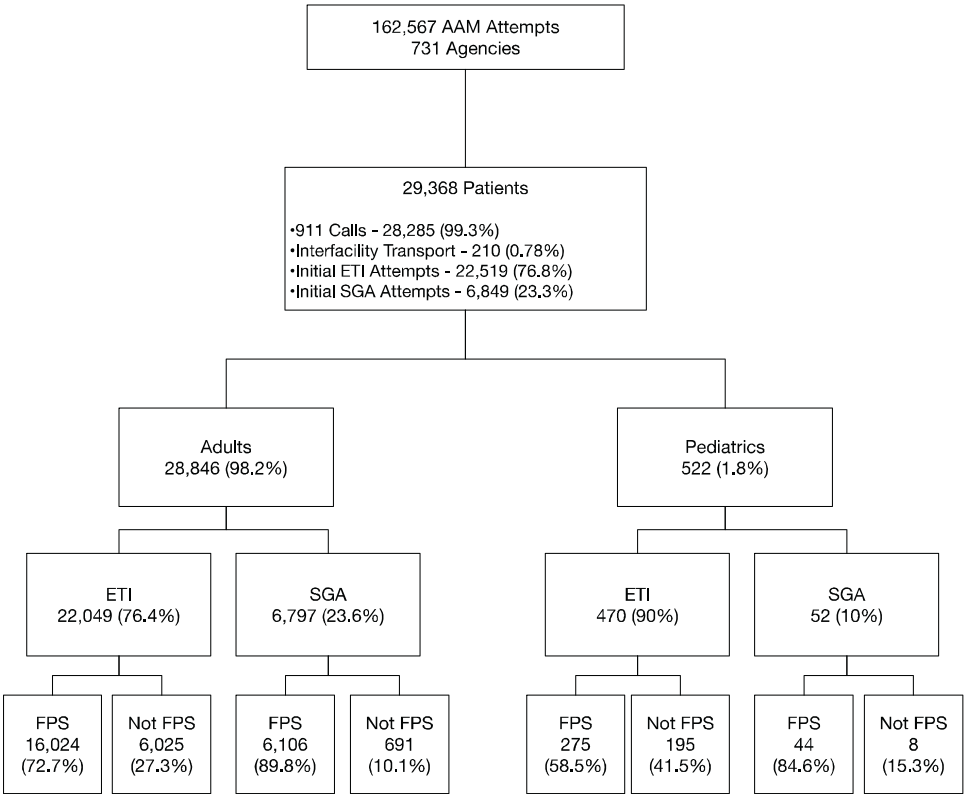

Fig. 1 – Description of patient selection.
***ETI = Endotracheal Intubation. SGA = Supraglottic Airway. FPS = First Pass Success.**

documented as successful or unsuccessful. In this way, the system removes the potential for ambiguity that might occur when multiple attempts are documented as a single procedure entry with only one successful/unsuccessful indication.

Outcomes

Our primary outcome was FPS. We determined FPS for each patient and airway method (ETI and SGA). An attempt was considered to be an FPS if the first attempt was documented by the EMS crew as successful. We further calculated FPS rate as the proportion of patients who had a successful first attempt documented divided by the number of patients with an AAM attempted. EMS personnel reported FPS. We did not base FPS upon independent ETI confirmation data because it was not available.

Consistent with prior studies, we categorized all patients as either pediatric (age $\leq$14 years) or adult (age $>$14 years).[27]

Analysis

We calculated the FPS rate for both ETI and SGA, expressing this rate as a binomial proportion with normalized 95% confidence intervals (CI). We described the characteristics of each age group. We also used a multivariable logistic regression model to calculate the Odds Ratio (OR), CI for FPS, adjusting for indication for AAM (cardiac arrest, non-arrest medical, and non-arrest trauma), use of medications to facilitate airway placement (RSI or SAI), gender, and identity. Recognizing that any age cut-off is arbitrary, we performed a sensitivity analysis using age in whole years as a continuous variable for both ETI and SGA FPS. We also evaluated the potential impact of using an age break point of 14 by performing the primary analysis using every potential age break point between 10 and 18 years old. All calculations were performed in R v3.5.0 (R Core Team. Vienna, Austria.) and visualizations created with ggplot2 v3.1.0.[31,32]

Results

We included data on 731 EMS agencies reporting at least one AAM attempt. There was a total of 162,567 AAM encounters, including 127,934 (78.7%) ETI and 34,633 (21.3%) SGA. At least one AAM attempt occurred among 29,368 unique patients, including 22,519 (76.8%) ETI and 6849 (23.3%) SGA. Of these patients, 28,846 (98.2%) were adults and 522 (1.8%) were pediatric. Of adults undergoing AAM attempts, 22,049 (76.4%) were ETI and 6797 (23.6%) were SGA. Of pediatric patients undergoing AAM attempts, 470 (90.0%) were ETI and only 52 (10.0%) were with SGA (Fig. 1).

Patients were encountered during a 911 emergency call 29,285 (99.3%) times compared to only 210 (0.7%) times encountered during an interfacility transfer. The majority of patients receiving AAM were for cardiac arrest in both adult (67.3%) and pediatric (67.6%) populations. Overall, there were fewer pediatric patients undergoing AAM than adults (522 vs 28,846) (Table 1).

Among all patients, ETI FPS was 72.4%. Among 22,049 adults, ETI FPS was 72.7% but only 58.5% among 470 pediatric patients. After adjusting for indication for AAM, use of medications (RSI and

Table 1 – Patient characteristics, by age group.

Characteristics	Adult (age $>$14 years)	Children (age $\leq$14 years)
Number	28,846	522
Age (median [IQR])	65.2 [51.2, 76.5]	2.3 [1.3, 6.7]
Identity (%)		
Asian	231 (0.8%)	6 (1.1%)
Black	5,091 (17.6%)	119 (22.8%)
Hispanic	610 (2.1%)	23 (4.4%)
Native American	80 (0.3%)	5 (1.0%)
White	18,743 (65.0%)	274 (52.5%)
Gender (%)		
Female	11,209 (38.9%)	216 (41.4%)
Male	17,464 (60.5%)	305 (58.4%)
Indication (%)		
Cardiac Arrest	19,406 (67.3%)	353 (67.6%)
Non-arrest Medical	7,297 (25.3%)	100 (19.2%)
Non-arrest Trauma	2,143 (7.4%)	69 (13.2%)
Method (%)		
Endotracheal Intubation	22,049 (76.4%)	470 (90.0%)
Supraglottic Airway	6,797 (23.6%)	52 (10.0%)
Drug Assistance (%)		
No Drugs Used	23,136 (80.2%)	455 (87.2%)
Rapid Sequence Intubation	4,063 (14.1%)	50 (9.6%)
Sedation Assisted Intubation	1,647 (5.7%)	17 (3.3%)
Run Type (%)		
911 Response	28,636 (99.3%)	513 (98.3%)
Interfacility Transfer	201 (0.7%)	9 (1.7%)
Other	9 (0.0%)	0 (0.0%)
Service Level (%)		
Advanced Life Support	15,370 (94.3%)	266 (92.7%)
Basic Life Support	154 (0.9%)	1 (0.3%)
Critical Care	780 (4.8%)	20 (7.0%)

Table 2 – Endotracheal intubation (ETI) and supraglottic airway (SGA) first pass success for adult and pediatric patients.

	Adult	Pediatric	Adjusted Odds Ratio (adults vs pediatrics)
	1st Attempt Success/Total 1st Attempts (FPS Proportion) (95% Confidence Interval)	1st Attempt Success/Total 1st Attempts (FPS Proportion) (95% Confidence Interval)	[a]aOR (95% Confidence Interval)
ETI	16,024/22,049 (72.7%) (72.1%–73.3%)	275/470 (58.5%) (53.9%–63.0%)	1.80 (1.49–2.17)
SGA	6,106/6,797 (89.8%) (89.1%–90.5%)	44/52 (84.6%) (71.9%–93.1%)	1.63 (0.70–3.31)

[a] Adjusted for indication, drug assistance, rapid sequence intubation, gender, and identity.

Table 3 – Factors associated with endotracheal intubation and supraglottic airway first pass success.

	Adult			Pediatric		
	1 st Attempt Success	Total 1 st Attempts	FPS Proportion	1 st Attempt Success	Total 1 st Attempts	FPS Proportion
Endotracheal Intubation						
Age Group	16,024	22,049	72.70%	275	470	58.50%
Cardiac Arrest	9,942	13,735	72.38%	184	313	58.79%
Medical Non-Arrest	4,787	6,477	73.91%	55	96	57.29%
Trauma Non-Arrest	1,295	1,837	70.50%	36	61	59.02%
No Drugs	11,800	16,634	70.94%	229	406	56.40%
RSI	3,155	3,937	80.14%	38	49	77.55%
SAI	1,069	1,478	72.33%	8	15	53.33%
Females	6471	8,619	75.08%	118	201	58.71%
Males	9,430	13,280	71.01%	156	268	58.21%
White	10,682	14,610	73.11%	147	249	59.04%
Asian	143	182	78.57%	4	5	80.00%
Black	2,308	3,383	68.22%	61	101	60.40%
Hispanic	330	471	70.06%	12	22	54.55%
Native American	49	66	74.24%	1	3	33.33%
Supraglottic Airway						
Age Group	6106	6,797	89.8%	44	52	84.6%
Cardiac Arrest	5144	5,671	90.71%	34	40	85.00%
Medical Non-Arrest	690	820	84.15%	3	4	75.00%
Trauma Non-Arrest	272	306	88.89%	7	8	87.50%
No Drugs	5835	6,502	89.74%	41	49	83.67%
RSI	113	126	89.68%	1	1	100.00%
SAI	158	169	93.49%	2	2	100.00%
Females	2316	2,590	89.42%	14	15	93.33%
Males	3,769	4,184	90.08%	30	37	81.08%
White	3681	4,133	89.06%	22	25	88.00%
Asian	44	49	89.80%	1	1	100.00%
Black	1,561	1,708	91.39%	14	18	77.78%
Hispanic	127	139	91.37%	1	1	100.00%
Native American	11	14	78.57%	2	2	100.00%

Table 1: FPS = first pass success.

SAI), gender, and patient identity, adults were more likely to have ETI FPS than pediatric patients, aOR 1.80 (CI 1.49–2.17). Overall, SGA FPS was 89.8%. Among 6797 adults, SGA FPS was 89.8% and 84.6% among 52 pediatric patients. After adjustment for confounders, SGA FPS did not significantly differ between adults and pediatrics, aOR 1.63 (CI 0.7–3.3) (Table 2). Factors independently associated with increased ETI FPS included use of RSI or SAI, female sex, and white race. The only factors independently associated with increased SGA FPS was SAI use (Table 3).

Our sensitivity analysis of these findings, using age in whole years as a continuous variable rather than a categorical one, confirmed these findings. The adjusted OR for ETI FPS was 1.007 (CI 1.006–1.009) for each additional whole year of age and the adjusted OR for SGA FPS was 0.999 (CI 0.995–1.004) for each additional year (Supplemental Table 1 and Fig. 2).

We confirmed the odds of ETI FPS were higher in adults than pediatric patients at each potential age break point between 10 and 18 years. We found that, when using 16 years of age, the odds of SGA FPS was higher in adults than pediatrics, but not significantly different at any other age break point (Supplemental Table 2, Figs. 3 and 4).

Discussion

Our results show that ETI FPS is more likely in adults than pediatrics patients. However, SGA FPS did not differ significantly between adults

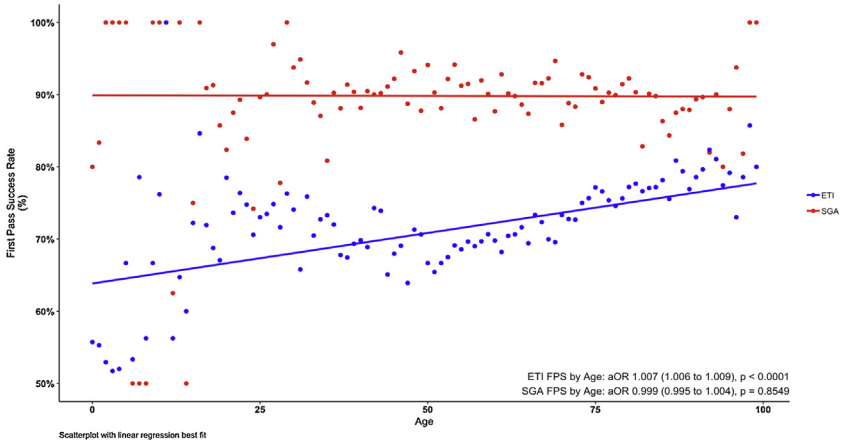

Fig. 2 – FPS by age.

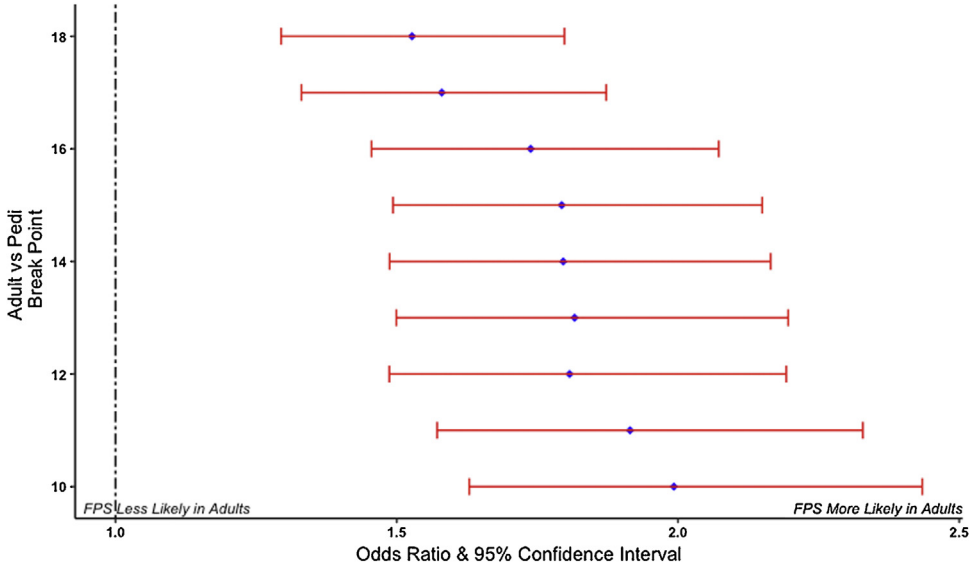

Fig. 3 – Likelihood of ETI first pass success by age group using different age break points.

and pediatrics. These associations persisted on sensitivity analyses with age modeled as both categorical and continuous models. These associations were also present when using different age break points between adult and pediatric populations, with the exception of 16 years old with SGA insertion.

These results are similar to prior literature showing increased difficulty with EMS intubation of younger patients.[26,27,29,33] Our findings are also consistent with hospital-based findings indicating that emergency department intubation of children is more challenging than in adults.[34] We found greater disparity in ETI FPS rates between adults and pediatrics than two studies of a national EMS cohort which found similar overall ETI rates between adults and pediatrics. Wang et al conducted an analysis of self-reported EMS overall success rates among patients in the 2008 NEMSIS dataset and found overall ETI success rates of 77% in adults and 74% in pediatric patients.[2] Diggs et al. essentially repeated the Wang study using the 2012 NEMSIS dataset and reported overall ETI success rates of 85% in adults and 87% in pediatric patients.[4] Consistent with prior studies of pediatric patients, we found that ETI FPS improves with age.[26,29,33] There are no prior studies comparing SGA FPS between adults and pediatrics. Our study provides the first evidence that SGA FPS is similar between adults and children.

Interestingly, the actual rates of ETI success are roughly consistent across several studies with ETI FPS in pediatrics between 55% and 67% and out-of-hospital ETI FPS in adults by non-physicians between 46% and 78%.[26, 28, 33,35,36,37] The ETI FPS we noted in this study are also higher than those seen with non-emergency physicians intubating in the ED but lower than that reported by emergency physicians in the ED.[34,38]

SGA FPS were higher than ETI FPS rates for both adults and children. We also found a multiple AAM attempts on many patients. Of the 29,368 patients in this cohort, there were 162,567 AAM attempts or 5.5 AAM attempts for each patient. While we did not specifically analyze the number of attempts for each specific patient, this does raise the concern that EMS personnel may not recognize the futility of multiple failed attempts. We have described the frequent occurrence

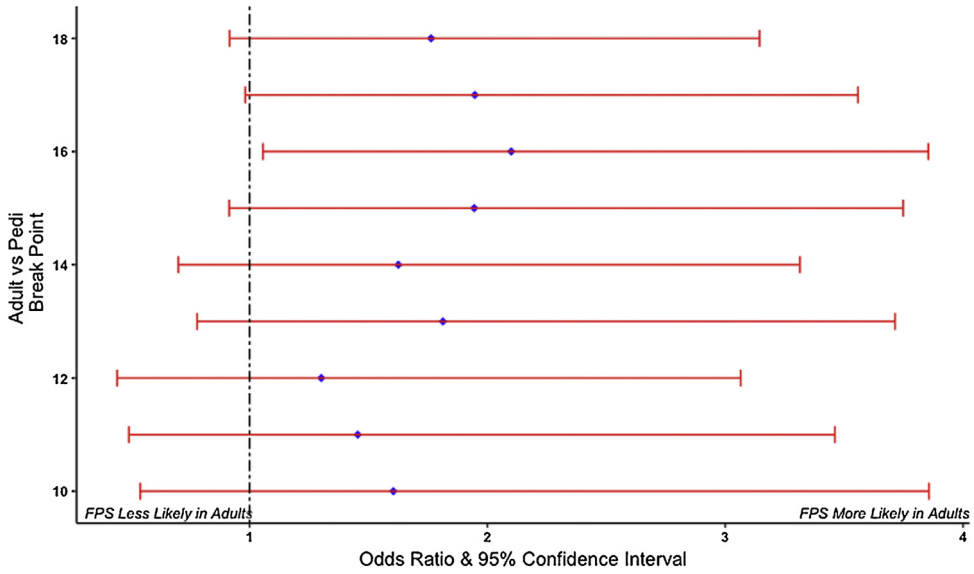

Fig. 4 – Likelihood of SGA first pass success by age group using different age break points.

of recurrent intubation attempts previously, including at least one patient with ten unsuccessful attempts.[8]

Increasing emphasis has recently been placed on the importance of FPS in avoiding adverse events, such as hypoxia, bradycardia, and cardiac arrest.[11,38] With focused effort, training, and oversight, EMS agencies are able to improve ETI FPS in adults.[7] However, that improvement comes at a cost in time and effort.[39] While it is possible to improve pediatric ETI FPS, it may not be worth the opportunity costs. Instead, it may be more practical to adopt an SGA-only approach for pediatric patients for most ground-based EMS agencies.[40,41] There are several theoretical reasons why EMS systems may wish to adopt an SGA-only approach to pediatric patients. First, our results suggest that intubation is rare in children and FPS is less successful in children than in adults. Next, while improving ETI FPS in pediatric patients is no doubt possible, doing so system-wide would likely invoke an opportunity cost, meaning the expenditure of resources that would otherwise be used on other improvement efforts (STEMI, trauma, stroke, sepsis, for example). Finally, there is no evidence that ETI is associated with improved outcomes compared with SGA or BVM in pediatric patients. Indeed, one large, prospective study demonstrated no difference with ETI compared to BVM alone.[33]

Limitations

There are several important limitations of this study. Chief among them is that this is a retrospective, non-randomized electronic review of patient care data not originally collected for this purpose. There were no standardized data definitions among the different agencies and no standardized way of validating the data entered. There was no universal definition of what constitutes an AAM attempt and success was self-reported. There is some indication that subjective reporting of successful airway placement may over-report success.[16,19] We are evaluating data collected utilizing one commercial vendor. It is unclear yet if the data in this dataset is representative of agencies not using ESO data. Further work comparing this dataset to the NEMSIS data would be helpful in understanding how well these results could extrapolate to other agencies. Even within customers using ESO, not all agencies consented to the use of their de-identified data for research purposes. It is possible that those consenting agencies perform differently than those agencies who did not consent to the use of the data. Our decision to group all methods of ETI together (including RSI and SAI, as well as all indications) may hide some important distinctions. It's possible that pediatric ETI FPS is as good or higher than adults in some groups but worse in others. The use of SGAs in pediatrics was too rare to justify breaking them into subgroups by type of SGA. It is possible that, with a larger dataset, we could have done so and reached different results. We had relatively few pediatric AAM, including only 52 SGA attempts. This should lead to caution with any change in practice. It is also possible that, had we had additional data elements such as BMI, history of prior difficult intubations, limited spinal mobility, etc, our calculations of the association between FPS and age might have differed.

We chose to analyze the effect of age on FPS in a dichotomous fashion, i.e. adult vs pediatric. In doing so, any age break point is necessarily arbitrary. It is possible that picking a different age cut-point might have yielded different results. To control for this limitation, we performed a sensitivity analysis using age as a continuous variable. This sensitivity analysis confirmed our findings. We also repeated the categorical analysis using each potential age break point between 10 and 18 years old and, with the exception of 16-year-olds in the SGA analysis, again confirmed the results. It is likely the 16-year-old break point SGA exception is not meaningful given the results using all break points above and below 16 and the effect seen in the analysis using age as a continuous variable. We were not able to reliably separate intubations performed with direct laryngoscopy vs video laryngoscopy. There is evidence that, in a population of inexperienced intubators such as most paramedics, FPS is higher with VL than DL.[7,12,24,27,42–47] Finally, if more adults were intubated with VL than pediatrics, this may have affected the overall success rates we observed.

Conclusion

Advanced airway management, either with ETI or SGA, occurs less frequently among pediatric patients encountered by EMS than in

adults. FPS is higher in adults than pediatrics when using endotracheal intubation but not significantly different between when using supraglottic devices. These results have important implications for EMS physicians and directors when determining their agency's initial approach to advanced airway management in pediatric patients.

Financial support

None.

Contributions

All authors conceived the study, JLJ acquired, analyzed the data and drafted the manuscript. All authors contributed to critical review and revision of the manuscript. JLJ assumes overall responsibility for the paper.

Conflicts of interest

JLJ, DW, HEW all report that they have no conflicts of interest.

Acknowledgements

We wish to acknowledge the assistance of Dustin Barton, MBA, EMT-P and ESO Solutions for providing the dataset for this study.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resuscitation.2019.06.002.

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