The Process of Prehospital Airway Management: Challenges and Solutions During Paramedic Endotracheal Intubation*

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Objectives: Endotracheal intubation success rates in the prehospital setting are variable. Our objective was to describe the challenges encountered and corrective actions taken during the process of endotracheal intubation by paramedics.

Design: Analysis of prehospital airway management using a prospective registry that was linked to an emergency medical services administrative database.

Setting: Emergency medical services system serving King County, Washington, 2006–2011. Paramedics in this system have the capability to administer neuromuscular blocking agents to facilitate intubation (i.e., rapid sequence intubation).

Patients: A total of 7,523 patients more than 12 years old in whom paramedics attempted prehospital endotracheal intubation.

Interventions: None.

Measurements and Main Results: An intubation attempt was defined as the introduction of the laryngoscope into the patient's mouth, and the attempt concluded when the laryngoscope was removed from the mouth. Endotracheal intubation was successful on the first attempt in 77% and ultimately successful in 99% of patients (7,433 of 7,523). Paramedics used a rapid sequence intubation strategy on 54% of first attempts. Among the subset with a failed first attempt ($n = 1,715$), bodily fluids obstructing the laryngeal view (50%), obesity (28%), patient positioning (17%), and facial or spinal trauma (6%) were identified as challenges to intubation. A variety of adjustments were made to achieve intubation success, including upper airway suctioning (used in 43% of attempts resulting in success), patient repositioning (38%), rescue bougie use (19%), operator change (16%), and rescue rapid sequence intubation (6%). Surgical cricothyrotomy (0.4%, $n = 27$) and bag-valve-mask ventilation (0.8%, $n = 60$) were rarely performed by paramedics as final rescue airway strategies.

Conclusions: Airway management in the prehospital setting has substantial challenges. Success can require a collection of adjustments that involve equipment, personnel, and medication often in a simultaneous fashion. (*Crit Care Med* 2014; 42:1372–1378)

Key Words: airway management; intubation; paramedics; prehospital emergency care; registries

***See also p. 1543.**

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Endotracheal intubation is performed to optimally oxygenate, ventilate, and protect critically ill patients from aspiration. Its use in the prehospital setting has been questioned due to concerns regarding both safety and efficacy (1–6), and some advocate abandoning this procedure in favor of alternative methods of invasive or noninvasive respiratory support (7, 8). In the context of this ongoing controversy, endotracheal intubation remains an established practice worldwide in many emergency medical services (EMS) systems. These systems have committed to training ground-based paramedics (9), flight nurses (10), or prehospital physicians (11–13) to perform endotracheal intubation in austere environments and face the inherent challenges of

acquisition and retention of airway decision making and technical skills. Therefore, improvement in intubation proficiency is an important and shared goal.

There is wide variability in the overall rate of intubation success across EMS systems (14–16), and while this metric is a commonly used measure of intubation proficiency, it does not provide insight into specific challenges or potential opportunities for improvement. The quality of care provided by an EMS system may be considered a function of three components: structure, process, and outcome (17). This conceptual framework has been used to enact improvements in hospital-based critical care, including emergency endotracheal intubation by critical care trainees (18, 19). Application of this quality-of-care model has the potential to improve prehospital advanced airway management, but studies that detail the process of prehospital intubation in a quantitative manner are lacking.

Our primary objective is to describe the process of prehospital advanced airway management. In doing so, we highlight the challenges and corresponding corrective actions that enable paramedic endotracheal intubation. The goal is to provide context for additional quality improvement among EMS systems performing this complex procedure and ultimately improve early care for critically ill patients.

METHODS

We evaluated advanced prehospital airway management performed by paramedics from September 2006 to November 2011 in a large metropolitan EMS system. We excluded encounters with children less than 12 years old. The study community includes urban, suburban, and rural areas with a size of approximately 2,000 square miles and a population of 1.3 million people. The EMS system employs a two-tier emergency response: firefighter-emergency medical technicians provide basic life support, and paramedics, working in teams of two, provide advanced life support including advanced airway management. The EMS system has approximately 150 paramedics who serve this population of 1.3 million persons.

Paramedics are permitted to intubate patients in cardiac arrest prior to physician consultation, with or without the use of paralytic agents. For patients not in arrest, paramedics consult with a physician providing online medical direction prior to attempting endotracheal intubation. Rapid sequence intubation (RSI) is typically performed with etomidate and succinylcholine. A nondepolarizing neuromuscular blocking agent is also available and may be given following confirmation of endotracheal tube position to achieve longer duration of paralysis. Available airway adjuncts include the bougie (i.e., tracheal tube introducer), needle jet ventilation, or surgical cricothyrotomy. Supraglottic airway devices were not used during the study period. The paramedics follow a common airway management algorithm (20).

This EMS system devotes resources to paramedic acquisition and maintenance of airway management skills (21). Paramedic students complete an airway management curriculum, which involves lectures, skill laboratories, simulation, and clinical training in the emergency department and operating room. A detailed description of paramedic airway training is included in the **supplemental data** (Supplemental Digital Content 1, http://links.lww.com/CCM/A849). As part of regional certification requirements, paramedics must successfully intubate at least 12 times annually or return to the operating suite to obtain the necessary count of intubations.

Measurements

Data from paramedic encounters involving invasive airway management have been prospectively collected in a registry since 2006. Following an attempt at endotracheal intubation, regardless of outcome, the paramedic operator completes an online form in order to fulfill requirements for continuous practice improvement. This form captures patient and encounter characteristics detailing the process of airway management. Operators report the best glottic view obtained during direct laryngoscopy as one of four grades, where a grade 1 view is optimal (full visualization of the vocal cords) and a grade 4 view indicates no visualization of the epiglottis (22). Following an unsuccessful intubation attempt, paramedics report any specific challenges encountered during the attempt and specific corrective actions taken with each subsequent attempt (upper airway suctioning, patient repositioning, change of operator, equipment change, rescue RSI, and use of the bougie).

An intubation attempt is defined as the introduction of the laryngoscope into the patient's mouth. The attempt concludes when the laryngoscope is removed from the mouth, regardless of whether or not the trachea was intubated. We defined RSI as an intubation attempt in conjunction with the administration of a paralytic agent (succinylcholine). We defined an intubation attempt as successful if correct endotracheal tube position was confirmed by capnography. Additional measures used to help confirm tube placement included visualization of the tube between the vocal cords and the presence of bilateral breath sounds plus chest rise. We confirmed successful endotracheal intubation in 200 randomly selected patients through review of hospital records.

Data Analysis

The airway registry data were linked to administrative EMS data using a composite of variables including the EMS incident number, age, gender, date, time, survival to hospital admission, and receiving hospital. This linkage enabled the calculation of the prevalence of endotracheal intubation as well as a more complete description of the cohort, including the prehospital diagnostic impression for each encounter. We summarize our results as means with SDs for continuous data (or medians with interquartile ranges when data do not approximate a normal distribution) or proportions for categorical data. We analyzed the data using Stata software release 12 (StataCorp, College Station, TX). The pertinent Institutional Review Board for Human Subjects Research approved this study.

RESULTS

Characteristics of Study Subjects

During the 5-year study period, there were 555,304 EMS activations. Paramedics responded to 120,789 of these activations

(22%) and attempted an advanced airway procedure in 7,523 encounters. Therefore, 1.4% of all EMS activations (6.2% of paramedic responses) involved at least one advanced airway procedure attempt.

Among the 7,523 patients undergoing an advanced airway procedure, the mean age (SD) was 59 (21) years, 60% were male, and 1,465 patients (19%) did not survive to emergency department admission. The most common prehospital diagnoses were cardiac arrest (35%, $n = 2,662$), respiratory failure (18%, $n = 1,329$), trauma (multiple organ system trauma 7%, $n = 511$; traumatic brain injury 6%, $n = 446$), and nontraumatic acute neurological decompensation (11%, $n = 803$).

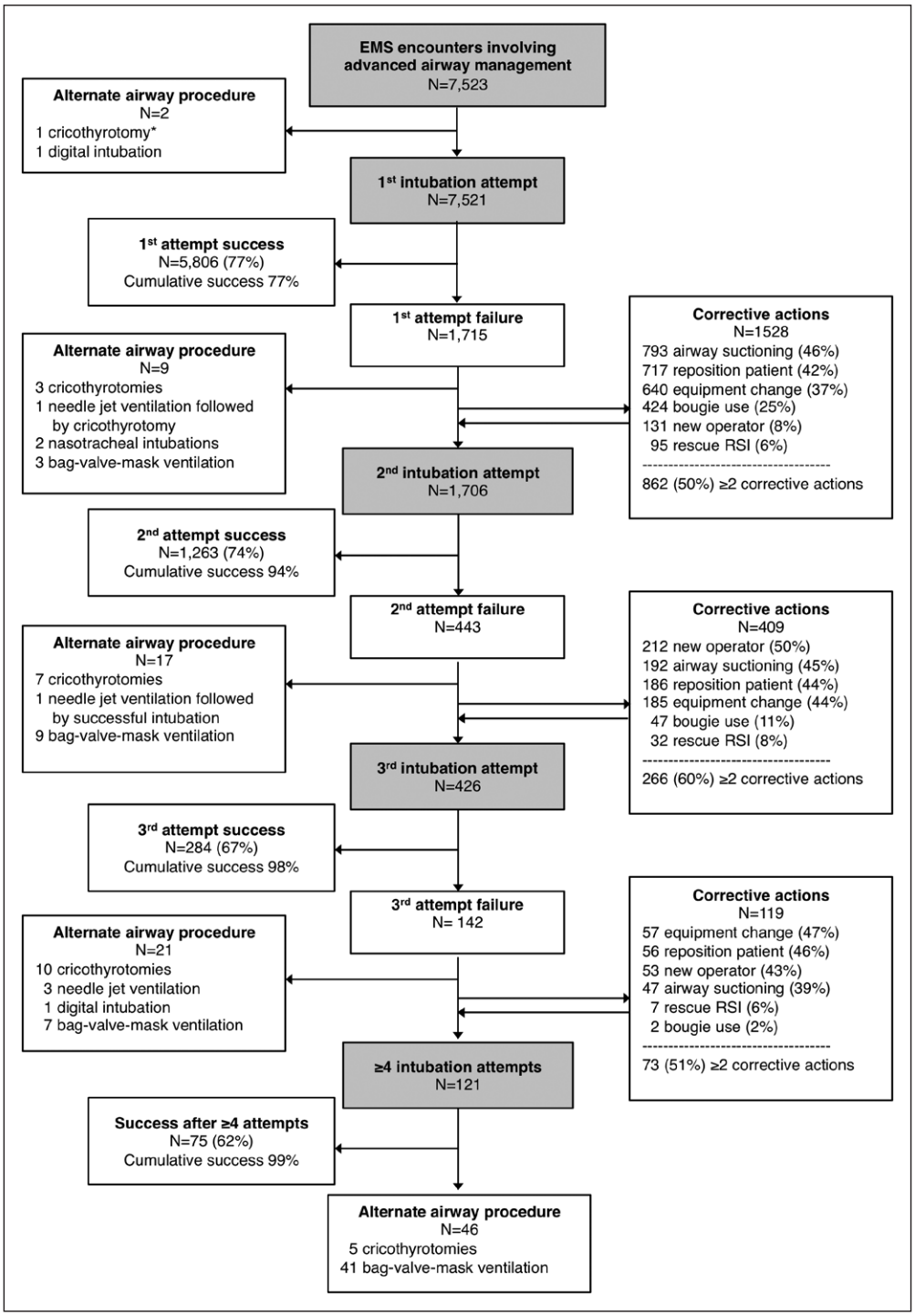

Figure 1. Flowchart detailing the process of paramedic airway management in 7,523 prehospital encounters. "Rescue RSI" refers to the use of a rapid sequence intubation strategy (i.e., neuromuscular blockade) to rescue a failed intubation attempt in cases where RSI had not been used during previous attempts. *In this single case, a patient with distorted anatomy due to head and neck cancer suffered a witnessed, out-of-hospital cardiac arrest (full code status). Paramedics performed a surgical cricothyrotomy without attempts at endotracheal intubation. EMS = emergency medical services.

Main Results

The process of advanced airway management is illustrated in **Figure 1**. The proportion of patients successfully intubated on the first attempt was 77%, and the success rate declined with subsequent attempts. First attempt success varied by prehospital diagnosis, from 86% success on the first attempt in patients with toxicologic emergencies to 71% in patients with cardiac arrest (**Fig. 2**). First attempt success also varied with laryngoscopic view, from 95% success when a grade 1 view was obtained (full visualization of the vocal cords) to 31% when the best view was grade 4 (epiglottis not visualized).

Paramedics elected to use RSI for the initial intubation attempt in approximately half of the patients (54%, $n = 4,032$). Without attempting to control for potential confounders, the group receiving RSI for the first intubation attempt had a higher proportion of favorable laryngeal views (grade 1 or 2) and higher first attempt success (83%) than the non-RSI group (73%) (**Supplemental Table 1**, Supplemental Digital Content 2, http://links.lww.com/CCM/A850).

Paramedics identified multiple challenges to successful prehospital airway management. Bodily fluids obstructing the laryngeal view (i.e., blood, emesis, or secretions) hindered intubation in half of patients not intubated on the first attempt

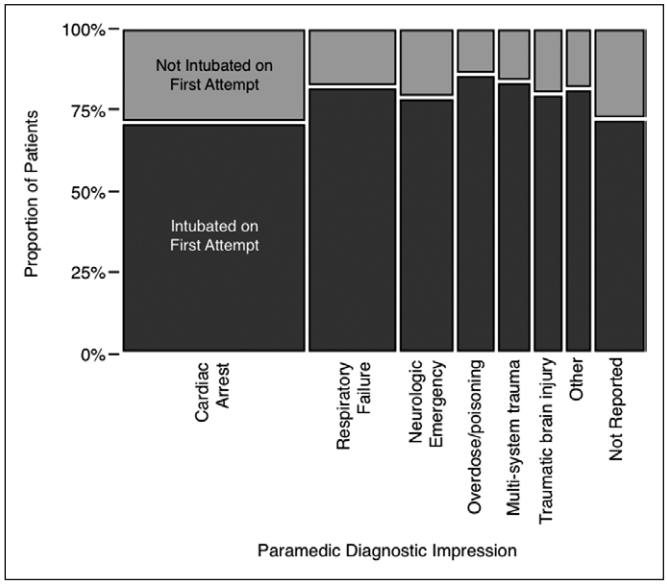

Figure 2. Mosaic plot of first attempt intubation success for prehospital patients grouped by paramedic-assigned diagnostic category. The height of the dark bars represents the proportion of patients intubated on the first attempt; the width of each bar on the *x*-axis is proportional to the frequency of that diagnosis in the cohort.

(50%, $n = 854$). Obesity (28%, $n = 484$), patient positioning (17%, $n = 299$), and facial or spinal trauma (6%, $n = 101$) were also cited as factors impeding intubation. Taken together, at least one airway challenge was encountered in 36% of cases of first attempt intubation success and 72% of cases requiring multiple attempts to successfully intubate. The prevalence of airway challenges varied by prehospital diagnosis, with bodily fluids obstructing the laryngeal view reported most often in patients with cardiac arrest or traumatic brain injury. (**Supplemental Fig. 1**, Supplemental Digital Content 3, http://links.lww.com/CCM/A851, which is described here: The proportion of patients with any of four discrete challenges to endotracheal intubation, grouped by prehospital diagnosis. A discrete challenge may be captured in these prevalence estimates if it was recorded during any intubation attempt. Bodily fluids refer to blood, emesis, or secretions that obscured the laryngeal view during attempted intubation.)

In cases of first attempt intubation failure ($n = 1{,}715$), paramedics performed a discrete corrective action before the next intubation attempt in the great majority of patients (89%), and in half of these cases, multiple corrective actions were taken (Fig. 1, right-hand column). Following corrective action, paramedics reported an improvement in laryngeal view from unfavorable (grade 3 or 4) to favorable (grade 1 or 2) between the first and second attempt in 112 of 675 patients (17%). Intubation was successful on the second attempt in 92% of this favorable view group (103 of 112 patients) when compared to 70% intubation success among those with a persistently unfavorable laryngeal view (395 of 563 patients).

In one in four patient encounters, paramedics identified a critical adjustment made during the process of airway management (i.e., without that specific corrective action, successful airway management in the field would not have been possible). **Table 1** lists these critical adjustments and their prevalences. Fundamental airway maneuvers such as suctioning,

TABLE 1. Adjustments Made After a Failed Intubation Attempt That Paramedics Deemed Critical to Subsequent Successful Endotracheal Intubation

		No. of Attempts for Successful Endotracheal Intubation		
Variable	All Intubated Patients $n = 7{,}428$	1 $n = 5{,}806$	2 $n = 1{,}263$	≥ 3 $n = 359$
Critical adjustment, *n* (%)[a]				
Airway suctioning	970 (13)	287 (5)	502 (40)	181 (51)
Reposition patient	658 (9)	66 (1)	410 (32)	182 (51)
Bougie use	589 (8)	106 (2)	308 (24)	175 (49)
Blade change[b]	264 (4)	–	168 (13)	96 (27)
Operator change[b]	248 (3)	–	81 (6)	167 (47)
Rescue rapid sequence intubation[b]	121 (2)	–	76 (6)	45 (13)
Other	500 (7)	100 (2)	276 (22)	124 (35)
No. of critical adjustments, *n* (%)				
None	5,459 (74)	5,333 (92)	115 (9)	11 (3)
1	1,131 (15)	383 (7)	680 (54)	68 (19)
≥ 2	834 (11)	90 (1)	470 (37)	274 (78)

[a]Critical adjustments shown are a subset of the corrective actions displayed in Figure 1 (right-hand column) and are not mutually exclusive.
[b]By definition, these adjustments could not have been made on the first intubation attempt, therefore the cells in that column are blank.

optimizing patient position, changing operators, and adjunctive bougie use were deemed critical in approximately 50% of the most difficult intubations (i.e., those patients requiring ≥ 3 attempts). Furthermore, critical adjustments were frequently combined in this group (Table 1).

The overall success rate for endotracheal intubation was 99% (7,433 of 7,523 patients) and was similar for patients with and without cardiac arrest (**Table 2**). Paramedics performed a surgical cricothyrotomy in 27 cases or 0.36% of airway management encounters. An invasive airway was ultimately not established in 60 encounters (0.8%) in which endotracheal intubation was attempted. In these 60 cases, EMS provided bag-valve-mask ventilation as the final strategy for airway management. Patient characteristics and prehospital outcomes are provided in the supplemental data (Supplemental Digital Content 1, http://links.lww.com/CCM/A849) for patients who received prehospital surgical cricothyrotomy (**Supplemental Table 2**, Supplemental Digital Content 4, http://links.lww.com/CCM/A852) and for those who received bag-valve-mask ventilation as the final airway strategy (**Supplemental Table 3**, Supplemental Digital Content 5, http://links.lww.com/CCM/A853).

DISCUSSION

In this study, we describe the process of prehospital endotracheal intubation using prospectively collected airway registry data on more than 7,500 patients. We detail the substantial challenges to prehospital emergency endotracheal intubation and the multifaceted solutions used by paramedics to overcome these challenges. Taken together, the findings can inform paramedic training and quality improvement and provide insight into the important issue of optimal prehospital airway management.

The intubation success rates achieved by paramedics on the first attempt (77%) and overall (99%) are comparable to select EMS systems with the ability to perform RSI (23–25). Furthermore, the first attempt and overall success rates are comparable to those of emergency physicians and trainees in the emergency department (26). While individual attempt success rates are infrequently reported in the current prehospital literature, this performance measure speaks directly to procedural efficiency and safety. Multiple attempts at emergent endotracheal intubation have consistently been associated with higher rates of complications (27, 28).

The foundation of the EMS system under study is a paramedic training program that emphasizes progressive responsibility in airway management decision making and procedural experience (21). Although not all paramedic training programs will have the same access to resources for airway training, these data support a training philosophy that emphasizes fundamentals (e.g., attention to patient positioning, preoxygenation, and airway suctioning) and teaches an airway algorithm with a limited number of escalating interventions to increase repetition and familiarity with each technique.

Paramedics performed an advanced airway intervention in 1.4% of all EMS activations and 6.2% of paramedic responses in this study, which is a greater frequency of attempted intubation as compared to other systems' reports (0.54% of all EMS

TABLE 2. Airway Management Outcomes Overall and Stratified by Cardiac Arrest

Variable	All Patients *n* = 7,523	Cardiac Arrest	
		No *n* = 4,864	Yes *n* = 2,659
Final airway outcome, *n* (%)			
Endotracheal intubation	7,433 (98.8)	4,806 (98.8)	2,627 (98.8)
Surgical cricothyrotomy	27 (0.4)	16 (0.3)	11 (0.4)
Needle jet ventilation	3 (< 0.1)	0	3 (0.1)
Bag-valve-mask ventilation	60 (0.8)	42 (0.9)	18 (0.7)
No. of attempts to achieve successful intubation, *n* (%)			
1	5,807 (78)	3,910 (81)	1,897 (72)
2	1,265 (17)	711 (15)	554 (21)
≥ 3	361 (5)	185 (4)	176 (7)
Laryngeal view[a]: Cormack and Lehane grade, *n* (%)			
Grade 1	2,723 (41)	1,902 (44)	821 (36)
Grade 2	2,281 (35)	1,471 (34)	810 (35)
Grade 3	1,085 (16)	645 (15)	440 (19)
Grade 4	546 (8)	325 (7)	221 (10)

[a]Best laryngeal view on the first intubation attempt. Data are missing for 886 patients (12%). Grade 1 is the most favorable view (full vocal cords seen) and grade 4 is least favorable (epiglottis not seen) for endotracheal intubation.

activations in a U.S. cohort [16], and 0.89% in Ottawa, Canada [29]). Individual paramedics in the current study system successfully intubate more than once per month, on average, whereas the median number of intubations per paramedic in other U.S. EMS systems is much less, perhaps only once per year (30). Previous literature has established a relationship between a provider's degree of intubation experience and the likelihood of success (31), and several characteristics of this system likely contribute to a high volume of intubations per paramedic. Paramedics responded to approximately one in five EMS activations in this two-tiered system, and the remainder were evaluated, managed, and transported by providers trained in basic life support. Compared to single-tier systems, there are fewer paramedics per shift and they generally see patients with higher acuity. In addition, two paramedics are present on each advanced life support response, and although only one paramedic may perform the actual intubation, both are involved in the advanced airway management process. The second paramedic can step in to attempt intubation if needed. RSI capability facilitates prehospital intubation in patients with airway reflexes who may be managed with noninvasive strategies in other systems. Finally, paramedics are required to provide a process-oriented report that details each intubation attempt. The requirement to review care in a systematic manner can serve as the basis for improvement (32).

The current study also provides useful insights into the process component of the quality-of-care model. Challenges were frequently encountered, such as airway secretions or craniocervical trauma, resulting in an initially unfavorable laryngeal view (grade 3 or 4) in nearly a quarter of patients. The spectrum and frequency of these challenges are generally greater than observed in an in-hospital setting such as the emergency department (33). A corrective action was necessary to achieve intubation in over a quarter of all patients and in nearly all patients who required more than one attempt. These interventions included airway preparation, medication, equipment modification, and operator change. A combination of corrective actions was commonplace; although not all EMS systems will have access to the same tools (e.g., bougie or paralytic medications), the observation that multiple discrete maneuvers may be required is an important concept that has wide relevance for training and practice. For example, one consideration is to be prepared to use the bougie with the first intubation attempt. There is no risk in the preparation and early use of the bougie and may enable first attempt intubation more often.

This investigation should be interpreted in light of its limitations. Data were not routinely available in this prehospital cohort about airway and ventilation management after intubation, potential downstream complications of prehospital airway management, and hospital-based patient outcome following endotracheal intubation attempts. The optimal set of prehospital and hospital measures to assure high-quality airway management has not been fully defined; future research should evaluate the usefulness of different elements of a proposed Utstein-style template for the uniform reporting of prehospital airway management (34, 35). The airway registry was populated with self-reported data from paramedics performing the advanced airway procedures. Underreporting of the number of intubation attempts, for example, may occur due to recall bias or a provider bias toward minimizing the reporting of complications. However, we assessed a subset of cases through review of hospital records to exclude occult endotracheal tube malposition using a combination of emergency department narrative notes, chest radiography, and capnography results and found no discrepancies. Additionally, we directly compared the airway registry with individual EMS clinical reports for certain cases to ensure accuracy, such as the 27 patients who ultimately received surgical cricothyrotomy in the field. Again, we observed that the registry and the clinical report were consistent. We are not able to analyze our data on a per-paramedic basis to account for variation in provider procedural experience due to the limitations of the airway registry structure. The frequency or effectiveness of noninvasive airway management (e.g., preoxygenation, bag-valve-mask ventilation) prior to intubation attempts was not captured.

The success rates and process measures would be different in some communities. For example, airway management during the study period did not include supraglottic airway devices, noninvasive positive pressure ventilation, or videolaryngoscopy. Thus, the role of these strategies and adjuncts cannot be evaluated in the current investigation. Recently, the study community has incorporated the laryngeal mask airway as a rescue airway per published guidelines (20). The results are not generalizable to the entire pediatric population. Not all studies have reported the high level of endotracheal intubation success; however, the high success rate was essential to undertake the detail-oriented report of challenges and solutions. We highlight these practice variations (36) but do not believe they detract from the outcome, structure, and process lessons of the current experience.

How do the results of this study fit in the evolving context of prehospital airway management? Importantly, the findings underscore the potential for paramedics to successfully achieve endotracheal intubation at a high rate that compares favorably to hospital-based emergency intubation. However, a substantial minority of prehospital endotracheal intubation is fraught with considerable challenge and that resolution of these challenges requires a broad variety of skills and resources. One interpretation is that prehospital intubation has the potential for great difficulty in a relatively uncontrolled environment, which would seemingly require well-trained, highly experienced providers who have mastery of a range of airway management skills. And yet, paramedics typically have modest experience and possess an incomplete set of tools required to achieve optimal endotracheal intubation outcomes (31, 37).

How might this circumstance be remedied? One option may be that paramedic intubation becomes a core reportable measure of clinical competence for individual paramedics and EMS agencies through mandatory case-based reporting. Results can inform training and education as well as direct decisions about the merit of endotracheal intubation. Such a strategy may not be welcome by some but seems appropriate given the need to guarantee competency in such a critical skill.

CONCLUSIONS

Prehospital advanced airway management has come under increased scrutiny. The current investigation demonstrates that paramedics can achieve a level of success that is comparable to emergency intubation in the hospital setting. However, the results also highlight the formidable challenges and required resourcefulness to successfully intubate. Given the central role of invasive airway management in the care of many critically ill patients, better outcomes may result from programmatic and comparative evidence that improves our understanding of the challenges and solutions of prehospital airway management.

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