Pediatric Intubation by Paramedics in a Large Emergency Medical Services System: Process, Challenges, and Outcomes

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Study objective: Pediatric intubation is a core paramedic skill in some emergency medical services (EMS) systems. The literature lacks a detailed examination of the challenges and subsequent adjustments made by paramedics when intubating children in the out-of-hospital setting. We undertake a descriptive evaluation of the process of out-of-hospital pediatric intubation, focusing on challenges, adjustments, and outcomes.

Methods: We performed a retrospective analysis of EMS responses between 2006 and 2012 that involved attempted intubation of children younger than 13 years by paramedics in a large, metropolitan EMS system. We calculated the incidence rate of attempted pediatric intubation with EMS and county census data. To summarize the intubation process, we linked a detailed out-of-hospital airway registry with clinical records from EMS, hospital, or autopsy encounters for each child. The main outcome measures were procedural challenges, procedural success, complications, and patient disposition.

Results: Paramedics attempted intubation in 299 cases during 6.3 years, with an incidence of 1 pediatric intubation per 2,198 EMS responses. Less than half of intubations (44%) were for patients in cardiac arrest. Two thirds of patients were intubated on the first attempt (66%), and overall success was 97%. The most prevalent challenge was body fluids obscuring the laryngeal view (33%). After a failed first intubation attempt, corrective actions taken by paramedics included changing equipment (33%), suctioning (32%), and repositioning the patient (27%). Six patients (2%) experienced peri-intubation cardiac arrest and 1 patient had an iatrogenic tracheal injury. No esophageal intubations were observed. Of patients transported to the hospital, 86% were admitted to intensive care and hospital mortality was 27%.

Conclusion: Pediatric intubation by paramedics was performed infrequently in this EMS system. Although overall intubation success was high, a detailed evaluation of the process of intubation revealed specific challenges and adjustments that can be anticipated by paramedics to improve first-pass success, potentially reduce complications, and ultimately improve clinical outcomes. [Ann Emerg Med. 2016;67:20-29.]

Please see page 21 for the Editor's Capsule Summary of this article.

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INTRODUCTION

Background

Airway management is a hallmark of pediatric emergency care, given the frequent involvement of the respiratory system in acute critical illness. The optimal timing and setting for invasive airway management (ie, intubation) in critically ill children is unclear.[1,2] Intubation by paramedics, if successful, allows early, controlled oxygenation and ventilation through a patent airway that can also protect against aspiration. However, emergency care systems must weigh these potential benefits against potential complications of pediatric intubation. Challenges to achieving proficiency in pediatric intubation include inadequate training, infrequent opportunities to perform pediatric intubation, anatomic differences in the pediatric versus the adult airway, inappropriately sized equipment, unfamiliar drug dosing, and the unpredictable out-of-hospital environment.[3-5] In the largest clinical trial evaluating pediatric intubation by paramedics, bag-valve-mask ventilation resulted in comparable patient survival and neurologic outcomes compared with intubation, with attempted intubation delaying transport to a hospital in an urban EMS system.[6]

Importance

Many EMS systems consider pediatric intubation a core paramedic skill.[7,8] And yet substantial variability in the use of pediatric intubation exists among US EMS systems. Moreover, overall intubation success in the

Editor's Capsule Summary

What is already known on this topic

It is highly controversial whether paramedics should attempt intubation in children, given the rarity of the procedure and the critical importance of success.

What question this study addressed

What were the frequency and outcomes of out-of-hospital intubation in one urban setting with a high level of training and oversight?

What this study adds to our knowledge

This retrospective review of out-of-hospital records identified 299 pediatric intubation attempts during 6.3 years, with 1 such occurrence per 2,198 out-of-hospital calls. Intubation was successful in 97% of attempts, with no esophageal intubations, in a system with a high level of paramedic experience and physician involvement (compared to other systems).

How this is relevant to clinical practice

Despite infrequent exposure, paramedics in this specific out-of-hospital system have a high frequency of pediatric intubation success, which cannot necessarily be generalized to other environments.

out-of-hospital setting has ranged from 57% to 98%, whereas unrecognized esophageal intubation has occurred in 1% to 3% of cases.[9-13] This variability highlights an opportunity for focused training in procedural and decisionmaking skills to establish and improve on quality benchmarks involving out-of-hospital pediatric intubation. A detailed description of the process used by paramedics to intubate children can be an important foundation for quality improvement. Such a foundation would incorporate information using an attempt-by-attempt account of the challenges and subsequent adjustments made by paramedics to achieve intubation.

Goals of This Investigation

In this investigation, we sought to characterize out-of-hospital pediatric intubation by paramedics experienced in airway management serving a well-defined county population. The study has 2 specific objectives: to estimate the incidence of out-of-hospital pediatric intubation within the study community and the EMS system, and to describe the process used by paramedics in their attempt to intubate these children, with a focus on the specific challenges to successful intubation, the corrective actions taken after a failed intubation attempt, and potential procedural complications. This study does not address the efficacy of out-of-hospital pediatric intubation; rather the focus is on the process of intubation in an EMS system that has adopted pediatric intubation as a core skill.

MATERIALS AND METHODS

Study Design and Setting

This investigation is a retrospective cohort study of all paramedic encounters with children younger than 13 years, involving at least 1 attempt at intubation from September 2006 through December 2012 in a metropolitan EMS system serving greater King County, WA (excluding Seattle). The study community includes urban, suburban, and rural areas of approximately 2,000 square miles and a population of 1.3 million people, including approximately 195,000 children younger than 13 years.[14] The EMS system uses a 2-tier emergency response: (1) approximately 3,000 firefighter–emergency medical technicians (EMTs) provide basic life support, and (2) approximately 150 paramedics in teams of two provide advanced life support, including vascular access, medication administration, and intubation. The institutional review boards of Public Health–Seattle & King County, Seattle Children's Hospital, the University of Washington, and Multicare Mary Bridge Children's Hospital approved this study.

Paramedic students receive standardized training in pediatric airway management, including didactics, simulation, and hands-on experience in a children's hospital operating room supervised by an anesthesiologist, as described previously.[15,16] The minimum requirement for graduation is 2 pediatric intubations; students perform an average of 6 pediatric intubations and 40 adult intubations. After graduation, paramedics are expected to follow an airway management algorithm that specifies patient preparation for oral intubation, involvement of medical control in the decision to perform rapid sequence intubation, and the process to advance to needle jet ventilation or surgical cricothyrotomy in a "cannot intubate, cannot oxygenate" scenario.[17] Paramedics are permitted to intubate children in cardiac arrest before physician consultation, with or without the use of neuromuscular-blocking drugs. Other indications for out-of-hospital intubation in this EMS system include shock, respiratory failure, and lack of airway protective reflexes, usually in the setting of a decreased level of consciousness. A Broselow tape is used to provide patient size- and age-based recommendations for equipment and medications. Succinylcholine is available for rapid sequence intubation, and a nondepolarizing neuromuscular blocker may be given to achieve a longer duration of paralysis after the tube is confirmed to be in the trachea by physical

examination and capnography. A pediatric bougie and a supraglottic airway device (introduced in 2011) are available as adjuncts to orotracheal intubation. As part of regional certification requirements, paramedics must successfully intubate at least 12 patients (of any age) annually or return to the operating room to obtain the necessary count of intubations.

Paramedics transport intubated children to 9 area hospitals; 4 of these hospitals have a pediatric ICU and are regional referral centers (2 children's hospitals, a Level I trauma center, and a large community hospital). The other 5 hospitals' emergency providers stabilize intubated children brought to their facility and arrange transfer, with the exception of community hospitals with a neonatal ICU to which intubated neonates could be admitted.

Selection of Participants

We chose to study patients younger than 13 years because this age cutoff was used in the largest clinical trial of out-of-hospital pediatric airway management.[6] We identified pediatric patients undergoing attempted intubation by cross-referencing the EMS clinical record with the out-of-hospital airway registry. Intubation was documented in the EMS clinical record by marking a checkbox in the procedure section. Encounters involving unsuccessful attempt(s) at intubation were captured through the mandated out-of-hospital airway registry. In addition, we reviewed all pediatric EMS encounters in which an end tidal CO_2 ($ETCO_2$) measurement was documented to identify any additional intubation attempts.

Data Collection and Processing

For each study patient, we merged data on the intubation attempt(s), which had been prospectively entered into the out-of-hospital airway registry by paramedics, with data collected by retrospective chart review. We retrospectively reviewed EMS clinical records, as well as either emergency department (ED) and inpatient medical records for children transported by EMS or autopsy reports from the county medical examiner when resuscitation was terminated in the field. The patient's name, date of birth, and the date of the index EMS encounter were used to ensure accurate data abstraction across multiple sources.

Since 2006, paramedics have completed a detailed airway report for each attempted intubation as part of continuous practice improvement and certification requirements (see Appendix E1, available online at http://www.annemergmed.com, for airway report form). This registry captures details about the indication, challenges, confirmation of placement, and treatments, using a categorical checkbox that also allows free-text explanation. For each intubation attempt, information is collected about airway view, specific challenges, and subsequent corrective actions if the previous attempt was unsuccessful.[18] An intubation attempt was defined as the introduction of the laryngoscope into the patient's mouth. The attempt concluded when the laryngoscope was removed from the mouth, regardless of whether the trachea was intubated. We defined an intubation attempt as successful if correct tracheal tube position was confirmed by capnography and subsequently verified in the hospital or at autopsy.

We also manually abstracted data from the EMS clinical report. This abstraction included patient vital signs, clinical diagnosis, vascular access, and use of rapid sequence intubation. We determined whether select out-of-hospital airway complications had occurred, namely, bradycardia requiring intervention, esophageal intubation that was recognized by paramedics and corrected, tracheal tube dislodgement during transport, and peri-intubation cardiac arrest. We defined this last complication as the onset of cardiac arrest requiring cardiopulmonary resuscitation (CPR) during or immediately after attempted intubation.

Using a standard data collection form, 2 study investigators (M.E.P. and F.D.) reviewed all hospital records, and 10% of them were reviewed in duplicate to ensure reliable abstraction. There was 100% agreement between reviewers with regard to bradycardia requiring treatment, endotracheal tube dislodgement, patient arrest in the ED, ED disposition, and patient outcome. There was less than complete agreement with regard to mainstem bronchus intubation (80% agreement between reviewers) and aspiration pneumonia (90% agreement between reviewers), with final determination of the discrepancy involving investigator consensus. For patients surviving to the hospital, we collected information about physiologic state on arrival and subsequent ED course and hospital outcome. We used the revised Pediatric Index of Mortality (PIM2) to describe severity of illness.[19] In the case of out-of-hospital death after intubation, we obtained the autopsy record from the medical examiner to determine the final location of the endotracheal tube and the cause and manner of death. We captured intubation complications not recognized by paramedics through review of both hospital and autopsy records. One such complication was suspected aspiration pneumonia, which we defined as lung opacities on chest radiograph, clinical suspicion of an aspiration event, and antibiotic administration.

Primary Data Analysis

We calculated the incidence of attempted intubation with the estimates from the county Bureau of Vital Statistics of the number of children younger than 13 years

and residing in the study community annually from 2006 through 2012. We also summarized the per-paramedic frequency of pediatric encounters involving intubation. We used descriptive statistics to summarize the distribution of out-of-hospital and hospital outcomes overall and stratified by patient age group (<1 year, 1–5 years, and 6–12 years). Data were analyzed with Stata (version 12; StataCorp, College Station, TX).

RESULTS

During the 6.3-year study period, the EMS system responded to 651,194 calls, 37,172 (6%) of which were for patients younger than 13 years, and 299 encounters (0.05% of all calls) involved attempted pediatric intubation by paramedics (Figure 1). Variables missing greater than 10% of data in the paramedic airway registry or EMS clinical record were paramedic response intervals (dispatch, scene, and arrival times), the laryngeal view on the first intubation attempt, and quantitative $ETCO_2$. Although capnography is the standard for tube placement confirmation, paramedics recorded "positive" or "negative" in 31% of cases instead of the quantitative $ETCO_2$ measurement. Hospital records were unavailable for 4 of the 223 patients (2%) who were transported by paramedics, leaving 219 patients with complete outcomes data. Last, autopsy records were unavailable for 8 of 76 patients (10%) who died before hospital arrival.

The incidence of an attempted pediatric intubation was 1 per 2,198 EMS responses. The median number of pediatric intubations per paramedic was 2 (interquartile range 1 to 3; range 1 to 7 intubations). Considering only the 123 paramedics with at least 1 pediatric intubation attempt during the study period, the exposure to this procedure was, on average, no more than 1 pediatric intubation per paramedic every 2.6 years in this EMS system. On a per-population basis, the average incidence of out-of-hospital pediatric intubation was 24 attempted intubations per 100,000 pediatric person-years, which was stable over time (Figure E1, available online at http://www.annemergmed.com).

Characteristics of Study Subjects

The 299 paramedic encounters involved the attempted intubation of 297 children (2 children experienced status epilepticus twice during the study period and were intubated by paramedics on both occasions). The median age was 2 years (interquartile range 0.4 to 6 years), 60% were boys, and 76 patients (25%) died on scene and were not transported to a hospital (Table 1). Cardiac arrest was the most frequent indication for

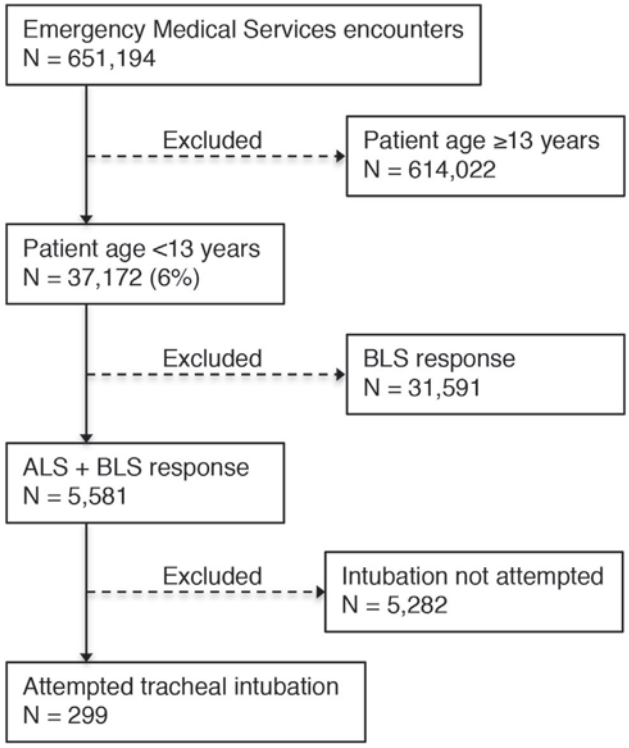

Figure 1. Patient accrual. *BLS*, Basic life support provided by EMT-firefighters; *ALS*, advanced life support provided by paramedics, who are able to intubate.

pediatric out-of-hospital intubation (44%), and this indication was especially prevalent among infants (77%). Among preschool and school-aged children, neurologic emergencies (predominantly status epilepticus) and trauma, respectively, were the most common diagnoses.

Main Results

Figure 2 details the process of pediatric attempted intubation by paramedics. Two thirds of children (66%) were successfully intubated on the first attempt. This proportion was lower among infants (53%) and children in cardiac arrest (56%) compared with children older than 1 year (74%) and those not in cardiac arrest (73%).

Paramedics reported the frequency of specific challenges to successful intubation (Table 1). Body fluids (eg, blood, emesis, secretions) interfering with the laryngeal view during direct laryngoscopy hindered intubation in 33% of cases. Patient positioning (6%), facial or spinal trauma (5%), or obesity (<1%) were implicated less frequently. Overall, 1 or more challenges to successful intubation were identified by paramedics in approximately half of cases (51%) when the first intubation attempt failed.

After a failed first attempt, paramedics took corrective action by changing intubation equipment in one third of

Table 1. Out-of-hospital characteristics according to age group.

Variable	Complete Data, No. (%)		All Patients (N=299)		Age Group, Years <1 (N=114)		1–5 (N=116)		6–12 (N=69)	
Male patient, No. (%)	299	(100)	179	(60)	61	(54)	72	(62)	46	(67)
Diagnostic category, No. (%)	299	(100)								
Cardiac arrest			131	(44)	88	(77)	23	(19)	20	(29)
Neurologic			57	(19)	6	(5)	36	(31)	15	(22)
Respiratory failure			40	(13)	13	(11)	18	(16)	9	(13)
Trauma, multisystem			31	(10)	2	(2)	16	(14)	13	(19)
Traumatic brain injury			30	(10)	3	(3)	18	(16)	9	(13)
Other			10	(4)	2	(2)	5	(4)	3	(4)
Paramedic response intervals, mean (SD), min										
Dispatch to arrival at scene	239	(80)	8	(4)	8	(3)	8	(4)	9	(4)
Time at scene	222	(74)	30	(13)	30	(14)	30	(13)	29	(13)
Scene departure to hospital arrival	131	(59)	22	(13)	21	(15)	22	(12)	23	(14)
Initial vital signs, No. (%)										
Pulse rate >60 beats/min	295	(99)	159	(54)	26	(23)	85	(73)	48	(70)
Systolic blood pressure >70 mm Hg	247	(83)	112	(45)	6	(6)	64	(71)	42	(68)
Respiratory rate >10 breaths/min	277	(93)	109	(39)	17	(16)	59	(57)	33	(51)
GCS score >8	280	(97)	39	(14)	7	(6)	14	(13)	18	(29)
$ETCO_2$, mean (SD), mm Hg										
Initial out-of-hospital	206	(69)	46	(25)	33	(23)	53	(25)	49	(21)
Final out-of-hospital	185	(62)	36	(16)	31	(18)	39	(15)	38	(16)
Vascular access, No. (%)	299	(100)								
Peripheral intravenous line			167	(56)	13	(11)	91	(78)	63	(91)
Intraosseous line			116	(39)	88	(77)	23	(20)	5	(7)
Central venous catheter			6	(2)	5	(4)	0		1	(1)
None			10	(3)	8	(8)	2	(2)	0	
Use of succinylcholine, No. (%)	299	(100)	152	(51)	18	(16)	87	(75)	47	(68)
Challenges to intubation, No. (%)	282	(94)								
Body fluids obstructing view			94	(33)	38	(36)	32	(29)	24	(36)
Patient positioning			16	(6)	6	(6)	7	(6)	3	(5)
Facial or spine trauma			14	(5)	0		9	(8)	5	(8)
Obesity			1	(<1)	0		0		1	(2)
First attempt laryngeal view, No. (%), grade*	239	(80)								
1 (most favorable)			116	(49)	40	(45)	49	(53)	27	(47)
2			69	(29)	26	(30)	21	(23)	22	(38)
3			37	(15)	16	(18)	15	(16)	6	(10)
4 (least favorable)			17	(7)	6	(7)	8	(9)	3	(5)
Intubated on first attempt, No. (%)	299	(100)	197	(66)	60	(53)	86	(74)	51	(74)
Out-of-hospital mortality, No. (%)	299	(100)	76	(25)	57	(50)	11	(9)	8	(12)

*Best laryngeal views were graded according to the Cormack-Lehane classification, with grade 1 indicating full visualization of the vocal cords during direct laryngoscopy and grade 4 indicating that the epiglottis was not visualized.

encounters (33%) while frequently suctioning the airway (32%) and repositioning the patient (27%) (Figure 2). In the difficult airway scenario (after the third intubation attempt), a change in paramedic or use of the pediatric bougie was a common strategy. Combinations of 2 or more corrective actions were performed concurrently for repeated attempts (55 of 112 repeat attempts, or 49%).

Ultimately, paramedics successfully intubated 97% of patients (291 of 299 encounters). In the remaining 8 encounters, paramedics managed 7 children with bag-valve-mask ventilation and 1 patient with a supraglottic airway device as the final intervention (Figure 2). Five of these 8 patients were intubated successfully in the ED, 1 patient died before further intubation attempts, and the condition of 2 other patients had improved to the point that intubation was not required.

Paramedics performed rapid sequence intubation in approximately half of all pediatric intubation encounters (51%), composing 88% of encounters in which the patient was not in cardiac arrest. Succinylcholine was administered by either the intravenous (88%) or the intraosseous route (12%) in these children. Among children who survived to hospital arrival, the time from arrival on scene to hospital arrival averaged 30 minutes in both the group intubated with rapid sequence intubation and those intubated without it.

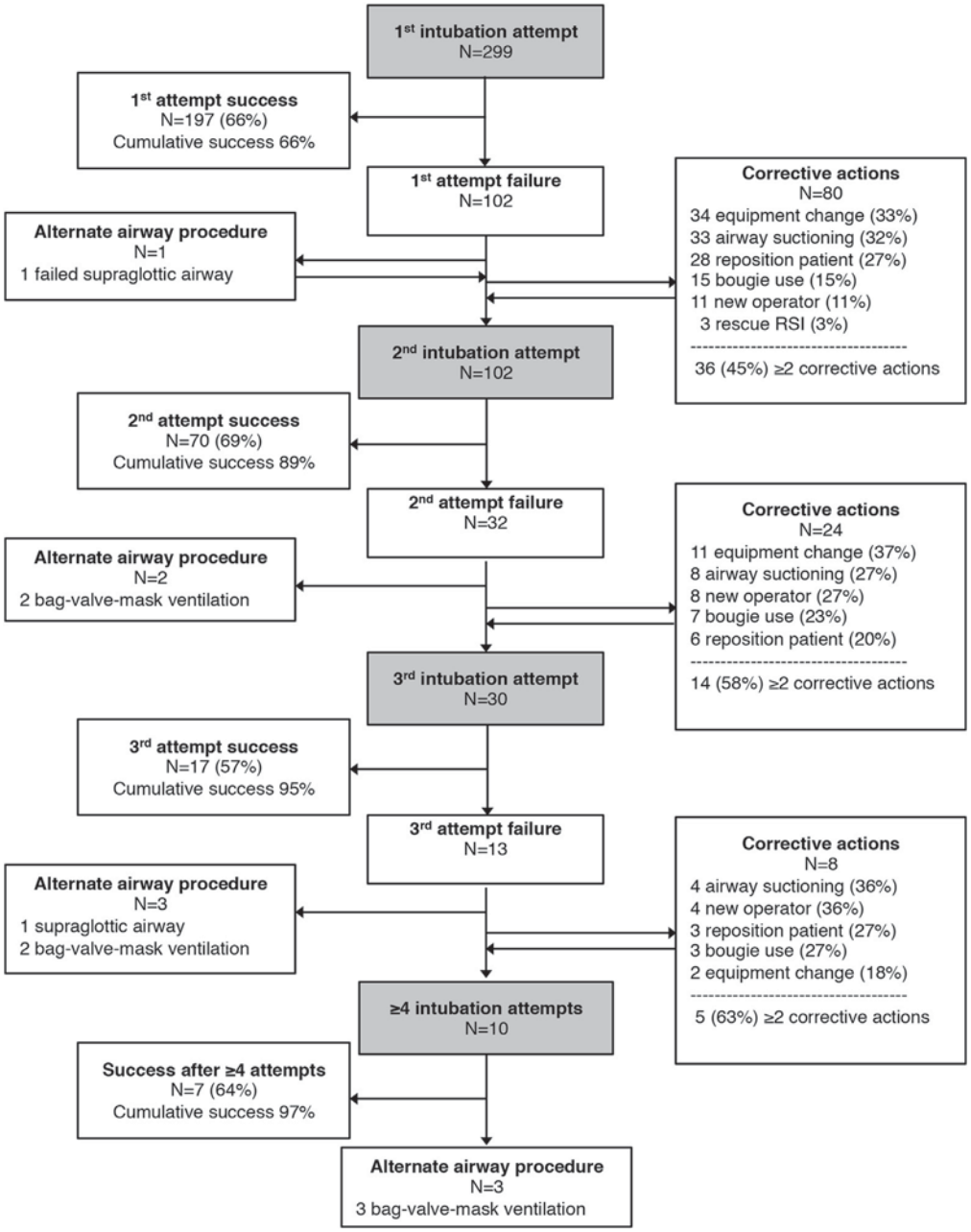

Figure 2. Flowchart detailing the process of pediatric airway management in 299 paramedic responses. *RSI*, Rapid sequence intubation.

Table 2 provides the prevalence of intubation complications. There were no unrecognized esophageal intubations among children who survived to the hospital (N=219) or had an endotracheal tube in situ at autopsy (N=26). A major complication, defined as peri-intubation cardiac arrest, endotracheal tube dislodgement during transport, injury to the respiratory tract, or bradycardia requiring out-of-hospital intervention, was recorded in 34 encounters (11%) (detailed case descriptions of the 6 patients with peri-intubation cardiac arrest are provided in Appendix E2, available online at http://www.annemergmed.com). Bradycardia requiring intervention and endotracheal tube dislodgement before hospital arrival occurred more commonly among children younger than 6 years (Table 2). The most frequent intubation complication was mainstem bronchus intubation (19%), which was recorded in all age groups, from 14% of school-aged children to 24% of children aged 1 to 5 years.

The Pediatric Index of Mortality scores for children transported to the hospital predicted an average mortality

Table 2. Complications of pediatric airway management, by age group.

Complication	All Patients (N=299)		Age Group, Years <1 (N=114)		1–5 (N=116)		6–12 (N=69)	
Complications recognized by paramedics, No. (%)								
Peri-intubation cardiac arrest	6	(2)	2	(2)	1	(1)	3	(4)
Bradycardia requiring intervention	12	(4)	6	(5)	6	(5)	0	
Esophageal intubation, recognized	5	(2)	3	(3)	1	(1)	1	(1)
Tube dislodged out-of-hospital, recognized	16	(5)	7	(6)	8	(7)	1	(1)
Complications unrecognized by paramedics, No. (%)*								
Tube dislodged out-of-hospital, unrecognized (N=241)	3	(1)	2	(3)	1	(1)	0	
Mainstem bronchus intubation (N=241)†	47	(19)	12	(16)	26	(24)	9	(14)
Respiratory tract injury (N=295)‡	1	(<1)	0		1	(1)	0	
Aspiration pneumonia (N=219)	46	(21)	3	(5)	25	(24)	18	(30)
One or more complications listed above, No. (%)	109	(36)	28	(25)	52	(45)	29	(42)

*The denominator for each complication not recognized until hospital arrival is given in parentheses.
†Mainstem bronchus intubation was diagnosed at ED arrival by initial examination (31%) or chest radiography (69%).
‡This was a tear in the posterior tracheal wall near the carina in a 5-year-old patient who was intubated for status epilepticus, the ED chest radiography showed pneumomediastinum leading to discovery of this injury, and no intervention was ultimately required.

of 30% (Table 3). The majority of children surviving to hospital admission (86%) were admitted to the ICU or taken directly to the operating room. The hospital mortality rate was 27%. A modest proportion of children (9%) were extubated in the ED (their characteristics are given in Table E1, available online at http://www.annemergmed.com), and 4 (1%) were discharged home.

LIMITATIONS

Our analysis of the process of pediatric intubation is limited by the use of self-reported data. For example, we could not independently verify the number of intubation attempts or the selected challenges to successful intubation reported by paramedics. Previous work has highlighted select complications of out-of-hospital intubation that may be underrecognized by paramedics.[20-22] Nonetheless, the information was consistent with data from other sources (eg, hospital record and medical examiner reports), suggesting that the approach taken in this investigation is a pragmatic way to monitor out-of-hospital airway management.

Paramedics in the study system have substantial training and experience, are equipped to provide rapid sequence intubation, and work in pairs. These characteristics may help explain the high overall success rate and should be considered relative to other community experience or published results. Yet this high level of competency was required to some extent to undertake a comprehensive assessment of the challenges and solutions to pediatric airway management. Furthermore, the decision to attempt intubation in non–cardiac arrest cases was based on the judgment of the treating paramedics in accordance with EMS system guidelines and consultation with online medical control. However, we cannot exclude selection bias introduced by variation between paramedics in their motivation to perform pediatric intubation.

Although no unrecognized esophageal intubations were observed among children transported to a hospital, the final position of the tube could not be determined in 50 cases in which resuscitation was terminated in the field (42 children did not have the endotracheal tube still in place at autopsy, and 8 children were missing autopsy records). These potential limitations should be considered in relation to the study's strengths; the investigation details a large experience that comprehensively captured the process of out-of-hospital pediatric attempted intubation and the downstream hospital-based assessment.

DISCUSSION

Pediatric intubation is considered a core paramedic skill among some EMS systems. However, there is variability in the use and proficiency of out-of-hospital intubation, especially among children.[23] In contrast to previous reports, the current investigation examined the pediatric intubation process in detail, including specific challenges, corrective actions, potential airway-related complications, and clinical outcomes among patients receiving attempted paramedic intubation. The results highlight the substantial cognitive and procedural aspects of out-of-hospital pediatric intubation that may deserve special attention in training or protocol development to improve effectiveness, safety, and ultimately patient outcome.

The investigation confirms that pediatric intubation is rarely performed, even in the study community in which

Table 3. Characteristics and outcomes of children transported to the hospital.*

Variable	All Patients (N=219)		Age Group, Years <1 (N=55)		1–5 (N=103)		6–12 (N=61)	
Severity of illness								
Pediatric Index of Mortality, median % expected mortality (IQR)	30	(37)	51	(40)	20	(31)	27	(36)
ED outcomes								
Vital signs on hospital arrival, No. (%)								
SBP >80 mm Hg	167	(84)	25	(56)	90	(91)	52	(93)
Pulse rate >60 beats/min	200	(93)	49	(89)	96	(94)	55	(93)
Pulse oximetry >94%	178	(85)	39	(78)	88	(86)	51	(88)
Initial blood gas measurement, No. (%)								
pH >7.25	90	(52)	12	(29)	48	(60)	30	(58)
pCO_2 <45 mm Hg	76	(44)	22	(54)	31	(39)	23	(44)
ED airway procedure, No. (%)								
Intubated	6	(3)	3	(5)	3	(3)	0	
Extubated	20	(9)	2	(4)	11	(11)	7	(11)
Reintubated	18	(8)	9	(16)	9	(9)	0	
ED disposition, No. (%)								
Admit to ICU	177	(81)	48	(87)	83	(81)	46	(75)
Admit to OR	11	(5)	0		6	(6)	5	(8)
Admit to general ward	11	(5)	0		7	(7)	4	(7)
Died in ED	16	(7)	6	(11)	6	(6)	4	(7)
Discharged from ED	4	(2)	1	(2)	1	(1)	2	(3)
Hospitalization outcomes								
Mechanical ventilation, median (IQR), days	2	(1–4)	3	(1–6)	2	(1–2)	2	(1–3)
ICU LOS, median (IQR), days	2	(1–5)	5	(2–9)	2	(1–4)	3	(1–4)
Hospital LOS, median (IQR), days	4	(2–9)	5	(2–12)	3	(2–6)	4	(2–10)
Hospital mortality, No. (%)	59	(27)	29	(53)	16	(16)	14	(23)
Primary hospital diagnosis								
Trauma, No. (%)	100	(46)	12	(22)	56	(54)	32	(52)
Blunt multiple trauma	28	(13)	2	(4)	16	(16)	10	(16)
Head injury, accidental	26	(12)	0		16	(16)	10	(16)
Head injury, child abuse	11	(5)	7	(13)	4	(4)	0	
Submersion injury	10	(5)	1	(2)	4	(4)	5	(8)
Asphyxia/strangulation	5	(2)	1	(2)	2	(2)	2	(3)
Foreign body aspiration	10	(5)	0		8	(8)	2	(3)
Poisoning	7	(3)	1	(2)	5	(5)	1	(2)
Burn	3	(1)	0		1	(1)	2	(3)
Medical, No. (%)	119	(54)	43	(78)	47	(46)	29	(48)
SIDS	17	(8)	17	(31)	0		0	
Status epilepticus	45	(21)	3	(5)	32	(31)	10	(16)
Cardiac arrest	15	(7)	4	(7)	5	(5)	6	(10)
Pneumonia	10	(5)	5	(9)	4	(4)	1	(2)
Respiratory arrest	12	(5)	9	(16)	1	(1)	2	(3)
Nonrespiratory infection	5	(2)	3	(5)	1	(1)	1	(2)
Asthma	6	(3)	0		3	(3)	3	(5)
Spontaneous intracranial hemorrhage	4	(2)	0		0		4	(7)
Other†	5	(2)	2	(4)	1	(1)	2	(3)

IQR, Interquartile range; *SBP*, systolic blood pressure; *LOS*, length of stay; *SIDS*, sudden infant death syndrome.

*The hospital records of 4 patients intubated and transported by paramedics were unavailable for review. Therefore, this table contains data on 219 of 223 (98%) patients who arrived at a hospital.

†The diagnoses in this category were anaphylaxis, heat stroke, brain tumor causing obstructive hydrocephalus, and ischemic stroke.

paramedics intubate more frequently compared with other EMS systems.[13] In this 2-tier EMS system, attempted pediatric intubation constituted 0.05% of all EMS responses and 0.8% of pediatric patient responses. And yet there exists a cohort of seriously ill children who present in the out-of-hospital setting who require airway management. Indeed, the majority of children presented with a Glasgow Coma Scale (GCS) score less than or equal to 8, and nearly half the children presented with cardiac arrest. Children who survived to hospital admission had an expected mortality of 30%, with nearly all being admitted to the ICU or going to the operating room. Thus, pediatric airway

management is an essential component of out-of-hospital emergency care. One topic requiring further research is the effectiveness of intubation versus other airway strategies relative to patient condition and the timing along the continuum from out-of-hospital to hospital-based critical care.

Successful intubation was ultimately achieved in 97% of the cohort, indicating that some measure of out-of-hospital competency can be attained in this high-acuity, low-frequency circumstance. However, overall success provides only 1 global measure of competency, with little insight into the mechanism required for proficiency. For example, we observed that a third of patients required multiple intubation attempts. Multiple attempts are associated with an increased risk of complications but also highlight the opportunity for improvement if the challenges can be identified and addressed.[24] To this end, paramedics identified body fluids obstructing the laryngeal view as a major challenge, highlighting the importance of a fundamental skill, airway suctioning, in procedural success. Multiple adjustments often occurred in concert before the next attempt (eg, pediatric bougie use and patient repositioning). The process information indicates the real challenges and resourcefulness sometimes required to achieve intubation in the out-of-hospital setting and provides important direction to focus training.

The current investigation provides a critical description of potential complications related to pediatric intubation by paramedics. Although more than a third of patients experienced a potential complication, some of these were readily identified and corrected, whereas other "complications" may not be directly attributable to the intubation but rather potentially to the underlying acute medical process (eg, aspiration).[25] Similar to that of previous studies, the most common complication was deep tube placement into a mainstem bronchus.[9,26] A smaller group experienced tube dislodgement. This set of complications might be anticipated, given the shorter tracheal anatomy, and requires additional attention relative to the adult circumstance. Peri-intubation arrest occurred in 2% of patients. In these instances, arrest may have occurred despite intubation and may simply be an indicator of the severity of disease. Conversely the intubation could have contributed to hypoxia, arrhythmia, or cardiovascular instability. Although attributing cause and effect can be challenging, the prevalence of these complications provides a system benchmark to be used to improve care.

In this population-based investigation, attempted pediatric intubation was uncommon and occurred in a cohort generally characterized by critical illness. Although overall success was high, detailed evaluation of the process of pediatric intubation using, in part, self-reported data from paramedics highlighted challenges, corrective actions, and potential complications that provide an important basis for improvement. The findings support the need to measure the process, not just the outcome, as part of a program of out-of-hospital intubation for children. Such information can help determine whether out-of-hospital pediatric intubation is appropriate for a system's scope of practice and help capable systems identify opportunities for improvement.

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Author contributions: MEP, HK, TVB, MAK, and TDR conceived and designed the investigation. MEP, FD, and JS supervised data collection and managed the study database. MEP analyzed the data. MEP, NJJ, and TDR drafted the article. All authors contributed substantially to article revision. MEP takes responsibility for the paper as a whole.

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CORRECTION

In the December 2008 issue, regarding the article by Müller et al ("The accuracy of an out-of-hospital 12-lead ECG for the detection of ST-elevation myocardial infarction immediately after resuscitation," pages 658-664), there is a discrepancy between Table 5 and the text leading to incorrect statistics for sensitivity and specificity. On page 661, the text states that sensitivity was 88%, specificity 69%, positive predictive value 77%, and negative predictive value 83%. According to the figures in Table 5, sensitivity should be 77%, specificity 83%, positive predictive value 88%, and negative predictive value 69%. *Annals* has tried to contact the author regarding the error but have been unsuccessful.

APPENDIX E2

Case descriptions of the 6 patients with peri-intubation cardiac arrest.

Case 1

Paramedics were called to the precipitous birth of a female neonate at 29 weeks' gestation (weight 1,460 g) at the parents' residence. The mother called 911 when spontaneous rupture of membranes occurred, and paramedics found a double footling breech presentation. The presenting legs were purple, the neonate was limp, and delivery of the head was delayed by several minutes. The initial Apgar score was 2. The neonate was in respiratory distress, with initial pulse recorded as ">100 beats per minute." Paramedics assisted with bag-valve-mask (BVM) ventilation and then intubated the neonate with a 3.0-mm uncuffed endotracheal tube. Tube placement was confirmed with capnography ($ETCO_2$ 37 mm Hg) and positive-pressure ventilation was begun. Soon after, the pulse rate decreased to approximately 60 beats/min and CPR was started. Epinephrine (total of 7 doses of 0.1 mg) was given down the endotracheal tube. The 5-minute Apgar score was 3. The neonate was transported with ongoing CPR to the nearest hospital. On primary survey in the ED, decreased breath sounds over the left lung were appreciated; the endotracheal tube was pulled back, with resolution. The neonate regained pulses in the ED. The early neonatal ICU course was complicated by severe hypoxemia and pulmonary hypertension treated with high-frequency oscillatory ventilation and inhaled nitric oxide. On hospital day 2, the neonate experienced a catastrophic intraventricular hemorrhage and life support was withdrawn. The patient died.

Case 2

Paramedics were called to the residence of an 8-year-old girl with asthma who was found to be in severe respiratory distress. The parents had given 2 albuterol nebulizations in the hour before EMS arrival; when the girl became agitated and restless, 911 was called. Paramedics found her lethargic, ashen, and with ineffective respirations. BVM ventilation was delivered, with improvement in respiratory effort and color; wheezing was appreciated on lung auscultation. The pulse rate was 120 beats/min, blood pressure 118/78 mm Hg, and oxygen saturation 94%. Continuous albuterol nebulization was started. During transport, the patient again developed respiratory failure. Subcutaneous epinephrine and intravenous magnesium sulfate were given. The pulse rate decreased to 60 then 23 beats/min and CPR was started. She was intubated with a 5.0-mm cuffed endotracheal tube on the second attempt. Tube position was confirmed with an $ETCO_2$ measurement of 48 mm Hg. Asystole developed and CPR and intravenous epinephrine were administered. Return of spontaneous circulation was achieved in the ED. Her initial arterial pH was 6.73, with $PaCO_2$ 130 mm Hg. She was admitted to the pediatric ICU and received therapeutic hypothermia. However, she did not awaken and was determined to have profound anoxic brain injury. Life support was withdrawn and the patient died.

Case 3

Paramedics were called to a swimming pool where a 10-year-old girl had been submerged for at least several minutes. She was rescued by bystanders. The girl had palpable pulses, with a pulse rate of 150 beats/min, and respirations were assisted by an EMT-firefighter using BVM ventilation at 15 breaths/min. She expelled copious pool water and emesis from her mouth. A peripheral intravenous line was established, succinylcholine 80 mg was administered, and she was intubated on the first attempt with a 7.0-mm cuffed endotracheal tube. Initial $ETCO_2$ was 73 mm Hg. Soon thereafter, pulses were not palpable and CPR was started. She received intravenous epinephrine, atropine, and crystalloid. Return of spontaneous circulation was achieved in 4 minutes. She was urgently transported to the nearest hospital, and by arrival she had spontaneous respiratory efforts. On ED arrival, the pulse rate was 163 beats/min, arterial pH 6.94, and $PaCO_2$ 53 mm Hg. She was admitted to the pediatric ICU, extubated on hospital day 3, and discharged to an inpatient rehabilitation facility on hospital day 11.

Case 4

Paramedics were called to a residential street where an 8-year-old boy had been struck by a vehicle estimated to be moving at 25 miles per hour. There were reports of seizure activity. The EMT-firefighters had placed the patient in a cervical collar on a backboard. His GCS score was 3. Blood pressure was 78 mm Hg systolic, pulse rate 178 beats/min, respiratory rate 4 breaths/min and agonal, and oxygen saturation 68% on 15 L/min through a nonrebreather mask. Physical examination revealed jugular venous distention and absent breath sounds and chest rise over the left hemithorax, with subcutaneous emphysema. Intravenous and intraosseous access was established. RSI was performed with etomidate and succinylcholine, a 6.0-mm cuffed endotracheal tube was placed on the first attempt, and $ETCO_2$ was 41 mm Hg. The pulse rate decreased to 32 beats/min, with loss of pulses. CPR was started, epinephrine was administered intravenously, and

left-sided needle thoracostomy was performed, with a rush of air and subsequent return of spontaneous circulation. He was transported urgently to a Level I trauma center. The patient rearrested in the ED and could not be resuscitated.

Case 5

Paramedics were called to a clinic where a 3-year-old boy with developmental delay and spasticity had presented with cough after a suspected aspiration event. He was found to be hypoxemic and in respiratory distress. His initial vital signs included a pulse rate of 180 beats/min and a respiratory rate of greater than 60 breaths/min. He was administered oxygen via a nonrebreather mask. Intravenous access was secured and the patient underwent RSI with valium and succinylcholine. A 3.5-mm endotracheal tube was placed. The boy became bradycardic, with a pulse rate between 30 and 40 beats/min because the endotracheal tube was found to be obstructed with emesis. The tube was removed, the oropharynx was suctioned, and the boy was reintubated with a 4.5-mm endotracheal tube. This larger tube also became obstructed and he remained bradycardic, so this process was repeated and he was reintubated with a 5.0-mm endotracheal tube. The boy was found to be in asystole and CPR was started. The endotracheal tube was removed and he received BVM ventilation during emergency transport to the hospital. He was intubated on arrival to the ED and achieved return of spontaneous circulation. The patient died after life-sustaining therapies were withdrawn on hospital day 2.

Case 6

Paramedics were called to a daycare center where a previously healthy 8-month-old girl had abruptly become unresponsive. She was found by basic life support personnel with a respiratory rate of 5 breaths/min and a pulse rate of 60 beats/min but with some purposeful movement. Assisted ventilations with BVM were begun by EMT-firefighters. On initial paramedic assessment, the pulse rate had increased to 120 beats/min. She had intermittent extremity posturing and conjugate gaze deviation. The blood glucose level was 260 mg/dL. Rectal diazepam was administered, given suspicion of seizure, and no change in neurologic examination result was observed. Tibial intraosseous access was obtained and she was given succinylcholine 40 mg and intubated on the first attempt with a 4.5-mm endotracheal tube. This tube was seen to pass between the vocal cords and bilateral breath sounds were auscultated; however, $ETCO_2$ was undetectable. The patient was reintubated in the same fashion, again $ETCO_2$ was absent, and the pulse rate decreased below 60 beats/min. The endotracheal tube was removed, CPR and BVM ventilations were started, and she was urgently transported to a children's hospital. She had a perfusing rhythm in the ED and was intubated for airway protection. Initial pH was 7.31 and arterial pCO_2 was 31 mm Hg. She was admitted to the pediatric ICU, and further testing supported a diagnosis of nonaccidental trauma. She was extubated on hospital day 7 and discharged after a total of 15 days.

Table E1. Characteristics of patients extubated in the ED.

Variable	All Patients (N=20)		Age Group, Years					
			<1 (N=2)		1–5 (N=11)		6–12 (N=7)	
Male patient, No. (%)	12	(60)	2	(100)	5	(45)	5	(71)
EMS succinylcholine use, No. (%)	17	(85)	1	(50)	11	(100)	5	(71)
ED disposition, No. (%)								
Admit to floor	9	(45)	0	0	5	(45)	4	(57)
Admit to ICU	7	(35)	1	(50)	5	(45)	1	(14)
Discharge home	4	(20)	1	(50)	1	(9)	2	(29)
Final diagnosis, No. (%)								
Seizure	9	(45)	0	0	5	(45)	4	(57)
Head injury, accidental	4	(20)	0	0	2	(18)	2	(29)
Airway obstruction, foreign body	2	(10)	0	0	1	(9)	1	(14)
Poisoning	1	(5)	0	0	1	(9)	0	0
Nonaccidental trauma	1	(5)	0	0	1	(9)	0	0
Pneumonia	1	(5)	0	0	1	(9)	0	0
Other, medical	2	(10)	2	(100)	0	0	0	0
Complications, No. (%)								
Bradycardia requiring intervention	2	(10)	1	(50)	1	(9)	0	0
Mainstem bronchus intubation	1	(5)	0	0	1	(9)	0	0
Aspiration pneumonia	3	(15)	0	0	3	(27)	0	0

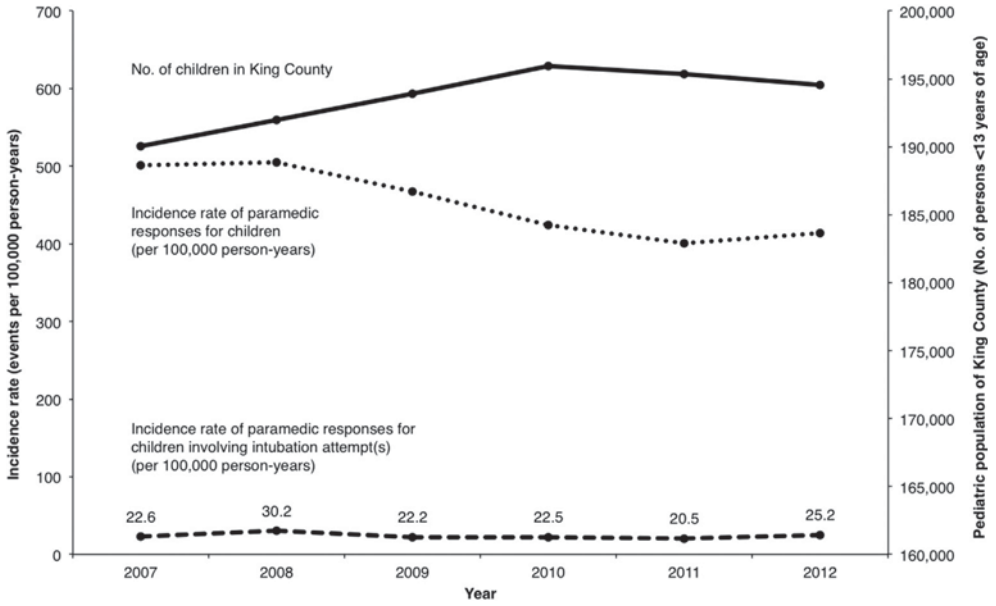

Figure E1. The epidemiology of out-of-hospital pediatric intubation by paramedics in King County between 2007 and 2012. Shown are the number of children younger than 13 years in King County (solid line; right-hand *y* axis), and the incidence rates of all paramedic responses for children (dotted line; left-hand *y* axis) and paramedic responses that involved at least 1 intubation attempt (dashed line; left-hand *y* axis).