Pediatric Prehospital Advanced Airway Management by Anesthesiologist and Nurse Anesthetist Staffed Critical Care Teams

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Abbreviations:
CPR: cardiopulmonary resuscitation
ED: emergency department
EMS: Emergency Medical Services
HEMS: helicopter Emergency Medical Services
RRC: Rapid Response Car
RSI: rapid sequence induction
TI: tracheal intubation

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Abstract

Introduction: Prehospital pediatric tracheal intubation (TI) is a possible life-saving intervention that requires adequate experience to mitigate associated complications. The pediatric airway and respiratory physiology present challenges in addition to a relatively rare incidence of prehospital pediatric TI.

Study Objective: The aim of this study was to describe characteristics and outcomes of prehospital TI in pediatric patients treated by critical care teams.

Methods: This is a sub-group analysis of all pediatric (<16 years old) patients from a prospective, observational, multi-center study on prehospital advanced airway management in the Nordic countries from May 2015 through November 2016. The TIs were performed by anesthesiologists and nurse anesthetists staffing six helicopter and six Rapid Response Car (RRC) prehospital critical care teams.

Results: In the study, 74 children were tracheal intubated, which corresponds to 3.7% (74/2,027) of the total number of patients. The pediatric patients were intubated by very experienced providers, of which 80% had performed ≥2,500 TIs. The overall TI success rate, first pass success rate, and airway complication rate were in all children (<16 years) 98%, 82%, and 12%. The corresponding rates among infants (<2 years) were 94%, 67%, and 11%. The median time on scene was 30 minutes.

Conclusion: This study observed a high overall prehospital TI success rate in children with relatively few associated complications and short time on scene, despite the challenges presented by the pediatric prehospital TI.

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Introduction

Oxygenation and ventilation are crucial in the resuscitation of the critically ill pediatric patient. While basic airway management, including bag mask ventilation, are the default methods, tracheal intubation (TI) remains the gold standard for achieving a secure airway.[1–3]

The pediatric airway anatomy and respiratory physiology differ from the adult, often making airway management challenging. The anatomical differences are age dependent and include a proportionally large head, a relatively large tongue, and a larynx that appears more anterior, all of which may restrict access to the trachea.[4,5] Furthermore, the pediatric patient is more susceptible to hypoxemia due to a higher rate of oxygen consumption, respiratory muscles that are predisposed to fatigue, and a reduced functional vital capacity compared to the adult.[4] The pediatric airway is also more vulnerable to trauma and prone to swelling during attempts of TI.[5]

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Importantly, pediatric prehospital TI is a rare event, further adding to the challenges. Children constitute roughly only five percent of the caseload of Emergency Medical Services (EMS), with an incidence of prehospital TI of 0.1% to 5.0% in those pediatric patients.[6] Unsurprisingly, studies confirm increased rates of TI failure and complications in pediatric patients.[6,7] Authors conclude that specialist competence in pediatric advanced airway management is crucial.[1,2,7–9] Research into pediatric prehospital airway management is considered a prioritized research area.[10–12]

The aim of the present study is to describe the characteristics and outcomes of pediatric patients undergoing prehospital TI. Furthermore, to compare these pediatric airway data with outcomes from an adult population obtained using the same database.[13]

Methods

Study Design

This is a pre-specified sub-group analysis of prehospital pediatric TI, using data from a prospective multi-center study of prehospital TIs.[13] Out of 2,028 patients in the original study,[13] 222 patients were excluded due to missing data regarding age, one patient was excluded due to duplicate registration, leaving 1,731 adult patients and 74 pediatric patients (<16 years of age). The population in this study includes all pediatric patients (<16 years of age) requiring prehospital TI on primary missions from May 2015 through November 2016. Records were collected by six helicopter Emergency Medical Services (HEMS) and six Rapid Response Cars (RRCs) operating in four Nordic countries. Patients on secondary missions (ie, inter-hospital transports) were excluded.

Setting

The data for the original study[13] were collected in Sweden, Norway, Finland, and Denmark in a combination of urban and rural settings covering 147,000 km^2. The area is populated by approximately 7.1 million inhabitants. The six HEMS were based in Helsinki in Finland, Trondheim and Stavanger in Norway, as well as Stockholm, Östersund, and Gothenburg in Sweden. The six RRCs were based in Aarhus and Odense in Denmark and Stockholm and Gothenburg in Sweden.

Eight of the twelve participating units were staffed by physician anesthetists. Two HEMS (Stockholm and Östersund), as well as two RRCs in Stockholm, were staffed with nurse anesthetists. Physicians and nurse anesthetists in the HEMS and RRCs in the Nordic countries commonly have several years of experience in a hospital setting before working in a prehospital unit. Nordic physician anesthetists are certified in both critical care and perioperative medicine.

All participating units were capable of performing rapid sequence induction (RSI) using anesthetic agents, neuromuscular blocking agents, sedatives, and opioids. All units were equipped with video laryngoscopes, with the exception of the HEMS in Trondheim and Stavanger.

Data Collection and Definitions

The data were originally prospectively collected for the study by Gellerfors, et al[13] using the Utstein-based template by Sollid, et al.[14] The data were registered on a paper case report form after mission completion and later transferred to a digital dataset. The data collected for each patient included demographic data, indication for prehospital intervention, Glasgow Coma Scale score, time on scene, prehospital survival rate, TI indication, number of laryngoscopy attempts, and TI success rates. The TI complications used in this study were previously defined by Sollid, et al.[14] They include hypoxemia (SpO2 <90%), bronchial or esophageal intubation, hypotension (<90mmHg), aspiration of blood or gastric contents, bradycardia (≤60 beats per minute), vomiting, or dental trauma. A TI attempt was defined as laryngoscopy with the purpose of tracheal intubation; RSI was defined as TI assisted by drugs including neuromuscular blocking agents; TI time was defined as the time from when the laryngoscope first passed the front teeth until correct tube positioning was verified with capnography or lung auscultation; and time on scene was defined as the time from arrival of the HEMS or RRC to the patient until leaving the scene carrying the patient.

Study Size

No power calculation was made due to the descriptive nature of this study.

Ethics

Ethical approval was acquired for the original study[13] and included sub-group analysis of the collected data. Ethical review board approvals are Sweden (2015/411-31, 2015/1519-32), Denmark (Danish Data Protection Agency no. 20087-58-0035, 15/16531 and the Danish Health and Medicine Authority no. 3-3013-941/ 1/), and Norway (2015/545/REK vest). In Finland, the study did not deviate from normal practice or documentation and did not require Ethical Review Board approval.

Statistical Analysis

Data are presented as numbers and percentages for categorical variables or medians with interquartile ranges for continuous variables. Comparisons between groups were made with Fischer's exact test for categorical variables and Wilcoxon rank-sum test for continuous variables. Statistical significance was set as $P < .05$. There were missing data in the dataset. The frequency of missing data among the pediatric patients were: total number of intubations 1.4%, time on scene 12.0%, sex 5.4%, TI time 4.1%, and number of TI attempts 1.4%. Missing data among the patients ≥16 years of age were: time on scene 7.8%, TI time 3.3%, alive at emergency department (ED) 1.2%, on-going cardiopulmonary resuscitation (CPR) at ED arrival 1.2%, and prehospital death 1.2%. Data analysis was performed using the statistical software Stata version 15 (Stata Corp.; College Station, Texas USA).

Results

During the study period, clinicians attended 74 children requiring TI (Figure 1). Of these, 18 were younger than two years (termed <2y). In all children, cardiac arrest and other medical conditions were the dominant medical categories (Table 1) in 26 (35%) children, followed by trauma in 21 (28%) children. Obstructive airway disease was the most common pathology in the category Other medical conditions in 13 (18%) children. Physician anesthesiologists intubated 56 (76%) of the children. The majority (59; 80%) were intubated by providers with at least 2,500 previous intubations.

TI Success Rates and Complications

The overall TI success rate was 98.6% and 94.0% for children <2y (Table 2). In all children, 61 (82%) were intubated using one laryngoscopy attempt, 71 (96%) within two attempts, and 73 (99%) after three attempts. For children <2y, success rates per attempt were lower at 67%, 89%, and 94%. The median TI time was 25 seconds for both groups. The median on-scene

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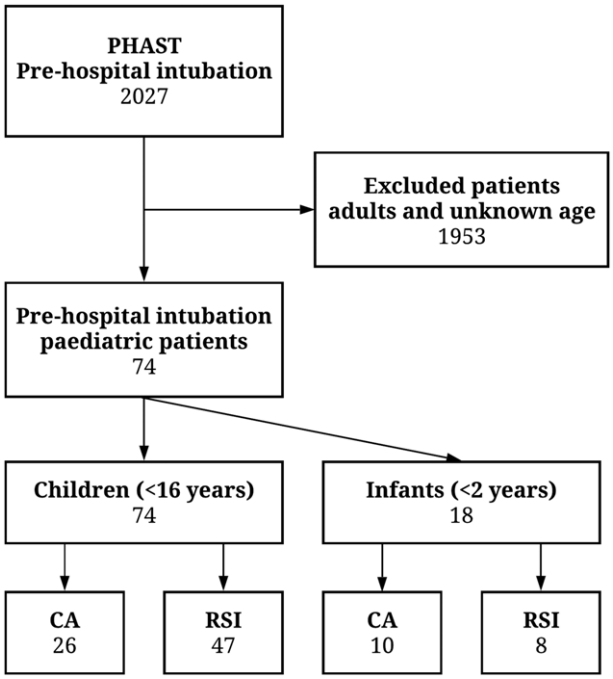

Figure 1. Flowchart of Pediatric Intubated Patients.
Abbreviations: PHAST, prehospital airway original study by Gellerfors, et al; CA, cardiac arrest; RSI, rapid sequence induction.

time was 30 minutes. On-scene time was somewhat longer in the <2y group at 33 minutes. Complications occurred in nine (12 %) children. Fifty-four (73%) children were alive at arrival at the ED (11 [61%] in <2y). Cardiopulmonary resuscitation was on-going at ED arrival in 10 (14%; 3 [17%] in <2y). Ten (14%) children (4 [22%] in <2y) were declared deceased before ED arrival.

RSI and Cardiac Arrest Sub-Groups

Airway data for each age category (<16 and <2y) in the sub-groups cardiac arrest and RSI are presented in Table 3. Among all children (<16) with cardiac arrest, TI was successful in 25 (96%). The TI first pass success rate in cardiac arrest was 73% among all children and children <2y was 60%. All children requiring RSI were successfully intubated with complications occurring in six (13%).

Comparisons with Adult Patients

Table 4 compares the children observed in this study with the adult population in the original study.[13] The overall TI success rate was 98.6% in children and 98.8% in adults (P = .59). The success rate for the first TI attempt was 82.4% for all children and 85.4% for adults (P = .50). The median on-scene time was 30 minutes in children compared to 25 minutes in adults (P = .089). Fifty-four (73%) children and 1,138 (66%) of adults were alive at arrival to the ED (P = .21); 10 (13.5%) children and 195 (11.3%) adults had on-going CPR at ED arrival (P = .57).

Discussion

This study on pediatric prehospital TI performed by experienced airway providers documented a high overall TI success, few associated complications, and short scene times.

	Age <2 n = 18	Age <16 n = 74
Provider Data		
Anesthetist, n (%)	14 (78%)	56 (76%)
Anesthetist Registrar, n (%)	0 (0%)	3 (4%)
Emergency Medicine Physician, n (%)	0 (0%)	1 (1%)
Internal Medicine, n (%)	0 (0%)	1 (1%)
Nurse Anesthetist, n (%)	4 (22%)	13 (18%)
Experience of Tracheal Intubations[a]		
50-200, n (%)	0	0
200-2500, n (%)	1 (6%)	14 (19%)
2500-10000, n (%)	16 (89%)	55 (75%)
>10000, n (%)	1 (6%)	4 (5%)
Patient Data		
Age, Median (IQR)	1.0 (0.0-1.2)	5.6 (2.0-11.0)
Male, n (%)	6 (38%)	38 (54%)
ASA Physical Status Classification, Median (IQR)	1.0 (0.0-1.0)	1.0 (1.0-2.0)
Patient Categories[b]		
Trauma Total, n (%)	2 (11%)	21 (28%)
Blunt Trauma, n (%)	2 (11%)	19 (26%)
Penetrating Trauma, n (%)	0 (0%)	2 (3%)
Traumatic Brain Injuries, n (%)	2 (11%)	16 (22%)
Cardiac Arrest, n (%)	10 (56%)	26 (35%)
Medical Other Total, n (%)	6 (33%)	26 (35%)
Cardiac Disease (Not Cardiac Arrest), n (%)	0 (0%)	1 (1%)
Stroke/Intracranial Hemorrhage, n (%)	2 (11%)	4 (5%)
Seizure, n (%)	0 (0%)	7 (9%)
Asthma/COPD, n (%)	4 (22%)	13 (18%)
Intoxication, n (%)	0 (0%)	3 (4%)
Ear-Nose-Throat Disease, n (%)	0	0
Other, n (%)	1 (6%)	10 (14%)

Table 1. Demographic Information
Abbreviations: ASA, American Society of Anesthesiologists; COPD, chronic obstructive pulmonary disease; IQR, interquartile range.
[a] Missing data, therefore percentages do not add up to 100%.
[b] Multiple response set, therefore percentages do not add up to 100%.

The high overall TI success rate of 98.6% in this study compares favorably to all but one of 19 included studies in a meta-study by Rodriguez, et al[7] and is in line with the study by Eich, et al[15] who documented a 98.3% overall success rate. The TI success rate was lower than reported by Nevin, et al (99.6%) in pediatric trauma patients.[16] Despite the underlying challenges of the pediatric airway and physiology, the high overall TI success rate in this study is nearly identical to that of the adult population reported in the original study[13] (98.6% compared to 98.8%). This result may be attributed to the experience of the participating teams, where 80% of providers had performed at least 2,500 intubations.

Trauma constitutes a significant portion of the pediatric prehospital caseload.[15] In the management of trauma patients, it is important to mitigate complications associated with TI to avoid

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	Age <2 n = 18	Age <16 n = 74
TI Success Total, n (%)	17 (94%)	73 (99%)
TI Success 1 Attempt, n (%)	12 (67%)	61 (82%)
TI Success ≤ 2 Attempts, n (%)	16 (89%)	71 (96%)
TI Success ≤ 3 Attempts, n (%)	17 (94%)	73 (99%)
TI Success ≤ 2 Attempts + No Complication, n (%)	15 (83%)	64 (86%)
Difficult Airway, n (%)	5 (28%)	26 (35%)
TI Success with Difficult Airway, n (%)	4 (80%)	25 (96%)
TI Time (sec), Median (IQR)	25.0 (22.5, 40.0)	25.0 (20.0, 30.0)
On-Scene Time (min), Median (IQR)	33.0 (20.0, 40.0)	30.0 (20.0, 40.0)
Use of Checklist, n (%)	6 (33%)	36 (49%)
No Complication[a], n (%)	16 (89%)	65 (88%)
Hypoxia, n (%)	0	4 (5%)
Bradycardia, n (%)	0	2 (3%)
Hypotension, n (%)	0	1 (1%)
Cardiac Arrest, n (%)	0	0
Bronchial Intubation, n (%)	0	1 (1%)
Esophageal Intubation, n (%)	1 (5.6%)	1 (1%)
Aspiration, n (%)	1 (5.6%)	2 (3%)
Dental Injury, n (%)	0	1 (1%)
Surgical Airway Necessary, n (%)	0	0
Other, n (%)	0	1 (1%)
Outcome		
Alive at ED, n (%)	11 (61%)	54 (73%)
On-Going CPR at ED Arrival, n (%)	3 (17%)	10 (14%)
Prehospital Death, n (%)	4 (22%)	10 (14%)

Table 2. Prehospital Intubation Success and Complications in Children <16 Years of Age and Infants <2 Years of Age
Abbreviations: CPR, cardiopulmonary resuscitation; ED, emergency department; IQR, interquartile range; TI, tracheal intubation.
[a] Multiple response set, therefore percentages do not add up to 100%.

	Age <2		Age <16	
	RSI n = 8	Cardiac Arrest n = 10	RSI n = 47	Cardiac Arrest n = 26
TI Success Total, n (%)	8 (100%)	9 (90%)	47 (100%)	25 (96%)
TI Success First Attempt, n (%)	7 (88%)	6 (60%)	42 (89%)	19 (73%)
TI Time (sec), Median (IQR)	25.0 (22.5-35.0)	30.0 (25.0-40.0)	25.0 (15.0-30.0)	25.0 (20.0-30.0)
On-Scene Time (min), Median (IQR)	33.5 (21.5-43.5)	37.0 (20.0-48.0)	30.5 (20.0-40.5)	30.0 (15.0-42.0)
No Complication, n (%)	7 (88%)	10 (100%)	41 (87%)	25 (96%)
Hypoxia, n (%)	0	0	3 (6%)	0
Hypotension, n (%)	0	0	1 (2%)	0
Outcome				
Alive at ED, n (%)	8 (100%)	4 (40%)	44 (94%)	8 (31%)
On-Going CPR at ED Arrival, n (%)	0	3 (30%)	1 (2%)	10 (38%)
Prehospital Death, n (%)	0	3 (30%)	2 (4%)	8 (31%)

Table 3. Prehospital Intubation Success and Complications in Children and Infants According to RSI and Cardiac Arrest
Abbreviations: CPR, cardiopulmonary resuscitation; ED, emergency department; IQR, interquartile range; RSI, rapid sequence induction; TI, tracheal intubation.

a secondary insult.[17] Prehospital hypoxia in patients with traumatic brain injury leads to increased disability and mortality.[17] First pass success rate is a relevant metric as each TI attempt is associated with additional risk of complications.[18] This study observed a first pass success rate of 82% of all children, and 67% in the <2y group, comparable to the first pass success rate in adult patients (85.4%) in the original study.[13] The first pass success rate is lower than observed by Schmidt, et al[19] (95.3%) but higher than reported by Tarpgaard,

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	Children (Age <16) n = 74	Adults (Age ≥16) n = 1731	P Value
TI Success Total, n (%)	73 (98.6%)	1711 (98.8%)	.59[a]
TI Success First Attempt, n (%)	61 (82.4%)	1479 (85.4%)	.50[a]
TI Time (sec), Median (IQR)	25.0 (20.0-30.0)	25.0 (15.0-35.0)	.90[b]
On-Scene Time (min), Median (IQR)	30.0 (20.0-40.0)	25.0 (19.0-34.0)	.089[b]
No Complication, n (%)	65 (87.8%)	1529 (88.3%)	.85[a]
Outcome			
Alive at ED, n (%)	54 (73.0%)	1138 (65.7%)	.21[a]
On-Going CPR at ED Arrival, n (%)	10 (13.5%)	195 (11.3%)	.57[a]
Prehospital Death, n (%)	10 (13.5%)	379 (21.9%)	.11[a]

Table 4. Prehospital Intubation Success and Complications in Children Compared to Adults
Abbreviations: CPR, cardiopulmonary resuscitation; ED, emergency department; IQR, interquartile range; RSI, rapid sequence induction; TI, tracheal intubation.

[a] Fisher's exact test.

[b] Wilcoxon rank-sum test.

et al[20] who observed a first pass success rate of 75% for all children <16 years and 54% for children <2y.

The incidence of complications observed in this study was consistent with previous studies at 12% for all children and 11% for the <2y group.[6,15,21] The complication rate was comparable to the adult patients in the original study[13] (12%) and with a study by Sunde, et al[22] (13%) with both adult and pediatric patients. It was, however, considerably lower than reported by Tarpgaard, et al who documented complication rates of 20% all children and 38% for children <2y.[20] A meta-study and systematic review by Garner, et al[6] observed a pooled incidence of complications in 10% of pediatric prehospital TI that was performed by physicians, and a significantly higher complication rate when performed by non-physician (30%-39%). The most prevalent complication in Targaard, et al[20] (8%), Sunde, et al[22] (25%), and the meta-study by Rodriguez, et al[7] (7%) was esophageal intubation. In this study, the most prevalent complication in all children was hypoxia (5%) and in the <2y group esophageal intubation (5.6%; n = 1) and aspiration (5.6%; n = 1).

In the original study,[13] HEMS and RRCs attended 32,007 patients, out of which 2,027 required TI. The 74 pediatric patients in this study therefore only comprised 3.7% of all TI, and the incidence of a pediatric TI in all patients attended by the RRCs and HEMS were only 0.2%. The observed incidence of prehospital pediatric TI in this study are in line with Garner, et al[6] who report an incidence of pediatric patients in approximately five percent of all patients tended to by EMS and TI in 0.1% to approximately 5.0% of those patients. Pediatric prehospital TI is extremely rare and this reinforces the need of maintaining adequate competence outside of strict prehospital exposure.

The effect of time on scene on mortality in trauma patients is heterogeneous and studies have failed to demonstrate a survival benefit of shorter scene times.[23] However, short response time and transport time may be associated with increased survival, indicative of prehospital time being of importance.[23] Tjissen, et al[24] observed that overly short (<10 minutes) as well as long (>30 minutes) times on scene in non-traumatic cardiac arrest in children may be associated with decreased survival. Time on scene might be the only time variable under the influence of EMS providers, which might suggest that the right type and amount of intervention be administered in the shortest time possible.[23]

This study observed a median time on scene of 30 minutes for all children and slightly longer, 33 minutes, for the children <2y. This was a longer on-scene time than in the adult patients, with a median time of 25 minutes (P = .089). A longer time on scene might, at least in part, be attributed to the underlying airway and respiratory differences in the pediatric patient as well as an increased likelihood of challenging scenes associated with a critically injured child. Nevin, et al[16] observed a median time on scene of 20 minutes in undifferenced trauma patients, with an increase to a median of 41 minutes when RSI was administered. This study found a longer median time on scene (30 minutes) among all children, but it was not significantly influenced by the administration of RSI (30.5 minutes). However, the observed median time on scene compared favorably to Burns, et al[21] who observed a median on-scene time of 50 minutes.

Seventy-three percent of the children were alive at arrival at the ED compared to 65.7% of the adult patients in the original study,[13] and 13.5% of the children were declared deceased prehospital compared to 21.9% of the adult patients. A result that, at least in part, may reflect a reluctance to terminate resuscitation attempts in children in the prehospital setting.

Generalizability

These data were collected in four rather homogenous Nordic countries with similar demographics and EMS; extrapolation to other settings should be done with caution. The results could be useful to similar EMS and demographics.

Limitations

This was a sub-group analysis with a relatively low number of children from a descriptive study and the results should therefore be viewed with caution. In addition, these data consist of self-reported data, which may under-report adverse events as reported by Kerrey, et al.[25] In order to mitigate the effect of recall and registration bias of self-reported data, the airway provider registered the data directly after mission completion on an anonymous data registration form. No data on in-hospital or long-term mortality and complications were collected in the original study,[13] which may underestimate complications related to prehospital TI.

Conclusion

This descriptive study observed pediatric prehospital TI with relatively few complications, short on-scene time, and a high overall

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prehospital TI success rate in children <16 years of age. The observed TI success rate was nearly identical compared with the adult patients in the same setting, as described in the original study,[13] despite the underlying challenges of the pediatric airway and respiratory physiology, as well as the rare occurrence of the prehospital pediatric TI. This favorable result might, at least in part, be attributed to the experience of the participating HEMS and RRCs and underlines the importance of competence in TI.

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