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## RESEARCH ARTICLE

# Frequency, indications and success of out-of-hospital intubations in Finnish children

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## Abstract

**Background:** Earlier studies have shown variable results regarding the success of paediatric emergency endotracheal intubation between different settings and operators. We aimed to describe the paediatric population intubated by physician-staffed helicopter emergency medical service (HEMS) and evaluate the factors associated with overall and first-pass success (FPS).

**Methods:** We conducted a retrospective observational cohort study in Finland including all children less than 16 years old who required endotracheal intubation by a HEMS physician from January 2014 to August 2019. Utilising a national HEMS database, we analysed the incidence, indications, overall and first-pass success rates of endotracheal intubation.

**Results:** A total of 2731 children were encountered by HEMS, and intubation was attempted in 245 (9%); of these, 22 were younger than 1 year, 103 were aged 1–5 years and 120 were aged 6–15 years. The most common indications for airway management were cardiac arrest for the youngest age group, neurological reasons (e.g., seizures) for those aged 1–5 years and trauma for those aged 6–15. The HEMS physicians had an overall success rate of 100% (95% CI: 98–100) and an FPS rate of 86% (95% CI: 82–90). The FPS rate was lower in the youngest age group ( $p = .002$ ) and for patients in cardiac arrest ( $p < .001$ ).

**Conclusions:** Emergency endotracheal intubation of children is successfully performed by a physician staffed HEMS unit even though these procedures are rare. To improve the care, emphasis should be on airway management of infants and patients in cardiac arrest.

## KEYWORDS

airway management, emergency medical services, paediatric, paediatric emergency medicine, rapid sequence induction and intubation

## Editorial Comment

This retrospective analysis presents findings for airway management and intubation by helicopter ambulance-based physicians in out-of-hospital emergencies in Finnish children. An impressive 100% success rate of tracheal intubations is reported.

Lauri Elonheimo and Harry Ljungqvist contributed equally to this study.

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## 1 | INTRODUCTION

### 1.1 | Background

Endotracheal intubation (ETI) outside of the operating room is a rare, but potentially lifesaving, procedure for airway management in critically ill and injured children. It is often performed in the emergency department (ED), and previous studies have shown both mixed results for success rates and relatively high numbers of complications.<sup>1-3</sup> Repeated intubation attempts have been associated with an increase in adverse events and complications, emphasising the importance of first-pass success (FPS), especially in children, who are more vulnerable to complications.<sup>4-7</sup>

### 1.2 | Importance

During the last few decades, the quality and safety of advanced airway management in prehospital settings have been addressed by several studies. Safety concerns have risen due to low reported success rates for intubation in some systems, but prehospital systems staffed by anaesthetists have yielded higher success rates that are comparable to or even exceed ED performance.<sup>5,8,9</sup> Notably, the success of prehospital intubation in paediatric patients has been investigated less often, and extremely high failure rates have been reported.<sup>10</sup>

### 1.3 | Goals of this investigation

The aim of this study was to describe the incidence of ETI and the characteristics of the paediatric population intubated by physician-staffed helicopter emergency medical services (HEMS) throughout Finland. We also wanted to estimate the overall success of ETI and FPS in different age groups and patient categories.

## 2 | METHODS

### 2.1 | Ethics

The Ethical Committee of Helsinki University Hospital approved the study protocol (HUS/3115/2019). The use of the database was approved by all the university hospital districts in Finland (Oulu University Hospital 200/2019 2.7.2019, Helsinki University Hospital HUS/280/2019 9.7.2019, Turku University Hospital J30/19 4.8.2019, Hospital District of Lapland 32/2019 22.8.2019, Kuopio University Hospital RPL 102/2019 22.8.2019 and Tampere University Hospital RTL-R19580).

### 2.2 | Study design

We conducted a retrospective observational cohort study of children (aged less than 16 years) whose endotracheal intubation was attempted by a HEMS physician. The recommendations of the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement were followed in the reporting.<sup>11</sup> The primary endpoints were (a) overall and (b) first-pass success of intubation attempt.

### 2.3 | Setting

This study covers the period from January 2014 to August 2019 at five HEMS units that are all part of the national HEMS system in Finland. The country is a sparsely populated, industrialised, high-income Nordic country with a population density of 16/km<sup>2</sup>. Of the 5.5 million inhabitants, 1 049 000 were under the age of 18 in 2019.<sup>12</sup> Healthcare in Finland is based on a single-payer model that is publicly funded by tax income, and the costs for patients are mainly covered by public health insurance.

The Finnish prehospital emergency medical services (EMS) and HEMS have been described in detail in a recently published article.<sup>13</sup> EMS in Finland is organised into 21 separate hospital districts, but it is publicly funded and governed by strict laws and regulations, making it an equal and just system for the whole population. In addition to the ground ambulances, Finland has a single nationwide publicly funded HEMS system that is governed by five university hospitals and a national administrative unit.

The national emergency number 1-1-2 is free-of charge and available to everybody in Finland. Calls are processed by the national Emergency Response Centre Agency, and, if certain criteria are met, an ambulance or other authorities are dispatched. The majority of prehospital patients are encountered only by ambulance personnel, and HEMS units are dispatched only to those most severely ill or injured, who it is assumed will benefit from prehospital critical care. The crew of a HEMS unit consists of a physician, a HEMS crew member (either a paramedic or a fire fighter) and a pilot. During the study period, total of 100 individual physicians worked in the service, including 70 senior anaesthesiologists, 25 anaesthesiology residents in their final year of specialisation, three internal medicine specialists and two residents in emergency medicine during their last year of specialisation. The proportion of prehospital and in-hospital work as well as exposure to paediatric anaesthesia in in-hospital work varies.

During the study period, there was no standardised protocol for the intubation of children. The techniques, medications and equipment were dictated by the physician on-call. Both video and direct laryngoscopes were available with blades ranging from one to five, supraglottic airway (SGA) devices and equipment, pre-inserted stylets and surgical airways. Bougies suitable for small

children were not available during the study period. Accessible drug classes included anaesthetics, opioids and neuromuscular blocking agents.

## 2.4 | Participants

We included all prehospital paediatric (younger than 16 years) patients for whom ETI was attempted by a HEMS physician from January 2014 to August 2019 (Figure 1). We excluded the children who were intubated by a HEMS unit that was not physician-staffed.

## 2.5 | Data and variables

Data were collected from a joint database (FinnHEMS database, FHDB) used by all HEMS units in Finland.<sup>13</sup> The data are entered by the physician on-call immediately after the mission and are recorded using consensus-based templates for the collection of data from prehospital physician-staffed units and for prehospital advanced airway management.<sup>14,15</sup>

From the FHDB, we collected the following descriptive data about the patients and the intubation: age, sex, patient category, reason for intubation and drugs used to facilitate airway management. We also gathered vital parameters measured by the first ambulance on scene—oxygen saturation and Glasgow Coma Scale (GCS), which were chosen as they are comparable between age groups, reliably obtained and associated with the decision to intubate. Oxygen saturation and GCS were not measured for patients in cardiac arrest.

We also gathered data on FPS and overall success rates from the FHDB. FPS was defined as the proportion of successful intubations on the first attempt at laryngoscopy. FPS was used as the variable to measure quality of intubation because it is well established, commonly used, easily comparable, intimately connected to the presence of complications and may be especially important in children.<sup>4-7</sup>

## 2.6 | Statistical methods

Normality of parameter distribution was tested with the D'Agostino-Pearson test. Because none of the variables were normally distributed, nonparametric tests were used, and continuous data are reported as median [1<sup>st</sup> quartile–3<sup>rd</sup> quartile].

For proportion variables, we calculated 95% confidence intervals (CI) according to Wilson/Brown. Comparisons of categorical data between the three age groups were performed using chi-squared tests and between two groups using Fisher's exact test. Changes in oxygen saturation during prehospital care were analysed with the Wilcoxon matched-pairs signed-ranks test. All analyses were performed using Prism 9 for macOS (GraphPad Software, San Diego, California, USA).

## 3 | RESULTS

A total of 2731 paediatric patients were encountered by HEMS during the study period from January 2014 to August 2019. Of these children, 265 (9.7%) needed airway management. HEMS physicians intubated 245 children (Table 1), and 20 children received SGA as the sole airway device. None of the children needed a surgical airway.

The indications for prehospital critical care varied between the age groups (Figure 2). The most common indications for airway management were cardiac arrest in patients younger than 1 year, neurological reasons (e.g., seizures) in patients aged 1–5 years and trauma in patients aged 6–15 years.

During the study period, the HEMS physicians had an overall intubation success rate of 100% (95% CI: 98–100), with no children requiring alternative airway devices or surgical airways due to failed intubation attempts. First intubation attempts were successful in 212 patients (86%; 95% CI: 82–90). Lower FPS rates were observed in younger patients and cardiac arrest patients (Figure 3).

Oxygen saturation immediately after airway management, excluding patients intubated during cardiac arrest, was 99% [98–100],  $n = 184$ . Both initial and final peripheral oxygen saturation were available in 170 patients. The oxygenation of the patients improved significantly ( $p < .0001$ ) during prehospital care from 96% [88–99] to 100% [98–100]. End-tidal partial pressure of CO<sub>2</sub> after intubation was 5.8 kPa [4.7–7.0],  $n = 193$ .

## 4 | DISCUSSION

The main results of the current study include an extremely high overall success rate of ETI and an FPS rate for the HEMS physicians that exceeds most of the ED rates, despite low incidence of the procedure. We also found that the indications for airway management were different for each age group and that, in a prehospital setting, the intubation of infants and children suffering from cardiac arrest seems to be more challenging.

The FPS rate is a well-established and frequently used parameter for the quality of ETI that is easily comparable between different settings. It is clinically relevant because repeated intubation attempts have been shown to increase complications and adverse events.<sup>4-6</sup> FPS is of increased importance in the unfasted and unstable patients met in emergent situations, who are more disposed to early deterioration than patients in elective anaesthesia.<sup>16</sup> Notably, children are more likely to have complications from prolonged intubation because of their physiological characteristics.<sup>7</sup>

Fortunately, children seldom require emergency ETI due to acute and severe trauma or illness, making it a rare and high-stress situation for the whole team. The number of patients in the current study corresponds only less than 5% of total number of adult intubations in the service during the study period. Studies from EDs have reported a wide variety of specialties, from paediatricians to surgeons, performing this procedure. The rates of FPS reported from paediatric EDs vary from around 60% to 80%.<sup>1-3</sup> In the current study, the

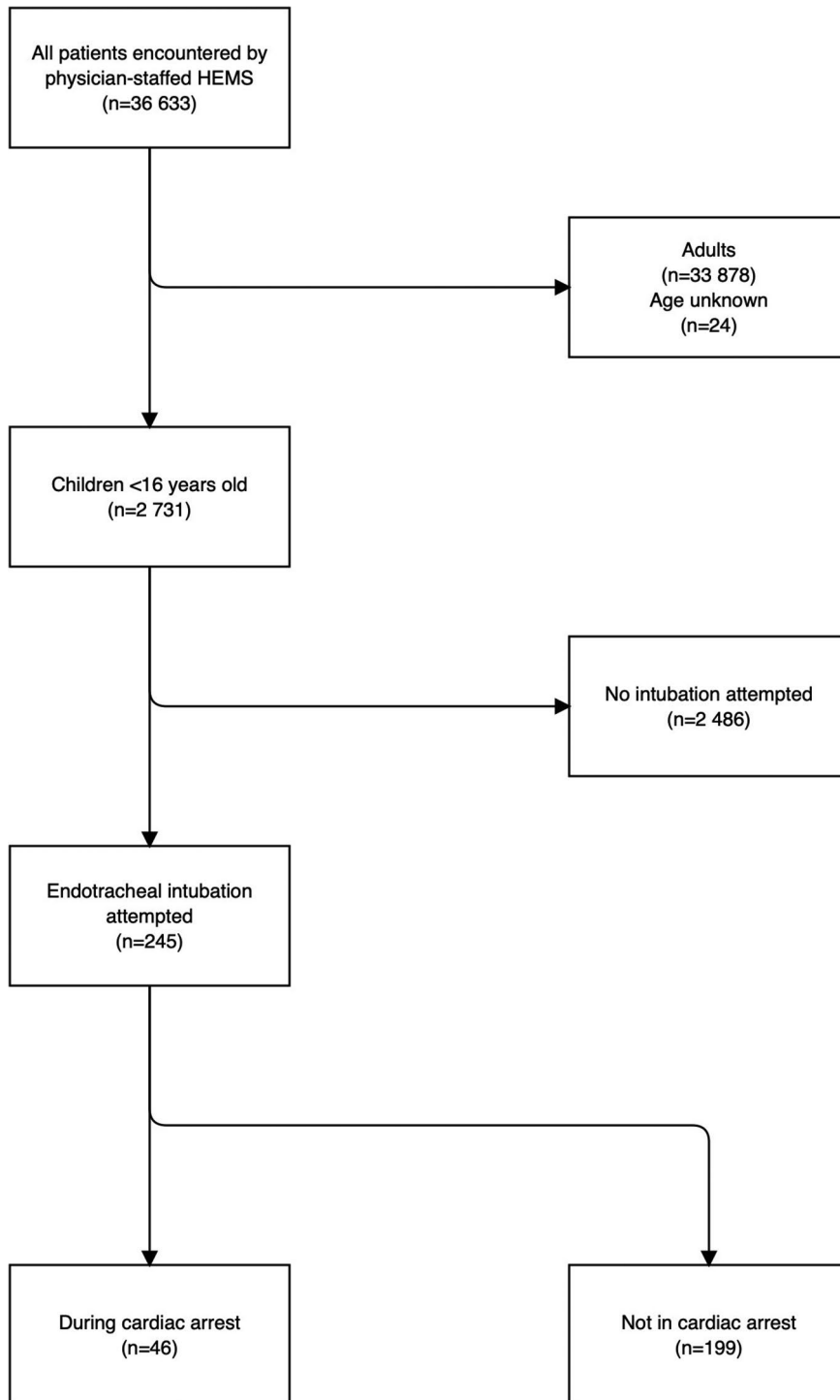


FIGURE 1 Flow chart of patient selection. HEMS, Helicopter emergency medical services

HEMS physicians achieved an FPS of 86%, which is consistent with the data from a recent systematic review of prehospital paediatric ETI comparisons between physicians and non-physicians.<sup>17</sup> There are probably several reasons for the high success rate in our setting. All the studied HEMS units are staffed by anaesthesiologists who, given their small and consistent teams, can achieve a high level of procedural experience in intubation, while physicians, such as paediatricians, in the ED confront these critical procedures more rarely.<sup>18,19</sup> We were unfortunately not able to evaluate individual HEMS physicians background or experience in specifically paediatric

ETI but they all have done a residency under paediatric anaesthesia during their specialisation. Furthermore, in studies from the ED, the use of neuromuscular blocking agents is less frequent, which is another factor associated with lower FPS rates.<sup>17,20</sup>

In our study, the FPS rate was significantly lower in infants younger than 1 year and in children in cardiac arrest, emphasising the need to study paediatric airway management by age and indication. The lower FPS rate among younger patients is potentially explained by greater anatomical differences at younger ages.<sup>7,21-23</sup> Another explanation could be that, in the current study, many

TABLE 1 Characteristics of the patients

	Age <1 year (n = 22)		Age 1–5 years (n = 103)		Age 6–15 years (n = 120)	
	0.2	(0.0–0.6)	2.8	(1.6–4.0)	12.5	(9.6–14.2)
Sex, male (%)	10	(45)	60	(58)	76	(63)
Vital signs at HEMS encounter						
Oxygen saturation, % <sup>a</sup>	98	(81–100), n = 8	98	(93–100), n = 78	98	(94–99), n = 105
Glasgow coma score	3	(3–5)	5	(3–7)	6	(3–8)
Drugs used to facilitate intubation (%)						
Any drug	5	(23)	88	(85)	110	(92)
Sedative/anaesthetic	5	(23)	88	(85)	110	(92)
NMB	5	(23)	84	(82)	109	(91)
Analgesic	4	(18)	73	(71)	93	(78)

Results are presented as either number (%) or median (interquartile range), as appropriate.

Abbreviations: HEMS, helicopter emergency medical service; NMB, neuromuscular blocking agent.

<sup>a</sup>Oxygen saturation not recorded for patients in cardiac arrest at encounter or if oxygen saturation was unmeasurable.

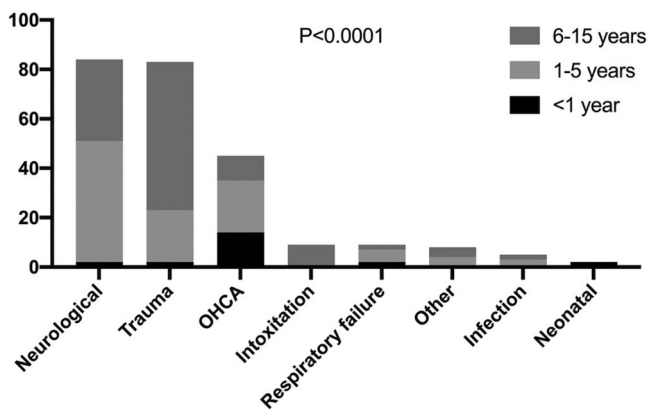


FIGURE 2 Indication of prehospital critical care in different age groups of patients in need of invasive airway management by helicopter emergency medical services. OHCA, out-of-hospital cardiac arrest, such as sudden infant death syndrome

patients in the youngest group were intubated without drugs. The use of neuromuscular blocking agents to facilitate intubation substantially increases the success rate.<sup>17</sup> This fact may partly explain the lower success rate in this group and highlights the importance of appropriate use of drugs to facilitate intubation. In the group of the youngest infants, we also found cardiac arrest to be the most frequent patient category, as older children suffered more frequently from neurological disorders or trauma. Other studies have also reported lower FPS rates in cardiac arrests, which might also help to explain the difference.<sup>24</sup> It should be noted that the use of bag-mask ventilation is preferred over intubation and the use of a SGA device in paediatric cardiac arrest by the latest ILCOR updates.<sup>25</sup> In light of these guidelines, the lower success rates in cardiac arrest in our study do raise concerns. Repeated attempts raise the risk of complications and also most likely prolongs the intubation,<sup>4–6</sup> thus possibly extending interruptions in chest compressions.<sup>25</sup> Our study does not however include children treated only with a SGA device or only with bag-mask ventilation and only procedures performed by

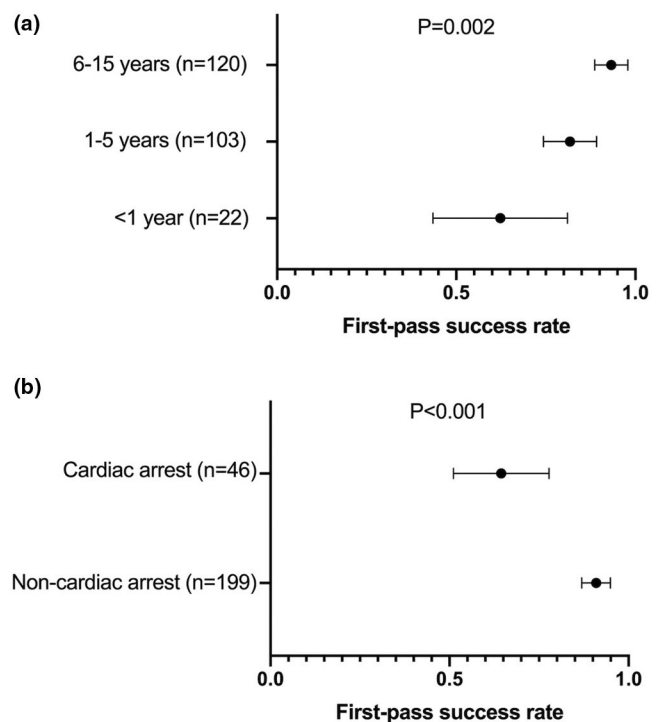


FIGURE 3 First-pass success rate in different age groups (A) and in cardiac arrest and non-cardiac arrest patients (B)

the HEMS teams were included in the study. Thus, the frequencies of SGA device usage by ground crews or resuscitation with only bag-valve mask ventilation are unknown. Therefore, conclusions regarding the frequency of methods of airway management during cardiac arrest should not be done based on this study.

Although intubation is still considered the 'golden standard' of adult prehospital advanced airway management, the evidence is not beyond dispute, even less so regarding paediatric intubation and one should be cautious to extrapolate findings from adults to children.<sup>10</sup> This cautiousness is especially highlighted when taking into consideration the

lower FPS in our study, a higher risk of complications with repeated attempts and a potentially higher susceptibility to complications in children as they tolerate apnoea poorly and are more prone to hypoxia.<sup>7,10</sup> As with the recommendations for cardiac arrest, less invasive methods like bag-mask ventilations and SGA devices might also be sufficient for children with other aetiology and indications.<sup>25</sup> However, in adults there is a group of patients described who require advanced airway management to maintain adequate oxygenation and airway.<sup>26</sup> Thus, there may be a place for intubation of paediatric patients in prehospital setting.<sup>1-3</sup> But similarly with adult prehospital intubation, the benefit is most likely only seen in a systems including advanced physician-staffed units with robust intubation experience.<sup>9,17</sup>

#### 4.1 | Limitations and strengths

Retrospective cohorts are innately susceptible to the influence of confounds not taken into consideration. One example is the lack of data on complications, and this absence is unfortunate because we focused particularly on the safety of ETI. This will hopefully be corrected in the future, with updates to the database and with education on how and when to record complications. The data are also recorded in the FHDB by the physician on-call and are not externally validated, predisposing it to self-reporting bias and mistakes.<sup>1,13</sup>

Due to databases restrictions, we had limited knowledge on the choice of equipment for intubation (e.g. choice between video or direct laryngoscopy, use of stylets or bougies) and were therefore not able to study them. However, a recent observational study that compared video-assisted laryngoscopy with direct laryngoscopy in a paediatric ED found no difference regarding first-pass success rate.<sup>27</sup>

Our study also has many strengths that support the conclusions reached. As the HEMS system covers almost all of Finland and there were only a few cases of cancellation due to technical factors, we had a high capture rate. The organisation of the healthcare and EMS systems in Finland makes for low levels of selectivity, strengthening the data on the incidence of paediatric ETI and EMSs are uniform throughout the nation in comparison to other countries. Taken together, these features support the findings from both the descriptive and safety data while highlighting that care should be taken when attempting to extrapolate the results directly to other EMS systems.

We had a relatively large sample of a rare intervention and were able to reliably separate patients into different age groups and categories, which has not been possible in many other studies. We believe this to be an important part of the study, as it clearly shows significant differences in success in the different age groups and categories, supporting the idea that paediatric patients are not a homogeneous group. We encourage researchers to take this into consideration in future studies.

## 5 | CONCLUSIONS

In summary, emergency ETI of critically ill children is successfully performed by physician-staffed HEMS units and seems to be a

reasonable option compared to ETI in the ED. Although prehospital ETI in our hospital system is successful overall, we note that the FPS for the youngest children is lower. A protocol standardising prehospital rapid sequence intubation, such as combining the use of video laryngoscopy with bougie, has dramatically improved the FPS in prehospital adult patients.<sup>28</sup> Based on the findings of the current study, we recognise the need for similar quality improvement studies in paediatric airway management, with a special emphasis on infants and airway management during cardiac arrest.

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#### CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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