

RESPIRATION AND AIRWAY

Pre-hospital advanced airway management by anaesthetist and nurse anaesthetist critical care teams: a prospective observational study of 2028 pre-hospital tracheal intubations

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Abstract

Background: Pre-hospital tracheal intubation success and complication rates vary considerably among provider categories. The purpose of this study was to estimate the success and complication rates of pre-hospital tracheal intubation performed by physician anaesthetist or nurse anaesthetist pre-hospital critical care teams.

Methods: Data were prospectively collected from critical care teams staffed with a physician anaesthetist or a nurse anaesthetist according to the Utstein template for pre-hospital advanced airway management. The patients served by six ambulance helicopters and six rapid response vehicles in Denmark, Finland, Norway, and Sweden from May 2015 to November 2016 were included.

Results: The critical care teams attended to 32 007 patients; 2028 (6.3%) required pre-hospital tracheal intubation. The overall success rate of pre-hospital tracheal intubation was 98.7% with a median intubation time of 25 s and an on-scene time of 25 min. The majority (67.0%) of the patients' tracheas were intubated by providers who had performed >2500 tracheal intubations. The success rate of tracheal intubation on the first attempt was 84.5%, and 95.9% of intubations were completed after two attempts. Complications related to pre-hospital tracheal intubation were recorded in 10.9% of the patients. Intubations after rapid sequence induction had a higher success rate compared with intubations without rapid sequence induction (99.4% vs 98.1%; $P=0.02$). Physicians had a higher tracheal intubation success rate than nurses (99.0% vs 97.6%; $P=0.03$).

Conclusions: When performed by experienced physician anaesthetists and nurse anaesthetists, pre-hospital tracheal intubation was completed rapidly with high success rates and a low incidence of complications.

Clinical trial number: NCT 02450071.

Keywords: airway management; emergency medical services; intubation; intratracheal

Editor's key points

- Pre-hospital tracheal intubation is frequently difficult and can be associated with severe adverse events.
- Providers should be competent to perform the procedure and capable of preventing and treating complications.
- When performed by experienced physician anaesthetists and nurse anaesthetists, pre-hospital tracheal intubation can be completed rapidly with high success rates and a low incidence of complications.

Pre-hospital tracheal intubation is a potentially lifesaving intervention.¹ However, pre-hospital tracheal intubation is challenging as a result of environmental factors, patient positioning, limited airway equipment, and the availability of assistance, creating a risk of serious complications that may threaten patient safety.^{2–4} Because tracheal intubation carries a risk of severe adverse events, providers must be both competent to perform the procedure and capable of preventing and treating complications.^{5,6}

The success rates of pre-hospital tracheal intubation performed by emergency medical services with providers with limited or heterogeneous levels of airway expertise have been investigated in previous studies.^{7–10} Small single-centre and single-country studies have demonstrated a high 99.7% pre-hospital tracheal intubation success rate when tracheal intubation is performed by airway experts.¹¹ However, there are no large international multicentre studies that validate these small studies or that report data only from units staffed with airway experts (i.e. anaesthetists and nurse anaesthetists). Several recently published guidelines concerning pre-hospital tracheal intubation and emergency anaesthesia recommend that these procedures be performed in accordance with the same standards as in-hospital procedures.^{5,12,13} The guidelines emphasise that pre-hospital providers should have a skill level that would allow them to perform unsupervised

emergency tracheal intubations in the emergency department. In hospitals in the Nordic countries, all tracheal intubations are performed by physicians or nurses from the anaesthesiology and intensive care units. Physician anaesthetists and nurse anaesthetists are widely used in emergency medical services and perform the vast majority of pre-hospital tracheal intubations in the Nordic countries.¹⁴ The objective of the present study was to investigate the success rate of tracheal intubation and the incidence of complications associated with tracheal intubation in a pre-hospital system in which intubation is performed only by anaesthetists and nurse anaesthetists.

Methods

This was a prospective, observational, multicentre study of pre-hospital advanced airway management. All patients who had undergone attempted pre-hospital tracheal intubation during a primary mission by the units listed below between May 2015 and November 2016 were included in the study. A tracheal intubation attempt was defined as laryngoscopy with the intent to intubate. Tracheal intubations performed during inter-hospital missions were excluded from the study.

Ethical and institutional approvals were acquired before patient enrolment, and the study was registered at Clinicaltrials.gov (NCT02450071). Ethical review board approvals were obtained from 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 consequently did not require Ethical Review Board approval.

In the Nordic countries, the national emergency medical services systems include rapid response car- and helicopter-based pre-hospital critical care teams. These teams act as a second tier of the immediate response system and are staffed by a physician anaesthetist or a nurse anaesthetist, with a few

exceptions. The pre-hospital critical care teams from six helicopter emergency medical services (HEMS) in Sweden (Stockholm, Gothenburg, Östersund), Norway (Trondheim, Stavanger), and Finland (Helsinki) and six rapid response car (RRC) teams from Sweden (Stockholm, Gothenburg) and Denmark (Odense, Aarhus) participated in this study. This study was conducted in the Nordic countries and encompassed both urban and rural areas of approximately 147 000 km² with a population of 7.1 million inhabitants. The overall population density was 48.4 inhabitants per km². The Nordic countries are similar in size, socioeconomic status, and health care systems. There is also a common requirement that professionals must have several years of in-hospital work in anaesthesiology departments to qualify for work on second-tier rapid response cars and ambulance helicopters. Eight of 12 participating units were staffed by physician anaesthetists, including the Helsinki HEMS, which also included one internal medicine and one emergency medicine physician. In the Nordic countries, anaesthetists are board certified in both anaesthesiology and intensive care. Anaesthetists in these countries work in perioperative medicine and critical care and are on the emergency medicine critical care response teams of hospitals. Four of the 12 participating units, all in Sweden (HEMS Stockholm, HEMS Östersund, RRC Sollentuna Stockholm, and RRC Huddinge Stockholm), were staffed with nurse anaesthetists. The vast majority of the providers in this study perform emergency anaesthesia and advanced airway management both in and outside the operating room as part of their daily work. Pre-hospital critical care teams attend both trauma and medical patients. All the services provide rapid sequence induction and access to anaesthetic agents, sedatives, analgesics, and neuromuscular blocking agents. These units have equipment to facilitate advanced airway management including supraglottic airway devices, conventional laryngoscopes, stylets, gum-elastic bougies, surgical airway equipment, and capnographs. All services except HEMS Trondheim and HEMS Stavanger carry videolaryngoscopes (McGrath, Glidescope, C-MAC, or Airtraq).

The data regarding pre-hospital advanced airway management were selected, defined, and collected according to the consensus-based core dataset definitions described in the Utstein-style airway template by Sollid and colleagues.¹⁵ Descriptive variables such as demographic data, patient categories, and indications for tracheal intubation were collected. Exposure variables, such as the type of airway management used, were documented. Rapid sequence induction was defined as a tracheal intubation aided by the use of any combination of a) a sedative or an analgesic drug, and b) a neuromuscular blocking agent. Endpoint and outcome variables included the overall success rate of tracheal intubation, the number of attempts at tracheal intubation, the success rate of tracheal intubation on each attempt, complications associated with tracheal intubation, tracheal intubation time, on-scene time, and the presence of a difficult airway. Successful tracheal intubation required lung auscultation, capnography verification of the tracheal tube position, or both. Tracheal intubation time was defined as the time from when the laryngoscope first passed the front teeth until the correct tube position was verified with capnography or lung auscultation. On-scene time was defined as the time from the arrival of the rapid response car or ambulance helicopter to the departure of the ambulance vehicle carrying the patient. A potentially difficult airway was defined as reduced neck mobility, severe obesity, a small mouth, a short thyromental distance (<6.5

cm), significant airway trauma, blood or mucus in the airway, prior difficult airway management, or pre-existing non-functional supraglottic airway. Tracheal intubation complications were defined in accordance with Sollid and colleagues¹⁵ as hypoxia (oxygen saturation <90%), hypotension (systolic blood pressure <90 mm Hg), bradycardia (pulse <60 beats min⁻¹), unintentional intubation of the oesophagus or right main stem bronchus, vomiting, aspiration of gastric contents or blood into the lungs, or dental trauma. The airway management methods used in patients of failed tracheal intubation were recorded. Survival data were recorded for the pre-hospital phase only. The data collection form used is available as an online appendix.

Data were registered by the attending airway provider on a paper form directly after the mission. The data on the paper forms were transferred to an SPSS database (IBM SPSS Statistics, version 23, New York, United States of America) by the study nurse. Data analysis was performed using SPSS, and descriptive statistics were generated. The χ^2 test was used to calculate differences between groups; statistical significance was set at $P < 0.05$. Study results are presented according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Guidelines for observational studies.¹⁶

Results

During the study period, the participating units attended to 32 007 patients, of whom 2028 (6.3%) required pre-hospital tracheal intubation (Fig. 1). The median age of the included

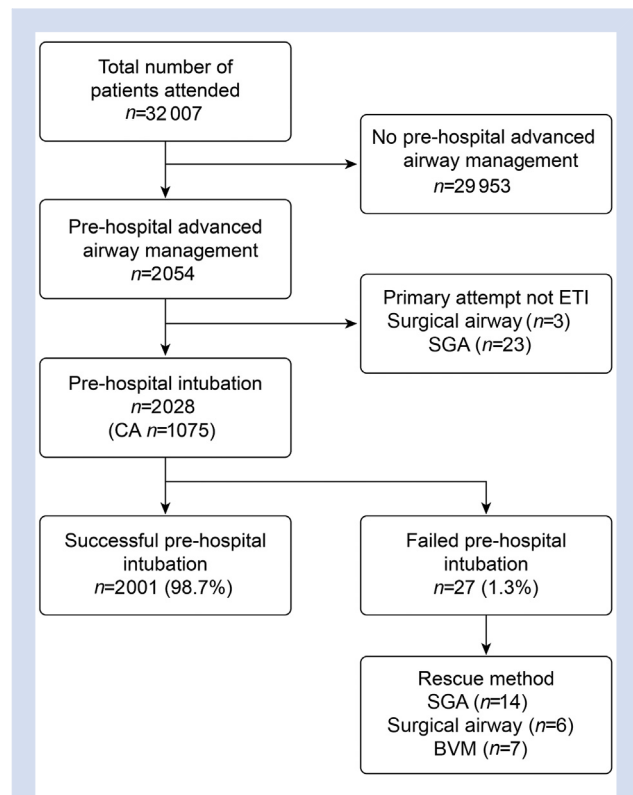


Fig 1. Flowchart showing the advanced airway management by the critical care teams. ETI, endotracheal intubation; SGA, supraglottic airway; CA, cardiac arrest; BVM, bag-valve-mask.

patients was 62 yr [inter-quartile range (IQR) 45–74 yr], and 66.9% were male (Table 1). Fifty-three percent of the patients experienced cardiac arrest, 26.3% sustained other medical conditions, and 19.1% experienced trauma.

Anaesthetists performed 67.1% of the tracheal intubations, nurse anaesthetists performed 25.2%, anaesthetist registrars performed 5.7%, and emergency medicine physicians performed 1.5%. Most (67.0%) of the patients were intubated by providers who had performed >2500 tracheal intubations, and 99.3% of patients were intubated by providers who had performed >200 tracheal intubations.

The overall success rate of pre-hospital tracheal intubation was 98.7% (2001/2028), with a median tracheal intubation time of 25 s (IQR 15–30 s, Table 2). Tracheal intubations were successful on 84.5% of the first attempts, 95.9% after the second attempt, and 98.2 after the third attempt. Successful tracheal intubation within two attempts with no complications was achieved in 88.3% of the patients. Conventional laryngoscopy and videolaryngoscopy were used in 58.4% and 41.6% of patients on first attempt, 62.9% and 31.6% on second attempt, and 42.6% and 41.1% of patients on third attempt, respectively (Table 3). The success rate of tracheal intubation at the first attempt was higher with videolaryngoscopy compared with conventional laryngoscopy (92.9 vs 78.6%, $P<0.01$). The first attempt tracheal intubation time was faster with conventional laryngoscopy compared with videolaryngoscopy (20 vs 25 s, $P<0.01$). A surgical airway was performed in 10 patients (0.5%). The 27 patients with

unsuccessful tracheal intubation attempts were further managed using supraglottic airway ($n=14$), a bag-valve-mask ($n=7$), or a surgical airway ($n=6$). Table 2 shows the tracheal intubation complications.

The tracheal intubation success rate for trauma patients was 98.4%. Tracheal intubations after rapid sequence induction had a higher success rate than tracheal intubations without rapid sequence induction (99.4 vs 98.1%; $P=0.02$, Table 4). Among cardiac arrest patients, the tracheal intubation success rate was 98.2%, compared with 99.1% for non-cardiac arrest patients ($P=0.08$). Among the 67% of patients presenting a difficult airway, the tracheal intubation success rate was lower than among patients without a difficult airway (98.1 vs 99.6%; $P>0.01$). Physicians had a higher tracheal intubation success rate than nurses (99.0 vs 97.6%; $P=0.03$).

The median time on-scene was 25 min (IQR 18–33 min). At the emergency department, 65.2% of the patients were alive, and an additional 13.1% of patients were receiving on-going cardiopulmonary resuscitation. Pre-hospital death was declared for 21.7% of patients. Ninety-three percent of patients with traumatic brain injuries were alive at the time of hospital admission.

Discussion

To our knowledge, this is the largest prospective study of physician and nurse anaesthetist pre-hospital tracheal intubations. When performed by experienced anaesthetist providers, pre-hospital tracheal intubation was rapid (25 s), had a high success rate (98.7%), and required only a short on-scene time (25 min). Pre-hospital tracheal intubation as described in the current study appears to at least meet the standards of in-hospital emergency anaesthesia.¹⁷

Eleven percent of the patients sustained complications during pre-hospital tracheal intubation. Using the definitions in the uniform template for airway data reporting,¹⁵ the corresponding complication rate was somewhat lower than that of an international multicentre physician HEMS-trial (13%)⁷ and another rapid response car study in Denmark (14.2%).¹¹ The hypoxia incidence after rapid sequence induction of 4.1% in this study was lower than the corresponding numbers reported for physician-staffed services in Germany (13.3%), Denmark (5.3%), UK (10.2%), and Hungary (8.1%).^{8,11,18,19} Patient heterogeneity and hypoxia before rapid sequence induction may partly explain these differences. Additionally, the new apnoeic oxygenation strategy, the development of novel airway equipment, and provider experience may have contributed to the low rate of hypoxia found in this study. These factors may also explain the relatively low incidence of hypotension (9.1%) after rapid sequence induction compared with previous pre-hospital and emergency department studies.^{8,20,21}

The low rates of hypoxia and hypotension after rapid sequence induction found in this study may have been beneficial for the treatment of patients with traumatic brain injuries, as 93% of these patients were alive at the time of emergency department admission. A Finnish study on traumatic brain injury demonstrated lower rates of hypoxia and hypotension when patients were treated by pre-hospital physicians compared with paramedics, with an increased 1-yr survival rate of 57 vs 42%.⁹ This finding is also in accordance with a recent meta-analysis demonstrating an increased mortality rate when providers with limited

Table 1 Demographic data of the providers and patients. IQR, inter-quartile range; COPD, chronic obstructive pulmonary disease

Provider data	n (2005)	%
Anaesthetist	1345	67.1
Anaesthetist registrar	115	5.7
Emergency medicine physician	30	1.5
Internal medicine	9	0.4
Nurse anaesthetist	506	25.2
Experience of tracheal intubations	n (2002)	%
50–200	14	0.7
200–2500	647	32.3
2500–10 000	1233	61.6
>10 000	108	5.4
Patient data		
Total number of patients	2028	
Age (median)	62 yrs	IQR 45–74
Male	1319/1972	66.9
ASA (median)	2	
Ischaemic heart disease	262/991	26.4
COPD	134/974	13.8
Patient categories	n (2028)	%
Trauma total	387	19.1
Traumatic brain injuries	215	10.6
Penetrating trauma	31	1.5
Cardiac arrest	1075	53
Medical other total	533	26.3
Cardiac disease (not cardiac arrest)	41	2
Stroke/intracranial haemorrhage	182	9
Seizure	61	3
Asthma/COPD	99	4.9
Intoxication	150	7.4
Ear–nose–throat disease	12	0.6
Other	210	10.4

Table 2 Pre-hospital intubation success and complication outcomes in cardiac arrest, trauma, rapid sequence induction, and total patients. RSI, rapid sequence induction; TI, tracheal intubation; CPR, cardiopulmonary resuscitation; ED, emergency department; IQR, inter-quartile range

	Cardiac arrests	%	Trauma	%	RSI	%	Total	%
TI success total	1056/1075	98.2	381/387	98.4	929/935	99.4	2001/2028	98.7
TI success 1 attempt	843/1075	78.4	339/387	87.6	856/935	91.6	1713/2028	84.5
TI success ≤2 attempts	1014/1075	94.3	375/387	96.9	916/935	98	1945/2028	95.9
TI success ≤3 attempts	1049/1075	97.6	380/387	98.2	926/935	99	1992/2028	98.2
TI success ≤2 attempts + no complications	989/1075	92	331/387	85.5	786/935	84.1	1790/2028	88.3
TI time							25 s (IQR 15–30)	
TI success with difficult airway	678/694	97.7	259/265	97.7	522/528	98.9	1215/1239	98.1
Total number of complications	76/1075	7.1	54/387	14	147/935	15.7	222/2028	10.9
Hypoxia	6/1075	0.6	17/387	4.4	38/935	4.1	44/2028	2.2
Hypotension	3/1075	0.3	19/387	4.9	85/935	9.1	90/2028	4.4
Bradycardia	3/1075	0.3	2/387	0.5	9/935	1	11/2028	0.5
Cardiac arrest	14/1075	1.3	4/387	1	9/935	1	21/2028	1
Bronchial intubation	2/1075	0.2	0/387	0	2/935	0.2	3/2028	0.1
Oesophageal intubation	26/1075	2.4	5/387	1.3	6/935	0.6	34/2028	1.7
Aspiration	2/1075	0.2	6/387	1.6	10/935	1.1	14/2028	0.7
Dental injury	2/1075	0.2	0/387	0	1/935	0.1	3/2028	0.1
Surgical airway necessary	9/1075	0.8	4/387	1	5/935	0.5	14/2028	0.7
Other	21/1075	2	12/387	3.1	22/935	2.4	39/2028	1.9
Ongoing CPR at ED arrival	228/1060	21.5	29/382	7.6	16/924	1.7	266/2028	13.1
Pre-hospital death	384/1060	36.2	32/382	8.4	19/924	2.1	441/2028	21.7
On-scene time							25.0 min (IQR 18–33)	

experience performed pre-hospital tracheal intubation of traumatic brain injury patients.²

Pre-hospital tracheal intubation has been recognised as a high-risk procedure. Several guidelines recently published for the UK, Germany and Scandinavia emphasise that pre-hospital emergency anaesthesia and tracheal intubation should be conducted according to the same standards as in-hospital procedures.^{5,12,13} Only anaesthetic consultants and registrars perform unsupervised emergency anaesthesia and tracheal intubations in hospitals in the Nordic countries. Therefore, most pre-hospital tracheal intubations in this study were performed by experienced anaesthesiology providers, 67% of whom had performed more than 2500 tracheal intubations. This finding is in contrast to the AIRPORT trial, which investigated both anaesthesiologists and emergency medicine physicians and in which only 52% of the providers had performed >1000 tracheal intubations.⁷

A retrospective study of 7256 pre-hospital tracheal intubations in London, UK suggested higher success rates when the procedures were performed by anaesthetists compared with emergency physicians.¹⁰ This finding is consistent with a study demonstrating a significantly higher incidence of difficult tracheal intubation amongst 'proficient' intubators, who performed a median of 18 tracheal intubations per year,

compared with 'expert' intubators who performed a median of 304 tracheal intubations per year.²² In a recently published meta-analysis of pre-hospital tracheal intubation, experienced consultant anaesthetists had the highest tracheal intubation success rate (99.4%).²³ In another study, anaesthetists comprised the category of physicians with the highest success rate of tracheal intubation at the first attempt.²⁴ Prolonged laryngoscopy may shift the focus of care and delay other lifesaving procedures, which may be more important than the intubation itself.¹²

When performed by the anaesthetist providers in the current study, tracheal intubation was accomplished rapidly (25 s). Additionally, on-scene times were shorter (25 min) in this study than those reported for pre-hospital services in Hungary (49 min), the UK (40 min), and Australia (42 min).^{14,25,26} These differences may be explained by differences in both patient characteristics and provider skills. The current pre-hospital practice in Nordic countries of devoting less attention to 360° patient access, not primarily using bougies on all tracheal intubations and using short 'challenge-response' checklists may favour shorter on-scene times without affecting the high tracheal intubation success rates in patients with time-critical conditions such as uncontrolled internal haemorrhage and traumatic brain injuries.

Table 3 Methods used for pre-hospital advanced airway management. TI, tracheal intubation

Method	Attempt 1	Attempt 2	Attempt 3	Attempt 4	Attempt 5
Conventional TI	2028	313	68	15	3
Videolaryngoscope	1185 (58.4%)	197 (62.9%)	29 (42.6%)	1 (6.7%)	0
Videolaryngoscope	843 (41.6%)	99 (31.6%)	28 (41.1%)	8 (53.3%)	1 (33.3%)
Surgical airway	0	4 (1.3%)	4 (5.9%)	0	2 (66.7%)
Supraglottic airway	0	13 (4.2%)	7 (10.3%)	6 (40.0%)	0

Table 4 Subgroup analysis. TI, tracheal intubation; HEMS, helicopter emergency medical service

	TI success (n)	%	P-value
Cardiac arrest	1056/1075	98.2	
Non-cardiac arrest	842/950	99.1	0.08
Rapid sequence induction	929/935	99.4	
No rapid sequence induction	1071/1092	98.1	0.02
Easy airway	786/789	99.6	
Difficult airway	1215/1239	98.1	<0.01
Rapid response car	881/899	98	
HEMS	1120/1129	99.2	0.03
Nurse	495/507	97.6	
Physician	1503/1518	99	0.03

The first-pass success rate of 84.5% in the current study was higher than that reported in a recently published meta-analysis of physician and non-physician pre-hospital tracheal intubation (77.8%).²³ The first-pass tracheal intubation success rate after rapid sequence induction in this study compared favourably to data from the physician-HEMS AIRPORT trial (91.6 vs 89%).⁷ Differences in indications to tracheal intubation and patient characteristics may partly explain the variations in first-pass success rates. Additionally, differences in provider experience may affect failure and complication rates, highlighting the need for airway expertise.^{1,2} This finding is also supported by a Cochrane review suggesting that competence is a key factor in emergency tracheal intubations.²⁷ The Scandinavian Society of Anaesthesiology and Intensive Care Medicine task force on pre-hospital airway management recommends that pre-hospital emergency anaesthesia and intubation should at least meet the standards for in-hospital emergency anaesthesia.^{12,28}

Among the 67% of patients who presented a difficult airway, the tracheal intubation success rate was high (98.1%). Although the providers' airway expertise may explain this result, different definitions of a difficult airway and the recent implementation of videolaryngoscopy may also account for some of the variation. Videolaryngoscopes were used on the first tracheal intubation attempt in 41.6% of patients, and were associated with a higher first-pass success rate compared with conventional laryngoscope use (92.9 vs 78.6%, $P < 0.01$). However, first attempt tracheal intubation using conventional laryngoscopy was faster compared with videolaryngoscopy (20 vs 25 s, $P < 0.001$). The low surgical airway incidence of 0.5% in this study is comparable with that reported by other physician-staffed pre-hospital services.^{10,11,18,29}

A limitation of the current study is its self-report design, which carries a risk of registration and recall bias. Another risk entails the under-reporting of complications. Several efforts were undertaken to reduce this risk, including the use of anonymous data registration forms. An additional limitation of this study is the risk of missing some intubated patients despite the systematic monitoring of patient inclusion by the national and local trial managers. Because assistants may affect the success rate of tracheal intubation, minimum standards for staff assisting with pre-hospital anaesthesia have been recommended by the Association of Anaesthetists of Great Britain and Ireland.⁵ However, data concerning

assistants' competence level were not collected in this study. This study was not designed to investigate either mortality or possible long-term complications related to pre-hospital tracheal intubation (e.g. minor tracheal injuries, acute respiratory distress syndrome, and pneumonia). This approach may have led to an underestimation of tracheal intubation complications.

Conclusion

This large prospective study demonstrated that pre-hospital critical care teams that include an anaesthetist provide rapid pre-hospital tracheal intubations with short on-scene times, high success rates, and a low incidence of complications. Rapid pre-hospital tracheal intubation with short on-scene times may be crucial in time-critical emergencies such as traumatic brain injuries and multitrauma. The reported pre-hospital tracheal intubation success and complication rates are comparable with in-hospital rates.

Authors' contributions

Conceived the study: M.G. and H.M.L.

Member of the trial steering committee: M.G., C.S., D.G., H.M.L.
Study design: All authors.

Trial site investigators: E.F., A.B., A.K., S.M., J.N., L.R., E.S., G.S.

Data collection: E.F., A.B., A.K., S.M., J.N., L.R., E.S., G.S.

Data management: M.G.

Author of first draft: M.G.

Author of subsequent drafts: All authors.

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Study nurse Mona-Britt Divander registered the information from the paper data collection forms in SPSS. Statistician Hans Pettersson reviewed the statistics. The pre-hospital physicians and nurses at all trial sites did excellent work with the patient inclusion.

Declarations of interest

S.C. has received grant support from Massimo Inc., and Kabi Fresenius Inc. S.C. has been editor of the Journal of Perioperative Medicine and a consultant for Massimo Inc. S.M. has been Honorary Associate Editor of the Scandinavian Journal of Trauma, Emergency Medicine and Resuscitation. None of the authors have any personal financial gain from the study and there are no other interests to declare.

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