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Respiration and the Airway

Prehospital tracheal intubations by anaesthetist-staffed critical care teams: a prospective observational multicentre study

Jacob Broms[1,*], Christian Linhardt[2], Espen Fevang[3], Fredrik Helliksson[4], Gabriel Skallsjö[5,6], Helge Haugland[7], Jens S. Knudsen[8], Marit Bekkevold[9,10], Michael F. Tvede[11], Patrick Brandenstein[12], Troels M. Hansen[13], Andreas Krüger[7,14], Leif Rognås[15], Hans-Morten Lossius[3,14] and Mikael Gellerfors[16,17,18,19]

[1]Department of Clinical Science and Education, Södersjukhuset, Karolinska Institutet, Stockholm, Sweden, [2]Department of Anaesthesia and Intensive Care, Södersjukhuset, Stockholm, Sweden, [3]Faculty of Health Sciences, University of Stavanger, Stavanger, Norway, [4]Department of Anaesthesia and Intensive Care, Karlstad Central Hospital, Karlstad, Sweden, [5]Department of Clinical Science, Section of Anaesthesiology and Intensive Care, Gothenburg University, Gothenburg, Sweden, [6]Helicopter Emergency Medical Service, Västra Götalandsregionen, Gothenburg, Sweden, [7]Department of Emergency Medicine and Prehospital Services, St. Olav's University Hospital, Trondheim, Norway, [8]Danish Air Ambulance, Billund, Denmark, [9]Department of Research, Norwegian Air Ambulance Foundation, Oslo, Norway, [10]Division of Prehospital Services, Air Ambulance Department, Oslo University Hospital, Oslo, Norway, [11]Danish Air Ambulance, Ringsted, Denmark, [12]Helicopter Emergency Medical Service, Region Västerbotten, Lycksele, Sweden, [13]Danish Air Ambulance, Aalborg, Denmark, [14]Norwegian Air Ambulance Foundation, Department of Research and Development, Oslo, Norway, [15]Danish Air Ambulance, Skive, Denmark, [16]Swedish Air Ambulance, Mora, Sweden, [17]Section for Anaesthesiology and Intensive Care Medicine, Department of Physiology and Pharmacology, Karolinska Institutet, Stockholm, Sweden, [18]Perioperative Medicine and Intensive Care, Karolinska University Hospital, Stockholm, Sweden and [19]Rapid Response Car, Capio, Stockholm, Sweden

*Corresponding author. E-mail: jacob.broms@ki.se, @jacobbroms

Abstract

Background: Prehospital tracheal intubation is a potentially lifesaving intervention, but is associated with prolonged time on-scene. Some services strongly advocate performing the procedure outside of the ambulance or aircraft, while others also perform the procedure inside the vehicle. This study was designed as a non-inferiority trial registering the rate of successful tracheal intubation and incidence of complications performed by a critical care team either inside or outside an ambulance or helicopter.

Methods: This observational multicentre study was performed between March 2020 and September 2021 and involved 12 anaesthetist-staffed critical care teams providing emergency medical services by helicopter in Denmark, Norway, and Sweden. The primary outcome was first-pass successful tracheal intubations.

Results: Of the 422 drug-assisted tracheal intubations examined, 240 (57%) took place in the cabin of the ambulance or helicopter. The rate of first-pass success was 89.2% for intubations in-cabin *vs* 86.3% outside. This difference of 2.9% (confidence interval −2.4% to 8.2%) (two sided 10%, including 0, but not the non-inferiority limit $\Delta = -4.5$) fulfils our criteria for non-inferiority, but not significant superiority. These results withstand after performing a propensity score analysis. The mean on-scene time associated with the helicopter in-cabin procedures (27 min) was significantly shorter than for outside the cabin (32 min, $P=0.004$).

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Conclusions: Both in-cabin and outside the cabin, prehospital tracheal intubation by anaesthetists was performed with a high success rate. The mean on-scene time was shorter in the in-cabin helicopter cohort.
Clinical trial registration: NCT04206566.

Keywords: airway management; critical care; emergency medical services; prehospital; tracheal intubation

Editor's key points

- Tracheal intubation can be required in a prehospital setting, but it is not clear whether tracheal intubation should be performed inside or outside the cabin of an ambulance or helicopter.
- The authors assessed, as a multicentre observational study, if the success rate of tracheal intubation at the first attempt, performed by trained anaesthetists, was similar inside or outside the cabin.
- The success rate of tracheal intubation at the first attempt was similar inside or outside the cabin, and mean on-scene time was significantly shorter in the in-cabin helicopter cohort.

According to current guidelines adopted by the UK, Germany, and Scandinavia, emergency prehospital anaesthesia and tracheal intubation should adhere to the same standards as the corresponding in-hospital procedures.[1–3] To optimise success and minimise complications, the personnel involved should be at least as well trained as those who perform unsupervised tracheal intubations in the emergency departments of hospitals.[1] In addition, to accommodate the complex logistical and environmental factors involved with such prehospital care,[4] local standard operating procedures have been put in place. For example, the British and Australian standard operating procedures state that tracheal intubation be attempted outside of the helicopter or ambulance, with 360-degree access and all necessary equipment laid out in a standardised manner, thereby reducing cognitive load and enhancing teamwork and safety.[1]

During the winter in Scandinavia, helicopter emergency medical system crews often face outside weather conditions that might expose the patient to a risk of hypothermia, and impair performance. Accordingly, they often perform emergency anaesthesia and tracheal intubation in the rear of the ambulance or in the helicopter ('in-cabin'). This approach, which despite the confined space believed by some to be suboptimal, has been incorporated into certain local standard operating procedures.[4]

To ensure constant high-quality care, the emergency anaesthesia and tracheal intubation needs to be evaluated continuously.[5] It is not known whether the success and complication rate associated with emergency anaesthesia and tracheal intubation performed by experienced prehospital anaesthetists differs when performed outside or inside the ambulance or helicopter. One indicator of quality is the rate of success associated with the first attempt at tracheal intubation (first-pass success), as multiple attempts involve an increasing risk of adverse events.[6,7]

Accordingly, the aim of the present study was to try proving non-inferiority in first-pass success rates after prehospital emergency anaesthesia when performed in-cabin *vs* outside by anaesthetist physician staffed critical care teams in Scandinavia.

Methods

In connection with this prospective, observational, multicentre study, prehospital advanced airway management data were collected from 12 helicopter emergency medical system bases in Denmark (Aalborg, Billund, Ringsted, and Skive), Norway (Oslo, Stavanger, Trondheim, and Ørland), and Sweden (Gothenburg, Karlstad, Lycksele, and Mora) between March 1, 2020 and September 1, 2021. Our application for ethical approval submitted to the Swedish Ethical Review Authorities was considered exempt from ethical review, with the advisory opinion that the agency could see no ethical issues (Dnr 2019-04943). Our ethical application in Norway was approved (REK 2019-63065), whereas in Denmark, the authorities concluded that our protocol followed local regulations and no ethical permit was required. The study was pre-registered at Clinicaltrials.gov (NCT04206566) and is reported in compliance with the 'Strengthening the Reporting of Observational Studies in Epidemiology' statement.[8]

In Denmark, Norway, and Sweden, the national emergency medical services encompass helicopter-borne prehospital critical care teams, almost all of which include anaesthetists, who back up the ground ambulance system. The four Danish helicopter bases utilise the Airbus H135 helicopter; three of the Norwegian bases the Airbus H135 as well and one base the Westland Sea King Mk 43; and three of the Swedish bases the Airbus H145 and one the Leonardo AW 169. In none of these helicopters do care providers have full 360-degree access to a patient lying on a stretcher in-cabin, which is also generally the case with ground ambulances in these same countries. However, the specific type of ambulance involved in the cases examined here was not reported.

All drug-assisted tracheal intubations which the care teams decided to attempt were eligible for inclusion. In this context, a drug-assisted intubation was defined as administration of a sedative together with a neuromuscular blocking agent and, optionally, an analgesic, followed by attempted tracheal intubation. Attempted tracheal intubations without the use of drugs (e.g. in connection with cardiopulmonary resuscitation) were excluded.

Based on the variables included in the revised Utstein airway template,[9] a case report form that focused on prehospital tracheal intubation and its location ('outside', 'inside the ambulance' or 'inside the helicopter') was utilised. The primary endpoint was the rate of first-pass success, whereas secondary endpoints included the proportions of prehospital tracheal intubations performed outside or in the helicopter or ambulance, the perceived difficulty involved in performing the procedure, the attempt (first, second, or third) on which tracheal intubation was successful, complications, characteristics of the airways, survival until arrival at the hospital, the time required to intubate, the total time at the scene of the procedure, and the prior experience of the operator and assistant.

Statistical analysis

A non-inferiority approach, with a clinically relevant limit of 4.5%, was used to compare the rates of first-pass success for intubations performed outside and in-cabin. This limit was chosen based on a previous report of an overall first-pass success rate of 84.5%[4] and the assumption that a first-pass success rate of 80% or more would be an acceptable limit for performing the tracheal intubation in-cabin as a trade-off considering the other logistical and environmental benefits. In other words, this analysis challenges the hypothesis that performance of prehospital tracheal intubation outside is associated with a first-pass success rate of at least 4.5% better than performance in-cabin.

In the case of continuous variables, descriptive data with a normal distribution are presented as means and standard deviations, with median and inter-quartile ranges being given for data not distributed normally. For categorical variables, nominal data are shown as absolute numbers and percentages and ordinal data with medians and inter-quartile ranges. Comparisons between groups were performed using the χ^2 test for dichotomous variables, Fisher's exact test for multiple choice variables, independent two-sample *t*-tests for continuous variables, one way analysis of variance (ANOVA) for the normally distributed continuous data for multiple groups, and the Kruskal–Wallis analysis for non-normally distributed continuous data and ordinal categorical data for multiple groups.

Propensity score matching was used to account for confounding by the included covariates to estimate the average marginal effect on the first-pass success rate depending on whether it was performed outside or in-cabin. A 1:1 nearest neighbour, Mahalanobis distance, propensity score matching with replacement, was performed and a propensity score estimated using logistic regression of the location for intubation on the covariates. This returned an adequate balance, as indicated in Figure 1. After matching, all standardised mean differences for the covariates were below 0.1, indicating adequate balance. The procedure matched 182/182 cases of the 'Outside' cohort with 96/240 of the 'in-cabin' cases, which left 144 unmatched and 0 discarded cases. To estimate comparable effect sizes and their confidence intervals, the data were assessed for non-inferiority before and after propensity score matching. The characteristics of the baseline data after propensity score matching can be seen in Table S1 in the Supplementary section.

Very few data were missing and those that were showed no pattern, appearing to be random. Therefore, the missing data were not analysed and were excluded before calculating proportions and central tendencies.

The propensity score matching procedure was performed using the 'MatchIt' package (version 4.5.4), and tables were created utilising the 'tableone' package (version 0.13.2) both software in R, which includes all the tests for significance mentioned above, and Bonferroni corrections for multiple hypothesis testing. The level of significance was set at <0.05. All analyses of data were carried out with the RStudio software (RStudio 2022.02.3+492 'Prairie Trillium' release for Windows).

Results

Patients and care providers

During the 18-month study period, 422 drug-assisted prehospital tracheal intubations were attempted by the 12-helicopter emergency medical system bases participating. Overall, this involved 3.5% of the total number of 11 916 patients attended (Fig. 2).

Approximately 70% of the patients on whom intubation was attempted were males, with a median age of 61.0 yr. Their median National Advisory Committee for Aeronautics (NACA) score for severity of injury[10] was 6, with 50% suffering from trauma of some form, 28% postcardiac arrest, 21% neurological disorders, and 18% other medical conditions. There were slight differences in the median baseline age and NACA score of the two different groups, but the proportions of males and females were similar (Table 1).

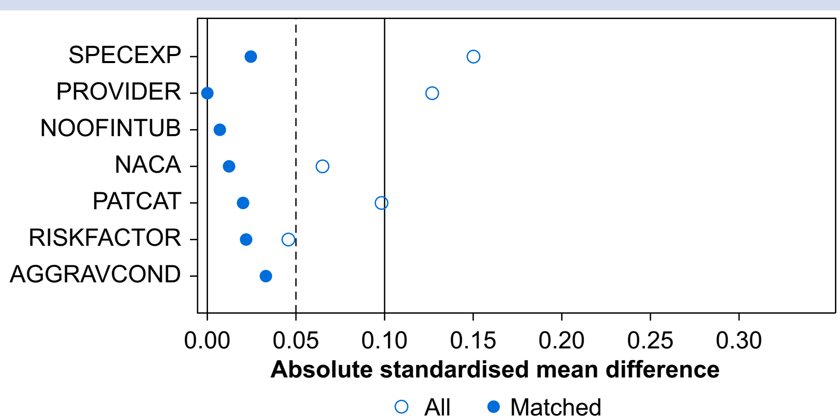

Fig 1. Plot showing covariate standardised mean differences after matching. AGGRAVCOND, aggravating conditions; NACA, National Advisory Committee for Aeronautics (NACA) score; NOOFINTUB, number of previous intubations; PATCAT, patient category; PROVIDER, intubation operator; RISKFACTOR, risk factor difficult airway; SPECEXP, experience as specialist in years.

Anaesthetists with mean specialist experience of >13 yr performed 408 (97%) of the intubations. Fifty-eight percent of these procedures were carried out by individuals who had previously performed >2500 tracheal intubations.

Fifty-seven percent of the intubations were performed in-cabin. There were no reported risk factors for difficult intubation in 38% of all cases. However, ~39% of the patients had blood, mucus, or vomit in their airways; 14% were severely obese or had a thick and short neck; and in 13% the neck was immobilised, all of which are such risk factors. The group intubated 'in helicopter' was associated with more risk factors concerning neck mobility than those treated outside, with no other differences.

Tracheal intubation and complications

There were no significant differences between the first-pass success and overall success rate of intubation at the different locations (Table 2). The frequency of complications was the same outside and 'in ambulance', and no significant difference with 'in helicopter'. In the helicopter in-cabin group one patient had an unrecognised oesophageal intubation and one patient had cardiac arrest.

Tracheal intubation performed outside was reported to be made more difficult by suboptimal positioning of the care provider (32% of the cases) and bright light or sunlight (35%). In-cabin, 4.6% of the care providers reported that their positioning was suboptimal and that they did not have 360-degree access to 64% of the patients.

The overall rate of first-pass success was 87.9% and the combined success rate with no complications on the first two attempts was 88.4% (Table 3). Of the 422 patients included, three had to be provided with a surgical airway; two were subjected to rescue procedures when intubation proved impossible; and one underwent primary airway surgery because of extensive upper-airway trauma. One patient ended up with a supraglottic device after two failed attempts at tracheal intubation using direct laryngoscopy (a video laryngoscope was not available at the time).

Analysis of the findings

After propensity score matching, the absolute difference in the rate of first-pass success was 2.8% higher for the 'in-cabin' procedures, compared with 2.9% before matching (with a confidence interval (two sided 10%, including 0, but not the non-inferiority limit $\Delta=-4.5$) of -4.0% to 9.7% (-2.4%–8.2% before matching). Consequently, the null hypothesis can be rejected before and after propensity score matching, with the outcome of 'in-cabin' emergency anaesthesia and tracheal intubation being neither inferior nor superior to the same procedure performed outside the ambulance or aircraft cabin.

There was no significant difference in either the mean number of attempts needed to achieve tracheal intubation outside (1.18) or in-cabin (1.13) or the best median Cormack–Lehane score (outside 1.0, in-cabin 1.0).

The overall frequency of complications was 10%, with 5.2% being hypoxaemia (oxygen saturation <90%) and 3.8% hypotension (blood pressure <90 mm Hg). Three (0.7%) of the 422 patients experienced cardiac arrest during the emergency anaesthesia; of these, two experienced spontaneous return of circulation and were alive upon arrival at the emergency department, while the other was declared dead on-scene and found to have a ruptured aortic aneurysm.

The median time required to achieve tracheal intubation was 15 s in-cabin and 20 s outside. On a scale of perceived difficulty in performing the procedure, with 1='easy' and 10='impossible'', the median score for all locations was 2.0, with no significant differences.

The mean time on-scene differed significantly ($P=0.013$) when intubation was attempted in helicopter (27 min [interquartile range 19–34 min]) or out of cabin (32 min [interquartile range 24–41 min]) (Table 4).

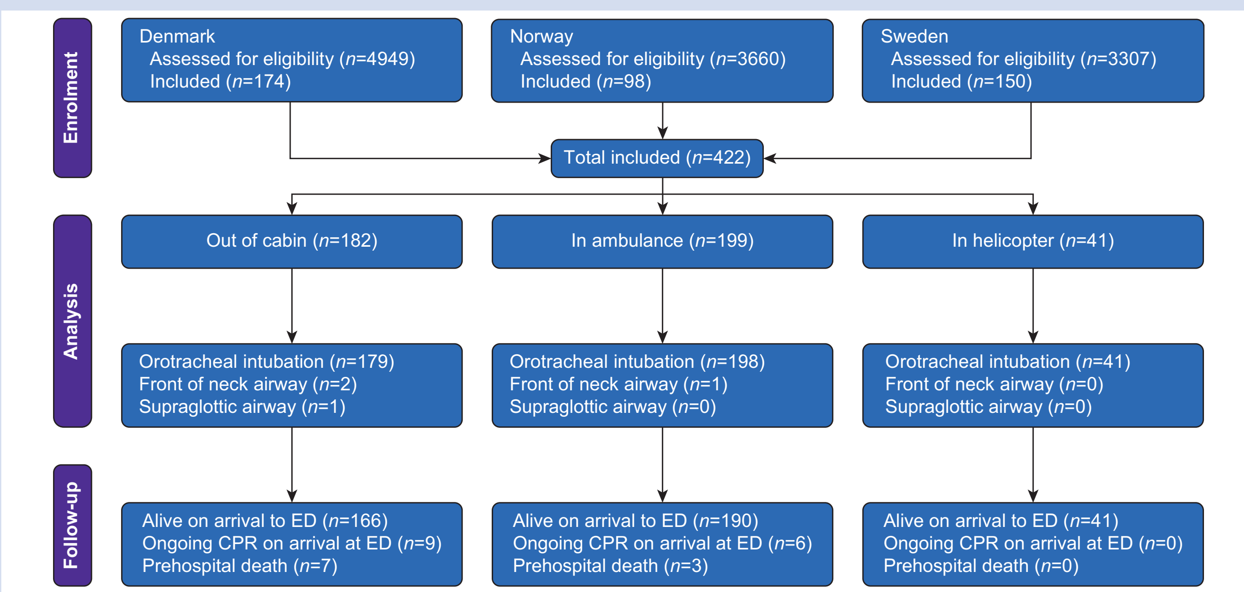

Fig 2. Flowchart showing the included patients out of all attended within the study period. CPR, cardiopulmonary resuscitation; ED, emergency department.

Table 1 Characteristics of the 422 patients who underwent prehospital intubation. ICU, intensive care unit; IQR, inter-quartile range; MILS, manualin-line stabilisation; NACA, National Advisory Committee for Aeronautics; SD, standard deviation.

	Outside (*n*=182)	In ambulance (*n*=199)	P	In helicopter (*n*=41)	P	Overall (*n*=422)
Provider, *n* (%)			0.955		0.978	
Anaesthetist/ICU—specialist physician	178 (97.8)	190 (95.5)		40 (97.6)		408 (96.7)
Anaesthetist/ICU—registered physician	0 (0.0)	2 (1.0)		0 (0.0)		2 (0.5)
Emergency medicine—specialist physician	1 (0.5)	0 (0.0)		1 (2.4)		2 (0.5)
Nurse anaesthetist	3 (1.6)	5 (2.5)		0 (0.0)		8 (1.9)
Paramedic	0 (0.0)	2 (1.0)		0 (0.0)		2 (0.5)
Years as specialist, mean (sd)	12.51 (7.62)	14.13 (7.51)	0.04	12.01 (5.41)	0.69	13.21 (7.41)
Experience of tracheal intubation, *n* (%)			0.97		0.066	
<250	0 (0.0)	1 (0.5)		0 (0.0)		1 (0.2)
251–1000	20 (11.0)	26 (13.2)		0 (0.0)		46 (11.0)
1001–2500	56 (30.9)	60 (30.5)		14 (34.1)		130 (31.0)
>2500	105 (58.0)	110 (55.8)		27 (65.9)		242 (57.8)
Patient characteristics, *n* (%)	182 (43)	199 (47)		41 (10)		422 (100)
Age (yr), median [IQR]	58.5 [41–71]	63 [42–74]	0.14	65 [51.5–75]	0.086	61 [42–73]
Sex, number of men (%)	127 (70.6)	136 (68.7)	0.88	27 (69.2)	0.19	290 (69.5)
NACA score (%)			0.767		0.909	
0 (No injury or disease)	1 (0.6)	0 (0.0)		0 (0.0)		1 (0.3)
1 (Minor disturbance)	0 (0)	0 (0.0)		0 (0.0)		0 (0.0)
2 (Slight to moderate disturbance)	1 (0.6)	1 (0.6)		0 (0.0)		2 (0.5)
3 (Moderate to severe disturbance)	2 (1.2)	2 (1.1)		0 (0.0)		4 (1.0)
4 (Serious incident)	13 (7.7)	20 (11.2)		2 (5.6)		35 (9.2)
5 (Acute danger)	55 (32.7)	69 (38.8)		15 (41.7)		139 (36.4)
6 (Respiratory arrest, cardiac arrest, or both)	90 (53.6)	75 (42.1)		18 (50.0)		183 (47.9)
7 (Death)	6 (3.6)	11 (6.2)		1 (2.8)		18 (4.7)
Patient categories (%)						
Trauma blunt	34 (19)	31 (16)	0.421	4 (10)	0.170	69 (16)
Trauma penetrating	2 (1)	6 (3)	0.193	1 (2)	0.501	9 (2)
Trauma head	46 (25)	49 (25)	0.883	11 (27)	0.837	11 (25)
Trauma other	18 (10)	11 (6)	0.109	1 (2)	0.123	30 (7)
Cardiac arrest	57 (31)	52 (26)	0.263	8 (20)	0.133	117 (28)
Medical respiratory	5 (3)	13 (7)	0.082	1 (2)	0.912	19 (5)
Medical intoxication	15 (8)	15 (8)	0.799	2 (5)	0.463	32 (8)
Medical infection	2 (1)	2 (1)	0.928	0 (0)	0.500	4 (1)
Medical other	2 (1)	11 (6)	0.017	2 (5)	0.100	15 (4)
Neurology stroke	16 (9)	25 (13)	0.235	13 (32)	<0.001	54 (13)
Neurology other	15 (8)	16 (8)	0.943	2 (5)	0.463	33 (8)
Psychiatric	1 (1)	1 (1)	0.950	0 (0)	0.634	2 (0.5)
Other	1 (1)	0 (0)	0.295	0 (0)	0.634	1 (0.2)
Risk factors for difficult intubation (%)						
None	68 (37)	78 (39)	0.713	16 (39)	0.843	162 (38)
Prior difficult intubation	0 (0)	2 (1)	0.175	0 (0)	N/A	2 (0.5)
Reduced neck mobility	17 (9)	12 (6)	0.224	5 (12)	0.580	34 (8)
Neck immobilisation device or MILS	25 (14)	21 (11)	0.341	9 (22)	0.186	55 (13)
Severe obesity or thick/short neck	27 (15)	24 (12)	0.427	6 (15)	0.974	57 (14)
Limited mouth opening	9 (5)	8 (4)	0.662	0 (0)	0.146	17 (4)
Short thyroid-mental distance	9 (5)	10 (5)	0.971	2 (5)	0.986	21 (5)
Significant upper airway trauma	18 (10)	8 (4)	0.023	1 (2)	0.012	27 (6)

Continued

Table 1 Continued

	Outside (*n*=182)	In ambulance (*n*=199)	P	In helicopter (*n*=41)	P	Overall (*n*=422)
Blood, vomit, or mucus in airways	70 (39)	80 (40)	0.728	13 (32)	0.419	163 (39)
Pre-existing airway device not working	12 (7)	6 (3)	0.100	1 (2)	0.305	19 (5)
Not assessed	2 (1)	5 (3)	0.305	0 (0)	0.500	7 (2)
Other	5 (3)	7 (4)	0.667	1 (2)	0.912	13 (3)
Aggravating conditions (%)						
Patient entrapped	4 (2)	0 (0)	0.036	0 (0)	0.338	4 (1)
No 360-degree access	19 (10)	131 (66)	<0.001	23 (56)	<0.001	173 (41)
Suboptimal positioning of care provider	42 (23)	22 (11)	0.002	8 (20)	0.621	72 (17)
Bright light/sunlight	43 (24)	3 (2)	<0.001	4 (10)	0.049	50 (12)
Darkness	12 (7)	1 (1)	0.001	5 (12)	0.222	18 (4)
Hostile environment	6 (3)	2 (1)	0.119	2 (5)	0.623	10 (2)
In moving helicopter/ambulance	0 (0)	3 (2)	0.096	3 (7)	<0.001	6 (1)
Other	13 (7)	3 (2)	0.006	1 (2)	0.262	17 (4)

Table 2 Comparison of the overall outcomes of prehospital intubation outside and in-cabin. IQR, inter-quartile range.

	Outside (*n*=182)	In ambulance (*n*=199)	*P*
Rate of first-pass success (%)	157 (86.3)	178 (89.4)	0.34
Overall successful intubation (%)	179 (98.4)	198 (99.5)	0.35
Incidence of complications (%)	18 (9.9)	19 (9.5)	0.91
On-scene time (min), median [IQR]	32 [24–41]	30.5 [23–40]	0.29
	Outside (*n*=182)	**In helicopter (*n*=41)**	***p***
First pass success rate (%)	157 (86.3)	36 (87.8)	1.0
Overall intubation success rate (%)	179 (98.4)	41 (100.0)	1.0
Complication rate (%)	18 (9.9)	6 (14.6)	0.40
On-scene time (min), median [IQR]	32 [24–41]	27 [19–34]	0.004

Table 3 Other outcomes after prehospital intubation at the different locations. BP, arterial blood pressure; CPR, cardiopulmonary resuscitation; TT, tracheal tube; IQR, inter-quartile range; sd, standard deviation; SpO_2, saturation of peripheral oxygen.

	Outside (*n*=182)	In ambulance (*n*=199)	*P*	In helicopter (*n*=41)	*P*	Overall (*n*=422)
Attempts required for success, *n* (%)						
1	157 (86.3)	178 (89.4)	0.341	36 (87.8)	0.794	371 (87.9)
2	176 (96.7)	194 (97.5)	0.648	41 (100.0)	0.239	411 (97.4)
3	180 (98.9)	198 (99.5)	0.511	41 (100.0)	0.500	419 (99.3)
2, No complications	162 (89.0)	176 (88.4)	0.861	35 (85.4)	0.511	373 (88.4)
Anatomical location of intubation, *n* (%)						
Orotracheal	179 (98.4)	198 (99.5)	0.273	41 (100.0)	0.408	418 (99.1)
Front of neck airway	2 (1.1)	1 (0.5)	0.511	0 (0.0)	0.500	3 (0.7)
Supraglottic airway	1 (0.5)	0 (0.0)	0.295	0 (0.0)	0.634	1 (0.2)
Types of complications, *n* (%)						
None	164 (90.1)	180 (90.5)	0.910	35 (85.4)	0.376	379 (89.8)
TT misplaced in oesophagus, recognised	4 (2.2)	2 (1.0)	0.350	0 (0.0)	0.338	5 (1.2)
TT misplaced in oesophagus, not recognised	0 (0.0)	0 (0.0)	N/A	1 (2.4)	0.035	1 (0.2)
TT misplaced in main stem bronchus	2 (1.0)	1 (0.5)	0.511	0 (0.0)	0.500	2 (0.5)
Aspiration during attempted intubation	1 (0.5)	0 (0.0)	0.295	0 (0.0)	0.634	1 (0.2)
Hypoxaemia (SpO_2<90%)	12 (6.5)	6 (3.0)	0.100	4 (9.8)	0.478	18 (4.3)
Hypotension (BP<90 mm Hg)	5 (2.7)	10 (5.0)	0.253	1 (2.4)	0.912	14 (3.3)
Cardiac arrest	0 (0.0)	2 (1.0)	0.175	1 (2.4)	0.035	2 (0.5)
Bradycardia	1 (0.5)	1 (0.5)	0.950	2 (4.9)	0.030	4 (0.9)
Subsequent outcome (%)						
Alive on arrival at emergency ward	166 (91.2)	190 (95.5)	<0.001	40 (100.0)	0.166	396 (94.1)
Ongoing CPR upon arrival at emergency ward	9 (4.9)	6 (3.0)	0.333	0 (0.0)	0.146	15 (3.6)
Prehospital death	7 (3.8)	3 (1.5)	0.154	0 (0.0)	0.202	10 (2.4)
Number of attempts, mean (sd)	1.18 (0.51)	1.14 (0.43)	0.346	1.12 (0.33)	0.477	1.15 (0.46)
Best Cormack–Lehane score, median [IQR]	1 [1–2]	1.00 [1–2]	0.244	1 [1–1]	0.115	1 [1–2]
On-scene time, median [IQR]	32 [24–41]	30.5 [23–40]	0.292	27 [19–34]	0.004	31 [23–40]

Table 4 Temporal variables and perceived difficulty of intubation associated with performance of the procedure at the different locations.

	Outside	In ambulance	In helicopter	Overall	P
Intubation time (s), median [IQR]	20 [10–30]	15 [10–25]	15 [10–20]	15 [10–30]	0.249
Perceived intubation difficulty, on a scale of 1–10, median [IQR]	2 [1–4]	2 [1–3]	2 [1–3.25]	2 [1–3]	0.426
On-scene time (min), median [IQR]	32 [24–41]	30.5 [23–40]	27 [19–34]	31 [23–40]	0.013
Time from first encounter with patient to starting to move him/her, (min), median [IQR]	20 [14–30]	22 [16–29.50]	8 [4–15]	20 [13–28]	<0.001
Time from starting to move the patient to takeoff of helicopter or start of ambulance transport (min), median [IQR]	8 [5–11]	6 [4–10]	17 [10–20]	8 [5–12]	<0.001

Discussion

Prehospital tracheal intubation performed by anaesthetists in an ambulance or in a helicopter had a similar first-pass success rate as when performed outside the vehicle. Airway-related complications were higher and scene time shorter after tracheal intubation in-helicopter compared with outside. In general, our findings are in good agreement with those of the earlier PHAST study.[4] However, to our knowledge, this is the first multicentre observational study of success and complications associated with prehospital emergency anaesthesia and tracheal intubation at different locations.

The baseline characteristics of the groups examined differ in certain clinically relevant respects, including patient diagnoses, NACA scores, factors which may make intubation more difficult, and unfavourable environmental conditions (Table 1). These differences have a direct impact on the decision of the attending physician on whether to perform the tracheal intubation outside or in-cabin. As an in-cabin procedure is more likely to be chosen for patients in acute need of intubation and without any apparent risk factors, the choice of location is biased.

Many of the few earlier investigations that have compared tracheal intubations performed outside or in-cabin are of relatively low quality, involve only a single centre or few patients, or both. The data they have reported are not directly comparable to the Scandinavian situation and, moreover, vary considerably because of differences in the preconditions and experience of the care provider.[11–18] One experimental comparison of an in-cabin and outside intubation procedure on mannequins with respect to the time required, success rates, and perceived level of difficulty indicated that in-cabin intubation could be performed in a timely manner and under conditions that are equally as good as or even better than those outside.[19] In another helicopter emergency medical system simulation, the investigators concluded that it was both possible and equally quick to perform tracheal intubation in the cabin of a helicopter as outside.[20]

The use of the rate of first-pass success as an indicator of effective prehospital airway management remains questionable. As stated above, high first-pass success rates are inversely proportional to the frequency of adverse events.[7] However, the Finnish helicopter emergency medical system recently published retrospective data showing no correlation between first-pass success rates and patient mortality, even though post-intubation hypoxaemia was more frequent in the group without first-pass success.[21] Utilising first-pass success rates as a quality indicator in comparisons between techniques or locations may prove valid, but the clinical relevance of such an approach to patient outcomes has not been established. The first-pass success findings reported here are similar to those documented in earlier prehospital studies[4,7,22] and superior to in-hospital studies.[23] Some single-centre studies have demonstrated excellent first-pass success rates after introducing protocols involving video laryngoscope as the primary technique, with or without bougies.[24,25] These results are promising but need to be examined with larger groups of patients with varying characteristics and by evaluation of additional outcomes.

In the present case, in connection with emergency anaesthesia and tracheal intubation in helicopters, the on-scene time was significantly shorter than when these procedures were performed outside (27 *vs* 32 min, $P=0{,}004$). In this context a recent retrospective Dutch observational study demonstrated a correlation between prolonged on-scene time and increases in both 24-h and 30-day mortality among patients with moderate and serious injuries caused by trauma.[26] In addition, the Swiss helicopter emergency medical system has reported on the feasibility of performing in-cabin tracheal intubation to reduce prehospital time.[27]

In attempt to achieve optimal conditions, prehospital emergency anaesthesia and tracheal intubation outside is often encouraged.[1] In the current case, the helicopter emergency medical system crews reported disturbance as a result of suboptimal positioning of the care provider and bright light in almost one-quarter of the tracheal intubations performed outside, and less than 360-degree access in approximately one of every 10 patients. Thus, our study may indicate that 360-degree access to the patient during emergency anaesthesia and tracheal intubation does not influence the success rate or frequency of complications, but it should be remembered that such access may have a greater impact in connection with other interventions and management of crew resources.

Tracheal intubation in helicopters was 100% successful after two attempts, with a low overall frequency of complications and all patients being alive upon arrival at the emergency ward. However, there were more complications in the in-helicopter intubation group compared with the outside intubation group, but did not reach significance. In addition, one patient in the in-helicopter intubation group had an unrecognised oesophageal intubation. The decision about where to intubate was made at the discretion of the care provider, so cases deemed difficult to treat might have been intubated outside, which could have influenced the outcome obtained.

Because of its observational nature, the present study can only indicate potential associations between tracheal intubation in-cabin and shorter on-scene times. In addition to new studies on this question, regular registration and evaluation of all prehospital advanced airway management activities would be of considerable value. Such assessments should be based on standardised variables taken from the Utstein template[9] and involve the use of quality indicators.[5]

Several confounding factors outside, including light, temperature, and precipitation, might influence the choice of location for attempted prehospital tracheal intubation. Thus, seasonal variations in such conditions might influence the proportion of certain types of patients being intubated in-cabin. Further subgroup analyses should explore such possibilities.

The external validity of our present study might be questioned on the basis that the participating helicopter emergency medical systems function quite well and prioritise quality monitoring of their services, which might also lead to superior airway management. Moreover, the services involved here are relatively homogenous in terms of staffing, caseloads, and case mix. Consequently, our results might not be applicable to other services involving different staffing with different training or operating in significantly different environments or within other healthcare systems.

Our study period coincided with the COVID-19 pandemic, which raised some concerns about altered routines as a result of differences in the types and numbers of patients. Indeed, during the periods of partial quarantine there were fewer cases of trauma. However, although the new hygiene routines introduced presented logistic challenges to the care crews, this was reported in general not to affect the number of patients responded to or treated.

We did not register the inclusion rate here, which introduces a possibility for bias. However, the cases included constituted 3.5% of the total number of patients attended to, which is similar to the 3.0% value reported earlier (when cardiac arrest was excluded as the primary indication).[4] A risk for recall bias is always present when care providers self-report, but as the case report form did not identify the providers in any way, they were free to report objectively.

In conclusion, both outside and in-cabin prehospital tracheal intubations by anaesthetists were performed with high first-pass and overall intubation success rate. When these procedures were performed inside the helicopter, the time on-scene was significantly shorter.

Authors' contributions

Study design: JB, HML, MG
Study coordinator: JB
Data analysis: JB, CL, HML, MG
Writing the first draft: JB
Registration of data: CL
Reviewing the first and the final manuscript draft: CL, EF, FH, GS, HH, JSK, MB, MFT, PB, TMH, AK, LR, HML, MG
Local base coordinator: EF, FH, GS, HH, JSK, MB, MFT, PB, TMH, AK, LR, MG
Data collection: EF, FH, GS, HH, JSK, MB, MFT, PB, TMH, AK, LR, MG
National coordinator: AK, LR

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Declaration of interest

The authors declare that they have no conflicts of interest.

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Appendix A. Supplementary data

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References

1. Lockey DJ, Crewdson K, Davies G, et al. AAGBI: safer pre-hospital anaesthesia 2017: Association of Anaesthetists of Great Britain and Ireland. *Anaesthesia* 2017; **72**: 379–90
2. Hossfeld B, Bein B, Boettiger BW, et al. Recommended practice for out-of-hospital emergency anaesthesia in adults: statement from the out-of-hospital emergency anaesthesia working group of the emergency medicine research group of the German Society of Anaesthesiology and Intensive Care. *Eur J Anaesthesiol* 2016; **33**: 881–97
3. Rehn M, Hyldmo PK, Magnusson V, et al. Scandinavian SSAI clinical practice guideline on pre-hospital airway management. *Acta Anaesthesiol Scand* 2016; **60**: 852–64
4. Gellerfors M, Fevang E, Bäckman A, et al. Pre-hospital advanced airway management by anaesthetist and nurse anaesthetist critical care teams: a prospective observational study of 2028 pre-hospital tracheal intubations. *Br J Anaesth* 2018; **120**: 1103–9
5. Kottmann A, Krüger AJ, Sunde GA, et al. Establishing quality indicators for pre-hospital advanced airway management: a modified nominal group technique consensus process. *Br J Anaesth* 2022; **128**: e143–50
6. Sakles JC, Chiu S, Mosier J, Walker C, Stolz U. The importance of first pass success when performing orotracheal intubation in the emergency department. *Acad Emerg Med* 2013; **20**: 71–8
7. Rognås L, Hansen TM, Kirkegaard H, Tønnesen E. Pre-hospital advanced airway management by experienced anaesthesiologists: a prospective descriptive study. *Scand J Trauma Resus Emerg Med* 2013; **21**: 1–10
8. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* 2007; **370**: 1453–7
9. Sunde GA, Kottmann A, Heltne JK, et al. Standardised data reporting from pre-hospital advanced airway management - a nominal group technique update of the Utstein-style airway template. *Scand J Trauma Resusc Emerg Med* 2018; **26**: 46

10. Raatiniemi L, Liisananntti J, Tommila M, et al. Evaluating helicopter emergency medical missions: a reliability study of the HEMS benefit and NACA scores. *Acta Anaesthesiol Scand* 2017; **61**: 557–65
11. Mishark KJ, Vukov LF, Gudgell SF. Airway management and air medical transport. *J Air Med Transp* 1992; **11**: 7–9
12. Stone CK, Thomas SH. Is oral endotracheal intubation efficacy impaired in the helicopter environment? *Air Med J* 1994; **13**: 319–21
13. Harrison T, Thomas SH, Wedel SK. In-flight oral endotracheal intubation. *Am J Emerg Med* 1997; **15**: 558–61
14. Slater EA, Weiss SJ, Ernst AA, Haynes M. Preflight versus en route success and complications of rapid sequence intubation in an air medical service. *J Trauma Acute Care Surg* 1998; **45**: 588–92
15. Thomas SH, Harrison T, Wedel SK. Flight crew airway management in four settings: a six-year review. Prehos Emerg Care 999; 3: 310–315.
16. McIntosh SE, Swanson ER, McKeone AF, Barton ED. Location of airway management in air medical transport. *Prehos Emerg Care* 2008; **12**: 438–42
17. Clemency BM, Roginski M, Lindstrom HA, Billittier AJ. Paramedic intubation: patient position might matter. *Prehos Emerg Care* 2014; **18**: 239–43
18. Wong K, Lui C, Chan W, Lau T, Tang S, Tsui K. Comparison of different intubation techniques performed inside a moving ambulance: a manikin study. *Hong Kong Med J* 2014; **20**: 304–12
19. Kornhall D, Hellikson F, Näslund R, Lind F, Broms J, Gellerfors M. A protocol for helicopter in-cabin intubation. *Air Med J* 2018; **37**: 306–11
20. McHenry AS, Curtis L, Ter Avest E, et al. Feasibility of prehospital rapid sequence intubation in the cabin of an AW169 helicopter. *Air Med J* 2020; **39**: 468–72
21. Ljungqvist H, Pirneskoski J, Saviluoto A, Setälä P, Tommila M, Nurmi J. Intubation first-pass success in a high performing pre-hospital critical care system is not associated with 30-day mortality: a registry study of 4496 intubation attempts. *Scand J Trauma Resusc Emerg Med* 2022; **30**: 1–7
22. Crewdson K, Lockey D, Røislien J, Lossius HM, Rehn M. The success of pre-hospital tracheal intubation by different pre-hospital providers: a systematic literature review and meta-analysis. *Crit Care* 2017; **21**: 1–10
23. Russotto V, Myatra SN, Laffey JG, et al. Intubation practices and adverse peri-intubation events in critically ill patients from 29 countries. *JAMA* 2021; **325**: 1164–72
24. Ångerman S, Kirves H, Nurmi J. A before-and-after observational study of a protocol for use of the C-MAC videolaryngoscope with a Frova introducer in pre-hospital rapid sequence intubation. *Anaesthesia* 2018; **73**: 348–55
25. Rhode MG, Vandborg MP, Bladt V, Rognås L. Video laryngoscopy in pre-hospital critical care – a quality improvement study. *Scand J Trauma Resusc Emerg Med* 2016; **24**: 84
26. Waalwijk JF, van der Sluijs R, Lokerman RD, et al. The impact of prehospital time intervals on mortality in moderately and severely injured patients. *J Trauma Acute Care Surg* 2022; **92**: 520–7
27. Knapp J, Venetz P, Pietsch U. In cabin rapid sequence induction. *Der Anaesthesist* 2021; **70**: 609–13

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