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Saviluoto, Anssi

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Association between case volume and mortality in pre-hospital anaesthesia management: a retrospective observational cohort

Anssi Saviluoto[1,2], Helena Jäntti[3], Hetti Kirves[4], Piritta Setälä[5] and Jouni O. Nurmi[1,6,*]

[1]Research and Development Unit, FinnHEMS, Vantaa, Finland, [2]University of Eastern Finland, Kuopio, Finland, [3]Centre for Prehospital Emergency Care, Kuopio University Hospital, Kuopio, Finland, [4]Prehospital Emergency Care, Hyvinkää Hospital Area, Hospital District of Helsinki and Uusimaa, Hyvinkää, Finland, [5]Centre for Prehospital Emergency Care, Tampere University Hospital, Tampere, Finland and [6]Emergency Medicine and Services, Helsinki University Hospital and University of Helsinki, Helsinki, Finland

*Corresponding author. E-mail: jouni.nurmi@hus.fi

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Pre-hospital critical care at major incidents by David Lockey, *Br J Anaesth* 2022:128:e82–e85, doi: 10.1016/j.bja.2021.10.002
Higher pre-hospital anaesthesia case volumes result in lower mortality rates: implications for mass casualty care by Paal et al., *Br J Anaesth* 2022:128:e89–e92, doi: 10.1016/j.bja.2021.10.022

Abstract

Background: Pre-hospital anaesthesia is a core competency of helicopter emergency medical services (HEMS). Whether physician pre-hospital anaesthesia case volume affects outcomes is unknown in this setting. We aimed to investigate whether physician case volume was associated with differences in mortality or medical management.

Methods: We conducted a registry-based cohort study of patients undergoing drug-facilitated intubation by HEMS physician from January 1, 2013 to August 31, 2019. The primary outcome was 30-day mortality, analysed using multivariate logistic regression controlling for patient-dependent variables. Case volume for each patient was determined by the number of pre-hospital anaesthetics the attending physician had managed in the previous 12 months. The explanatory variable was physician case volume grouped by low (0–12), intermediate (13–36), and high (≥37) case volume. Secondary outcomes were characteristics of medical management, including the incidence of hypoxaemia and hypotension.

Results: In 4818 patients, the physician case volume was 511, 2033, and 2274 patients in low-, intermediate-, and high-case-volume groups, respectively. Higher physician case volume was associated with lower 30-day mortality (odds ratio 0.79 per logarithmic number of cases [95% confidence interval: 0.64–0.98]). High-volume physician providers had shorter on-scene times (median 28 [25th–75th percentile: 22–38], compared with intermediate 32 [23–42] and lowest 32 [23–43] case-volume groups; $P<0.001$) and a higher first-pass success rate for tracheal intubation (98%, compared with 93% and 90%, respectively; $P<0.001$). The incidence of hypoxaemia and hypotension was similar between groups.

Conclusions: Mortality appears to be lower after pre-hospital anaesthesia when delivered by physician providers with higher case volumes.

Keywords: air ambulance; airway management; clinical competence; critical care; emergency medical services; tracheal; intubation; pre-hospital; rapid sequence induction and intubation

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Editor's key points

- Prior pre-hospital anaesthesia case volumes may influence outcomes in major trauma and mass casualty events.
- This registry-based cohort study of patients in Finland examined whether the case volume of pre-hospital physicians undertaking anaesthetic-drug-facilitated intubation was associated with hypoxaemia, hypotension, or death.
- In 4818 patients, a higher case volume was associated with lower mortality, although no differences were observed for hypoxaemia or hypotension after intubation.
- Specialist physicians delivering higher case volumes of pre-hospital anaesthesia may contribute to lower mortality.

The quality and safety of delivering anaesthesia and advanced airway management in pre-hospital care may influence outcome.[1] In traumatic brain injury, pre-hospital anaesthesia undertaken by a senior anaesthesiologist is associated with better outcomes, in contrast to providers with less experience.[2,3] Higher case volume for many complex procedures associates with better outcomes.[4–6] Specialised surgical care is therefore limited in many countries to centres that perform sufficient case volumes annually. However, the effect of case volume on outcomes after anaesthesia and related procedures is less well known. The learning curves of physicians reveal that not only the number, but also the frequency of procedures is an important factor in conferring better outcomes.[7] Of note, these studies evaluate only procedural success, rather than physiological stability or team and time management.

The focus in pre-hospital critical care has increasingly moved from successful placement of a tracheal tube towards optimising oxygenation, ventilation, and perfusion pressure.[8–11] To provide pre-hospital advanced airway management and anaesthesia safely and effectively, providers need to consider several factors unique to the pre-hospital setting. Therefore, experience in in-hospital anaesthesia alone does not necessarily directly translate into expertise in pre-hospital advanced airway management and anaesthesia.

The number of pre-hospital anaesthesia cases undertaken varies both between and within different helicopter emergency medical services (HEMS),[12,13] including amongst physicians working in Finnish HEMS.[14] As case volume in complex procedures appears to be an important factor in outcome, we hypothesised that the frequency of pre-hospital anaesthesia cases undertaken by physician providers (rather than cumulative experience) would be associated with mortality after pre-hospital advanced airway management and anaesthesia.

Methods

Study design

We conducted a retrospective cohort study using patient data obtained between January 1, 2013 and August 31, 2019. Permission to access and analyse these data was granted by each university hospital district (Oulu University Hospital 200/2019 July 7, 2019, Helsinki University Hospital HUS/280/2019 July 7, 2019, Turku University Hospital J30/19 August 4, 2019, Hospital District of Lapland 32/2019 August 22, 2019, Kuopio University Hospital RPL 102/2019 August 8, 2019, and Tampere University Hospital RTL-R19580). The Ethical Committee of Helsinki University Hospital reviewed and approved the study protocol. We have reported the study according to the Strengthening the Reporting of Observational Studies in Epidemiology statement.[15]

Inclusion and exclusion criteria

We included all patients who underwent pre-hospital anaesthesia managed by a HEMS physician. We defined pre-hospital anaesthesia as any patient who was tracheally intubated and received any medication for airway management. Patients intubated without any medication or in cardiac arrest when encountered by the HEMS crew were excluded.

Setting

Finland has a national HEMS, with five physician-staffed and one paramedic-staffed HEMS units. The physician-staffed units are located in the vicinity of the five university hospitals of the country. All units operate in rural and urban areas. One hundred physicians worked in HEMS during the study period. Seventy of them were senior anaesthesiologists, 25 were anaesthesiology residents in their final year of specialisation, three specialists in internal medicine, and two emergency medicine residents in their last year of specialisation. In Finland, specialising in all of the aforementioned specialities takes 6 yr. The required competence for national HEMS is at least 2 yr of prior experience in anaesthesia. HEMS are dispatched to all missions where pre-hospital anaesthesia may be necessary. Dispatch is activated on predetermined criteria by national emergency response centres or requested by ground-based emergency medical services (EMS). Dispatch criteria and the national HEMS have been described in a previous paper.[16] During the study period, two of the five physician-staffed HEMS bases (March 2015 in Vantaa and March 2016 in Tampere) implemented a standard operating procedure (SOP) for pre-hospital rapid sequence intubation (RSI),[17] whilst others do not utilise a uniform SOP at the time of writing.

Data collection

The FinnHEMS database (FHDB) is a database shared by all HEMS units in the country. All HEMS mission data are prospectively added to the database promptly after mission completion by the physician or the HEMS paramedic (in the paramedic-staffed unit). Data are recorded according to international guidelines regarding physician-staffed EMS, HEMS, and pre-hospital advanced airway management.[18–20] The database contains additional variables not required by the guidelines, including timestamps, patient details, medications administered, and vital signs at various points.[16] The database contains unique patient identifiers, which can be used to acquire additional data from other national registries. The governmental Finnish digital and population data services agency maintains a national register containing basic information on all Finnish citizens and residents, temporary or permanent, including death records. For mortality data, we requested the dates of death or the living status for all the patients encountered by HEMS until the end of August 2019. Dates of death were obtained until the end of October 2019.

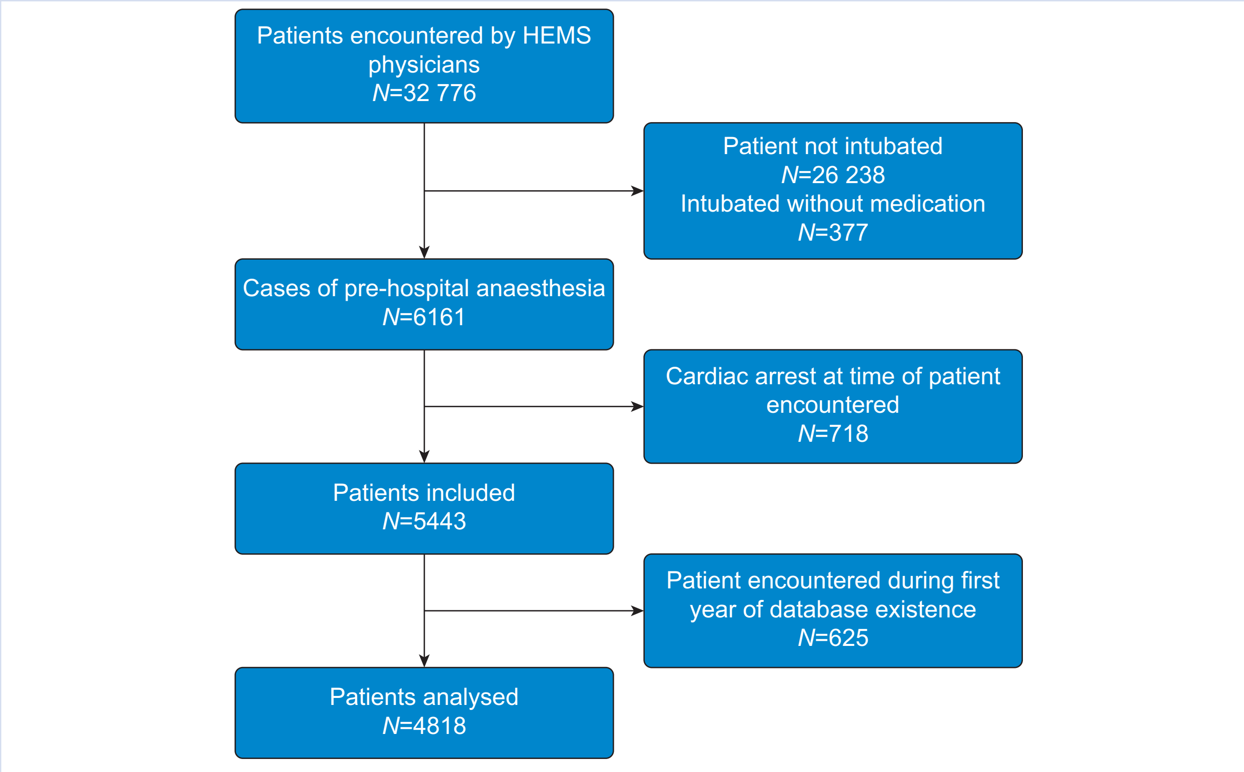

Fig 1. Patient selection flow chart. HEMS, helicopter emergency medical services.

The user interface used to enter mission data to the FHDB has a separate section for airway management, including medicines used to facilitate airway management by category (neuromuscular block, analgesic, anaesthetic/sedative, local anaesthetic, or other). All patients receiving any of the medicines listed previously were considered to have received medication for airway management. Similarly, other medication categories, such as vasoactive medications, are recorded. Using the same interface, physicians enter the main medical problem for each patient, as defined by guidelines.[19] We used the first vital signs measured by the HEMS crew after patient contact. For the values at handover, we used the last values measured by the crew at the end of transportation. Vital signs are recorded and entered into the database manually by the HEMS crew. Mechanical ventilation was defined as use of a ventilator after intubation.

Primary outcome

The primary outcome was 30-day mortality.

Secondary outcomes

The secondary outcomes were:

(i) First-pass success of intubation
(ii) Hypotension (systolic arterial pressure <90 mm Hg) or hypoxia (blood oxygen saturation <90%) after tracheal intubation or at patient handover[21]
(iii) Duration of treatment on scene (defined as minutes elapsed at the scene, from the 'at scene' timestamp to the 'beginning of transport' timestamp): for the time from the alarm to reaching the patient, we used the time from the HEMS unit receiving the alarm until the at-scene timestamp submitted by the HEMS crew.

Explanatory variable

Physicians' case volume in managing pre-hospital anaesthesia was defined for each patient by counting the number of episodes of pre-hospital anaesthesia that the attending physician had managed in the preceding 12 months. We analysed patients individually and counted 12 months backward from the date of the patient encounter. Cases encountered during the first year of data collection (2012) were used only to determine the physicians' subsequent case volumes. Prospectively, the definitions for low-, intermediate-, and high-volume cases used for the secondary analyses were 0–12 cases (low case volume) corresponded to one pre-hospital anaesthetic delivered per month or fewer, 13–36 corresponded to two to three per month (intermediate case volume), and more than three for ≥37 (high case volume).

Statistical methods

For the primary outcome (30-day mortality), we performed logistic regression analysis using sex, age, systolic BP, HR, Glasgow Coma Scale, time from the alarm to reaching the patient, transport to a university hospital, medical problem, and the physician pre-hospital anaesthesia case volume as covariates. Previous studies have shown the learning curve of anaesthesia skills to resemble a logarithmic curve rather than a linear one.[22] Presumably, the significance of additional repetitions

Table 1 Patient and operational characteristics according to physician case volume of pre-hospital anaesthesia during the preceding 12 months. Data are presented as median (25th–75th percentile) or n (%). SpO_2 and BP immediately after intubation were available for 3444 (72%) and 3453 (72%) patients and at handover for 4348 (90%) and 4380 (91%) patients, respectively. On-scene time could not be calculated for 254 (5%) cases because of missing timestamps. First-pass success was not recorded in 1143 (24%) cases. For all the other variables regarding medical management, there were no missing values (Supplementary material 1A).

	0–12 cases n=2274		13–36 cases n=2033		≥37 cases n=511	
Patient characteristics						
Age	59	(37–71)	56	(36–69)	50	(30–67)
Sex; male	1472	(65)	1299	(64)	326	(64)
Medical problem						
Trauma	636	(28)	514	(25)	124	(24)
Out-of-hospital cardiac arrest	269	(12)	276	(14)	76	(15)
Neurological	836	(37)	697	(34)	169	(33)
Intoxication	305	(13)	345	(17)	107	(21)
Other	228	(10)	201	(10)	35	(7)
Vital signs at time of patient encounter						
Ventilatory frequency (bpm)	16	(12–22)	18	(12–23)	16	(12–22)
Oxygen saturation (%)	96	(90–98)	97	(92–99)	97	(94–99)
HR (beats min^{-1})	90	(74–113)	95	(77–115)	100	(80–118)
Systolic BP (mm Hg)	134	(110–166)	132	(110–160)	133	(109–156)
Glasgow Coma Scale	4	(3–6)	4	(3–7)	5	(3–7)
Operational characteristics						
Time from alarm to patient contact (min)	26	(17–38)	23	(17–34)	20	(16–28)
Transport duration (min)	29	(17–42)	25	(16–39)	23	(16–32)

would diminish as experience accumulates. Therefore, in this multivariate analysis, we used a base 10 logarithm of the physicians' pre-hospital anaesthesia cases in the preceding 12 months. The results of the model are reported as odds ratios (ORs). Goodness of fit was evaluated by reporting the Nagelkerke R^2 value. Patients with one or more missing covariates or unknown mortality status were excluded from the analysis.

In our secondary analysis, we divided the patients into three groups according to the treating physician's pre-hospital anaesthesia case volume. Because logarithmic ORs are not intuitive to interpret, we divided the groups by the absolute number of repetitions in the preceding 12 months. We compared medical management between the groups by reporting the proportion of patients receiving medications for airway management by drug category. We also compared on-scene time and the proportion of patients mechanically ventilated or receiving vasoactive medication.

All proportions are reported as percentages and 95% confidence intervals (CIs). Continuous variables are reported as medians (25th–75th percentile). P-values for continuous values were calculated using the Kruskal–Wallis test for independent samples. For proportions, we used the Pearson χ^2 test.

Missing data were excluded from the analysis. The types and proportions of missing data for each variable are reported in an online supplement (Supplementary material 1A). The study size was not determined by power calculations, as we instead used all the available data. All statistical analyses were done using SPSS Statistics for Mac, version 27 (IBM Corp., Armonk, NY, USA).

Sensitivity analyses

We excluded all patients treated after implementation of the SOPs by the two bases with SOPs. We also performed a separate sensitivity analysis, in which we replaced the physicians' pre-hospital anaesthesia cases with the total number of cases the physician had treated up to that point. Previous studies have shown that the Finnish HEMS treat many intoxication cases with low mortality.[16,23] Because this might introduce bias and limit generalisability, we performed a sensitivity analysis excluding all intoxication patients. All the other factors remained identical to the original model in these sensitivity analyses.

Results

Study participants

During the study period, 4818 patients met the inclusion criteria (Fig. 1). The median patient age was 57 yr (25th–75th percentile: 36–70). In addition, 3097 (64%) of the patients were male with the majority (4428; 92%) transported to a university hospital. Then, 88, 56, and 12 physicians were assigned to low (n=2274), intermediate (n=2033), and high (n=511) physician case-volume groups, respectively (Table 1). The median time from alarm to patient contact was 24 (17–35) min, but differed between physician case-volume groups. Moreover, 1469/4602 (32%) patients died within 30 days (for whom complete mortality data were available; Table 2).

Primary outcome

Four thousand cases (83%) with all covariates were included in the multivariate logistic regression analysis, which achieved a Nagelkerke R^2 value of 36%. A higher physician pre-hospital anaesthesia case volume was associated with lower 30-day mortality (OR 0.79; 95% CI: 0.64–0.98; Fig. 2; Supplementary material 1B).

Sensitivity analyses

Cumulative experience was not associated with 30 day mortality (OR 0.85; 95% CI: 0.71–1.02) (Supplementary material 1C). The association between 30 day mortality and pre-hospital anaesthesia case volume remained when intoxicated

Table 2 Medical management and outcomes according to physician case volume managing pre-hospital anaesthesia during the preceding 12 months. Data are presented as median (25th–75th percentile) or percentage (95% confidence interval).

Medical management	0–12 cases n=2274		13–36 cases n=2033		≥37 cases n=511		P-value*
Rapid sequence intubation							
First-pass success	90	(88–91)	93	(92–94)	98	(96–99)	<0.001*
Neuromuscular block	85	(83–86)	87	(85–88)	94	(91–96)	<0.001*
Sedative agent	87	(86–88)	87	(85–88)	91	(88–94)	0.016*
Analgesia	78	(76–80)	71	(69–73)	60	(55–64)	<0.001*
Mechanical ventilation	76	(74–77)	84	(82–85)	95	(92–96)	<0.001*
Use of vasoactive medications	54	(52–56)	53	(51–55)	48	(44–52)	0.045*
On-scene time (min)	32	(23–43)	32	(23–42)	28	(22–38)	<0.001†
Patient outcomes							
Hypoxaemia post-intubation	6	(5–7)	6	(5–7)	6	(4–9)	1.000*
Hypotension post-intubation	12	(11–14)	13	(11–15)	11	(8–15)	0.681*
Hypoxaemia at time of handover	3	(2–4)	2	(2–3)	4	(3–7)	0.084*
Hypotension at time of handover	6	(5–7)	5	(4–6)	5	(3–8)	0.928*
30-day mortality	36	(34–38)	29	(27–31)	25	(21–29)	<0.001*

* Pearson χ^2 test.
† Kruskal–Wallis test.

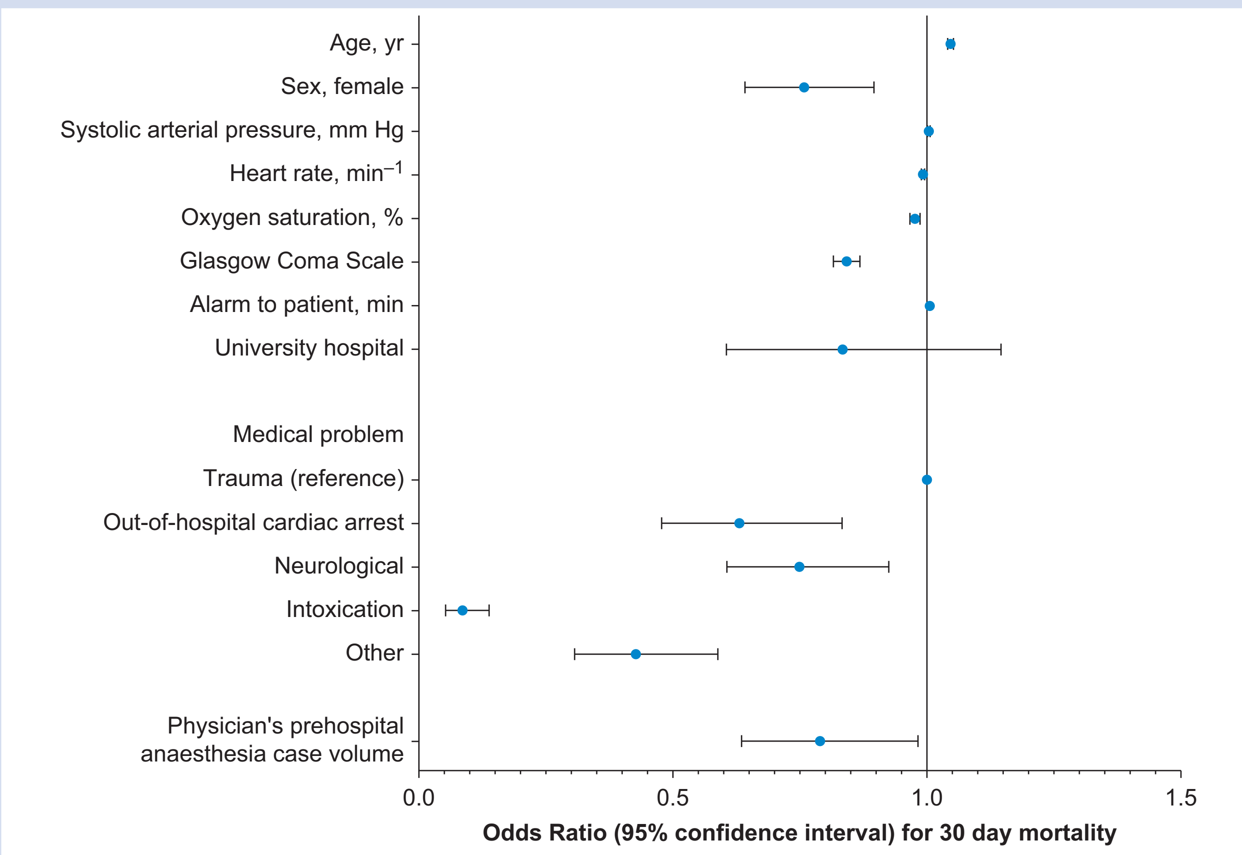

Fig 2. Multivariate logistic regression analysis results for 30 day mortality. All covariates are shown in the figure. Physicians' pre-hospital anaesthesia case volume refers to a base 10 logarithm of the number of repetitions the physician performed in the 12 months preceding the mission. University hospital refers to patients transported directly to university hospital. CI, confidence interval; OR, odds ratio.

patients were removed from the original model (OR 0.79; 95% CI: 0.63–0.98) (Supplementary material 1D). We found similar results when excluding all patients from the two bases with an SOP for pre-hospital RSI after its implementation (OR 0.74; 95% CI: 0.55–0.98) (Supplementary material 1E).

Secondary outcomes

Highest case volume was associated with shorter on-scene times (median: 28 min [25th–75th percentile: 22–38] *vs* 32 [23–42] and 32 [23–43] for intermediate and lowest case volumes, respectively; $P<0.001$) and a higher first-pass success rate for tracheal intubation (98% *vs* 93% and 90%, respectively; $P<0.001$). No difference was observed between case-volume groups for episodes of hypoxaemia or hypotension after intubation or at handover (Table 2).

Discussion

We found that a higher case volume of delivering pre-hospital anaesthesia during the preceding year to be associated with decreased 30-day mortality. This is the first time that the potential significance of frequently performing pre-hospital procedures by physicians on outcome has been demonstrated.

The differences in medical management, on-scene time, and first-pass intubation success rate may, in part, explain our main finding. When case volume was high, physicians had better first-pass intubation success rates, which has been shown to be associated with better outcomes in critically ill patients.[24] In the group treated by physicians with the highest case volume, use of neuromuscular block was more common, which may have helped achieve the higher first-pass intubation success rate. It is reasonable to assume that a high case volume would translate to better time management; indeed, the group with the highest case volume had shorter on-scene time while the same procedures were performed. Shorter pre-hospital delays have been shown to affect outcomes in various patient groups.[25–27] We also saw the use of mechanical ventilation increase as case volume grew. Correction of deranged physiology has been linked to better outcomes, and mechanical ventilation allows for more precise control of ventilation, oxygenation, and circulation.[28] Apart from HR, other vital signs were similar, and there was no difference in frequency of hypoxaemia or hypotension after intubation or at handover between groups.

Managing pre-hospital anaesthesia encompasses several aspects beyond RSI and the treatment of circulation and ventilation. Tactical decisions, such as patient transfer options or timing of procedures, may have important implications downstream. In addition, the ever-changing environment and composition of the available supporting crew place special demands on crew resource management. It therefore makes sense that a well-established routine and familiarity with the pre-hospital setting may play an important role in patient safety and outcomes. All physicians working in the national Finnish HEMS are experienced in anaesthesiology and airway management. Most have their primary occupation in an ICU or operating theatre inter-dispersed by shifts in HEMS. The ratio of in-hospital to pre-hospital work varies. To accumulate the highest case volumes, a physician needed to consistently have frequent shifts in HEMS. We surmise that frequent experience in pre-hospital anaesthesia specifically is important to provide excellent level care. However, we do not have data on physicians' in-hospital service, and further study is needed to evaluate how it affects the quality of pre-hospital care.

A strength of our study was that all HEMS missions in the country are recorded in the FHDB, and the levels of missing data are relatively low. HEMS units are dispatched to all missions where pre-hospital anaesthesia is thought to be necessary, and most pre-hospital anaesthesia cases may be presumed to be included in the database, constituting a study strength. The patient groups differed in age and medical problems. This can, at least in part, be explained by geographical differences. The physicians who accumulate the most experience in pre-hospital anaesthesia are likely to work in highly populated areas with a younger population. However, we saw a difference in mortality, even after controlling for age and pre-hospital delays. We found that the group with the highest case volume had a larger proportion of intoxication cases, but excluding all patients with suspected intoxication produced a virtually identical result. Although the results might be affected by patient selection, the association between pre-hospital anaesthesia case volume and mortality was seen in all sensitivity analyses, increasing our confidence in the findings.

A further limitation is that because of the retrospective observational design, we cannot infer causation. The study design and national system might have introduced selection bias in at least two phases. First, although the national HEMS is dispatched automatically based on predetermined criteria, the physician decides which missions to attend. Physicians with higher case volumes might choose to attend to less critical patients, biasing the results in their favour. However, our previous study suggests otherwise.[14] Second, if physicians with a greater case volume have a lower threshold for intubation, they might intubate less critically ill patients, thus biasing the results in their favour. Comparing vital signs at the time of the patient encounter, this trend could not be discerned, but our data are not detailed enough to rule out selection bias at the point of inclusion. Because of anonymity, we do not have details on individual providers. Therefore, we cannot evaluate the effect of training, specialty, or in-hospital service. The data in the database are not externally validated, and therefore are subject to typing errors. However, any recording errors may be presumed to be distributed evenly amongst the groups, hence not contributing to bias.

The indications and benefits of pre-hospital anaesthesia and airway management remain controversial.[2,3] It must be noted that our study does not evaluate the efficacy of pre-hospital anaesthesia and airway management *per se*, as we did not include patients with only basic airway management. Our findings call in to question whether provider case volume accounts for some of the inconsistences reported in the earlier studies demonstrating the mixed efficacy of pre-hospital anaesthesia and airway management. We also suspect that the case volume of the entire team and service might be as important as that of individual providers, but this is beyond the scope of this study. Although we cannot infer a causation, it is well established in the medical literature that sufficient repetition and frequency are important factors that often affect outcomes.[4–6] We surmise our results to be generalisable to similar HEMS staffed with an anaesthesiologist. Our data do not include details about the physicians' in-hospital service, and therefore, their experience outside the pre-hospital setting is undetermined. Consequently, the number of necessary repetitions may differ in other systems. However, we strongly believe in the generalisability of the principle that sufficient case volume is a prerequisite for proficiency.

In summary, we found that higher case volumes in pre-hospital anaesthesia were associated with lower mortality. We recommend that pre-hospital anaesthesia should be limited to a finite pool of providers with frequent shifts and a sufficiently large population base to ensure sufficient case volume. More studies are needed to show whether there is a causal relationship between pre-hospital anaesthesia case volume and mortality, and if so, what practices drive this effect and how they can be modified to improve practice when case volume is low. The effect of in-hospital experience and simulation training also needs to be further studied in this context. This knowledge could be utilised when planning the orientation of physicians entering HEMS.

Authors' contributions

Study concept/design: all authors.
Data analysis: AS.
Data interpretation: all authors.
Writing of first draft: AS.
Writing of subsequent drafts: HJ, HK, PS, JON.

Declarations of interest

The authors declare that they have no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2021.08.029.

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