An analysis of prehospital critical care events and management patterns from 97 539 emergency helicopter medical service missions : A retrospective registry-based study

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ORIGINAL ARTICLE

An analysis of prehospital critical care events and management patterns from 97 539 emergency helicopter medical service missions

A retrospective registry-based study

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BACKGROUND It is largely unknown how often physicians in emergency helicopter medical services (HEMS) encounter various critical care events and if HEMS exposure is associated with particular practice patterns or outcomes.

OBJECTIVES This study aimed: to describe the frequency and distribution of critical care events; to investigate whether HEMS exposure is associated with differences in practice patterns and determine if HEMS exposure factors are associated with mortality.

DESIGN A retrospective registry-based study.

SETTING Physician-staffed HEMS in Finland between January 2012 and August 2019.

PARTICIPANTS Ninety-four physicians who worked at least 6 months in the HEMS during the study period. Physicians with undeterminable HEMS exposure were excluded from practice pattern comparisons and mortality analysis, leaving 80 physicians.

MAIN OUTCOME MEASURES The primary outcome measure was a physician's average annual frequencies for operational events and clinical interventions. Our secondary outcomes were the proportion of missions cancelled or denied, time onsite (OST) and proportion of unconscious patients intubated. Our tertiary outcome was adjusted 30-day mortality of patients.

RESULTS The physicians encountered 62 [33 to 98], escorted 31 [17 to 41] and transported by helicopter 2.1 [1.3 to 3.5] patients annually, given as median [interquartile range; IQR]. Rapid sequence intubation was performed 11 [6.2 to 16] times per year. Physicians were involved in out-of-hospital cardiac arrest (OHCA) 10 [5.9 to 14] and postresuscitation care 5.5 [3.1 to 8.1] times per year. Physicians with longer patient intervals had shorter times onsite. Proportionally, they cancelled more missions and intubated fewer unconscious patients. A short patient interval [odds ratio (OR); 95% confidence interval (CI)] was associated with decreased mortality (0.87; 95% CI, 0.76 to1.00), whereas no association was observed between mortality and HEMS career length.

CONCLUSION Prehospital exposure is distributed unevenly, and some physicians receive limited exposure to prehospital critical care. This seems to be associated with differences in practice patterns. Rare HEMS patient contacts may be associated with increased mortality.

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Introduction

Emergency helicopter medical services (HEMS) are an essential part of prehospital care of the critically ill around the world.[1] The benefits of HEMS are not only faster transport to hospital, which can result in better outcomes but also the ability to provide special equipment and expertise during prehospital care for a larger area than ground-based units.[2,3] Some studies have found lower mortality in patients treated by HEMS compared with ground-based units, regardless of similar prehospital delays.[4,5]

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In Europe, HEMS units are often staffed with a physician specialising in anaesthesia or critical care.[2,6,7] The wide operational area a helicopter can cover may enable a physician to gain experience in critical care procedures that he or she would rarely encounter in a ground-based unit servicing a smaller population.[2,8] Gaining and maintaining proficiency in any procedure requires frequent repetition,[9–11] and without it exposure skills decline.[12] The prehospital environment comes with unique challenges. One must be comfortable in multidisciplinary teamwork and in performing procedures under challenging conditions, while maintaining situational awareness and planning strategy for treatment and transport. It is reasonable to presume that a certain level of experience in such a setting is necessary for performing safely and effectively under these conditions.

It is largely unknown how frequently HEMS physicians encounter critically ill or injured patients and perform various procedures. Additionally, it is undetermined if experience in HEMS affects treatment strategies or outcomes. To plan and schedule clinical practice and training for HEMS physicians in terms of maintaining a high-level HEMS performance, it is essential to explore how frequently they gain exposure to HEMS practice.[11,13,14] We hypothesised that physicians with less HEMS exposure might have a higher threshold for performing critical care procedures and differ in their operational characteristics.

The aims of this study are to describe the frequency and distribution of patients and procedures among HEMS physicians, to investigate whether a physician's HEMS exposure is associated with differences in practice patterns and to investigate if physicians' HEMS exposure factors are associated with 30-day mortality.

Methods

Ethics approval

The study protocol was approved by the Ethical Committee of Helsinki University Hospital (HUS/3115/2019 §194), and permission was granted by each hospital district having medical responsibility for the HEMS service (Oulu University Hospital 200/2019 2.7.2019, Helsinki University Hospital HUS/280/2019 9.7.2019, Turku University Hospital J30/19 4.8.2019, Hospital District of Lapland 32/2019 22.8.2019, Kuopio University Hospital RPL 102/2019 22.8.2019 and Tampere University Hospital RTL-R19580). As this was an observational study and did not affect treatment, patient consent was not required according to Finnish legislation and was not acquired.

Study design

We performed a retrospective study taking data from a national HEMS quality register.[15] The analyses employed three approaches:

(1) frequency and distribution of various HEMS events and procedures among physicians.
(2) a comparison of practice patterns between groups of physicians with different levels of HEMS exposure.
(3) a multivariate analysis to assess the association of HEMS exposure with 30-day mortality.

Setting

Five of the six Finnish HEMS bases are staffed with a physician. In addition to traveling by helicopter, the same HEMS teams operate by rapid response car when weather conditions do not permit flying or when a patient can be more quickly reached by ground. In addition to their HEMS missions, the HEMS physicians consult for emergency medical services (EMS), treating critically ill patients in most of the country. The medical responsibility, including medical standard operating procedures (SOPs), of the service lies with local university hospital districts. FinnHEMS, an administrative company owned and funded by the state, is responsible for providing or acquiring the service's infrastructure, including helicopter services and property. FinnHEMS also provides a national HEMS database used by every base since a nationally organised HEMS was launched in 2012. HEMS as part of EMS in Finland, and also the properties of the national HEMS database have been previously described.[15]

The study material consisted of data in the national HEMS quality register. Data from all HEMS missions and patients encountered by the physician-staffed bases between January 2012 and August 2019 were used. Using unique patient identifiers in the database, mortality data were acquired from the Finnish digital and population data services agency until the end of October 2019.

Participants

Out of the 100 physicians who worked in HEMS during the study period, 70 had specialised in anaesthesiology and intensive care, whereas 25 had entered the service during their final year of training; 3 had specialised in internal medicine and 2 had entered during the final year of specialising in emergency medicine. Training in any of these specialties requires completion of a 6-year program after receiving a medical degree. A variable number of physicians work in HEMS and other prehospital services full-time, for example, as an EMS medical director or full-time HEMS physician. The remaining physicians have their primary occupation in hospitals, mostly in operating theatres or ICUs, and perform regular shifts in HEMS. The frequency of HEMS shifts is not regulated and varies among physicians and HEMS bases. Due to anonymity of the physicians, we could not seek data on the in-hospital experience or training of any individual.

We included all physicians who worked in HEMS during the study period. A physician's HEMS period

was defined as the interval between the first and last shifts recorded in the database. We chose to exclude physicians with a HEMS period shorter than 6 months. This is the minimum length of time for which a physician is hired and short time periods would create erroneous results when extrapolating event frequencies to longer intervals.

The database includes physicians who were working in the HEMS when the database was established but left before the end of the study period. Physicians who left before meeting the threshold for long experience used in the study were excluded as the true length of their HEMS experience was undeterminable.

Variables

The HEMS exposure of the physicians was determined by two factors: the length of their HEMS careers (HEMS period) and the time interval between patients (patient interval).

Descriptive variables related to the operational events included dispatch, patient encounter, escorting a patient and transport via helicopter. Respectively, the analysed clinical events included drug-facilitated endotracheal intubation [rapid sequence intubation (RSI)], out-of-hospital cardiac arrest (OHCA), post-resuscitation care provided until hospital arrival after successful resuscitation from OHCA and the use of advanced haemostatic methods.

The operational and clinical practice patterns were compared between the physicians grouped by HEMS exposure. These practice patterns included the proportion of missions denied or cancelled, proportion of unconscious patients [defined as Glasgow Coma Score (GCS) $\leq$9] undergoing RSI and time onsite (OST). RSI was defined as any event where a patient was administered sedative medication and had an endotracheal tube placed.

To calculate OST, we used timestamps recording by the HEMS crew during the mission. The timestamp 'at scene' is recorded when the crew arrives at the mission location. The 'at patient' timestamp is recorded when arriving at the side of the patient. 'Beginning of transport' timestamp is recorded when transport by ground or air begins. When the patient is handed over to ground-based EMS, the 'available for dispatch' timestamp is immediately transmitted and recorded. OST was defined as the interval between 'at scene' and 'beginning of transport' for missions where the patient was transported by helicopter or escorted by the physician inside a ground-based unit. When 'at scene' time was not available, we used 'at patient' time instead, if available. When the patient was not escorted or transported by helicopter, the timestamp 'available for dispatch' was used to mark the endpoint for OST.

Statistical methods

Event frequencies were determined by dividing the total number of each event by the length of physicians' HEMS period and multiplying it by 365 days to produce an annual average. For analysing HEMS exposure, a patient interval was determined for each physician. This was done by calculating a 5% trimmed mean of intervals between missions on which a patient was encountered. A trimmed mean was used to reduce the effect of extreme values.

Physicians were plotted according to the length of HEMS period and patient interval. We visually chose a 5-year cut-off for the HEMS period and 7 days for patient interval to form four distinct groups for comparison: short interval/short experience (SISE), short interval/long experience (SILE), long interval/long experience (LILE) and long interval/short experience (LISE).

The association of physicians' HEMS exposure with 30-day mortality was analysed by a logistic mixed model. Mission medical reason (MMR), age and sex of patient, HEMS base, a physician's HEMS period and patient interval were used as explanatory variables. The HEMS base was included in the model to adjust for varying case-mix between the bases, in addition to the effect of hospital care in different areas. Vital signs or other physiological data were not included as they affect mortality differently depending on underlying disorder. The results are reported as odds ratios (OR) with 95% confidence intervals (CI). In the descriptive analyses, data are presented as median [IQR] range. Proportions are reported as *n* (proportion, 95% CI). The Pearson χ^2 test was used to calculate *P* values for all proportions whereas the independent samples Kruskal–Wallis test was used for continuous variables.

The sample size was not based on a power calculation but on the data available for analysis. We included all missions entered in the database during the study period. Logistic mixed models were fitted by lme4-package Version 1.1–21 (RStudio Version 1.1.463, RStudio Team, PBC, Boston, Massachusetts, USA). All other statistical analyses were done using SPSS Statistics for Mac, Version 25.0 (IBM Corp., Armonk, New York, USA).

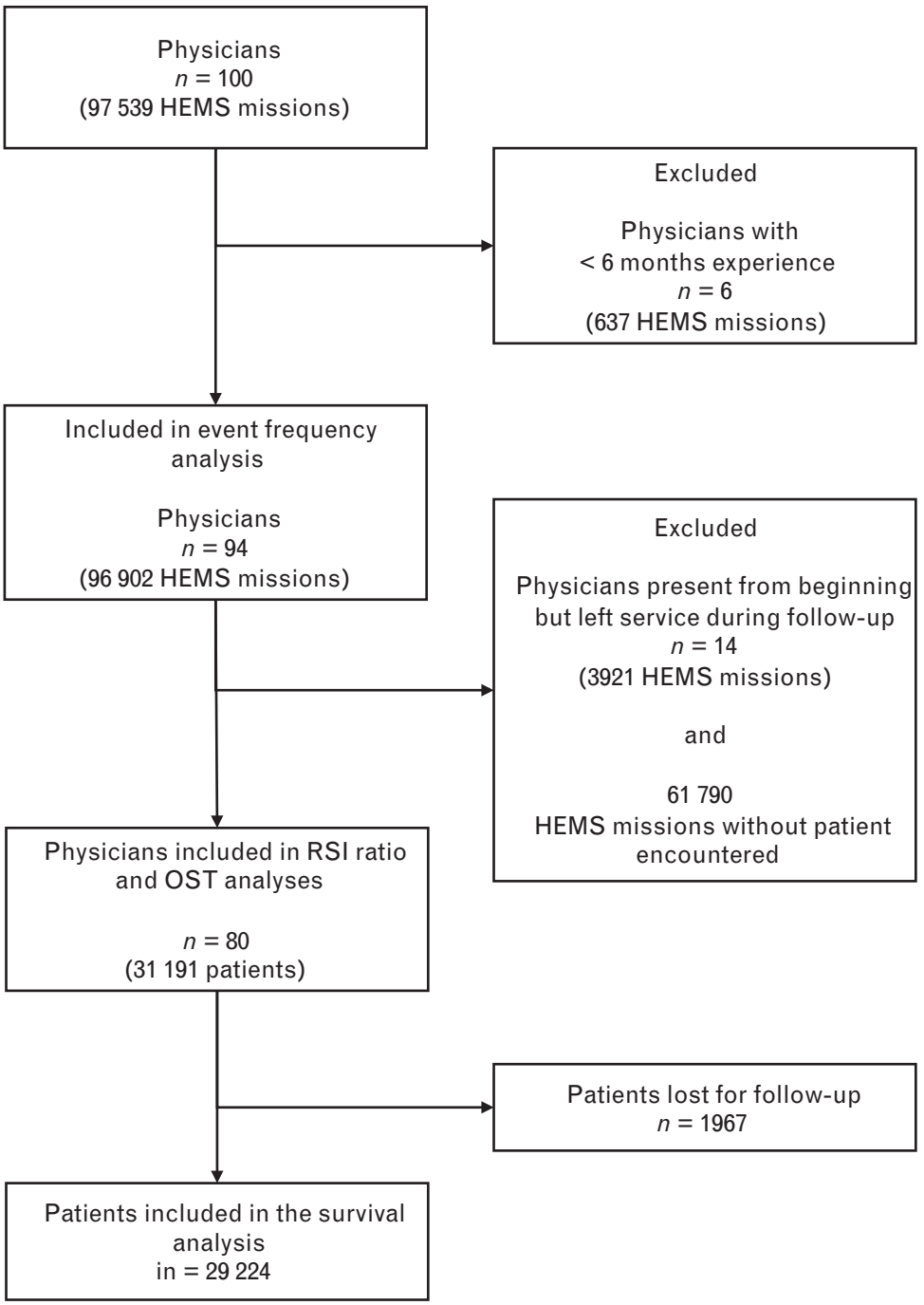
Results

A total of 97 539 HEMS missions, 94 physicians and 31 191 patients were included in the analyses (Fig. 1). The median [IQR; range] numbers of HEMS missions and patients per physician during the study period were 1034 [450 to 1479; 77 to 2993] and 322 [71 to 156; 15 to 1028], respectively.

Event frequencies

The annual number of patients encountered by a physician was 62 [33 to 98; 12 to 218], whereas the numbers for patients escorted and helicopter transports were 31 [17 to 41; 3.7 to 96] and 2.1 [1.3 to 3.5; 0 to 18] respectively. Physicians performed annually 11 RSIs [6.2 to 16; 1.0 to 63], were involved in 10 [5.9 to 14; 0.9 to 40] OHCA cases and provided postresuscitation care 5.5 [3.1 to 8.1; 0 to 22] times. Advanced haemostatic procedures were

Fig. 1 Study flowchart.



HEMS, helicopter emergency medical services; OST, time onsite; RSI, rapid sequence intubation.

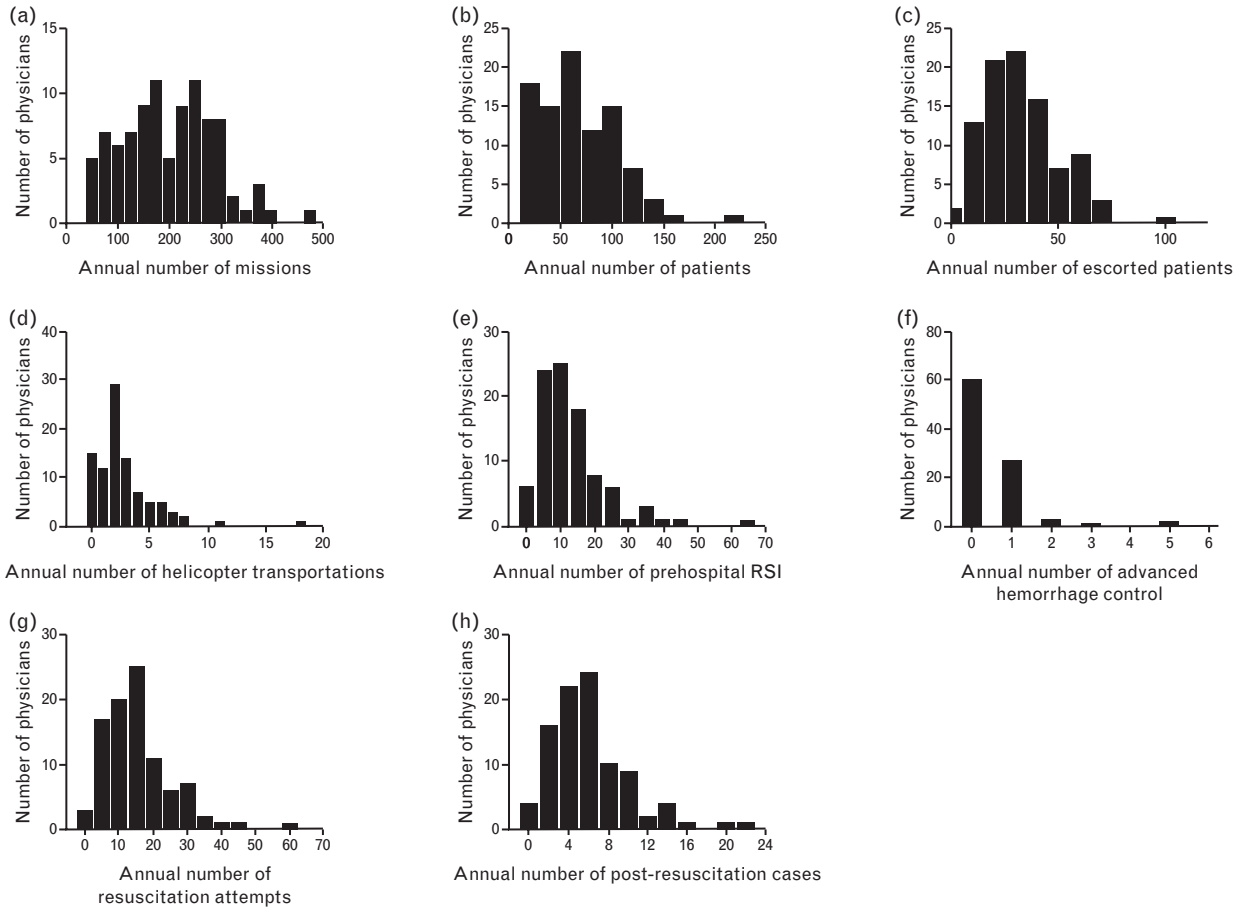
performed 0.3 [0 to 0.6; 0 to 12] times per year. The distributions of all events among the physicians were unequal (Fig. 2).

Differences in practice pattern

The mission and patient data of 80 physicians were used in practice pattern comparisons (Fig. 1). The median length of the physicians' HEMS service was 7.3 [4.1 to 7.7; 0.7 to 7.7] years, and the median patient interval was 3.6 [2.4 to 5.8; 1.2 to 12.6] days (Fig. 3).

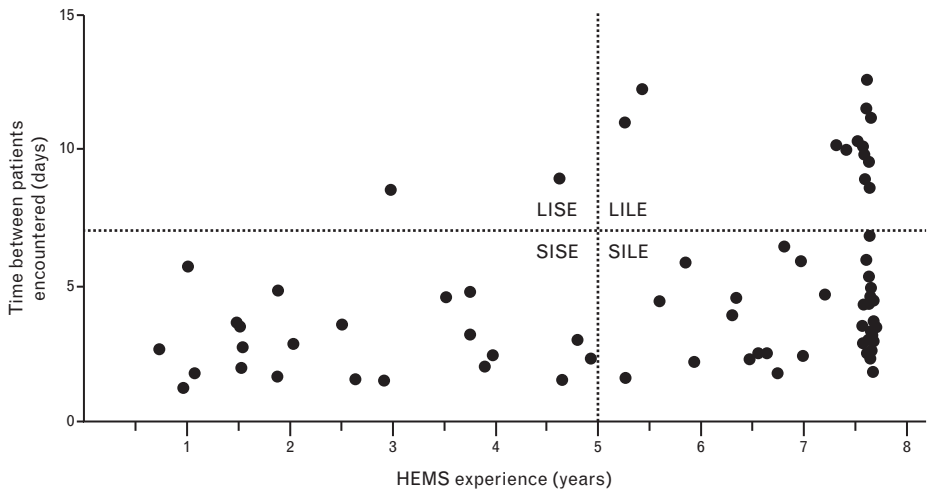
The SISE group consisted of 22 physicians, whereas the SILE, LILE and LISE groups included 43, 13 and 2 physicians, respectively. Patient characteristics are presented in Table 1, whereas practice patterns and

Fig. 2 (a–h) The distribution of the average annual helicopter emergency medical service events among physicians.



Please note the different scales of the *x*-axes. RSI, rapid sequence intubation.

Fig. 3 Helicopter emergency medical services experience and 5% trimmed mean time between patients by physician.



Physicians were divided into four groups: 1, short interval short experience (SISE): time between patients 7 days or less, HEMS experience 5 years or less; 2, short interval long experience (SILE): time between patients 7 days or less, HEMS experience more than 5 years; 3, long interval long experience (LILE): HEMS experience more than 5 years, time between patients more than 7 days and 4, long interval short experience (LISE): time between patients more than 7 days, HEMS experience 5 years or less. HEMS, helicopter emergency medical services.

Table 1 Comparison of patient characteristics between the different groups of physicians regarding helicopter emergency medical service exposure

	Short interval/short experience (SISE)	Short interval/long experience (SILE)	Long interval/long experience (LILE)
Missions, *n* (% of all patients)	14 444 (16)	66 798 (72)	11 184 (12)
Patients (% of all patients)	5270 (17)	23 074 (74)	2619 (8)
Patient characteristics			
Age (years)	57 [33 to 72; 0 to 116]	57 [33 to 72; 0 to 197]	56 [32 to 70; 0 to 108]
Sex, male [*n* (%)]	3309 (63; 61 to 64)	14 543 (63; 62 to 64)	1665 (64; 62to 65)
Heart rate (beats min^{-1})	90 [78 to 110; 0 to 230]	90 [77 to 109; 0 to 280]	90 [76 to 108; 0 to 230]
SBP (mmHg)	131 [112 to 151; 17 to 300]	130 [111 to 152; 0 to 280]	130 [112 to 150; 10 to 270]
Oxygen saturation (%)	97 [94 to 99; 7 to 100]	97 [94 to 99; 0 to 100]	97 [94 to 99; 10 to 100]
Respiratory rate (breaths min^{-1})	16 [14 to 20; 0 to 89]	16 [14 to 20; 0 to 99]	16 [14 to 20; 0 to 60]
Glasgow Coma Score	10 [3 to 15; 3 to 15]	11 [3 to 15; 3 to 15]	10 [3 to 15; 3 to 15]
Patient category, *n* (% of patients inside group)			
Trauma	1477 (28; 27 to 29)	6322 (27; 27 to 28)	697 (27; 25 to 28)
Cardiac arrest	1242 (24; 22 to 25)	4962 (22; 21 to 22)	558 (21; 20 to 23)
Neurological	997 (19; 18 to 20)	4389 (19; 19 to 20)	513 (20; 18 to 21)
Intoxication	510 (10; 9 to 11)	2519 (11; 11 to 11)	250 (10; 8 to 11)
Other	1044 (20; 19 to 21)	4882 (21; 21 to 22)	601 (23; 21 to 25)

Vital signs are the first values recorded by the HEMS crews. Reported as median [IQR; range], *n* (proportion; 95% CI). CI, confidence interval; HEMS, helicopter emergency medical services; IQR, interquartile range.

Table 2 Comparison of practice patterns and patient outcomes between the different groups of physicians regarding helicopter emergency medical service exposure

	Short interval/short experience (SISE)	Short interval/long experience (SILE)	Long interval/long experience (LILE)	*P* value
Proportion of missions denied or cancelled [*n* (%)]	9174 (64; 63 to 64)	43 724 (65; 65 to 66)	8565 (77; 76 to 77)	<0.001[a]
Onsite time (min)	18 [10 to 29; 0 to 159]	19 [11 to 29; 0 to 390]	16 [9 to 26; 0 to 184]	<0.001[b]
Proportion of RSI in patients with GCS ≤9 (%)	743/1255 (59; 56 to 62)	2644/4882 (54; 53 to 56)	286/617 (46; 42 to 50)	<0.001[a]
30-day mortality (*n*) deceased/status known (%)	1487/4959 (30; 29 to 31)	5871/20 859 (28; 28 to 29)	695/2436 (29; 27 to 30)	0.036[a]

Reported as median [interquartile range; range], *n* (proportion; 95% confidence interval). GCS, Glasgow Coma Score. [a] Pearson χ^2 test. [b] Independent samples Kruskal–Wallis test.

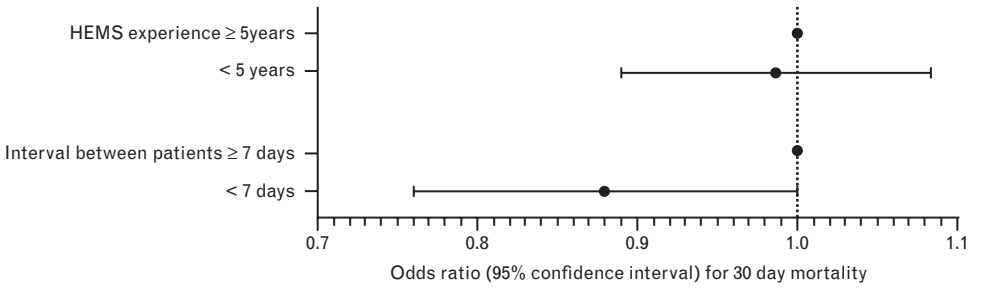
outcomes are compared in Table 2. Because of the extremely small number of physicians and patients in the LISE group, they were not included in the comparisons between the groups.

No marked differences were observed in the characteristics of the patients encountered by the physician groups (Table 1). The proportion of missions cancelled or denied was higher in the LILE group (Table 2). Furthermore, that group's OST was shorter and the proportion of unconscious patients undergoing prehospital RSI lower compared with the other groups.

Outcome

The 30-day mortality was highest in the SISE group (Table 2). After adjusting for patient category, age, sex and HEMS base, a long interval between patients strongly trended towards increased mortality ($P = 0.055$), whereas length of HEMS experience was not associated with changes in mortality ($P = 0.73$) (Fig. 4).

Fig. 4 Multivariate model for odds ratios for death within 30 days after the helicopter emergency medical service mission (n=29 224) depending on HEMS experience and interval between patients, adjusted for mission medical reason, age, sex of patient and HEMS base. HEMS, helicopter emergency medical services.



Discussion

We made four key findings. First, missions were distributed unequally with half of the physicians seeing three-quarters of all patients. Second, there was considerable variation between the physicians in the frequency of prehospital critical care events, such as RSI or postresuscitation care. The third finding showed that a physician's HEMS exposure was associated with differences in practice patterns, whereas the fourth determined that a long interval between patient contacts was associated with a trend towards increased 30-day mortality.

To our knowledge, this is the first study reporting patient distribution among physicians working in a nationwide HEMS. Physicians performed RSI a little less than once a month on average, a number comparable to services in Germany and Norway.[8,16] They attended an OHCA on average 10 times a year, again similar to German HEMS physicians.[16] These averages might be considered sufficient to maintain proficiency.[12,17] However, more than a fifth of the physicians performed five or less RSIs per year and one in eight attended an OHCA five or fewer times per year. Experience in helicopter transport was acquired very rarely; one in eight physicians had not been involved in transporting any patients via air. This lack of experience could be because of the Finnish HEMS's low rates of helicopter transport,[15] making it unlikely that a large proportion of physicians could maintain a level of competency in efficient and safe helicopter transportation. Furthermore, the use of advanced haemostatic methods was exceedingly rare, with most physicians seldom performing them more than once a year. Though the frequency of some critical care procedures was low, it was probably higher than in ground-based units covering smaller populations.[2,8,16] A study done in Germany reported that HEMS physicians performed CPR, intubated patients and inserted chest tubes more often compared with physicians in ground-based EMS units.[16]

A physician's HEMS exposure was associated with differences in practice patterns, as physicians with a long experience and patient interval had shorter OSTs and lower rates of RSI while having a larger proportion of missions cancelled or denied. The high cancellation rate among this group could indicate that the differences in OST and RSI might be a result of more stringent patient selection, choosing to treat only critically ill patients likely to benefit from prehospital critical care. However, a comparison of patient characteristics fails to support this explanation and the patients seen by the three groups seem to be almost identical when it comes to vital signs, age, sex or patient category. This observation deserves deeper analysis to discover why the difference exists. It should be noted that the optimal indications for prehospital drug-facilitated advanced airway management are not definitively determined.[18,19]

A long interval between patient contacts trended towards a higher mortality rate after controlling for MMR, age, sex and HEMS base in a logistic mixed model. Although the 95% confidence interval is relatively wide, our results imply that the routine developed by frequent patient contact in the prehospital setting might have an effect on patient outcomes. This finding needs to be interpreted with caution as very coarse clinical variables were included in the analysis of a heterogenous patient group. To further investigate this preliminary finding, a more comprehensive and detailed study is needed. Although our finding is far from conclusive, it is widely accepted in most specialties that frequent exposure creates competency in procedures, and therefore, elective procedures are routinely centralised to subspecialists to improve outcomes.[20]

Strengths and limitations

The strength of this study is that it is based on a large nationwide HEMS quality registry with low levels of missing data.[15] Its main limitation is that patient data were available only for patients encountered by HEMS and that the need for HEMS involvement on a mission is at the discretion of the physician on call. Information on patients not encountered by HEMS is not included in the database, allowing differences observed in practice patterns and mortality to be caused by biased patient selection; direct comparisons between ground-based EMS and HEMS cannot be made. Data in the database is not independently validated, and errors during input are possible.[21]

Unlike physicians, the other HEMS crew members work regular shifts and solely in the HEMS. The presence of an experienced crew might dampen differences brought on by changing physicians, the effect of which was not analysed. Also, we do not have information on how often the physicians encounter critically ill patients or perform procedures in-hospital.

We saw considerable variation in OST between and within the groups. It may be because of patient selection that warrants a strategy of fast transport or procedures performed onsite. The variation in OST needs to be addressed in future studies.

Generalisability

We anticipate that the results are generalisable to other Nordic countries and similar HEMS systems with comparable staffing.[7] However, it is noteworthy that the distribution of MMRs differs somewhat compared with other European services.[15] Most importantly, drug and alcohol related issues (intoxications) are common while stroke and chest pain are rare compared with other services.[15] Standing operating protocols (SOPs) may unify practice patterns,[22] and therefore, our findings might not apply to strongly protocol-oriented services or services staffed with less experienced clinicians.

Recommendations

Although this study cannot evaluate if quality of care differed according to patient frequency, it is well established that repeated exposure affects competency in care and procedures.[9,12,20,23] We, therefore, recommend HEMS be staffed with a finite pool of physicians with frequent and regular shifts to ensure sufficient exposure. We also recommend that exposure to procedures be monitored on an individual basis and that simulation training be scheduled to maintain competency in rarely performed events.[24,25] Furthermore, we recommend that SOPs be formulated and implemented more efficiently for general HEMS operations and common medical situations to make practice patterns among physicians more uniform.

Future studies are necessary to confirm and further evaluate our findings. A more comprehensive analysis, one controlling for more confounders, is recommended to evaluate if a physician's patient frequency contributes to mortality. In addition, our study was unable to explain the differences in practice patterns among the groups of physicians. A separate study would be necessary to investigate, which patient-based factors might explain differences in OST and rate of RSI and whether a physician's HEMS exposure remains a contributing factor, especially after the implementation of SOPs.

Conclusion

Prehospital exposure is distributed unevenly among physicians, leading to limited prehospital critical care exposure for some physicians. Their practice patterns, thus differ from those of other physicians. Rare patient contacts in HEMS service may be associated with increased mortality. We recommend SOPs be formulated for common events and targeted training for rarely encountered events to unify practice patterns and quality of care across the spectrum of situations encountered in HEMS.

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Conflicts of interest: none.

Presentation: none.

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